MAKING DECISIONS

An Assessment of the Climate-Related Needs of Oklahoma Decision Makers

SCIPP

Southern Climate Impacts Planning Program
University of Oklahoma
Louisiana State University

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Executive Summary

Twenty-three decision-makers in local, tribal, state, federal, non-profit, and for-profit agencies across Oklahoma participated in semi-structured interviews in 2010 and 2011 to inform a climate needs assessment for the state. The assessment sought to answer the following research questions:

RQ1: What do decision makers in Oklahoma think are the most significant climate-related issues facing them today?

RQ2: What do decision makers in Oklahoma think are the most significant climate-related issues they will face in the future?

RQ3: What are the spatial and temporal scales in which Oklahoma decision makers make decisions?

RQ4: What do decision makers perceive as their biggest climate-related research needs? What are the research gaps?

Decision-makers were already dealing with a plethora of climate hazards that take a toll on their financial resources and infrastructure. Climate has an enormous impact on the sectors in which the decision-makers worked, including water resources, energy, transportation, agricultural production, ecosystems, human health, and society/public safety. The participants stated that flash floods and droughts, ice and snow storms, water resource issues, and tornadoes create the most significant climate-related issues. Severe winds, extreme heat and cold, wildfires, and hail were rated as less significant, but still have an impact. Many decision-makers use weather and/or climate information on a daily or weekly basis, and especially during extreme or high impact events.

Under a changing climate in Oklahoma, it is expected that more intense but less frequent rain events will occur; there will be an increase in the frequency of hot extremes and heat waves; the warm season will become longer and arrive sooner; and cold extremes will decrease. The decision-makers said their most significant climate change-related issues will arise from more intense but less frequent rain events. An increased chance of floods and drought can be problematic for many agencies. The rest of the projected changes would be problematic for some agencies, but to a lesser degree. Some climate changes could be beneficial to decision-makers, but it is not yet known how many of the benefits will outweigh the costs.

Canadian River during drought (courtesy of SCIPP) and flash flooding in Oklahoma City, OK (courtesy of JC Reiss).

The bulk of the participants in this study said their maximum planning timescale was less than 15 years. The exceptions were the transportation and water resources sectors, which generally plan out to 50 and 100 years respectively. Spatially, local weather data is used for the majority of short-term decisions. For longer planning horizons where climate model projections would be relevant, the participants generally agreed that grid spacing that breaks the state into 4 to 5 regions would be sufficient. A few participants commented on how they did not expect the spatial resolution of climate models to be as high as those of weather models.

Several research, data, and educational needs were identified during this study. Meeting these needs would provide decision-makers with climate information that is relevant to their planning horizons and the multi-faceted nature of their work. For many agencies, weather and climate is just one of the many variables they have to consider in their planning exercises.

Climate-Related Needs and Priorities
• Climate model projections that focus on 10- to 20-year timescales
• Improved seasonal climate forecasts
• Historical climate data analysis and model projections that show changes in extremes and distributions, rather than just averages
• Analysis and display of second order variables (e.g., evaporation, humidity) and climate hazard events (e.g., droughts, floods), rather than just first order variables (e.g., temperature, precipitation)
• Understand the critical thresholds that are used for decision-making, and then analyze and present data according to those thresholds
• More precipitation and ground water data
• Cross-sector analysis and collaboration
• Education on various aspects of climate change, depending on the job function of the decision-maker

1. Introduction

Weather and climate have a tremendous impact on society. Lazo et al. (2011) estimated that up to $485 billion (in 2008 dollars) annually, or 3.4% of the annual U.S. Gross Domestic Product, is impacted by weather variability. Weather and climate can be characterized from both climatological and societal perspectives (Morss et al. 2011), and Oklahoma is no stranger to the extremes. Ice storms, tornadoes, floods, drought, and wildfire, among others, impact the state. In fact, Oklahoma received the most federal disaster declarations among any other state over the last decade (Federal Emergency Management Agency 2010a) and ranked 3rd nationally between 1953 and 2011, the period of record (Federal Emergency Management Agency 2011, Table 1). The consequences of some hazards like tornadoes and wildfires are immediately seen. The impacts of other slow-onset hazards, such as drought, are not always recognized but can actually be more costly. For example, more than $2.2 billion (in 2007 dollars) in damage was caused by a tornado outbreak that occurred in Oklahoma and Kansas on May 3, 1999, but a 1988 drought and heat wave across the central and eastern U.S. caused an estimated $76.4 billion (in 2007 dollars) in agriculture and related industry losses (National Climatic Data Center 2011).

Oklahoma is not adapted to the weather and climate it already experiences and projections show that extreme weather, such as more intense but less frequent precipitation events and more frequent heat waves, could become more common as the climate changes in the future (U.S. Global Change Research Program 2009a). Many societal sectors including, but not limited to water resources, energy, transportation, agriculture, ecosystems, and human health will be impacted by climate change (U.S. Global Change Research Program 2009a). Yet, some of the decision-makers in these sectors do not have the proper knowledge to make informed climate-related decisions about the future (Oklahoma Climatological Survey 2010). In addition, gaps exist between the needs of users and the state of the science (Dow and Carbone 2007). This study explored those gaps, particularly those related to climate information and education. This study also investigated the most significant weather and climate issues with which local, tribal, state, and federal decision-makers in Oklahoma have to cope. Future climate-related concerns were also examined, in addition to spatial and temporal scales of decision-making and planning.

Rank	State	# of FEMA Disaster Declarations Declared, 1953-2011
1	Texas	86
2	California	78
3	Oklahoma	70
4	New York	65
5	Florida	63
6	Louisiana	58
7	Kentucky	55
7	Alabama	55
9	Missouri	53
9	Arkansas	53

Table 1: Top 10 states who received the largest number of Federal Emergency Management Agency (FEMA) declared disasters, 1953-2011. Oklahoma ranked 3rd nationally and 1st for the years 2000-2011 (Federal Emergency Management Agency 2011).

This assessment was conducted by the Southern Climate Impacts Planning Program (SCIPP), a National Oceanic and Atmospheric Administration (NOAA) Regional Integrated Sciences and Assessments (RISA) team that aims to bridge the gap between climate science and hazard planning decision-makers (Figure 1). RISAs are designed to, "create linkages and act as coordinators among federal, state, and local agencies in different regions to identify, undertake, and evaluate integrated research on climate-sensitive issues" (Pulwarty et al. 2009 p. 377). SCIPP studies hazard planning in a six-state region in the southern United States: Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas; however this assessment focuses solely on Oklahoma.

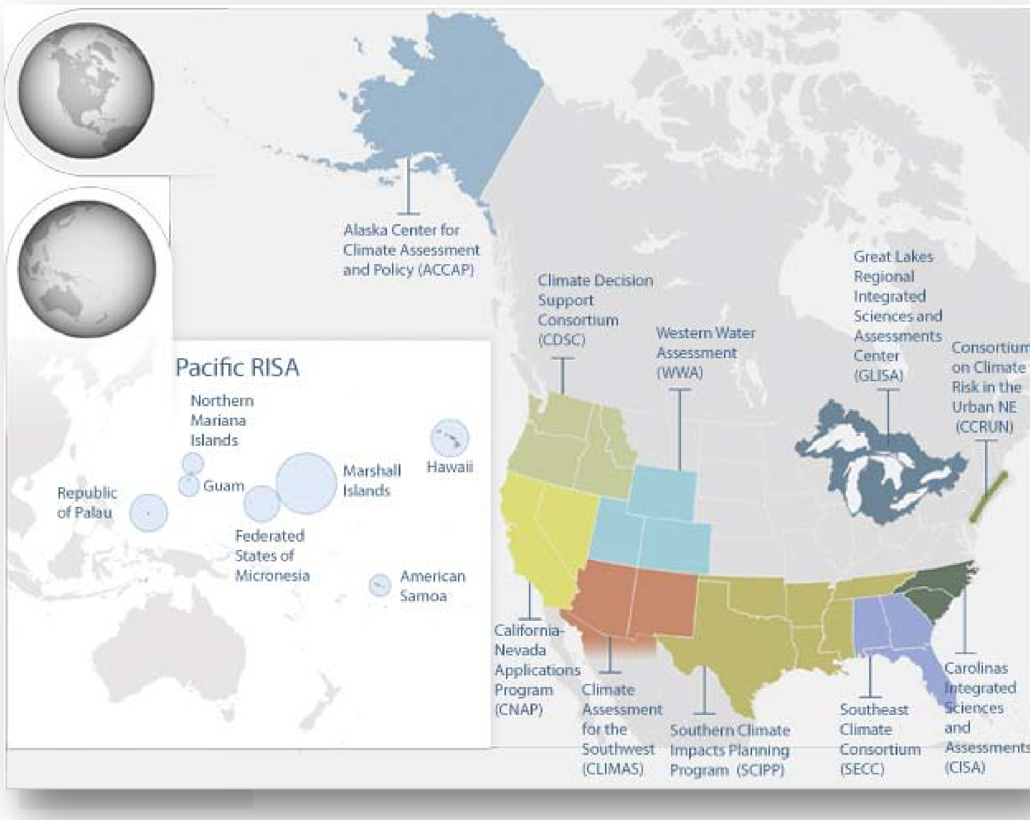


Figure 1: Locations of the 11 Regional Integrated Sciences and Assessment (RISA) teams (Climate Program Office 2012). The Southern Climate Impacts Planning Program (SCIPP) works with decision-makers in six states: Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas.

This assessment begins to build capacity for sustainable programs and relationships with decision-makers to assist them with their hazard and climate change planning needs. The National Research Council (2008) defines capacity building as strengthening knowledge, abilities, relationships, and values that enable individuals and organizations to reach their goals. Quite often the lack of an adequate needs assessment is one of the most significant barriers to producing capacity building programs (National Research Council 2008). Thus, this assessment addresses a vital step in building sustainable relationships with decision-makers across Oklahoma. In addition to this report, the data will be used to help develop a climate adaptation plan for the State. This assessment provides a means to communicate with decision makers and begin to understand their needs in order to execute effective adaptation measurers.

2. Background

Climate change is often discussed on a global scale but climate impacts are experienced on a local scale. For example, a record amount of rain fell in June 2010 that broke a 40-year record for the most rainfall in a single day in Oklahoma City (7.62 in.) and caused major urban flooding (National Weather Service 2010a). Moreover, wildfires broke out in central Oklahoma in April 2009 (Figure 2) due to strong winds and very low relative humidity (National Weather Service 2010b). Federal assistance for the fires exceeded $2.9 million (Federal Emergency Management Agency 2010b). These events were declared

Figure 2: Wildfires broke out across Oklahoma in April 2009 (courtesy of KOCO-TV).

disasters on a national scale, but the impacts occurred on the local scale.

While a particular extreme weather event cannot be attributed to climate change in and of itself, a multitude of "extremes" influence climate averages. Weather and climate are two distinct yet related terms; weather can be characterized by hour-to-hour changes in temperature, wind, and precipitation, or by a single event (e.g., thunderstorm, ice storm, straight-line winds), whereas climate is typically characterized as the long-term average of the weather conditions. Climate change is often portrayed as the average trend in a particular direction (e.g., Figure 3), but the variability (i.e. extremes) of the climate frequently has the greatest impact on people and infrastructure. Hence, the terms weather and climate cannot be used exclusive of one another.

Local, state, tribal, and federal leaders have the ability to influence adaptation and mitigation measures which can address some of the impacts of climate. However, the decision-makers must be knowledgeable and have access to the appropriate information in order to make sound choices. It is therefore essential that providers of weather and climate information understand the needs of their users. Interaction between climate scientists and decision-makers is crucial (U. S. Global Change Research Program 2009b) so that research is fruitful and decision-makers' needs are being met. This assessment is an in-depth look at the weather and climate-related issues about which Oklahoma decision-makers are concerned and aims to provide some understanding of their needs.

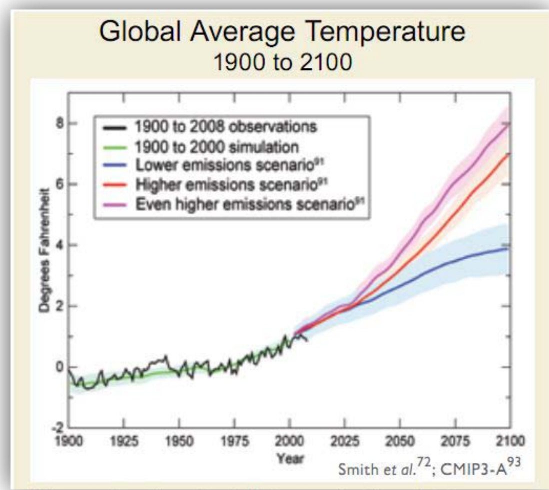


Figure 3: One example of how climate change is portrayed in a graphical format by showing the changes in an average as opposed to showing the extremes (U.S. Global Change Research Program 2009a).

3. Methodology

Data for this assessment were collected using a semi-structured interview approach. This study aimed to provide an in-depth understanding of decision makers' needs for climate information and how their agencies are impacted by particular climate events. However, the qualitative nature of the study meant that the results did not necessarily showcase *every* climate issue that impacts all decision-makers in Oklahoma. Representatives from 23 local, tribal, state, federal, non-profit and private agencies across the state of Oklahoma were interviewed in person in 2010 and 2011. Conducting the interviews in person aided in producing familiarity and trust between the interviewee and the researcher (Kirk and Miller 1986). The semi-structured approach allowed for consistent findings across the interviews but also provided participants with the opportunity to focus on the climate-related issues they deemed most important. Additional insight was also gleaned through a one-day climate adaptation meeting hosted at the National Weather Center in Norman, OK in May 2011 (Lunday 2011).

The interview protocol was rooted in best practices for stakeholder participation, which emphasizes that stakeholders should be included as early as possible throughout the process of developing new products and services. The engagement process was based on a philosophy of "empowerment, equity, trust and learning" (Reed 2008, p. 242). The protocol was designed not only to gather information about the climate-related needs of decision makers, but to also understand their social considerations which are vital to knowledge planning, decision-making, and governance (U.S. Global Change Research Program 2009b).

Partnering with stakeholders takes interdisciplinary understanding of the problem (Pulwarty et al. 2009). The research team's expertise covered a vast number of academic fields including communication, climatology, geography, meteorology, and political science. This engagement method will help develop a sustained relationship with Oklahoma decision makers, an important component of research-stakeholder partnerships (Pulwarty et al. 2009).

