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LOCAL KNOWLEDGE AND CLIMATE INFORMATION: THE ROLE OF TRUST AND RISK IN AGRICULTURAL DECISIONS ABOUT DROUGHT

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Local knowledge and climate information: The role of trust and risk in agricultural decisions about drought

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Abstract

Climate change is projected to dramatically impact agricultural production across the world. Agricultural producers must adapt to changing conditions by implementing practices and utilizing knowledge that creates resilient operations. This study explores how Montana farmers and ranchers use of different types of knowledge during periods of drought and how risk perceptions and trust influence the use of knowledge. To understand the role trust and risk in producers' use of local knowledge and climate information, I conducted five focus groups with 34 Montana agricultural producers. Producers explained that they encounter many agriculture-related risks, including uncertain forecasts, financial losses, and adverse weather. To manage these risks, producers rely on knowledge gained from past experiences. Producers also test out new practices and information through small-scale experimentation to expand their knowledge of what works on their farm or ranch. Agricultural agencies should support producers by promoting producer-conducted experimentation. To do so, agencies need to address financial barriers to on-farm experimentation through programs that reduce expenses and incentivize experimentation.

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Preamble

Drought is common in Montana's semi-arid climate and scientists predict that drought will become more frequent and severe by mid-century as a result of climate change. More intense and frequent drought is projected to have significant impacts on Montana's agricultural industry (Whitlock, 2017). In responding to drought, farmers and ranchers draw upon a variety of resources and types of knowledge. This study seeks to understand what types of knowledge and information Montana producers use to make decisions about drought, and in particular the roles of local knowledge and climate information. Previous research has found that local knowledge is particularly important for agricultural producers, as it is relevant to their operation and local context and regarded as trustworthy. But in the context of drought, scientists are increasingly touting the benefits of climate information, from soil moisture maps to seasonal climate forecasts to mid-century climate projections. The assumption is that climate information will help producers make better decisions in the face of more frequent and severe drought.

The goal of this study is to examine how producers use different types of knowledge, such as local knowledge or climate information, in periods of drought and how trust and risk influence their decisions about what kind of information to use. This study was conducted as part of a larger interdisciplinary project entitled, Improving the Efficacy of Climate Information for Water Use Decisions. The larger project seeks to transform climate information and forecasts to better meet the needs of agricultural producers and better understand how producers use climate information and forecasts in their decision making.

The following questions guide this study: How do Montana farmers and ranchers use local knowledge to respond to drought? How do Montana farmers and ranchers use non-local and scientific knowledge to respond to drought? How do these types of knowledge compare in terms of utility/usefulness? How do these types of knowledge compare in terms of trustworthiness?

To explore these questions, five focus groups across different Montana communities engaged a range of agricultural producers to better understand the use of knowledge to respond to drought. A total of 33 agricultural producers and one technical advisor participated in this study. Focus groups were recorded, transcribed, and analyzed using an iterative process that compared data to existing theory and literature, and produced implications for climate information providers, agricultural producers, and future research.

This thesis is organized as follows: The first chapter provides a detailed description of the study methods, including study site selection, sample characteristics, and data collection and analysis. The next chapter is a draft manuscript, which includes relevant literature, findings, and conclusions. The final chapter provides further discussion of the findings. Specifically, this chapter explores limitations to this research, implications for agricultural producers and climate information producers, and directions for future research. Two appendices follow. Appendix 1 is the interview guide utilized by researchers in the focus groups completed for this study. Appendix 2 is the questionnaire provided to participants at the beginning of each focus group.

Study Methods

1 METHODS

In this chapter, I provide a more detailed description of the methods I utilized to address the research questions: How do Montana farmers and ranchers use local knowledge to respond to drought? How do Montana farmers and ranchers use non-local and scientific knowledge to respond to drought? How do these types of knowledge compare in terms of utility/usefulness? How do these types of knowledge compare in terms of trustworthiness?

I begin by defining my study population, study sample, and discuss the multiple study sites where this research occurred. Next, I explain why focus groups are an appropriate method to investigate this topic and how they were conducted. I end this section by discussing my approach to analyzing data and how that process informs my conclusions.

This study is part of a larger interdisciplinary project of the Montana Climate Office at the W.A. Franke College of Forestry and Conservation and is funded by the USDA National Institute for Food and Agriculture. This larger project, Improving the Efficacy of Climate Information for Water Use Decisions**,** is working to transform climate information and forecasts to better meet the needs of agricultural producers. In doing so, the USDA-funded project seeks to understand how agricultural producers use climate information and forecasts in their decision making. In the early stages of the project, insights from the focus groups described below were utilized to develop improved climate information. Thus, the focus groups contained questions for this thesis as well as the larger project.