3.1 Participants

Participants were recruited by email and phone based on their participation in a December 2009 meeting on climate adaptation planning (Oklahoma Climatological Survey 2010), a prior relationship with a SCIPP or Oklahoma Climatological Survey (OCS) employee, or snowball sampling where one participant suggested another person to contact for an interview (Biernacki and Waldorf 1981; Salganik and Heckathorn 2004). Twenty-three interviews were conducted in total. One participant from an agency was present for the majority (n=16) of the interviews. The rest were conducted with two to six representatives. Nine females and 27 males

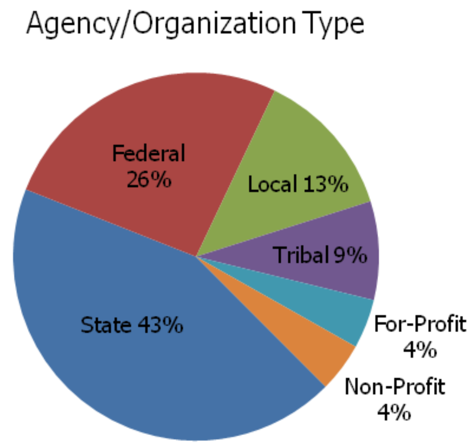


Figure 4: Type of agencies and organizations that participated in the assessment.

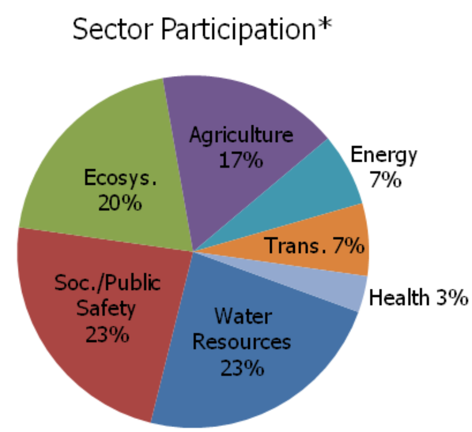


*Figure 5: Sectors in which the participants represented. *Some were classified as representing more than one sector, depending on their response to a particular question.*

participated and they represented a variety of local (n=3), state (n=10), tribal (n=2), federal (n=6), non-profit (n=1), and for-profit (n=1) agencies (Figure 4). Figure 5 shows that they also represented various sectors including water resources (n=7), energy (n=2), transportation (n=2), agricultural production, including crops and livestock (n=5), ecosystems, including natural resources and wildlife (n=6), human health (n=1), and society/public safety (n=7). Some participants fell into more than one sector based on their response to a particular question. For example, one participant's agency focused on preserving natural resources which related to ecosystems. However, his agency also had frequent contact with private land owners, many of whom were farmers. Consequently, some of his responses related to the agriculture sector.

3.2 Protocol

The interview protocol was designed to answer four research questions (RQ):

RQ1: What do decision makers in Oklahoma think are the most significant climate-related issues facing them today?

RQ2: What do decision makers in Oklahoma think are the most significant climate-related issues they will face in the future?

RQ3: What are the decision makers and temporal scales in which Oklahoma stakeholders make decisions?

RQ4: What do decision makers perceive as their biggest climate-related research needs? What are the research gaps?

Prior to gathering information on climate-related needs, it was important to understand how decision makers perceive weather and climate to impact their agencies, now and in the future. Moreover, scientifically-based decisions are dependent on information that is provided on relevant spatial and temporal scales (Morss et al. 2011), so this study sought to understand those scales. Understanding the participant's climate-related research needs encompassed multiple best practices of stakeholder participation (Reed 2008) and will help shape future climate research so that it is relevant and useful to decision makers. The protocol was comprised of 16 questions (Appendix A). The questions were refined throughout the interview process to reveal the most relevant and appropriate protocol. The participants were given a copy of the protocol and consent form prior to the interview. At the beginning of the interview, the interviewer described the purpose of the study, discussed the difference between weather and climate, and asked the participants to fill out a short demographic survey. The survey asked about their job title, the name and area (local, county, region, state, federal, non-profit, private) of the agency/tribe/organization with which they were affiliated, and the primary Oklahoma city(s) or county(s) with which they worked and/or were responsible for managing. Finally, the participant(s) was asked about the number of years they had worked for their organization and the other agencies across the state with which they commonly worked.

3.3 Data Analysis

Interviews were recorded with the participant's consent. Detailed notes were taken in the event that the participant did not consent (n=3). The interviews were transcribed and the data were analyzed thematically and according to the sectors that were consistent with the 2009 National Climate Assessment (U. S. Global Change Research Program 2009a). Sectoral analysis was preferred for this assessment so that the state's need for climate information could be examined on an in-depth basis. Cross-sector analysis also occurred since many climate issues were not bounded by a single sector. Microsoft Visio was used to visualize responses from the participants.

4. Results

4.1 Current Climate-Related Issues & Impacts

Prior to assessing the needs of decision makers pertaining to future climate conditions, one must first understand how weather and climate *currently* impact them. The participants most frequently cited heavy rain that caused flooding, droughts, water resource issues, ice storms, and tornadoes as problematic. The participants also cited being impacted by extreme cold and heat and severe winds. The protocol was designed to reveal the issues that were most significant from the perspective of the decision maker, not that of climate scientists. The issues described below were for the most part, not explicitly prompted. However, a short survey was emailed to the participants following their interview to get a comprehensive list of all the issues and to determine, quantitatively, which had the greatest overall impact. Figure 6 shows that the survey results were fairly consistent with the qualitative findings with heavy rain/flood and drought ranking as most problematic followed by winter storms, water resource issues, and tornadoes, among other issues.

Water Resources. The most significant climate-related issues water resource managers in Oklahoma currently faced were quantity issues, whether too much or too little. Heavy rain can cause flooding and flash flooding, which create the potential for dams to break. Flood control measures such as monitoring reservoirs and directing releases out of dams can be implemented so it does not happen, however. Flooding is also a problem for water treatment facilities if sewer lines reach capacity and water backs up. For example, the historic amount of rain that fell in parts of central Oklahoma in June 2010 caused manholes to overflow in one city. A pump station was also submerged, which caused millions of gallons of sewage to be mixed into water. One participant said that to combat overflow and capacity issues in his city, they recently completed a wastewater monitoring project to size sewer lines and treatment facilities to account for expected rainfall. They were also working with a private company to model rainfall and the flow of water through basins to gain a better understanding of how water flows through the city limits.

Heavy rain also impacts water quality. One water scientist noted that "anywhere from 70-95% of the contaminants, albeit nitrogen, phosphorus, or bacteria" that get into the rivers and reservoirs, occur during heavy rain events. It is very difficult,

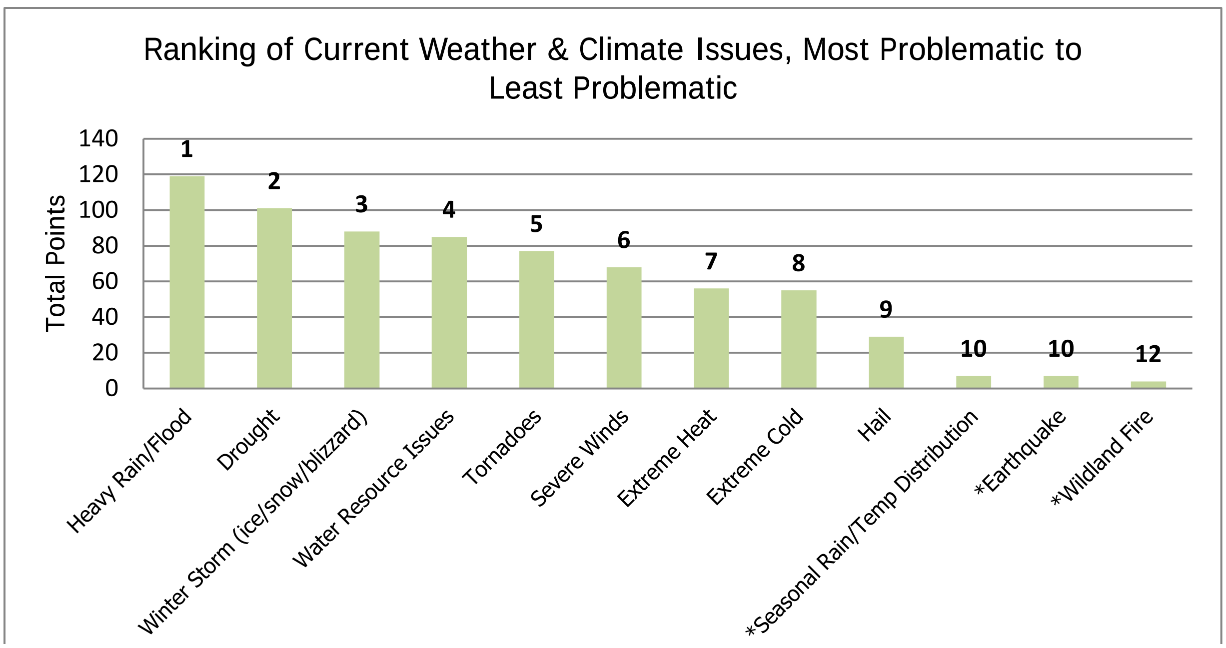


Figure 6: Ranking of weather and climate issues from most problematic to least problematic. Participants could also rank the issues as equally problematic. The key to the result is the relative ranking of each issue rather than the overall score. An asterisk indicates categories written in by the participants in the "other" category ("earthquake" is not a climate hazard but is a natural hazard for which some decision makers plan). Five participants did not respond to the emailed survey.

however, to collect measurements from high flow events due to resource limitations, safety reasons and the somewhat random nature of the events.

Drought can also be a problem, particularly in the western half of the state. Drought has the potential to limit water supply, especially in small communities where they do not have an alternative water supply option. One representative of a federal agency commented, “When we get into a severe drought, that has a very big impact on us.” Conservation practices are often encouraged to stretch the supply. One water quality official said that her agency typically tells residents to improve efficiencies rather than conserve water because “conservation” can be seen as a negative term since local municipalities receive revenue from water use.

Not only does drought decrease the available water quantity, it can also damage infrastructure. Dry ground can cause pipes to shift and break, as was the case in several U.S. states, including Oklahoma, in 2011 (Patterson 2011).

Drought planning is a major component of some agencies’ planning activities. A representative of a federal agency noted, "A lot of what we do is plan for drought. Implementing measures that will help our beneficiaries be better prepared when that drought happens, and that water will be available during a time of drought.” One planning mechanism that can help address limited water quantity is to encourage cities to build pipelines so they are able to purchase water from other cities, provided the source of the purchased water is sustainable. This may not always be the best solution, however, and might only be appropriate for short-term, emergency situations. Engineering practices can also help during times of limited water. Water efficiencies can be improved by lining canals to prevent seepage loss and by converting irrigation canals to pipeline to reduce and prevent evaporative loss. Despite these technological improvements, some parts of Oklahoma face limited quantity issues right now or might in the near future. In fact, one large city has fully allocated its water source, which has major implications for the city’s water future given that the source cannot support future population growth. To address this problem water authorities are looking at alternative sources outside of the main supply basin.

Concerns over future water supply are certainly not confined to decision makers in Oklahoma. In fact, some Texas officials are interested in purchasing some of Oklahoma’s water to support their growing population. No such agreement has been made to date, however. One participant said, “The state of Oklahoma wants to ensure long-term future water needs for Oklahoma are protected prior to allowing sales to Texas.”

Like heavy rain, drought also has an impact on water quality. Many cities and towns across the state rely on reservoirs for their water, but the quality of that water decreases as the amount of water in it decreases. Thus, municipalities have to treat the water with more chemicals, which increases their operational costs.

Aside from floods and droughts, water resource decision makers also described dealing with extreme cold, severe winds and tornadoes, and ice and snow storms. Extreme cold can cause pipes to freeze, which can impact water treatment facilities. However, this issue can be mitigated if the proper steps are taken at the treatment facilities. Severe winds, including tornadoes, can also be problematic. Some water towers may be vulnerable to high winds that cause damage. Extreme tornadic winds can destroy water towers altogether, potentially causing water shortages for the affected area. Damaging winds and ice storms can also cause power outages, which is problematic for water treatment facilities. However, all treatment facilities in Oklahoma are required to have back-up generators so that service can continue without disruption if at all possible.

Energy. Extreme heat impacts the energy industry most significantly since it puts a strain on power line loads. Cold temperatures also strain the load but not as significantly as heat since electricity flows more easily through cold lines than hot lines. Power lines are designed to handle the load that accompanies extreme heat, so if the lines are designed properly and the electricity supply is able to meet the demand, no major problems should occur. In fact, extreme heat can benefit the energy industry because it helps boost their revenue. Of course, this is not a positive result for consumers.

Figure 7: Ice accumulated on a speed limit sign during a storm in 2010. Ice also accumulates on power lines, which can cause widespread power outages (courtesy of Rachel Riley).

Ice storms also have a major impact on energy infrastructure because the events are typically widespread (Figure 7). One energy official noted, “In a lot of ways, [ice is] much, much worse than a tornado. Tornadoes have definitive paths, and definitive damage. Ice storms hit hard, wide-spread across our whole system.” Like heat, power lines are designed to handle a certain amount of ice, but it is not necessarily financially possible to design for the maximum load. Since ice storms can cause widespread power outages, energy officials have to pre- position resources before the storm begins. Otherwise, it takes a significantly longer amount of time to get the power back on. "If you have a major event like an ice storm . . . if you don’t have folks at least close to the storm area staged and ready to go with the treacherous conditions that they can create, it could take days to get someone in," one participant said. The other energy participant said that if 0.75-1.00 in. of ice are forecasted they “begin calling crews . . . start to reserve hotels rooms . . . we’ll start changing our hours to accommodate the ice.”

“In a lot of ways, [ice is] much, much worse than a tornado. Tornadoes have definitive paths, and definitive damage. Ice storms hit hard, wide-spread across our whole system.”

Tornadoes and severe winds also destroy power lines, but as previously noted, are not as widespread as ice storms. High humidity also creates difficult conditions for personnel and equipment. Workers tire more easily in high humidity and condensation can damage equipment. Drought is also problematic since low lake levels can be problematic for the energy entities that depend on electricity generated by hydropower.

Transportation. The transportation industry is also impacted by weather and climate. Heavy rain and flooding cause the most problems for transportation infrastructure. One transportation maintenance official said, “Rain is a big weather condition for us all the time.” Roads and bridges can become blocked by debris

Figure 8: Low water crossing in Moore, Oklahoma. City officials installed gates to keep people from crossing the creek when it floods (courtesy of Gayland Kitch).

or wash out. When this occurs, officials have to shut them down and put up signs that detail an alternative route, which is an inconvenience to motorists (e.g., Figure 8). Furthermore, time and money have to be used to restore infrastructure, which can strain budgets. A transportation engineer said her agency has not yet studied the correlation between rain events and bridges that flood but that it is a long-term goal now that they have the capability of using GIS (geographical information systems). She noted, however that county maintenance crews know what roads need to be shut down during heavy rain events.

Extreme heat and cold can also be problematic. Extreme heat causes roads to buckle, which increases maintenance costs. Extreme cold, coupled with thaw-freeze cycles, creates potholes, which also increases maintenance costs.

Severe winds, tornadoes, ice storms, and snow storms can cause power outages which means that traffic signals do not work. Road maintenance crews must go to the affected locations and fix the problem, sometimes implementing a temporary solution such as putting out stop signs. Winter weather is especially dangerous for people who are traveling. Thus, transportation officials have to implement measures to keep the roads safe. Road crews will sand and salt the roads in an effort to keep them ice free. They will also plow them to clear the snow that can otherwise inhibit travel.

Drought can also be problematic for the transportation industry because it provides people with a false sense of security. For example, a person might not notice that they travel over a creek bed every day during their drive to work during a drought. When heavy rain falls, however, the previously nonexistent creek could turn into a raging river.

***Agricultural Production.*** Agricultural production such as livestock, wheat, cotton, hay, peanuts, and peaches has a $28 billion (2008 dollars) impact on Oklahoma's economy (Shideler et al. 2008) and is affected by a plethora of climate-related issues. Crops are dependent on precipitation and livestock are out in the elements so they are susceptible to the variability that comprises Oklahoma's climate. Untimely freezes and warmth can be problematic for crop producers. Invasive species can take hold and damage crops if the temperature warms too quickly in the spring or does not get cold enough in the winter to kill them off. Crops can also be damaged by temperature alone. To address the untimely temperature issues, some producers use different planting schedules and researchers are working on developing cold tolerant crops.

Heavy rain, severe wind, hail, and tornadoes also damage crops. Heavy rain produces runoff which can cause pesticides and fertilizer to flow into lakes and streams. One participant noted, "The use of assorted manures as a green fertilizer requires surface spreading which is vulnerable to heavy precipitation events and huge run-off with impacts downstream." Heavy rain also creates the potential for dams to break, which can impact producers if their cropland becomes flooded. Drought is also a problem, as seen in figure 9 which shows barren soil in the Oklahoma panhandle in April 2011 due to limited rainfall. Oklahoma has a history of drought, lasting from a

Figure 9: Field conditions in the Oklahoma Panhandle in April 2011 during a drought (courtesy of Ladene Beer).

single season to a decade. Even a seasonal drought can have a huge impact on agriculture. In fact, agricultural losses were estimated at $2 billion during a drought in 1998 (Thurman 1998). If crops do not receive the rain they need to grow, a producer can lose their entire yield. For example, wheat is one of the most common crops grown in the winter. One participant said that some producers might use other feeds, forages, and hays to feed their cattle since winter wheat is not as reliable as it once was. Drought can also be problematic for livestock if they do not have the proper water to drink or wash in. Poor timing of precipitation can also limit crop growth and impact cattle grazing and purchasing decisions.

Producers purchase crop insurance and use risk management programs to mitigate some of the risk involved in farming since traditional practices are unreliable. Researchers are also working on developing weather-resistant crops, such as plants that "mature later to try to avoid some of the hail damage that can occur in late Spring, or varieties where the seed doesn't shatter onto the ground so badly during heavy rainstorms . . ." Some agencies are working with producers to find more efficient soil and water conservation methods such as no-till or low-till practices which reduce the amount of soil moisture lost to evaporation and soil lost to erosion. They are also looking at using alternative crops or different crop rotations to get around the drought problem. One participant said that some farmers across the country are being forced to alter their practices due to the changing natural resources landscape. She commented, "West Kansas has already had to make the transition from being irrigated to dry land farming within the last decade because they can't afford to pump the remains of the Ogallala or the High Plains Aquifer anymore. It's too deep, it's too salty." Deficit irrigation is another practice being used, which means that if a producer realizes they are not receiving as much precipitation as they once did, the producer will look into growing a crop that requires less precipitation to grow.

Ecosystems. Weather and climate events impact ecosystems, including natural resources and wildlife. Weather events affect wildlife officials' ability to monitor species. A wildlife biologist noted that his office mostly focuses on monitoring species as opposed to intervening since they do not have much control over wild animals. The official said that if a particular animal cannot survive in the wild there is probably a reason for that. He also noted that endangered species are treated differently than species that are not endangered. Special attention is given to the habitats of endangered species to support their ability to thrive in the wild. The one intervening mechanism that can be put in place if officials notice a declining population is to reduce hunting and fishing bag limits.

Typically, a single climate-related event does not impact wildlife enough to cause concern, but several harsh winters, for example, could stress a population. A wildlife biologist commented, "Most animals have enough fat reserves that, you know unless they're just stranded out in the open where they can't get to cover, they can handle [a harsh winter]." A multi-year drought may also have an impact if wildlife are unable to find food.

Additionally, an extreme weather event can have a bigger impact if it occurs during the time of year when wildlife are particularly vulnerable, such as during breeding and nesting season. The season varies depending on the animal, however, so no single time of year is worse than another.

Heavy rain and floods can have an enormous impact on the land and natural resources. Erosion can be a problem along rivers. One participant noted that a section of the Washita River was moved 50 feet after the remnants of Tropical Storm Erin dropped up to 11 inches of rain on the area (National Weather Service 2011). The heavy rain also took some cropland down to bedrock. This was very costly for the State because carbon that had previously been sequestered by land owners who were utilizing best management practices was released into the air. The land owners had been compensated for utilizing best management practices so the State ended up compensating them with no positive end result on carbon sequestration. Aside from erosion, runoff is also a problem with heavy rain because it negatively impacts water quality and causes non-point source pollution in rivers and streams.

Another climate-related event that wreaks havoc on the environment are ice storms. According to one of the participants, one ice storm in January 2010 damaged more than 1 million trees across Oklahoma. Wildfires can also be problematic. Although they are a natural part of ecosystem restoration and fire managers use prescribed burns to reduce the amount of catastrophic fires, drought can increase the risk of wildfires that are not prescribed. Dry and dead trees and shrubbery are fuel for out of control fires.

Severe weather can be problematic for those who manage public natural resource areas. One such area in Oklahoma has 400 campsites. When severe weather is imminent, campers are forced to seek shelter in a nearby town. "[A] quick evacuation and early event warnings for tornadoes could be a major issue for our park," a park ranger said.

Human Health. Human health is impacted by weather and climate events and some effects last longer than others. A representative of a health agency noted that "weather is a major factor" in his organization. Extreme events such as tornadoes, ice storms, and snow storms have an enormous impact on health. Drought also impacts the health industry, as do floods and extreme heat. Some of the direct impacts of extreme events include injuries or fatalities caused by the storms (e.g., slips, falls, and automobile accidents). In fact, a January 2007 ice storm caused 6,000 injuries across the state. These types of extreme events create significant medical expenditures, which generate lots of medical bills, straining Medicare, Medicaid, and the overall healthcare system.

There are also indirect impacts of extreme events on human health. If roads are impassible, either because of tornado/severe storm debris or snow and ice, patients may be unable to get to dialysis, for example. Moreover, doctors and nurses may be unable to get to hospitals and clinics to assist those patients. The health participant noted that part of the issue can be addressed by utilizing volunteers from faith-based organizations who use their four-wheel drive vehicles to transport people to hospitals and clinics to receive proper care. Hospitals can also reach capacity if patients are unable to be discharged due to hazardous weather and/or road conditions. "[If] we have patients who go to a hospital and then a blizzard hits while they are in treatment and they're getting ready to be discharged that night we have patients that are stuck in hospitals. That puts a crisis on our hospitals," the participant said. Another impact of snow and ice storms is that winter vaccine clinics can be interrupted or canceled. The participant from the health agency commented, however, that those vaccine clinics could be moved to the fall if winter weather events become more common in the future.

The participant from the health agency also spoke about the impact of drought on public health. During the interview there was an ongoing drought across the state. The participant was concerned about it because farmers who typically pay for their own insurance do not have the ability to do so during a season or year of drought(s). Thus, they have to go to the local health department to meet their medical needs, which can be taxing on public medical resources.

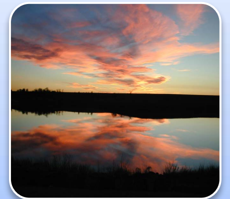
Extreme heat can be also be problematic, although not as much as it is in other parts of the U.S. Most Oklahomans are used to dealing with heat because it is a common occurrence. The health agency participant said that they do deal with heat-related injuries, but it is not as big of an issue as with other climate-related events.

Society & Public Safety. Weather and climate events have the potential to disrupt the ebb and flow of society. Cities and tribes in Oklahoma encounter just about every climate-related extreme one can fathom: extreme heat and cold, poor air quality, severe winds, tornadoes, hail, wildfires, ice and snow storms, heavy rain and floods, and drought. One tribal representative said they have emergency action plans in place for their casinos to address any problems that might arise. State emergency managers are also prepared to deal with extreme events. Helicopters are prepositioned and put on standby when wildfires are expected, and commodities and generators are deployed to the appropriate locations before snow and ice storms occur. An emergency management official emphasized that his agency's actions are based on relationships that are already in place with a variety of state and federal agencies and non-profit organizations across Oklahoma. Because of these relationships they only need a few days notice to gear up for a potentially disastrous event. "On pretty much every event except ice storms, we're just ready. By using the guidance from our [National] Weather Service partners . . . we will just make sure the people in the agency know . . . don't stray too far from the E[mergency] O[perations] C[enter], if you've got meetings make sure you have your phone on you, keep abreast, be safe, know what's going on in your area . . .," he said. The ice storm exception is due to the fact they need a couple of days to move generators from a storage facility in north Texas, in the event of power outages.

Climate-related events also impact the normal operations of various agencies. More maintenance is required on transportation infrastructure following extreme heat and cold events, which can put a strain on the city and/or state's finances. High winds and ice storms cause power outages, which impact a citizen's ability to go about their daily routine. Heavy rain can be dangerous for motorists when streets flood and/or roads and bridges wash out. According to the Oklahoma Department of Emergency Management (2010), the State Department of Health reported 136 storm-related injuries in the aforementioned June 2010 heavy rain event. In fact, extreme rainfall has caused major problems for cities and communities across the state in recent years. A participant from a large city in Oklahoma said that his city is "prone to flooding and we have gone to such great lengths to manage that storm water." He also noted that the city has looked into using permeable pavement and other sustainable building practices to help address flooding issues, but so far none have been implemented.

> *"[My city is] prone to flooding and we have gone to such great lengths to manage that storm water."*

Climate



- Increase in the magnitude and frequency of extreme events
- More untimely freezes
- Longer summers
- More intense but less frequent rain events
- Increase in the frequency of ice storms and blizzards
- Fewer cold, hard winters

Plants

- Northward shift in plant hardiness zones
- Invasive red cedar trees, milo, and kudzu
- Fewer plant varieties due to lack of rainfall
- Changes in the wheat-cattle cycle

Wildlife

- White-winged doves exist in Oklahoma but did not used to
- Geese do not migrate like they used to
- Horned frogs and lizards have died off
- Decrease in roadrunner and jackrabbit populations
- Increase in rattlesnake population
- Creek no longer contains bass because of reduced streamflow
- New bug species

Figure 10: Summary of anecdotal changes in climate, plants, and wildlife. Many of the participants cautioned that they were not sure whether the changes were due to climate change, land use change, or that their memory was biased toward recent events.

4.2 Anecdotal Evidence of Change

Prior to discussing the impact that climate change could have on future planning decisions, the participants were asked whether they had noticed any local changes in their climate and/or environment. As seen in figure 10, the participants described some changes but many of them cautioned that their observations were purely anecdotal. Some participants also said they were not sure whether the changes were due to changes in the climate, land use, or whether their memory was biased toward recent events. One decision-maker also commented how the extreme variability of Oklahoma's climate makes it difficult to know whether it is actually changing. Despite these caveats, some decision makers spoke about anecdotal changes in climate, plants, and wildlife.

Climate. Six decision-makers said the magnitude and/or frequency of extreme events is increasing, although one person noted that variability is part of Oklahoma's climate. For example, the summer of 2011 was the hottest summer on record for Oklahoma, but one participant spoke about how hot summers are not unprecedented. He stated, "You know it's interesting to read the papers from 1934 and 1954 and people were saying the same thing I'm saying right now. They were tired of [the heat] then because they had a really bad hot summer . . ."

Four participants spoke about temperature-related changes in particular. One person said there are more untimely freezes, another said summer seems to last longer, and another said he had not experienced a really cold, hard winter for a long time. Several decision-makers also said they have noticed changes in precipitation. Longer, deeper droughts and more intense but less frequent rain events, especially those that cause flash flooding, seemed more common to a few people. One agriculture participant said, "I think [the forestry producers in southeast Oklahoma will] tell you, and I think this would probably be a true statewide, that we get longer times with limited rainfall, but then when we do get that rainfall we may get six inches of rain." Four people commented on the increase in the frequency of ice storms and/or blizzards. One participant did not recall having as many ice storms as a kid in the 1950s and 1960s. He also said, "[F]rom 2000 moving forward, we've seen these massive amounts of ice storms that we've never seen in the history of Oklahoma." Another participant said that it seemed like the freezing line has moved north in the winter which has caused more ice storms and another said that having three high end snowstorms in 14 months (Dec. 2009, Jan. 2010, and Jan./Feb. 2011) seemed unusual. One participant has noticed "more intense variations in the daily weather expressions," which have cumulative impacts on crops.

Plants. Observed changes in plant species were also mentioned. One decision-maker said plant hardiness zones have shifted northward. An explosion of woody invasive tree species was also cited, and four people said red cedar trees have invaded the state, which taxes the hydrological budget. Invasive kudzu and extreme amounts of milo were also topics of conversation. One person cited disappearing plants due to the lack of rainfall. Agricultural practices have also changed. One participant revealed, "In the last 10 years the established business of putting in winter wheat in early September and running calves and cattle on it starting in October, and running all winter long has changed. The percentage of winter wheat that is established early enough has dropped radically, by at least a factor of five, over the last five years."