1.1 Study Location and Population

Montana is an ideal location for this research due to the economic importance of agriculture, recent experience with drought, and the availability of climate projections that show a prevalence of drought conditions for the future. The National Agriculture Statistics Service identifies agriculture as the largest economic sector in the state with a 4.6 billion dollar impact in 2015. Montana agriculture is largely composed of individual and family owned operations, as opposed to large agribusinesses. The study population of this research includes agricultural producers who manage operations throughout the state of Montana. The term agricultural producer refers to individuals who self-identify as working farmers or ranchers and actively engage with agriculture.

1.2 Focus Groups

Focus groups "present a natural environment where participants are influencing and influenced by others-just as they do in real life" (Krueger, 1988, p. 30). This replication of real-life interactions compares to the inherent social nature of knowledge production and dissemination. Focus groups are also uniquely structured so participants can present similar or dissimilar viewpoints (Morgan, 1996). For these reasons, focus groups were utilized as the data collection method for this study.

On the day of each focus group, all participations were provided an informed consent form detailing the nature of the research, expectations for participation, and other relevant information regarding their participation in this study. Written consent was obtained from all participants before sessions began. Producers also answered a short questionnaire about their experience in agriculture (see Appendix 2). To accurately capture the discussion, focus groups were audio recorded.

Focus groups were moderated by multiple USDA team members who were assigned different topics. In addition, the presence of multiple moderators and researchers at these focus groups was important because of the study's interdisciplinary structure. While social science researchers were present to fill the traditional role of moderator, climate scientists were also in attendance to provide clarity regarding complex climate science information. Focus group sessions lasted approximately two hours each. Producers were provided refreshments and a light meal during the session.

Participants were asked a series of questions, such as: *what is your previous experience with drought*? *How did you know what to do in periods of drought? What information did you rely on to make decisions in periods of drought*? An interview guide was utilized (see Appendix 1). Participants were also asked to reflect on newsletters that provided a variety of types of climate information, such as descriptions of recent conditions, three-month seasonal climate forecasts, and mid-century climate projections. The interview guide includes questions designed to solicit information specific to the USDA-funded project and is beyond the scope of this research. The guide contained a series of open-ended questions and probes. An interview guide allowed for comparability across groups while also allowing participants provide the rich, descriptive narratives that they determine to be the most salient relative to the research topic (Hesse-Biber, 2006).

1.3 Study Sample

For this investigation, I developed a purposive sample of Montana agricultural producers in five locations throughout the state. The goal of this sample is to obtain a range of producers while also sampling for specific attributes characteristic to Montana agriculture. The sample aims to represent producers' diversity across geography and agricultural practices (dryland farming, irrigated farming, and ranching).

When developing a focus group sample, Krueger (1988) suggests that a certain level of homogeneity of participants often elicits enough common experiences among a group to fuel an active discussion. To accomplish this, three focus group sessions were planned for homogeneity based on operation type: dryland farming, irrigated farming, and ranching. The remaining two sites were planned to include a mixture of different types of operations. Although the final two focus groups included producers managing irrigated and dryland operations, as well as ranchers, I accounted for their common experiences within the same landscape to support active discussion.

To populate this sample, the USDA team and I elicited referrals for potential participants. Team members contacted individuals who were likely to have contacts with producers in the study sites. These individuals included county extension agents, staff at local NRCS and USDA offices, representatives from agriculture membership organizations, local government officials, and other community members. Once we received lists of potential participants, we invited eligible producers to participate. We set a target of 50 participants, or approximately 10 participants per site, knowing that we would encounter some attrition between the invitations and the actual focus groups.

1.4 Study Sites

Study sites were selected based on the community's proximity to producers practicing dryland farming, irrigated farming, ranching, or a mixture of operation types, and availability of appropriate meeting spaces. Although study sites were chosen to reflect different types of operations, we realized that Montana producers sometimes do not fit within these three specific categories. Rather, there are many mixed operations that include a combination of irrigated hay or cropping, dryland cropping and/or livestock. However, we were able to use these categories as a proxy for diversity to support the goal to understand a variety of perspectives. The five study sites included: Chester, Choteau, Fairfield, Harlowton, and St. Ignatius.

1.4.1 Chester

Located in north central Montana in an area known as the Highline, Chester lies amidst many dryland farming operations. Without access to water for irrigation, producers at the Chester focus groups reported growing rainfed pulses and wheat, similar to other producers in this region. One producer noted that a portion of their operation was devoted to growing organic lentils and wheat. Chester producers differed by age, ranging from early 20's and 60's, and previous farming experience, from fifteen to forty years. All producers identified as male and indicated that they currently manage family farms where they were raised.