Wildlife. Changes in birds, reptiles, insects, and fish were also noted, although one participant said they think land use changes have had a larger influence on wildlife populations than changes in climate. The same participant said white-winged doves are new to Oklahoma but he was not sure it was due to changes in the climate or land. Another participant has observed that geese do not migrate like they used to. Others noticed that horned frogs and lizards have died off. "The horned frogs . . . have really died off in the past 10 years in this area. Before it seemed all the time we'd catch them, play with them but now, I saw maybe one all of last summer," one participant stated. One person also mentioned that the roadrunner and jackrabbit populations have decreased, while rattlesnakes have become more prevalent. Another decision-maker said there is "some bug that I have never seen before eats my [Chinese Elm] trees." A creek that no longer has bass in it because of reduced streamflow was also mentioned.

4.3 Future Climate-Related Concerns

The decision makers were asked how the projected changes in future climate and variability in Oklahoma would impact their job duties and which would have the greatest impact. Before asking the question, however, the projected changes were described to them, which are shown in Table 2. More intense but less frequent rain events which would lead to an increase in flooding rain and drought was the most commonly cited change that would have the greatest impact. However, some of the participants said the other projected changes would concern them. Since the projections for climate change in Oklahoma were described in broad terms, the cited impacts were broader than when the participants discussed the current issues that impact their decision-making. Future climate-related concerns accounting for the

Projected Changes in Oklahoma's Climate	Resulting Impacts
More intense but less frequent rain events	• More runoff and flash flooding • Drought frequency and severity will increase • Wildfire risk will increase
Increase in frequency of hot extremes and heat waves	• Water resources will be stressed • Cattle will be stressed
Warm season becomes longer and arrives sooner; cold extremes will decrease	• Crops more vulnerable to late freeze events • Pests may increase • Increased year-round evaporation from ground • Increased transpiration from green vegetation due to longer growing season

Table 2: Projected changes in the climate of Oklahoma and some of the resulting impacts.

projected changes are described for each sector below.

Water Resources. One participant from a water management agency said that all of the stated changes in Oklahoma's climate would impact their operations, however the most commonly cited change that would have an impact was more intense but less frequent rain events. If floods and droughts were to occur more frequently it would be taxing on resources. In fact, several decision makers were concerned about drought and the resulting decrease in water supply that would occur. Competing interests for water (e.g., energy production, drinking, and recreation) mean that problems can arise when water is in short supply. For example, the participants at a water management agency said that they had an issue with one eastern Oklahoma lake in 2006 because the public questioned why water was being drawn from the lake during a substantial drought. What the public did not know was that the water was being used for hydropower purposes, a contractual obligation. Another impact of drought is that it depletes soil moisture and can cause pipes to crack. A utility engineer said, ". . . we have clay soil and when the moisture content of the soil dries up, the clay cracks and will snap our pipes." Dry soil can cause water lines to break which depletes the water source even more and increases maintenance costs. This was an exceptional problem in Oklahoma City during the summer of 2011, when water main breaks occurred at more than four times the normal rate (Patterson 2011). Drought also exposes sediment, which increases the probability that the sediment will flow into rivers and streams once rain does fall. Increased sediment transport can negatively impact water quality, which may cause water suppliers to have to treat the water more.

Heavy rain and floods deposit sediment into locations where it can cause further problems, such as reservoirs. Excess sediment takes up reservoir storage capacity that would otherwise be allocated to water. Flooding can also cause raw sewage and petroleum products to leak into the water supply. One water quality expert commented that safety controls are in place in industrial areas that might have contaminated soils, but that the controls are not designed for a 100-year rain event. If 100-year storms become more common, the potential exists for water supplies to become contaminated. More broadly, if extreme events such as droughts and floods are to become more common, resources could be depleted since decision makers have to spend time and money cleaning up afterwards.

In addition to concerns about drought and decreased water supply, the increased frequency in hot extremes and heat waves would also be problematic for water resource decision makers. As two participants pointed out, more heat would increase evaporation rates which would decrease water supplies. Evaporation rates already exceed annual rainfall in some parts of Oklahoma, so warmer temperatures would only exacerbate the problem. In conjunction with hot extremes and heat waves, a longer warm season would also stress some water supplies that are used by irrigation districts. For example, farmers in southwest Oklahoma use water from Lugert-Altus Lake for their cotton crops. A longer growing season would increase the demand on a water supply that is already stressed.

Energy. Both of the participants in the energy sector said that an increase in the frequency of hot extremes and heat waves would have the biggest impact. This projection would concern the participants if their system was not designed to handle the load that accompanies extreme heat because service could be disrupted. Load issues were not a problem, however, during the record heat in the summer of 2011. In fact, hot weather can actually be beneficial for the energy industry because it increases their revenue. Revenue would also increase with a longer warm season.

Transportation. A changing climate could also impact the transportation sector. One participant said that they need to know about changes weather so they can plan ahead because it takes several years for cities to make large purchases such as snowplows. A transportation engineer said that bridge and road designs would need to be changed to accommodate the projected changes. The engineer said that heavy rain and flooding is abusive to road and bridge infrastructure. She also noted that design equations take shear velocity into account, which is very different for flash flood type events. So, the equations would need to change if the rainfall patterns were to change.

Agricultural Production. The agricultural-related participants were concerned about several of the projected changes for Oklahoma. More intense but less frequent rain events would impact the industry in a variety of ways. First, changing hydrologic cycles affect plant species. Also, drought can decrease crop production, which has an economic impact on farmers. For example, during the 2010-2011 drought, farmers in the western part of the state were hit particularly hard. Stock ponds dried up and farmers had to sell their cattle (Oklahoma Climatological Survey 2011). Hay was also in short supply. In July 2011, hay shortages were so significant that Governor Mary Fallin signed an executive order that waived wide load permit requirements for haulers, allowing them to carry hay that was 12 feet wide as opposed to 11 feet wide (a standard hay bale is six feet wide) (Fallin 2011). This allowed more efficient transport of hay from sources outside of Oklahoma. Overall crop production was expected to be rather dismal. For example, the U.S. Department of Agriculture forecasted that the 2011 Oklahoma cotton crop would produce 85,000 bales, down from 422,000 in 2010 (Hays 2011).

A lengthening growing season would produce tradeoffs for the agriculture sector. On one hand, a warmer climate would mean that there would be more time for crops to grow. For example, a representative from an agricultural agency said that a warmer climate could be beneficial to cattle producers. ". . . if it's warmer they don't have to put out as much hay through the winter time. That saves them money," she said. Alternatively, a warmer climate is also conducive for invasive pests, which can be problematic for producers.

". . . if it's warmer [cattle producers] don't have to put out as much hay through the winter time. That saves them money."

A warmer climate does not necessarily mean that temperatures will not get below freezing, and a late freeze can devastate crops. In fact, one participant said that late hard freezes in April have already had a major impact on winter wheat and fruiting trees.

Ecosystems. Ecosystems and natural resources are closely tied to agriculture and just as a changing climate would impact agriculture, it would impact ecosystems as well. A representative from a natural resource stewardship agency said the projected changes would have equal impact on their operations because they deal with so many parts of nature and the ecosystem. An official from a wildlife agency said his biggest concern was the projected change in the amount and frequency of precipitation. He was concerned about it getting drier, especially between March and June, because it is a critical season for breeding. He stated that "unusually dry conditions can affect [wildlife's] reproductive success" but that it typically takes several years of drought to have profound effects. A drought can also impact the ability of wildlife to survive Oklahoma's hot summers. One biologist commented, "Many grassland birds; lesser prairie chickens and bobwhite quail . . . are very dependent on shrubs for thermal cover in the summer." If the shrub growth is stunted by drought, these particular species may have a difficult time surviving. Decreased land cover can also be a problem for the entities involved in carbon sequestration verification activities. If crops and natural grasses die off, officials cannot verify that carbon was sequestered. On the other hand, flooding is also problematic for carbon sequestration programs because heavy rains and floods can wash away land and expose sequestered carbon.

Warmer temperatures and lengthening warm seasons will also impact wildlife. One participant from a wildlife agency noted that summer night time temperatures could be problematic if, for example, the low temperature only reaches 80°F as opposed to the 60s or low 70s. Additionally, one biologist commented on how temperature changes can alter the timing of incubation. He stated:

> There are several documented studies about premature incubation because of temperature in ground-nesting birds. A lot of ground nesting birds will lay their eggs and wait until all the eggs are laid and then they sit on them and begin to incubate them so they hatch simultaneously. But if the temperature begins incubating before the hen decides to sit on those eggs, then you're going to have unsynchronized hatching possibly, and they can't take care of all their chicks.

Also at risk with an increase in hot extremes is the increased risk of wildfires. While fire is a natural process used to rebuild ecosystems, it can also be devastating. Wildfire is also an additional threat to verifying carbon sequestration.

Temperature tolerance is an issue for land-based species, but it is of particular importance for aquatic species. Unlike their land based counterparts, aquatic dependent species "cannot exactly just pick up and move," a biologist stated.

This could be especially problematic in Oklahoma because the rivers generally flow west-east as opposed to north-south, which limits the ability of aquatic species to move northward to cooler water.

One participant noted that a decrease in cold extremes could also impact ecosystems. While the participant did not provide specific details, he said that historically cold weather events have probably been important for "driving some processes and decreasing something that needed decreasing."

Human Health. The individual from the health sector did not get into specifics, but said a changing climate would have a "major impact on the at-risk population." The participant said the state is already seeing a shift toward at-risk populations. "The younger work force is the minority whereas the retirees are the majority," he said. Given the older generations generally have more health issues than younger generations; a changing climate would only exacerbate the problem.

One emerging health issue within the last few years is that there has been an increase in harmful algal blooms in water. While many variables such as high levels of phosphorous and nitrogen promote the growth of the organism (Oklahoma Department of Environmental Quality 2011a), climate also plays a role. According to one participant, changing flows, whether faster due to heavy rain or stagnant because of drought, changes the sediment transport which can feed the algal blooms. Stagnant flow coupled with high temperatures could be especially problematic as the climate continues to change. In fact, blue green algae problems were cited for several Oklahoma lakes during the summer of 2011 (Oklahoma Department of Environmental Quality 2011b).

Society & Public Safety. The projected changes in climate and variability for Oklahoma will certainly impact society. If disaster declarations continue to mount, resources will be stretched thin. An emergency management representative said that it is difficult to respond to disasters when they happen so close to one another. Drought would be a concern from a drinking water standpoint in addition to the fact that lower lake and river levels would keep people from going swimming and boating. Drought and water shortages could have a significantly negative impact on state parks and recreation areas, especially for those where water is the main draw to the park. A park ranger said, "If we started to see a dramatic decline in the amount of water, or an increased frequency in the amount of time the stream goes dry . . . we would get a lot of people who would come in and say, 'Where can I go swimming? How come I can't go swimming anymore? What's happening?'." Drought would also be problematic for city planning. A participant from one Oklahoma city said his town has historically been prone to flooding and has worked on measures to reduce flooding issues for years. The current management plan involves getting rid of storm water as fast as possible. However, city officials would have to change their policies if rainfall was to occur less frequently. Instead of treating rainfall as runoff they would have to store more of it.

An increase in the frequency of hot extremes and heat waves would also impact society. A tribal representative said utility bills would increase if people had to run their air conditioners and fans more often because of the heat.

In addition to economic impacts, a changing climate would also impact cultural traditions. For example, one Oklahoma tribe does a pilgrimage after the first thunderstorm of the year. One participant noted that in 2011 the pilgrimage began in January, which was earlier than normal.

4.4 Adapting to Climate Change

The participants were asked whether their agency was doing anything in regards to climate adaptation only when it made sense to do so, based on their answers to previous questions. Even for those who answered the question, very few participants actually called their actions “adaptation.” Some decision-makers cautioned that while they occasionally took proactive measures to address some of the problems that climate-related hazards create, they did not want their actions being labeled as “adapting to climate change.” One participant noted, for example, “. . . I definitely wouldn’t want us going on record that we’re gonna be looking at climate change for potential . . . modifications in the future." He continued by saying one reason is that the cost of performing modifications is expensive and that, “You have to have a very high level of confidence in climate change data before you ever drive yourself down that path" and that his agency is more likely to adapt operations than infrastructure. Participants in water resources and agriculture cited the most examples of adaptation-like actions, followed by ecosystems, health, and society/public safety officials. The participants in the energy sector were not asked about adaptation actions because their planning timescales did not match up with the timescales for which adaptation actions would be relevant.

Water Resources. Some of the adaptation-like measures that water resource officials have implemented or may implement in the future include properly sizing sewer lines and treatment facilities. This flood control measure will help the governing agency be able to handle expected rainfall. There are also several actions that can be taken to adapt to drought or limited water supply. One action is to improve water efficiencies. This can be accomplished by lining canals to prevent seepage loss and converting irrigation canals to pipeline to reduce and prevent evaporative loss (e.g., Figure 11). If current water supply is insufficient to meet the demand, water resource officials noted that looking for alternative water sources is an option, which may include building pipelines between cities so that they can purchase water from other cities, as long as it is sustainable and mutually agreed upon.

Figure 11: Example of a water pipeline (courtesy of San Francisco News).

Agricultural Production. Many agricultural producers are already using techniques to deal with the variability that is present in Oklahoma’s climate. To get around untimely freezes, producers can use different planting schedules. Producers are using more efficient irrigation techniques such as no-till and low-till practices which reduce their need for water (e.g., Figure 12). They are also using different crop rotations to mitigate drought. One participant noted that producers in Kansas have

Figure 12: Example of no-till farming (courtesy of Mark Carlton).

already transitioned from irrigated to dry land farming within the last decade. “They can’t afford to pump the remains of the Ogallala or the High Plains Aquifer anymore. It’s too deep, too salty.” Transitioning to a less-lucrative farming technique has “shifted the economics of the culture,” she commented. Producers also have to use other feeds, forages, and hays to feed cattle because they can no longer rely on being able to feed them winter wheat. Another important aspect of agricultural production that plays into their ability to adapt to the variability of the climate is the financial market. Due to the unreliable nature of traditional farming practices, many producers invest in the financial market. They typically invest in something opposite of what they plant so that if they have a low yield, their investment will produce enough money to support them and vice versa, so that they have revenue on which to rely.

In addition to operational practices, there are also several ideas currently in the research stage that could help producers in a changing climate. Researchers are working on developing weather resistant crops, such as those that mature later to avoid hail damage that typically occurs in the spring, or developing seeds that do not shatter so badly during heavy rain. Adapting to drought is also a research focus. Some researchers are trying to develop crops that can survive on limited rainfall; others are looking into using alternative crops. Deficit irrigation is one technique in which researchers and producers are looking to adapt to a potential decrease in rainfall. One participant explained that instead of using 20 inches of water to produce a crop, for example, one starts to look at the crop they can produce with 16 inches or 14 inches, which may be closer to reality. Producing a crop with the amount of rain that is consistent with that which actually falls will decrease irrigation pressures.

Ecosystems. A few ecosystem-related adaptation measures surfaced in the interviews. One wildlife biologist noted that his agency will adjust hunting and bagging limits based on population monitoring and whether the wildlife have experienced prolonged stresses such as a drought, or multiple severe winters in a row. It is not a long-term change, however, and typically done on a seasonal basis. Another participant working with wildlife noted that his agency has been given guidance on building adaptation strategies but “adaptation” is a “wildly defined” term. Consequently, the actions that he and his co-workers are supposed to take are unclear. A park ranger gave an example of an adaptation practice that could be implemented if the situation warranted. The ranger said that if drought were to occur more frequently, the recreational options in the park that are rooted in water would become less desirable. In order to adapt they could start to focus on the park resources unrelated to water, which would hopefully limit the potential drop in park visitation.

Another participant affiliated with the ecosystem sector commented that he had not yet put a lot of thought into adaptation. The participant acknowledged that up to this point his agency had solely focused on mitigating climate change through carbon sequestration projects but that they should probably start to focus on adaptation as well. He said, "You know we’ve been focused on mitigation and we’re having some luck on that but . . . even under the best case scenario [we’re gonna have to adapt]."

Health. One adaptation measure that the health official noted was that if snow and ice storms were to become more common in the winter, they could move their vaccine clinics to the fall so that they would not be disrupted as frequently.

Society/Public Safety. One city official noted that his city has looked into using permeable pavement practices to adapt to heavy rains that occur (e.g., Figure 13). They have also looked into using other adaptation and sustainability projects but those are typically the first thing to be cut if it is an added expense. The participant also noted another limitation. City government decisions have to be socially acceptable, which creates a challenge when one is trying to implement a practice that might be outside of those bounds.

Figure 13: Example of permeable pavement (courtesy of Miami Group Sierra Club).

4.5 Current Use of Weather & Climate Information

Understanding the impacts of weather and climate and how decision makers are currently addressing the issues they face is the first step to being able to provide them with more useful information. Another important component is understanding the spatial and temporal scales of their decision-making, both for short-term decisions and long-term planning. Thus, we looked at the frequency in which decision-makers use weather and climate information, their planning timescale(s), and the spatial scale(s) at which information is relevant to them.

4.5.1 Frequency of Use

Decision makers in Oklahoma use weather and climate information at a variety of frequencies. Most agencies and tribes monitor weather, climate, and water conditions and forecasts on a daily basis during particular seasons (e.g., severe weather, winter weather, wildfire, heat, growing, and harvest) or surrounding extreme events. The water resources community monitors water conditions over a variety of timescales (monitoring long-term to extreme events) whereas health and public safety officials focus on the days prior to, during, and after significant events. The agricultural community monitors weather and water conditions daily and seasonally to make decisions regarding crop production, chemical applications, and harvesting, and the energy industry uses weather information on a daily and weekly basis.

Water Resources. Water resource officials use weather and climate information to make decisions at a variety of frequencies ranging from daily to decadal, and the information often plays a more significant role during extreme events. One participant said they use weather and climate data to make decisions "constantly, daily, and hourly." Hydrologic technicians monitor forecasted and fallen precipitation and streamflow conditions on a daily basis in order to determine when personnel need to be sent into the field. Daily monitoring of temperature forecasts are also important during the winter when pipes can burst during freeze events. Heavy rain and flooding also impact daily operations. Crews might have to go out and look for overflowing manholes or washed out pipes from an embankment that has been eroded.

Decisions are made on a seasonal and yearly basis as well. Water utility officials have to plan for cold weather and "make sure that the sewage and lift stations and treatment plants are weatherproof enough that they can operate" when temperatures are below zero. A tribal participant said they analyze the gap between water supply and demand on a yearly basis.

Occasionally climate information is used to make decisions on a decadal basis during certain projects. A participant from a federal agency cited an example of a time in which they had to look at the past hydrologic record for one of their reservoirs. A water supply entity wanted to raise the level of the conservation pool so they would have a larger water supply to meet future demand, and the participant had to complete an analysis to see whether their request could be granted.

Energy. The officials in the energy sector use weather information on a daily to weekly basis. One participant commented, “We constantly monitor the weather and we have meteorologists we turn to on a regular basis.” Another participant described how they use weather information to make decisions. “. . . we use basic temperature forecasts to determine the time of day we can re-route power . . . because there are a lot of things we cannot do on a day like today [when it is above 100°F], just because [the power lines] can’t handle that much load. But if it’s below 85°F, there’s a lot more things we can do,” he said.

Weather-related decisions are also made during extreme events. One participant said that during an extended period of temperatures greater than 100°F he constantly communicated with employees about the high heat and the potential dangers that accompanied it. “. . . we don’t want to have any heat strokes today because yesterday one of our employees was overcome by the heat,” he commented.

“We constantly monitor the weather and we have meteorologists we turn to on a regular basis.”

Transportation. Weather and climate impact transportation officials every week. Weather conditions impact work schedules since, for example, crews cannot lay asphalt on roads when it is raining. A public works participant said weather plays a big role in their projects. He said, “One of our caveats we always use when people ask, ‘When are you going to do this project?’ . . . It’s always ‘weather permitting’ simply because the weather gets in the way of us doing work.” Weather and climate information also plays a role during decisions that occur every decade or so during large projects. A transportation engineer said that bridge design and placement are based on the history of road closings, overtopping, and traffic advisories, as well as historical streamflow and precipitation data. She also noted that bridges are designed for 25- to 50-year storms to prevent frequent roadway overtopping.

Agricultural Production. Climate-related decisions are made on a daily and seasonal basis in the agriculture community. It is vital to know daily wind and temperature forecasts to know when to spray pesticides and insecticides. One participant noted, “Wind is one criterion that affects our regulations because . . . various chemicals can’t be sprayed with a certain amount of high wind speed." The frequency and timing of rainfall is also crucial for crop growth since intense events will primarily produce runoff and not recharge the ground. Deciding whether to take livestock off of a crop is a daily to weekly decision because grazing time affects the yield of a crop. One participant cited the Oklahoma Mesonet (McPherson et al. 2007) as a valuable tool used on a daily basis to make decisions about planting, harvesting, and fertilizing. Daily weather information is also important for post-mortem analysis of crop failure and post-event response. For example, one agriculture agency worked with the state emergency management agency to drop hay for cattle after a major ice storm. Producers also monitor weather conditions during certain seasons to make decisions about whether to purchase cattle. Purchases may be delayed depending on crop growth rates.

Ecosystems. Decision makers in the ecosystem sector use weather and climate information on a daily to decadal basis to make decisions. Daily and weekly weather conditions impact timing for when to survey plants and wildlife. Prescribed burning decisions are also impacted by weather conditions on a weekly basis during certain seasons, since fire is an important component in maintaining wildlife habitat areas. Extreme events may impact wildlife management decision-making if there are several years of back-to-back events. A wildlife biologist commented, ". . . if we have a prolonged drought you'll see a bunch of restrictions on turkey harvest," although a single short-fused event typically doesn't have a large effect on wildlife.

Weather conditions also impact the ability of conservation personnel to complete training exercises on a yearly basis, and wildlife managers make decisions about hunting bagging limits on a 5- to 10-year basis.

Health. The health sector uses weather information on a daily basis during particular seasons and during extreme events. Vaccine clinics are hosted by health officials during certain times of the year and they monitor current conditions and forecasts to determine whether or not to open the clinics. The participant from the health agency told a story of a time where they made a decision to cancel a vaccine clinic based on a forecast. "It's a good thing we didn't [open the clinic] because they got hit with severe thunderstorms and severe lightning, and we kept those people off the street," he said. The participant also noted that he emails forecasts to his co-workers to let them know about impending severe weather.

Society/Public Safety. The society/public safely sector mainly uses weather information during daily operations, including extreme events. Some weather-related decisions are made on a yearly basis. Emergency management officials prepare for potential natural disasters, and the impact that weather information has on their decision-making depends on the magnitude of the forecasted event. The relationships they need to accomplish tasks are already established, but actual preparations and moving supplies happens no more than a week in advance of the storm. The officials make decisions as to whether to prepare based on weather models, which may sometimes lead them astray. "The hardest part of dealing with this is when we're a few days out we really have to govern, 'Okay, how many resources are we going to start moving, committing, putting on standby,' based on, what are really just models," one emergency management representative said. Severe weather also impacts parks and recreation areas. A park ranger noted that his agency's law enforcement division is responsible for alerting park visitors about impending severe weather.

Yearly decisions based on weather and climate information in one city in Oklahoma are currently infrequent, but one city official expected the information will play a bigger role in future decisions once the duties of his position, which was relatively new at the time of the interview, become more diversified.

4.5.2 Planning Timescales

The maximum planning timescale for most of the participants in this study was 15 years or less. Figure 14 depicts the maximum planning timescale mentioned in each sector. Comprehensive planning occurs on longer timescales but the bulk of the planning decisions focus on one to five years. Agencies that plan, construct and monitor transportation and water resources infrastructure have a longer planning horizon; typically 25 to 50 years for

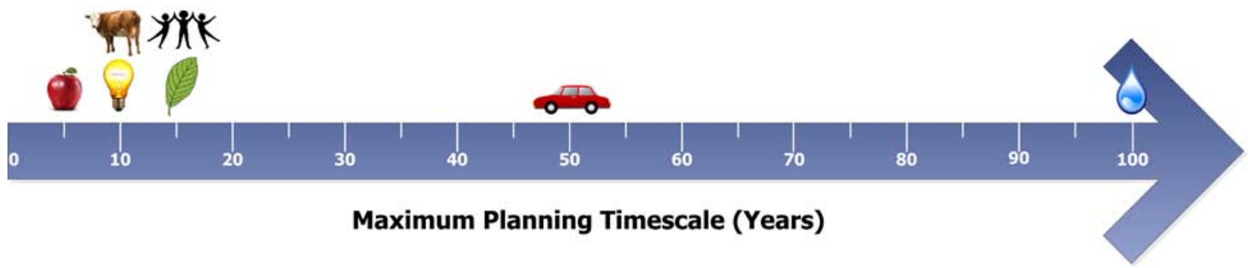


Figure 14: Maximum planning timescale for each sector, as stated by the participants.

transportation and up to 100 years for water resources. Even then, five year plans are often used in regards to weather and climate-related activities. This is especially true of cities and tribes. Due to the constant barrage of weather and climate extremes in Oklahoma, it is difficult for decision makers to focus on planning ahead. Oftentimes they are just trying to stay afloat and address and react to current issues.

 ***Water Resources.*** Water resources represented the sector with the longest planning horizon. Although some budget and science plans focus on 10 years or less, the majority of water resource planning focuses on 20 to 100 years in the future. For example, a participant from an agency that focuses on environmental issues said their drinking water plans look out 20 years and account for projections in population growth and the subsequent demand in water that will take place. She also pointed out that their drinking water loan and grant program involves 20- to 30-year loans. City and tribal water plans focus on the 30- to 50-year time frame. Although their budget cycle is only five years, one city representative said their waste water master plan looks out 20 years and they use 30- to 50-year growth projections to plan for changes and updates to infrastructure such as pipes and sewer lines. The state's water plan is also a 50-year plan. One agency responsible for major water resource infrastructure had the longest planning horizon, 50 to 100 years. A participant said they complete 100-year yield analyses for infrastructure planning purposes.

 ***Energy.*** Like many agencies, energy officials said their maximum planning timescale was 10 years, although one participant pointed out that most plans are less than that. He also noted that seasonal planning is important, especially during the fall when they gear up for ice storms and stock up on extra power poles and wires. The other energy official said he plans on a yearly basis but gives himself the ability to go five years without additional action. The participant explained the reasoning behind the relatively short timescale by saying that the "distribution system is kind of a living animal, so it's always constantly changing. We have growth; we have lines that get re-routed. It's really tough to sit there and say what I'm seeing there today I can extrapolate over five years." Weather and climate is only one of many variables that must be considered when planning for the future in the energy sector.

 ***Transportation.*** Transportation was the other sector with relatively lengthy planning horizons. Constructing roads and bridges is a time consuming and expensive process, so major infrastructure projects must last for a while. One engineer said that bridges are designed to last 25- to 50-years.

Shorter time scales are used for smaller projects. A public works official said his planning horizon is typically 18 months; his annual budget planning begins about six months before the budget is due. He said, "We've got six months from the time we say, 'Okay, this is what we want to do,' until that fiscal year starts and then we've got a full year that the project has to go." An activity such as obtaining salt for the winter season is incorporated into the annual budget, and the city begins the process to procure the salt about five months in advance of when it is needed.

Agricultural Production. Planning in the agriculture sector occurs on a much shorter timescale than water resource and transportation planning. Agricultural researchers need about 10 years to breed a crop due to the time needed to grow and test a new variety. However, the planning horizon for the agricultural producer is five years or less. One participant said agricultural loans typically last five years, and planning horizons follow the availability of funding. The individual also spoke a lot about the influence of business interests in the agriculture community. She said the business interests control the timing of planning because "once you've made a major investment in irrigation [for example,] it is business smart to utilize it to the maximum to increase your return." An even shorter planning horizon was cited by one participant, who said that from the perspective of a producer, "I can't worry about what's happening 10 years from now, if I'm still not making money two to three years from now I'm gone."

Ecosystems. Planning timescales for ecosystem and natural resource activities are similar to the agriculture sector in that most planning horizons are 10 years or less. A participant from a conservation agency said their non-point source pollution plan looks out 15 years, but that was the longest planning timescale. One reason for this shorter planning horizon is that natural resource conservation work often involves private land owners who do not want to make decisions that will impact their children and grandchildren. Since 97% of land in Oklahoma is privately owned, ecosystem managers must collaborate with land owners to accomplish their goals. A participant from a natural resources management agency said that private land owners are not going to sign a contract that lasts 100 years. He said:

> Every once in a while you'll have somebody who has a lot of gas wells that they can tie it in with hunting quail because that's all they got the land for and they'll sign up a 100 year contract. But other than that, these guys are like, "You know I don't even know what I'm going to be doing next year, let a hundred years from now, I don't want to tie it up for my kids."

Thus, 10-year contracts are typical for land owners. A participant from a wildlife-related agency also cited 10 years as their maximum planning timescale. In addition, he noted that their planning is not very precise but that their skills have improved since the early 1990's. A participant from another wildlife agency said their threatened and endangered species and strategic plans look out five years, but 80% of their planning focuses on three years or less.

Health. The participant from a health agency indicated that his agency-wide plan looks out five years. However, he noted that they "don't include weather in that [plan]." The participant's main planning activities included emergency exercise preparation that occurred six months in advance. This planning coincided with his emergency manger-type duties.