1.4.2 Choteau

Choteau is in an area known by some as Rocky Mountain Front, where many ranches are located. Although chosen as a community representing ranching, the area also boasts a diverse composition of operations. Runoff from the Rocky Mountains brings surface water to irrigators in the region. Dryland farming becomes an increasingly common practice when travelling northeast of Choteau.

Although nearly all producers in Choteau reported raising cattle as a part of their operation, many of these ranchers had diversified their operations with other livestock and crops. Half of these producers described mixed operations that included livestock, and irrigated and dryland farming. In addition to ranching, 38% of producers reported practicing exclusively dryland farming, mostly in the form of rainfed hay fields and rangelands. Consistent with other ranches across the state, Choteau ranchers primarily grew irrigated and dryland hay, as opposed to other types of crops. Additionally, a few producers also reported growing crops such as wheat or barely. The only producer that had no livestock had an exclusively irrigated operation that grew wheat, barely, and flax. Two producers identified as female and were the only producers to report that they did not grow up on a farm. Producers in Choteau were consistently older than the other four locations. Two producers recorded their ages in the 40s, while the remaining three-fourths of producers ranged between 62 and 70 years old. Nearly all producers reported having thirty or more years of experience.

1.4.3 Fairfield

Fairfield is located approximately 20 minutes south of Choteau and is notable for its proximity to a high concentration of irrigated farming operations. The Greenfield Irrigation District supplies water to agricultural operations in an area commonly referred to as the Fairfield Bench. Although irrigated farms are prevalent in this area, ranching and dryland farming practices also exist outside of the highly productive Fairfield Bench.

Similar to the Choteau group, Fairfield was represented by diverse operations. All producers raised livestock and practiced at least some irrigated farming. Two thirds of these ranchers raised cattle and one third exclusively raised sheep. Several producers practice irrigated farming and reported growing small grains, such as barely, wheat, and rye. Dryland farming was practiced by two thirds of producers who mostly grew hay. All but one producer identified as male. Producers reported ages ranging from 47 to 61 years old. Nearly all producers grew up on farms or ranches and had more than 40 years of experience.

1.4.4 Harlowton

Harlowton is located in south central Montana along the Musselshell River. The area surrounding Harlowton contains a mixture of operations, including ranching, irrigated, and dryland farming. The Musselshell River is an important source of water for local irrigators.

All participants who attended the Harlowton focus group raised livestock. While all participants had experience with cattle, a couple of participants reported raising sheep as well. The majority of these ranchers grew both irrigated and dryland hay. Only twenty percent of ranchers did not practice any irrigated farming. Eighty percent of Harlowton producers reported growing up on farms or ranches. Thirty percent of producers identified as women. Producers’ ages ranged from 19 to 61 years old with years of experience that ranged from 4 to 40 years.

1.4.5 St. Ignatius

The only community in Western Montana, St. Ignatius enjoys the highest annual precipitation of all of the study sites, 16.84 inches annually (Desert Research Institute, 2019). Situated on the Flathead Indian Reservation, operations near St. Ignatius benefit from runoff originating in the Mission Mountains. The area includes many diverse farms and ranches, ranging from cow/calf operations to smaller vegetable farms.

Each St. Ignatius participant reported raising cattle. Some producers also reported raising other types of livestock, including sheep, pigs, and hens. Other producers stated that they grow grains such as corn, wheat, and barley as well as vegetables, including tomatoes and garlic. Nearly all participants described having access to water for irrigation. However, five-sixths of producers indicated that they also practiced dryland farming. Half of producers reported being raised on a farm or ranch. Producer's ages ranged from 35 to 76 years old and all identified as male. Producer's experience varied between 4 to 50 years.

1.5 Sample Size and Characteristics

A total of 34 individuals participated in this study. Participants were distributed through five focus groups as follows: Chester (*n*=3), Choteau (*n*=8), Fairfield (*n*=6), Harlowton (*n*=10), and St. Ignatius (*n*=7). There was one participant that did not identify as a producer, while the remaining 33 participants did identified as producers. The participant who did not identify as a producer was a Natural Resource Conservation Service employee and known by other participants to be a technical advisor.