Society/Public Safety. The participants' plans who were affiliated with the society/public safety sector ranged from three to 15 years. One participant who is affiliated with emergency management said their plan is updated every three years. A tribal representative said their planning timescale looks out a maximum of five years and that they focus on short-fused hazards like ice storms, snow storms, and tornadoes. He said their plan does not include anything related to drought or future water resources. A city participant said that aside from comprehensive plans which might look out 15 years, city plans generally focus on five years or less. He said, "A lot of that's a function of the fact that you're working with elected officials. So they have to draw that balance on what's gonna be happening 10 years down the road . . . and what can I do right now that's gonna impact [the city]." He also noted that the time frame one cites might be deceptive because the amount of time one actually spends on the work may be nowhere near the amount of time that it took to complete a project. "In most cases, the day you start planning, or thinking about the project, by the time you develop it and get it funded, then you're looking at 7 or 8 years, but you've only worked for 24 months or 36 months on actual work," the participant noted.

4.5.3 Spatial Scales

The participants were asked about the spatial scale(s) at which weather information is useful to them. Their responses ranged from city/local scale, to county scale, to sub-state regions. City and county-level data is used most frequently, however. Decision-makers also use information that extends beyond state boundaries. The agriculture and water resources communities are primarily interested in basin and sub-basin scales, as opposed to scales based on political boundaries. It is important to note that basins can vary in size from several states (Mississippi basin) to sub-state regions (Arkansas-Red basin) to a few counties (Blue basin).

Water Resources. Water resource officials use weather information that is as local as possible. They also prefer data that spans across the state's boundaries. Much of their analyses are completed according to river basins, which do not necessarily stay inside the confines of the state. One participant explained, "You're looking ultimately at everything that's gonna end up into a reservoir." Understanding how water transfers among basins is important, so as one participant stated, "Probably the more refined the better . . ." A couple participants cited the Oklahoma Mesonet (McPherson et al. 2007) as being a sufficient data source but wished other states had a similar system.

Energy. The two energy sector participants said they focus on local to regional (within the state) weather information. One participant commented on the importance of looking at forecasts for regions within the state because for ice storms, for example, actual ice accumulation can be off by 10's of miles from the forecast. He also does the same thing for thunderstorms, and focuses on the general region of the state that is forecasted to be impacted.

Transportation. The participants in the transportation sector cited using the Oklahoma Mesonet (McPherson et al. 2007) as a data source, and for the most part, its county-based weather instruments provide sufficient data. A transportation engineer said that data is interpolated to obtain information at desired locations. Finer scale data would also be useful, however. She noted that Tulsa and Oklahoma City have city-scale flood issues and could use finer resolution rainfall data. In fact, Tulsa had about 130 stream gauges installed at one point; some are no longer in operation. The other participant in the transportation sector agreed that higher resolution data would be really helpful. He and his colleagues "were excited" about the Oklahoma City Micronet (Basara et al. 2011) when it was operational; 36 stations were located in and around the City.

Agricultural Production. Participants from the agriculture sector prefer localized weather information: ideally, field-specific data. One participant noted, "Having something that's an average for a county or a climate division or a forecast division is not useful, especially for precipitation." The same participant also said that watershed specific data is very important.

Ecosystems. The spatial scale that is useful to the participants in the ecosystems sector varied from local to a multi-state region. One biologist stated that the scale depends on the objective of the work. He said the scope of their studies range from an individual land owner's property to portions of multiple states. Another participant said county-level data is sufficient for conservation districts.

Society/Public Safety. Local weather information is needed for extreme heat and heavy precipitation events from a public safety perspective, but the desired spatial scale is highly dependent on the type of event (e.g., tornadoes are extremely localized whereas ice storms impact a much broader area). One participant noted that emergency managers wish they had data for each intersection in a city but he realized that is not feasible. He said, "The local emergency manager wants to know about his town down to 5th and Main, which we know you can't predict." Localized data is unnecessary for city planning, however. One city official said that cities often compare themselves to "peer" cities that have similar demographic and economic situations. Weather and climate is only one component of many variables that play a role in their decision-making. He also noted that they typically look at data on a regional basis within the state.

4.6 Incorporating Climate Projections Into Planning

After talking to the participants about their planning timescales and the spatial scales at which weather information is useful, they were asked whether they have considered or have already incorporated climate projections into planning efforts as opposed to just using historical data. Figure 15 shows that only three participants said their offices have used climate projections in planning activities. An agricultural participant said extension agents have been trying to warn producers of potential problems, especially drought. He noted that best management practices are promoted and producers are encouraged to conserve the resources they have. A participant working in the ecosystem sector said that they have been working with several agencies on a complex

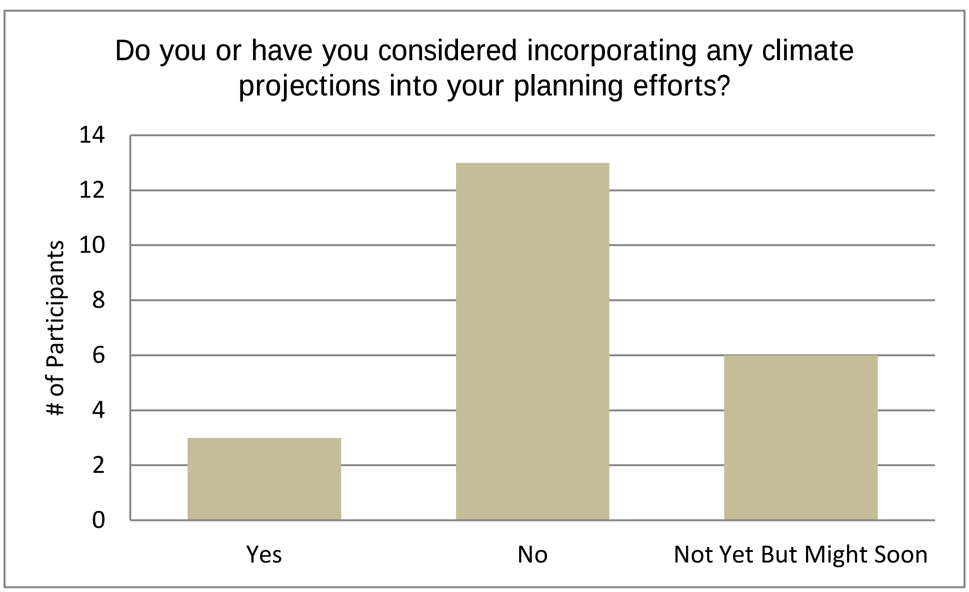


Figure 15: Whether the participants have considered or have already incorporated climate projections into their planning efforts.

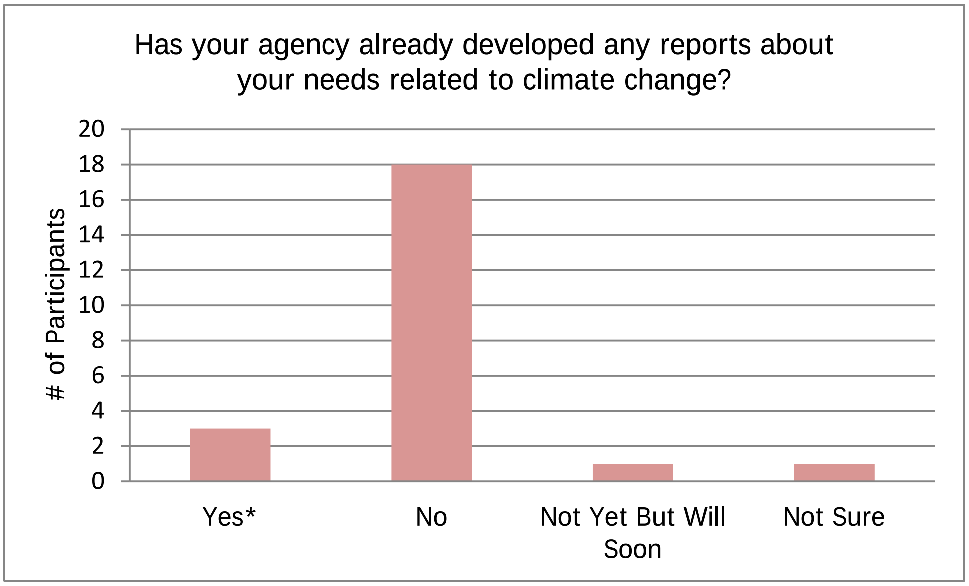


*Figure 16: Whether the participant's agencies have developed a report(s) about their needs related to climate change. *Of the three agencies who said yes, two of them were agencies that worked together on the same report.*

mapping tool that projects changes in species migration patterns. Nevertheless, the majority of the participants (n=13) said they have not incorporated projections into planning efforts. The rest (n=6) said something to the effect of, "not yet but we might soon." Some of the reasons the participants said they have not but might in the future were because it was not a priority until recently, they were waiting from guidance from headquarters, and/or they planned on incorporating the projections in the next iteration of their strategic plan. Reasons for having no plan to include projections in the near future were that the climate projections were not reliable and there was too much uncertainty to make decisions, they did not have much freedom to change design specifications and design changes would have to come through federal mandates, and political concerns.

4.7 Research, Data & Educational Needs

The participants were asked a series of questions pertaining to their need for climate information, education, and decision-support tools. So as not to be redundant and ask questions that they might have already answered in internal reports, the participants were first asked whether their agencies had already compiled information on their needs related to climate change (Figure 16). An overwhelming majority (n=18) of the participants said their agencies had not. Of the three that said their agencies had, two had worked together on the same report. Finally, one participant said that the next update to his agency's strategic plan will have a small section on climate change, and another participant said he was not sure whether his agency had created such a report.

The participants were also asked about their need for long-term climate projection information. They were given some information on climate models and asked to describe what their ideal climate model would show them, putting aside scientific and computing limitations. Some decision-makers remarked about how their *ideal* was not possible, and may never be. Thus, the conversation often turned towards the point at which climate projections become *useful*.

The question was changed to add more specificity about half-way through the interviews because the original question was too vague. In the revised version, the participants were asked about the temporal and spatial scales in which climate projections would be helpful, as well as how they would like temperature and precipitation projection information displayed (e.g., averages, extremes, or changes in distributions). These questions were not applicable for the participant in the health sector because of his relatively short, emergency management-focused planning timescale.

4.7.1 Temporal Resolution Needs for Climate Projections

The temporal scales at which the decision-makers said climate projections would be useful were closely related to their planning timescales. Water resource officials were interested in temporal scales out to 100 years. Transportation officials said long-term projections out to 50 years would be helpful. Alternatively, seasonal and up to decade-long projections would be important for agriculture, ecosystems, energy, and public safety.

Water Resources. A variety of timescales would be helpful to water resource officials, and longer timescales would be more useful to them than some of the other sectors. Fifty to 100 year projections could inform long-term infrastructure investments. One representative said that 40- to 50-year projections could change their regulations. Another said 20- to 30-year projections could inform budget planning since water treatment units and pipes are financed for 30 years (although, as she also noted, some have been in place for 100 years).

Energy. The two participants from the energy sector were interested in projections up to five years. One participant commented that he was "not going to pay as much attention to a long-range 100-year model . . ."

Transportation. In the transportation industry, 10 year projections would be useful as a planning tool, especially for capital improvement projects. From a longer term perspective related to the lifetime of roads and bridges, 50-year projections would be the maximum timescale at which the information would be useful.

Agricultural Production. Consistent with their aforementioned planning activities, the agriculture representatives were interested in relatively short timescales. Seasonal to 3-year projections are important from an economic standpoint, especially since one might not have the same job in 10 years. An agricultural researcher was interested in 10 year projections, however, because it coincides with the time it takes to breed new crop varieties. "What I'm developing today is not going to be on the market for anywhere from 3-10 years depending on what the product is," he noted. Another participant said that skepticism grows as the projections get further out and that 80- to 90-year projections are too far out and do not give people enough concrete information to make decisions.

Ecosystems. Seasonal, annual, and decadal projections would be useful from a wildlife management perspective. One biologist emphasized that validation would be an important factor as to whether he could make decisions based on a model. From a public education standpoint, nothing longer than 10 years would be useful to ranger personnel who frequently interact with the public. One park ranger said, "Once you get past five or 10 years, it's too abstract. People just can't wrap their heads around that." He noted that he is used to thinking in 100- to 1000-year time periods but that most people are not able to make the connection to then and present day.

Society/Public Safety. The useful timescales for the societal-focused participants varied considerably. Seasonal (3- to 6-month) projections are important from a disaster preparedness perspective, but a tribal representative was interested in 80- to 90-year projections because they wanted to know how their children and grandchildren would be impacted.

4.7.2 Spatial Resolution Needs for Climate Projections

A few of the participants seemed to understand that while they can obtain localized weather forecasts, climate model projections cannot be provided on the same scale. Thus, their stated spatial needs for climate projection information were broader than their need for weather information. Their choices ranged from city/farm scale to the entire state but the most commonly cited scale was regional within the state (i.e., breaking the state into four or five regions).

Water Resources. The most commonly cited scale by the water resource representatives was regional within the state. Understanding interactions on a basin to sub-basin scale and using an ecoregion approach were also very important for these decision makers, since some water resource planning depends on what happens with inter-basin transfers. One participant explained:

> The way the state is going is that they're trying to manage things on a watershed basis in terms of what the future supplies are and what the future demands in that watershed are going to be. So that type of information would be critical for the water plan to know how much water is going to be available in the basin.

Scaling the projections to the basin would also help capture the variability of precipitation across the state.

Other participants said a more refined scale would be needed. One participant said that at a minimum, county-level projections were needed because that is the point at which local decision-makers begin to understand how the information relates to and impacts them.

Energy. Both of the energy sector participants were interested in projections at the regional level. One of the participants noted that climate projections do not need to be too specific because he generalizes across the system when calculating certain load factors related to the climate. Typically, he uses a single city in the center of his service area as a proxy for the rest of the locations.

Transportation. Regional projections would be useful for the transportation sector. However, one transportation engineer noted that spatial resolution is not incredibly important to her. She also noted that she would not rely on the projections exclusively but would keep them in the back of her head so it would not appear that certain design specifications came out of thin air.

Agricultural Production. Ideally, producers would like farm-scale climate projections. However, one participant noted that they realize that is not possible. Thus, regional projections might be useful, but that is only one factor they consider when making decisions. Producers must incorporate a variety of variables, such as world markets, into their decision-making processes.