Table 1
Sample Characteristics

Primary Function	Gender (%)		Age (Mean)	Experience (Years)	Grew Up on Farm/Ranch (%)	Total (%)
	Male	Female				
Ranch	79	21	52	32	83	73
Irrigated Farm	83	17	56	25	33	18
Dryland Farm	100	0	42	33	100	9
Total	82	18	52	32	76	100

The majority of producers (see Table 1) indicated that the primary function of their operation was raising livestock (cattle, sheep, swine), meanwhile, only about a quarter of producers identified primarily as farmers. Although the sample appears to be strongly skewed towards ranchers, the make-up of the sample was more mixed than initially appears. Once considering the many different aspects of each operation, producers often managed fairly diverse operations (see Table 2). While, ranches were the most represented type of practice, either irrigated and dryland farming was also practiced by the majority of producers as well. One reason for low turnout among producers that primarily practiced farming could be due to the timing of focus groups. All focus groups were completed between May and June of 2018. Not only did these dates fall in the middle of the growing season, many Montana agricultural producers, specifically farmers, started extremely late in the season due to large snowpack and widespread flooding and were busy catching up.

Table 2
Producer and operation function by focus group

	Primary Function			All Functions		
	Ranch	Irrigate	Dryland	Ranch	Irrigated Farm	Dryland Farm
Fairfield	4	2	0	6	6	4

Chester	0	0	3	0	0	3
Choteau	6	2	0	7	5	7
St Ignatius	4	2	0	5	6	3
Harlowton	10	0	0	10	6	4
Total	24	6	3	28	23	21

Female agricultural producers were another underrepresented group in this sample. While the 2017 Census of Agriculture reports that 40% of all Montana agricultural producers identify as female, only 18% of producers identified as female in this study. In addition, producers in this study were notably younger than the average aged Montana agricultural producer. The 2017 Census reported the average age of all producers to be 58 years old as compared to 52 years old within this sample. As an exploratory study, this sample provides the opportunity to explore different opinions but also serves as a springboard for future research as well. The deficiencies in the sample should be a focus for future research to further explore these gaps.

1.6 Data Analysis

For this project, I utilized a qualitative analysis that was completed through an iterative process that consulted relevant literature, generated theory, and examined the data. To begin the analysis, I familiarized myself with the data through multiple readings of the transcripts and began to write memo notes. Memo notes are reflective writings that a researcher uses to document and organize thoughts and ideas. After several readings and compiling of my thoughts and impressions via memo notes, I developed 14 initial codes. Codes are the conceptual organization of reoccurring themes. Through a process of open coding, I assigned segments of text to codes when they related to such themes. Although the open coding process started with 14 codes, additional codes were created as different themes emerged from within the data. Once I completed open coding all the data, I began the process of axial coding, relating codes to one another to create further abstract codes. Emerging abstract codes such as “risk” or “experience” were the foundation for developing theory. I returned to the data to examine how well these codes continued to represent the data. In addition, I reviewed the literature relevant to the emergent codes. This process is notable for oscillating between the inductive and deductive relationship of theory, constantly evaluating the relationships between high-level codes, low level codes, and the data (Corbin & Strauss, 2008). While high-level codes emerged from the data, the data excerpts were then chosen to represent these high-level codes, the relationship between such codes and data excerpts included in the manuscript illustrate the iterative process and provide evidence to support interpretations and conclusions outlined there. Prior to analysis, audio recordings were professionally transcribed and proofread for accuracy. The software NVivo 9 was used to organize the data.

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LOCAL KNOWLEDGE AND CLIMATE INFORMATION: THE ROLE OF TRUST AND RISK IN AGRICULTURAL DECISIONS ABOUT DROUGHT

1 INTRODUCTION

Climate change has direct and substantial impacts on agriculture and global food security (Campbell et al., 2016). Extreme temperatures, excessive rainfall, and prolonged drought are some examples of climate stressors that have made crops and livestock particularly vulnerable (Walthall et al., 2013). To develop resilient agricultural operations, scientists and agricultural producers have sought to identify the knowledge and technologies that support drought adaptation. Agricultural scientists have attempted to reduce drought impacts through the development of drought tolerant crops and livestock breeds, and enhanced climate information (McFadden et al., 2019). At the same time, farmers and ranchers navigate drought, in part, by drawing upon their own experiences (Kloppenburg, 1991; Lyon et a., 2011; Goulet, 2013). These different types of knowledge are often created by producers and scientists independently. For example, scientists create new forecasts and projections intended to assist agricultural producers in adapting to climate change, but this climate information rarely takes into account producer's local knowledge and needs. Understanding how producers use different kinds of knowledge can provide insight into what producers need to adapt to drought.

To examine knowledge in periods of drought, this research has been guided by the following questions: How do Montana farmers and ranchers use local knowledge to respond to a drought? How do Montana farmers and ranchers use non-local and expert knowledge to respond to a drought? How do these types of knowledge compare in terms of utility/usefulness? How do these types of knowledge compare in terms of trustworthiness?

2 LITERATURE REVEIW

Agriculture is a complex system of interconnected relationships, between soil and weather, markets and policy, family and labor, and networks and knowledge. Contemporary agricultural producers must navigate this system to achieve their goals. To do so, they rely on diverse systems of knowledge to make decisions (Kaup, 2008; Lehebel-Peron et al., 2016). Decisions about drought are made amidst uncertainty and risk, inherent components of agricultural systems (Moschini & Hennessy, 1999; Harwood, 1999; Hardaker, 2004). To better understand decisions made by agriculture producers in the context of drought, we must explore the interactions between knowledge systems, uncertainty, and risk within an agricultural context.

Systems of local knowledge exist throughout the world and are tied to specific locations (Conklin, 1954; Thrupp, 1989; Leach & Fairhead, 2000; Tsing, 2008; Knapp & Fernandez-Gimenez, 2009; Naess, 2013; Goulet, 2013; Sumane et al., 2018). When knowledge is bound to a specific location, it is often referred to as local knowledge (Kloppenburg, 1991; Feldmen & Welsh, 1995; Hassanein, 1997; Sumane et al., 2018). Local knowledge is rooted in the direct experiences of individuals with the physical and social features of a specific location (Kloppenburg 1991) and through social interactions and interactions between human and nature (Agrawal 1995). Biologic and ecological processes also inform local knowledge (Knapp & Fernandez-Gimenez, 2009; Lyon et al. 2011). Hassanein (1999) summarizes local knowledge as the "practical skill that develops within mindful attention to the unique, yet shifting, social and physical features of a locality and that is fundamentally tied to direct personal experience of a particular place or activity" (p. 77).

Agricultural producers in particular rely on first-hand experience for knowledge acquisition (Kloppenburg, 1991; Feldmen & Welsh, 1995; Hassanein, 1999; Knapp & Fernandez-Gimenez, 2008; Ingram, 2008; Davis & Wagner, 2017; Sumane et al., 2018). For example, in a study in Colorado, ranchers shared that experience was one of the most important ways to learn the required knowledge for ranch management (Knapp and Fernandez-Gimenez 2009). Another study underscored how direct experience with local conditions was extremely important to beekeepers (Davis & Wagner, 2017). Work, labor, and toil are often seen as important for generating and acquiring local knowledge (Kloppenburg, 1991; Feldmen & Welsh, 1995; Hassanein, 1997, 1999).

More generally, people familiarize themselves with the natural and social worlds around them through daily practice. Consider a cab driver traversing traffic among New York City's skyscrapers. An experienced driver has likely developed a familiarity with the physical features of their route, helping them navigate the city efficiently. These features can include living biological beings (i.e. pedestrians, cross walkers, dogs) or inanimate physical objects (i.e. buildings, telephone poles, medians). Farmers and ranchers develop a similar knowledge through years of interacting with the local landscape, becoming intimately aware of the dynamic features of the land they manage (Knapp & Fernandez-Gimenez, 2009; Goulet, 2013; Sumane et al., 2018). Producers' knowledge of the landscape can include animal behaviors, vegetation changes, climate conditions, and environmental disturbances (Knapp & Fernandez-Gimenez, 2009).

According to Lyon et al. (2011), the social features of landscapes often include "social relationships, economic realities and personal values" (p. 386). As discussed above, local knowledge is generated through direct interaction with both the biophysical and social features of the landscape (Feldman & Welsh, 1995, Lyon et al., 2011). However, social features of landscapes are often overlooked in discussions of local knowledge (Kloppenburg, 1991; Feldman & Welsh, 1995; Hassanein, 1997). From the decision that one's ancestors made regarding where to build a barn to a community's focus on protecting wildlife habitat, family history, social norms, and community values interact with the biophysical features of the landscape in important ways.

Individuals interpret and experience the world through their own personal values and experiences. However, groups of individuals often form a shared understanding of the specific landscape they experience. Hassanein (1999) characterizes this process as the "socializing of local knowledge" (p. 92), where knowledge is the product of social processes that build common understandings. Thus, local knowledge is a dynamic social entity "contained in the heads of farmers and agricultural workers" (Kloppenburg, 1991, p. 248-249). While local knowledge is often shared, it is also inherently heterogeneous and often divided along lines of class, race, and gender (Feldmen and Welsh 1995). Therefore, spaces where a shared knowledge is generated and shaped may be inaccessible to some.