Ecosystems. The spatial scale at which climate projections become useful for decision-makers in the ecosystem sector varied from local to the multi-state scale. One biologist said that the scale depends on the organism, as some are more widespread than others. Another participant said that county-level information would be ideal but that regional projections would be useful.

Society/Public Safety. From a public safety standpoint, regional projections would be useful. One city official said the data needs to be fairly local but not necessarily at the city level. He also pointed out, "As you get further geographically from your city, the less credible the data is in terms of presenting it to elected officials."

4.7.3 Effective Statistical Representation of Climate Projections

Typically, climate models project future average changes in precipitation and temperature. Other variables such as evaporation rates, humidity, and soil temperature and moisture are more useful to some decision makers, which is discussed below. For simplicity, the participants were only asked about their preferences pertaining to the statistical representation of precipitation and temperature trends. Most of them preferred projections that would show the changes in extremes and distributions, because as one city official commented, "It's the variations that cause problems."

Water Resources. The type of projection information in which water resource officials were interested varied greatly. For instance, one water quality official said that averages would be important as they inform the environmental standards. She also noted, "All the state and federal environmental rules have caveats for extreme weather events." One water resource engineer said he would like to see, for example, "[The month of] May will, on average in the future, be X% wetter or drier." Alternatively, more details pertaining to changes in extremes or distributions would also be important. One drinking water official mentioned that knowing the changes in seasonal extremes is important because high water demand correlates with high temperatures. If they could determine what demands might be given a particular projection, they could better prepare for the future. Distributional changes in temperature would be informative as well. One water resource official was interested in the seasonal (i.e. distribution) changes in temperature, subsequent changes in evaporation, and whether it would increase or decrease. Evaporation rates are important to know when making water supply decisions.

Water resource engineers were interested in risk-based probabilistic information accompanied by confidence intervals (e.g., 80% probability of a 3 in. rainfall in a watershed, 100% probability of a 1 in. rainfall, +/- 10%). Frequency and timing of precipitation was also noted to be important, not just the total amount. One participant commented on how average flow is not necessarily a good measure of reality. "You know, average daily flow over a year has some flood events and some drought events, and what you really want to base a water plan on is base flow." Projected changes in regional rainfall rates and intensity were also cited as important.

Energy. Both projected changes in averages and extremes would be useful in the energy industry. One participant said it would be useful from a budget revenue planning standpoint. He also noted that he was not particularly interested in precipitation projections since temperature has a greater impact on energy than precipitation, excluding freezing rain and ice storms.

Transportation. Projections in the changes in extremes would be most useful for the transportation sector. One participant said he was interested in the extremes over certain thresholds, although the thresholds were not discussed. An engineer said that the frequency of the extremes is important to know because it impacts projects that are tied to the rivers. She noted that it is easier to complete construction projects when the rivers are low. The participant also said that funding is a big challenge, so understanding future projections sooner rather than later is ideal so she could plant seeds for funding.

Agricultural Production. The agriculture participants responded with a variety of answers. A researcher noted that average values are the most valuable from a long-term perspective. However, the same participant said that understanding the distribution of events, such as whether "unusually warm or unusually wet years" are expected, would help with economic planning. That way, crops could be planted that would thrive in the projected conditions. Another participant said he would want to see projected extremes rather than averages. Another important factor in agricultural decision-making is the probability that a hard freeze will occur, especially during a critical period. A crop may thrive in a warmer climate but it is also susceptible to late freeze events.

Ecosystems. A park ranger acknowledged that averages are important from a scientific standpoint, but from a public education standpoint the extremes are what catch people's attention. A biologist was interested in projections that show the number of days at certain temperature thresholds rather than an average trend. However, he was unable to cite the threshold(s) at which he was interested and it would probably depend on the plant or wildlife specie. Another biologist said seeing the projected changes in the seasonal distribution and frequency of rainfall would be important; he was interested in whether there would be few heavier events and more lighter events, or vice versa.

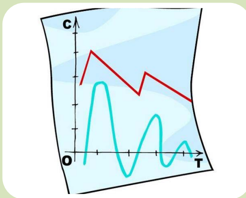
Society/Public Safety. The participants in the society and public safety sector were interested in extremes and probabilities; the extremes are problematic for people and infrastructure. One emergency manager commented, "If there's 6 in. of rain over a 2 month period, I'm not interested in that. If there's 6 in. of rain in [a city] in 2 hr., I'm interested in that." One city official also agreed that averages are useful but that it is the extremes that cause problems. He said, "It's the variations that cause problems with streets and water lines and things like that." The probability that heat-related hazards would occur was also a topic of interest.

4.7.4 Need for Data & Tools

The participants were asked whether they could envision any kind of weather or climate tool or visualization that would help them make more informed decisions in their operations. A few participants said they could not think of anything, a few mentioned that they use data from the Oklahoma Mesonet or that they needed more data and others described various kinds of tools that would be helpful (Figure 17). One substantial need that surfaced with and without prompting was the need to understand the thresholds for decision-making or taking action. Morss et al. (2011) also came to this conclusion. Meteorologists and climatologists have their ideas as to what thresholds are important (e.g., 100°F, 57 mph winds) but information is valuable to decision makers only when it is presented in a way that is consistent with the point(s) at which they take action.

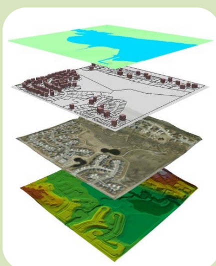
Another need that surfaced across numerous sectors was the need to understand changes in second order variables such as evaporation and stream inflow as opposed to just first order variables like precipitation and temperature. The need to model second order variables was also a finding during a sectoral breakout session at the climate adaptation meeting (Lunday 2011). Some of the meeting attendees were interested in the variables such as evaporation rates, soil

Data Needs



- Up-to-date historical precipitation records
- Better ground water measurement network
- Improved data quality, especially for precipitation records
- Climate data that is compatible with geographic information systems (GIS) formats
- Time series analysis of historical precipitation trends at certain thresholds

Tool Needs



- Prepackaged software that city planners can use to develop climate action plans
- GIS-based tool that shows changes in temperature and precipitation
- Severe weather situational awareness tool
- GIS-based tool that maps or graphs the impact of rainfall events at certain thresholds
- Tool/model that relates atmospheric temperature to water temperature
- Join information across state boundaries
- Tool that manages computer programs and switches them to storm mode when appropriate to collect data
- Graphical representation of trends in precipitation events

Figure 17: Compiled list of the decision makers' need for various data and tools.

temperature and moisture, days near or below freezing, humidity levels, and pollutants (for air quality alert days). Some attendees also said that knowing the trend of particular weather events (e.g., floods, ice storms, droughts, etc...) as opposed to precipitation and temperature would be informative. There seemed to be a general consensus across all of the sectors at the meeting that temperature and precipitation are too abstract whereas weather events are concrete and people are able to relate to them more easily. Furthermore, most decision makers do not have the time or in-house expertise to complete their own analysis and compute indices for second-order variables.

Water Resources. Two water resources representatives said that their biggest need is more observational data. One water resource engineer said their critical need is up-to-date precipitation information. He said they are basing their infrastructure design decisions on NOAA Technical Report 40, which was last revised in 1983. "It's out of date . . . we're missing 30 years of data," he noted. Another water resource official said they need a better network to measure ground water in real time and to be able to measure surface-groundwater interactions. She noted in order to "understand climate models or adaptive management models, we need the groundwater network . . . and we need it to interface with the surface water network." A participant whose work focuses on water quality said they already have a GIS-based tool that shows drinking water intake, landfill, and waste water facility activity occurring at their facilities. However, they might have a need for a tool that provides maps or graphics of rainfall events at certain thresholds. She also noted that storm water consultants generally know the correlation between rainfall and pipe capacity but that they could probably use more data to increase the accuracy of their calculations.

Energy. One energy participant was interested in an automated system that could manage his intelligent devices. He described how he has multiple computers that monitor various aspects of their electric grid and that they run in two different modes: regular mode and storm mode. Switching to storm mode requires that someone complete the task manually. This can be inconvenient, especially when storms occur in the middle of the night. The participant mentioned that it would be very helpful if a program was developed that could automatically switch the computers into storm mode when weather events (e.g., severe winds, ice storms, lightning strikes) occur.

Transportation. Of the two participants in the transportation industry, one said they could not think of any tools that would be useful. The other said that trends are very important to his decision-making. One product that might be helpful would be to have a time series analysis of precipitation trends at certain benchmarks (e.g., 2 in. snow events because 2 in. requires plows). The participant did not specify the timescale, but said he would be interested in various lengths of scale. The participant also said that in general, any time a graphical representation can be given to them as opposed to a text description is helpful. "It's easier for us to make the leap on what's gonna happen versus trying to decipher [from the text] what forecasters think is gonna happen," he commented.

Agricultural Production. The agriculture participants did not have any suggestions for a new tool, although two decision makers said that a lot of producers use data from the Oklahoma Mesonet (McPherson et al. 2007). An individual from one state agency said, "I think the most valuable thing that we've done in Oklahoma is the Mesonet. I mean I think it's a tool that all of the agriculture industry uses every day." He also noted that many producers are extremely tech savvy and welcome new information and technology. An individual from a federal agency said that she needs better data in order to produce the tools she wants. She noted that data quality can be an issue and some of the precipitation data, which is very important to the agriculture industry, is not reliable. Many producers do not understand this limitation. She commented, "The users do not have the training or the background or the experience to understand any of the data quality issues, the spatial-temporal issues, or the skill issues."

Ecosystems. One participant from a conservation agency could not think of a specific tool but noted that it would be important to join information across state lines (e.g., Illinois River) since ecoregions do not stop at state borders. A wildlife biologist said they would like a tool developed that relates atmospheric temperature to water temperature. They do experiments to determine why fish kills happen, for example, but an equation that models the air-water temperature relationship has yet to be developed. He also noted that they are able to obtain some water temperature measurements from U.S. Geological Survey stream gauges, but there are not nearly enough of them to model the system in its entirety.

Society/Public Safety. The participants included in this sector worked in a range of positions, and their suggestions were diverse. The individual from an emergency management agency said the people in his office are working on a situational awareness tool but that it is still in its infancy. One of the tribal participants was particularly interested in how climate change might impact contaminants and how that in turn might affect water quality. He noted that it would be nice to be able to monitor where the contaminants go after heavy rain as well as the effect of wind on soil contaminants (e.g., particulate dispersion, pesticides). The other tribal representative was interested in the health impacts of poor water and air quality. A tool that could predict and/or monitor these variables and their locations would be useful. The participant from a large city said that cities would be interested in prepackaged software containing information on variables in which they are interested. He did not specify what those variables would be but gave some contextual information which may be able to lead developers in a particular direction. For example, the participant said that it could contain information on what a city would need to know to update their climate action plan and include cost-benefit analyses. He also commented, "Cities typically do not have somebody who has the capacity to interpret [the information] very far. So it needs to be in a useful format so somebody doesn't have to sit down and have their own . . . meteorologist or your own statistics person specializing in climate data." Thus, the information would need to be useable and understandable to someone who does not have a background in meteorology or climatology.

4.7.5 Educational Needs

One of the top needs that came out of the December 2009 meeting on adapting to climate change in Oklahoma (Oklahoma Climatological Survey 2010) was the need for climate change education and training programs for agency decision makers. Consequently, we aimed to gather more specific information on the educational needs of decision makers to use as a springboard for action. The participants of this assessment were asked whether their agency had a need for a representative of OCS to come in and talk about climate science and climate change. Eleven of the participants said yes, two said no, three said maybe later but their agency was not yet ready for the information, and six said not them in particular but recommended another group for which the information would be more appropriate. Those who said yes were asked to choose one or more subtopics, the results of which are displayed in figure 18. These results will assist the SCIPP and OCS team with knowing how best to connect with their audiences.

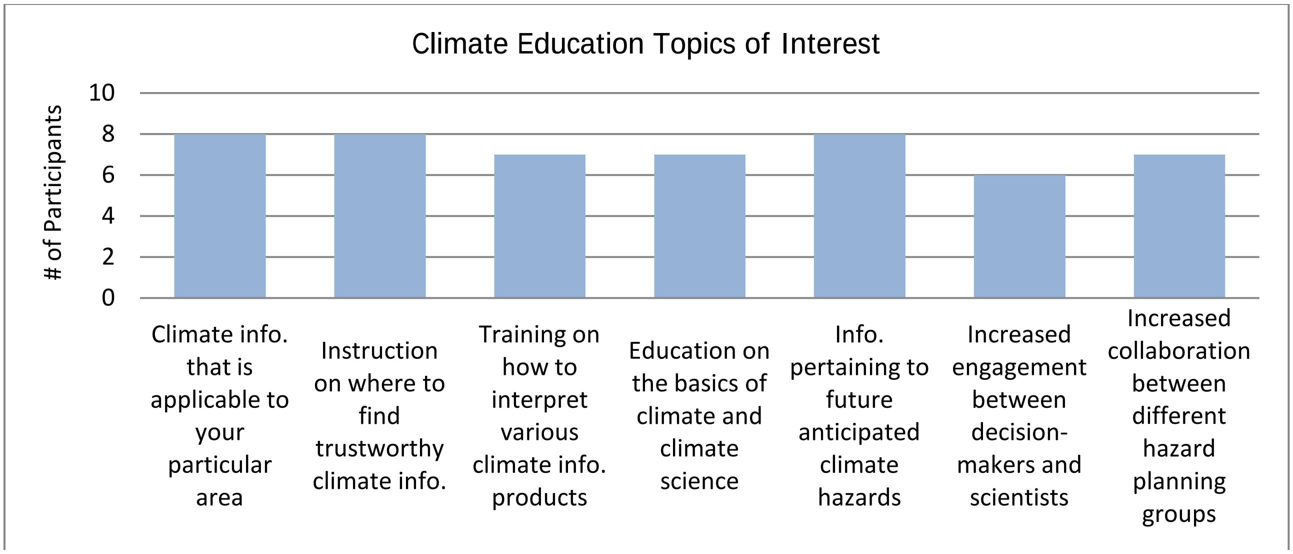


Figure 18: The participants were asked whether their agency had a need for climate education. The 11 participants who answered "yes" chose one or more subtopics that would be of interest to them.

5. Discussion

Given that the vast majority of decision makers we talked to said their agencies have not assessed their climate variability and change-related needs, the findings of this assessment are all the more useful and informative. Most of the agencies did not have the time nor in-house expertise to understand the impact that changes in the variability of the climate are having and will have on their operations, let alone the adaptation actions they could implement to mitigate some of the negative outcomes associated with the changes. Despite these limitations, the decision makers acknowledged that weather and climate-related events have a tremendous impact on their agencies and many of them use weather and climate information on a frequent basis.