In addition to local knowledge, agricultural producers also utilize scientific information (Lyson, 2004). Producers have experimented on their farms or ranches for millennia, but the Morrill Act of 1862 (which created the land-grant colleges) institutionalized the scientific approach as another means to finding solutions to agricultural problems on college campuses (Hassanein, 1999). Further, the establishment of the United States Department of Agriculture and experimental research stations (Hatch Act 1887) formed an institutionalized agricultural science, providing research, education, and outreach (Hassanein, 1999). Today, science is integrated into agriculture through its provision of new disease resistant crop varieties, research on the efficacy of different planting systems, and information about crop nutritional needs. This shift put significant financial resources into agricultural science but also marginalized the local knowledge that past and present producers often rely upon.

More recently, scientists suggest that climate and weather forecasts could help agricultural producers make better informed short- and long-term decisions, such as when to plant, what to plant, or when to harvest (Canales et al., 2006; Haight et al., 2014; Chatrchyan et al., 2017). Weather and climate describe the state of the atmosphere above the earth's surface and is measured in elements such as temperature, moisture, air pressure, wind, among others. Weather and climate are often differentiated by the timescales in which these elements are represented. Weather describes the dynamic changes of these components across hours, days, or weeks. In contrast, climate is a summary of changes in weather over an extended period of time, commonly recognized timeframes include a month, a season, or across multiple decades (Stern and Easterling, 1999).

Climate information includes "historical data, analyses and assessments based on these data, forecasts, predictions, outlooks, advisories, warnings, model outputs, model data, climate projections and scenarios, climate monitoring products, etc." (Scott and Lemieux, 2010, p. 152). Examples of climate information include averaged records over extended timescales, such as record precipitation over the course of a year or average daily temperature across a 100-year period. Climate information can also include recorded weather extremes (NSIDC, 2019). In addition to historic records, climate information also includes forecasts and projections. As an example, the Climate Prediction Center provides seasonal forecasts that project the likelihood that temperature and precipitation over a three-month period will be above normal, near normal, or below normal. These categories are based on Climate Normals, averages over a 30-year period (currently 1981-2010) (National Oceanic and Atmospheric Agency, 2019). Climate information can also include mid- and end-of-century projections about changes in temperature and precipitation based on downscaled global circulation models.

Southeastern United States farmers have suggested that climate forecasts could provide insight on climate risk mitigation strategies, such as utilizing different crops and crop varieties, modifying insurance policies, or reducing agriculture inputs to account for lower yields (Crane et al., 2011). In this study, producers also highlighted how climate forecasts may also help farmers take advantage of good conditions.

Despite its potential, a number of barriers prevent producers from utilizing climate information (Cash et al., 2006; Sarewitz & Pielke, 2007; Breuer et al., 2008; Crane et al. 2010; Dilling & Lemos, 2011; Mase & Prokopy, 2014; Jones et al., 2017), including inflexible producers and operations (such as preference for established rather than new or innovative practices), lack of trust in scientific information, lack of financial resources, inaccessible information, and lack of relevancy (Dilling & Lemos, 2011). Several barriers also limit producers from using seasonal climate forecasts specifically. Perceptions of low forecast accuracy and risks associated with forecast use, as well as difficult to understand forecasts can prevent producers from using seasonal climate forecasts. In addition, it may not be clear to producers which action to take in response to seasonal climate forecasts. Producers may also be constrained by factors outside the forecast itself, such as market conditions, lack of resources, or social norms (Mase & Prokopy, 2014).

One of the key problems is that climate information is not always relevant to the local social, economic, and biophysical contexts where decisions are made (Cash et al., 2006; Dilling & Lemos, 2011, Dunne et al., 2015; Jones et al., 2017). Sarewitz & Pielke (2007) conceptualize this disconnect in economic terms, the "supply and demand" of science information. Supply refers to the institutions, groups, and individuals responsible for the production of scientific information (e.g. climate scientists), while demand represents end users, such as farmers and ranchers who may rely on climate information to make decisions. Cash et al. (2006) says that supply and demand often interact on the "loading dock," where climate information is created, packaged, and delivered but the consumer (user) has no or little influence over when, how, or what information they receive. Without consumer (user) input, climate products lack saliency within the multidimensional context where they are intended for use (Letson, 2001; Cash et al., 2006; Dessai, 2009; Dunne et al., 2015).

Exemplifying the "loading dock" approach, climate information is often presented at spatial and temporal scales that are not necessarily relevant to producer decision-making (Charles et al. 2007; Dilling & Lemos, 2011; Mase and Prokopy, 2014; Dunne et al., 2015; Wilke & Morton, 2017). Some producers have a preference for shorter term forecasts such as seasonal, weekly, or daily weather and climate forecasts because they best match many of their decision timescales (Breuer et al., 2008; Crane et al., 2010; Mase & Prokopy, 2014; Dunne et al., 2015, Chatrchyan et al., 2017; Wilke & Morton, 2017). For longer-term decisions, some producers indicate a preference for 5-10 year forecasts (Dunne, 2015; Wilke & Morton, 2017). With regard to spatial scales, climate information is typically presented at scales larger than users desire (Berkhout et al, 2013; Dunne et al., 2015). Current climate models produce low-resolution projections at approximately 150 to 300 km^2 (Jones et al., 2017). Downscaling of high-resolution models is possible through various methods but large uncertainties still remains across all techniques, making it difficult to meet producer needs in terms of spatial scale.

Agricultural producers also perceive that seasonal climate forecasts are not sufficiently accurate, especially at the specific yet highly uncertain spatial scales that producers prefer (Breuer et al., 2008; Crane et al. 2010; Dilling & Lemos, 2011; Mase & Prokopy, 2014; Jones et al., 2017). This is an important tension because downscaled projections are inherently less accurate, but producers want both downscaled projections and increased accuracy. In a study of Australian viticulturalists, a majority of producers (65%) agreed that forecasts must become more accurate to be valuable to their decision making. Producers have indicated throughout multiple studies that climate forecasts must be accurate for multiple years before they utilize them in their management decisions. (Chatrchyan et al., 2017). Further, producers form perceptions of forecasts based on their past experiences, which serve as references for future decision making (Crane et al., 2010; Wilke et al., 2017). Thus, lack of accuracy can lead producers to mistrust forecasts.

Producers evaluate the utility of both local knowledge and climate information, in part, based on their perceptions of risk and uncertainty. Changing climate, fluctuating weather, dynamic commodity prices, and shifting policies create uncertainty within agriculture (Harwood, 1999; Pannell et al., 2000; Hardaker et al., 2004; Hay, 2007; Menapace et al., 2016; USDA, 2018). Therefore, uncertainty and subsequent risk are essential to understanding decision making within an agricultural context and in particular how different kinds of knowledge is used in decision-making. The terms risk and uncertainty are sometimes used and understood interchangeably (Pannell et al., 2000) and there is a lack of agreement on the precise definition for risk (Goodwin & Ker, 2002; Hardaker, 2004). Smith, Barrett, and Box (2000) suggest that there are two dominant approaches to understanding risk: subjective or frequentist. A frequentist risk is uniform and objectively measured across people, while a subjective risk is based on an individuals' subjective perceptions of the situation.

Regardless of the approach, all risk involves the possibility of unwanted outcomes, such as financial loss, resource loss, or harm to self or others. Therefore, to take a risk, one must become vulnerable to the possibility of harm or injury (Hardaker, 2004). Risk is contrasted to uncertainty, which makes no assumptions regarding outcomes, neither favorable nor unfavorable (Harwood, 1999; Smith et al., 2000; Moschini & Hennessy, 2001; Hardarker, 2004). Uncertainty can be described as "imperfect knowledge" (Smith et al., 2000, p. 1946) or situations where individuals are unsure what will happen (Harwood et al., 1999, p. 2). Uncertainty begets risk; however, uncertainty does not always lead to risk (Harwood et al.,1999). Risk also considers the likelihood that harm will occur (Hay, 2007). Producers endure frequent low impact risks, such as daily changes in weather or fluctuating fuel prices. They also experience low frequency but high-impact risks, such as severe prolonged drought or dramatic environmental policy changes.

There are a variety of sources of risk within agriculture (Baquet et al., 1997; Harwood et al., 1999; Hardaker et al., 2004; Hay, 2007; Menzie, 2007; USDA, 2018) related to production and yield, price and market, institutional, human or personal, and financial factors (Hardaker et al., 2004; Hay, 2007; Menzie, 2007; USDA, 2018). Yield risk, the potential for changes in crop/livestock production, is a risk unique to the agriculture sector (Harwood, 1999). Yield risk "occurs because agriculture is affected by many uncontrollable events that are often related to weather, including excessive or insufficient rainfall, extreme temperatures, hail, insects, and diseases" (Harwood, 1999, p. 7).