5.1 Current & Future Climate Concerns

Drought, heavy rain/flash floods, and water resource concerns were the most commonly cited issues that have the most significant impact on agency operations. Ice storms and tornadoes closely followed. Typically, the participants went in depth about recent events such as a flash flood event that occurred in June 2010, or the drought which began in the winter of 2010 and persisted through summer 2011 (and was ongoing as of the conclusion of this study). Ice storms were also a common topic of discussion, perhaps because Oklahoma has experienced a rash of ice storms within the past decade. A wide variety of climate-related issues were discussed during the interviews but there may have been a slight bias toward recent events. This was not surprising since the recency effect, a phenomenon where people remember recent events more clearly than those which are distant (Baddeley and Hitch 1993; Broadbent and Broadbent 2007), may have influenced the discussions.

Given that droughts, floods, and water resource concerns were the most commonly cited historical problems, it was not surprising that the projected change of more intense but less frequent rain events (i.e. increased chance of drought and flood) was the most commonly cited future concern. However, this finding may have been skewed by the fact that a large number of the participants fell into the water resource, agriculture, and ecosystems sectors, all of which are directly impacted by the hydrologic system. Had more participants been from the energy sector, for example, the projected increase in the frequency of hot extremes and heat waves may have been cited as being a bigger concern overall. The participants were not asked about their future concerns related to short-fused severe weather events such as hail, severe winds, and tornadoes because a significant amount of uncertainty exists regarding future trends in localized extreme events.

5.2 Scales of Decision-Making

Oklahoma decision makers used weather and climate information at a variety of frequencies, mainly on a daily to weekly basis and especially during high impact events. It was clear that weather and climate play significant roles in their decision-making.

The decision makers' planning timescales, most commonly on the order of 15 years or less, were much shorter than expected. This is important to note from a climatological perspective, which typically focuses on the period of record (~115 years). A variety of factors might play into this relatively short planning horizon including lack of personnel/time to plan, having to deal with a constant barrage of disasters and not having time to plan ahead, lack of know-how for how to incorporate climate information into long-term plans, and the fact that climate is just one of the countless variables to consider during planning activities. As one participant in the energy sector described, there are so many factors to consider and they can change year to year. So, for many agencies it is unrealistic to look out 50 to 100 years. This is especially true for agriculture. Since the success of crops and livestock are closely tied to seasonal weather, it is not worthwhile for them to plan 50 years in the future. Of course, some sectors such as water and transportation plan on a longer scale because their infrastructure is built to last for decades. They may demand more long-term climate projection information than others. If that is the case, long-term climate projections should be tailored to those industries because they might have the greatest use for the information.

Most of the participants used weather information at a variety of spatial scales. Many commented on how local weather information is important but some projects only require data on a regional (within the state) scale. The one exception was the agriculture sector. As previously noted, crops and livestock are extremely sensitive to local changes in weather so producers prefer information that is as local as possible.

One topic that would have been useful to discuss with the participants prior to asking them questions was the difference between the spatial resolution of weather observations and model projections. Moreover, the difference between historical climate observations and future climate projections should also have been discussed. Near the end of the data gathering stage it was clear that the interviewer should have defined these terms since their spatial resolutions are not necessarily aligned. Because this was not done it was difficult to understand the differences between the spatial scales at which decision makers currently use weather observations and their current and future use of climate projections.

5.3 Research & Educational Needs

The overwhelming majority of the decision makers who participated in this study said their agencies had not yet come to their own conclusions about their needs related to climate change. This shows that there is a great need for collaboration between climate scientists and decision makers. This partnership will ensure that the findings and information offered by climate scientists is useful to end-users.

It was not surprising that the decision makers' need for climate projections were closely tied to their planning timescales. While one might have initially thought that 80- to 100-year projections would be useful to many agencies, it was understandable to hear that many of them were only interested in seasonal to decade-long projections. Though long-term (50- to 100-year) projections are useful for water and transportation sectors, climate modeling should focus more on seasonal climate predictions and projections out to 20 years. Eighty to 100 year projections are commonly shown when discussing climate change but for many decision makers those projections do not provide enough concrete information to make decisions.

In addition to climate modeling needs, there are also needs for decision-support tools. Some of the participants provided enough detail about a tool that would be helpful to them, but more interaction between climate scientists and decision makers may be needed to establish their tool-related needs.

While a plethora of needs currently exist, the interaction with decision makers through this study has led to the opportunity to fulfill a variety of short-term needs. For example, SCIPP is working on developing a climate change fact sheet to be distributed at a public venue. An OCS employee provided a city planner with rainfall data to accompany a sustainability project. Further, a utility official asked for soil moisture products for each of the Mesonet sites and an internet link and accompanying data was sent to him. A tribal representative was interested in data which showed precipitation rates for different regions in Oklahoma. The data were sent to him via an internet link. Recently, a meeting was held that focused on climate-related issues that Oklahoma tribes are having to and will need to deal with, and adaptation strategies that can help address those issues. Twenty-one Oklahoma tribes were represented at the meeting (Riley 2012). OCS and SCIPP will continue to work to fulfill additional needs as determined by this study and those that surface in the future.

5.4 A Cross-Sector Approach to Decision-Making

The results in this report were separated into sector classifications for simplification purposes. However, it was clear in numerous instances that various sectors are closely tied to one another. For example, water resource issues are deeply connected to human health. More intense but less frequent rain events increase flood chances and intensify drought, which greatly impacts the amount of water available for consumption and recreation. It also supports the growth of harmful algal blooms. Water-related issues also impact decision makers working in agriculture and ecosystems, among others. The amount of water, whether too much or too little, has a significant impact on how the decision makers in these sectors function. Competing interests, whether for agricultural or energy production, drinking water supply, recreation, or the health of the natural landscape, can create difficult decisions about how to manage water supplies.

Agriculture is also connected to ecosystems. As previously noted, one participant's agency was categorized as both agriculture and ecosystems because while he worked to promote natural resources stewardship, he also worked directly with agriculture producers since they own most of the rural land in Oklahoma. Additionally, one participant noted that "everything a producer does has an impact downstream." An agriculture producer may use fertilizers and pesticides to protect their crops and increase their yields, but the chemicals can have a negative impact on water quality.

A longer growing season also has cross-sector implications. For instance, it might allow farmers to increase their revenue by growing more crops and keep cattle on pastures longer. Alternatively, a longer growing season would mean that farmers in southwestern Oklahoma would need more water for their cotton crops, as one water resource participant pointed out. Drawing more water from their main irrigation supply, Lugert-Altus Lake, would impact the amount of water available for consumption in surrounding cities.

Climate-related issues are incredibly complex and cannot be solved or adapted to without cross-sector analysis and understanding of the problems. One way to effectively address climate impacts may be to use a hazard-centric approach. In other words, to better determine how society should plan for and adapt to heavy rain events, for example, it would be beneficial to pull together all the sectors impacted by a particular hazard to discuss how planning can be better integrated. Climate issues cut across so many agencies and organizations that rely on and affect one another. Therefore, the development of effective policies and strategies for dealing with these issues requires a consideration of not only individual sectors, but the dynamic relationships between them.

6. Conclusions

The goal of this study was to understand the climate-related needs of decision makers in Oklahoma so that future climate research findings are relevant and useful to them. From a qualitative standpoint it was clear that climate has an enormous impact on agencies and organizations across the state. Decision makers are already dealing with a plethora of climate hazards that take a toll on their financial resources and infrastructure.

Heavy rain, drought, and water resource problems were the most significant climate-related issues Oklahoma decision makers were currently facing, followed closely by ice storms and tornadoes. Some of the participants mentioned seeing anecdotal changes in climate, plants, and wildlife, but cautioned that they were purely anecdotal and were not sure whether the changes were due to land use change (especially for plants and wildlife), climate, or other factors.

In terms of future projections, the decision makers were most concerned about an increase in the number and intensity of droughts and floods, especially since the impacts are typically widespread. An increase in climate variability would be taxing on already stressed resources. In fact, all of the projected changes would be problematic in some way or another. A few decision-makers pointed out that a changing climate could benefit some sectors such as agriculture because there would be more time to produce crops, for example. However, the benefits might be outweighed by the costs (e.g., invasive pests).

Work is ongoing to address the issues that decision makers face. While a few participants noted that they were taking proactive steps to adapt to the changing climate, most did not label their actions as adaptation. Almost none of the agencies had completed internal studies about their needs pertaining to climate change information, so further assessment and collaboration may be useful to the bulk of the participants in this study.

One reason for the lack of internal needs assessments and adaptation planning may be that the timescales in which climate projections are typically displayed are not applicable to the timescales in which many of the decision makers plan. Most of the decision makers in this study said they monitor the weather on a daily to weekly basis, especially during particular seasons or severe weather, so it is clear that weather impacts their decision-making. Yet, the bulk of their planning occurs in 15 years or less. There were a few exceptions, though. Water and transportation agencies plan on longer timescales such as 25 to 50 years, and possibly even 100 years for large infrastructure projects such as dams and reservoirs.

The participants' interest in climate models coincided with their planning timescales. Water and transportation officials were interested in 50-

to 100-year projections and the decision makers from the other sectors were generally interested in less than 15 year projections. In addition, there was also a need for more information on seasonal timescales. Model validation was also important since decision-makers need confirmation that model projections are reliable. For many agencies, weather and climate is just one of the many variables they have to consider in their planning activities, and 80- to 100-year projections are too vague and do not provide enough concrete information to make decisions.

In terms of spatial resolution, many of the participants stated using weather data that is as local as possible to make short-term decisions. However, when it came to climate projections, they generally agreed that grid spacing that breaks the state into 4-5 regions would be useful. High spatial resolution was not incredibly important, except for agriculture because producers are so dependent on the weather conditions that impact their field(s). For many participants, their preferred spatial scale depended on the context of their work. For example, a transportation planner may only need climate projections at a regional scale within the state whereas someone who works for a conservation district would need county-based information. Producing models that account for hydrological interaction of basins and sub-basins were also seen as important, in addition to providing information that spanned across state boundaries. There was also a general need for information on projected climate extremes and variability as opposed to just averages. The extremes and variability are what typically have the greatest impact on people and infrastructure.

Another tremendous need was for second order variables to be modeled rather than just first order variables such as precipitation and temperature. Many decision makers do not understand how a changing trend in temperature or precipitation impacts them locally, but would be able to make more informed decisions if they were shown trends in second order variables such as evaporation and humidity and climate events such as droughts and floods. There was also a need to understand the critical thresholds for decision-making in each sector, more observational data for water resource officials to monitor stream flow, and a toolkit that could guide city officials through creating a climate action plan. There was also a strong need to educate some decision makers about climate change depending on their job duties. Many of those who did not have a significant educational need suggested other groups and organizations to which the information would be relevant and useful. Additionally, given the complex nature of the climate system and climate-related decisions, problems should be analyzed and addressed with a cross-sector perspective in mind.

This climate needs assessment provided a stepping stone for understanding the climate-related issues that decision makers in Oklahoma face and their need for climate information and tools. We were able to gather a wealth of information by building on prior relationships as well as beginning new ones. The findings of this assessment represent part of a long-term effort to help foster a greater level of climate resiliency, not only for Oklahoma but the south central U.S. as well.

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Appendix A: Interview Questions

IQ1: Could you please describe your professional responsibilities in a few sentences?

IQ2: What weather and climate issues do you deal with? Can you rank them from most problematic to least problematic?

IQ3: For these issues you are dealing with, how are you addressing them? Are other people in your agency/tribe tackling them as well?

IQ4: How often does weather and/or climate information impact your decision-making?

IQ5: How far ahead does your agency/tribe plan? Does it depend on the issue? What is the maximum timescale?

IQ6: On what kind of spatial scales is weather information helpful to you?

IQ7: Do you feel you have enough weather and climate information to make informed decisions in your daily operations and hazard planning activities? If not, what kind of information would be helpful to you?

IQ8: Shifting gears a little bit to climate change. There has been a lot of talk about a changing climate. Have you noticed any changes yourself? If yes, please describe them. Do these changes concern you?

IQ9: [Start off by telling them the future climate projections for Oklahoma] Given the projections of climate change and variability for Oklahoma, do you think the just described possible changes are likely to impact your job duties? If so, what issues do you think might have the greatest impact?

IQ10: Do you or have you considered incorporating any climate projections into your planning efforts rather than just using *historical* climate data? If yes, how have you done that? What information have you used? Where is that information from? If not, what are the barriers to incorporating climate projections into your operations?

IQ11: [If appropriate] Are you doing anything in regards to climate adaptation?

IQ12: Is there any kind of special weather or climate tool or visualization you can envision that would help you make more informed decisions in your operations?

IQ13: Climate models are used to project what future climate conditions might be, given different scenarios. Examples of what the models might project are changes in precipitation and temperature. Many climate models project changes on a global scale, although there are also models that project changes on a regional scale. Currently computing power and scientific skill are two limitations for why climate models are unable to show a lot of detail (e.g., showing the exact number of precipitation events that will occur in the year 2030). However, putting computing power and scientific skill aside, what would your ideal climate model show you? [This question was originally designed to be open-ended but it was not producing much information and was revised half-way through the interview process to include the sub-questions 13a-d.]

IQ13a: For temperature projections, would you want to see overall averages, extremes, or distributions?

IQ13b: For precipitation projections, would you want to see overall averages, extremes, or distributions?
IQ13c: On what kind of timescales (e.g., 5 years, 10 years, 80 years) would climate projections be helpful to you?
IQ13d: On what kind of spatial scales (e.g., city, county, region within state, state, etc…) would long-term climate projections be helpful to you?

IQ14: Has your agency already developed any reports about your needs related to climate change? If so, would you be willing to share it?

IQ15: Do you have any projects on the horizon that involve deciphering weather or climate information? Would you like any help with those?

IQ16: One of the top needs that came out of the climate adaptation meeting was climate change education and training programs for agency decision-makers. Would your organization be interested in having someone or a few people from OCS come in to [your organization] and talk about climate science and climate change? This could be strictly for your organization, or if you think it would be beneficial we could bring in some people from other organizations as well.

[If yes, give them piece of paper with the following education choices:]

- ☐ Climate information that is applicable to your particular area
- ☐ Instruction on where to find trustworthy climate information
- ☐ Training on how to interpret various climate information products
- ☐ Education on the basics of climate and climate science
- ☐ Information pertaining to future anticipated climate hazards
- ☐ Increased engagement between decision-makers and scientists
- ☐ Increased collaboration between different hazard planning groups
- ☐ Other____
- ☐ No help is needed in these areas

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