These risks vary by frequency, impact, and source, and producers respond to risks in a variety of ways (Gardebroek, 2006; van Winsen et al., 2016). These responses are typically mitigated by risk perceptions and attitudes (Pennings and Garcia, 2001; Gardebroek, 2006; Menapace et al., 2016). Risk perceptions are judgments about the likelihood that risks will result in harm (Boholm, 1998; Gardebroek, 2006; van Winsen et al., 2016). Risk attitudes represent the propensity to act upon these risks, from more open to taking risks (seeking) to more reluctant to take risks (averse) (van Winsen et al., 2016). Hardaker et al. (2004) explains that risk averse individuals may be willing to exchange potentially high returns for reduced risk. Risk seekers, however, pursue opportunities for high reward despite the accompaniment of high risk.

Producers' risk perceptions and attitudes may impact how they utilize knowledge and information in their decision making (Liu, 2013; Araujo, 2017). New information may result in high levels of perceived risk "because the farmer has had no first-hand experience of the new method" (p. 12). However, producers' perceived risk decreases as they accumulate evidence that knowledge or information can be successfully applied (Hardaker, 2004). For risk seekers, new knowledge may be viewed as an opportunity with a potential high reward. In contrast, risk averse producers may be more likely to focus on experiential knowledge, trading potential rewards for more security (Hardaker et al., 2004; Liu, 2013; Jianjun et al., 2015; Araujo, 2017).

While making decisions amidst such risk, producers are also more likely to accept and use information that they trust (Morgan & Murdoch, 2000; Carolan, 2006a, 2006b; Knapp & Fernandez-Gimenez, 2009; Oreszczyn et al., 2010). Producers often find family, friends, or neighbors to be highly trustworthy sources of information (Carolan, 2006; Knapp & Fernandez-Gimenez, 2009; Roche et al., 2015). However, producers also recognize other sources of relevant information to be trustworthy as well. Roche et al. (2015) found that California ranchers indicated a high level of trust for industry organizations, such as California Cattlemen's Association or the California Farm Bureau Federation, and some government agencies, such as Extension or the Natural Resource Conservation Service. Meanwhile, other researchers have found that producers have limited trust in both private and public agricultural organizations (Arbuckle et al., 2015). This is particularly true regarding climate science (Breuer et al., 2008; Crane et al., 2010). Agricultural producers' perceptions of climate information as not trustworthy is a major barrier to utilization (Breuer et al., 2008; Bruno Soares & Dessai, 2016).

While a large body of research has focused on the role of knowledge (Fonte, 2008; Kaup, 2008; Sumane et al., 2018) and risk in agriculture (van Winsen et al., 2016; Mase et al., 2017; Wilke, 2017), few studies have examined how producers use different types of knowledge to manage agricultural risk associated with climate change. To fill this gap, we studied how agricultural producers use local knowledge and climate information to respond to drought-related risks.

3 STUDY SITE

Montana is an ideal location for this research due to the economic importance of agriculture, recent experience with drought, and the availability of climate projections that show a prevalence of future drought conditions. Communities were chosen in areas known for different types of agricultural operations. The five study sites included: Chester, Choteau, Fairfield, Harlowton, and St. Ignatius.

Located in north central Montana, Chester is a small town that lies amidst many dryland farming operations that grow a variety of pulse crops and wheat. Choteau sits at the foothills of the Rocky Mountains and is primarily known as a ranching community. Fairfield is located approximately 20 minutes south of Choteau and is notable for its proximity to the Fairfield Bench, an area with high concentration of irrigated farming operations. Harlowton is a community of about 1,000 residents with diverse operations in the area. Irrigated farms are prevalent along the Musselshell River, meanwhile many ranches are located in the surrounding area, especially at the foothills of the Crazy Mountains, southwest of Harlowton. The only community in Western Montana, St. Ignatius enjoys the highest annual precipitation of all of the study sites and includes a mix of farms and ranches. While dryland farming is sometimes practiced in this area, access to water for irrigation is higher than other study sites.

4 METHODS

This study employed focus groups to learn how farmers and ranchers utilize different types of knowledge in responding to drought. Focus groups "present a natural environment where participants are influencing and influenced by others-just as they do in real life" (Krueger, 1988, p. 30). This replication of real-life interactions reflects the inherent social nature of knowledge production and dissemination. Focus groups are also uniquely structured so participants can present similar or dissimilar viewpoints (Morgan, 1996). Although this format can provide valuable insight into social interactions and shared experiences, some of those same social processes can alter how producers participate in focus group dialogue. Thus, one of the limitations of focus groups is that some participants might not share their opinions or they might adopt the views of others in order to avoid conflict.

To populate the focus groups, we purposively sampled Montana agricultural producers in five study sites throughout the state. The sample aims to represent producers' diversity across geography and agricultural practices. Although the five study sites were chosen to represent different types of agricultural operations, we recognize that Montana producers sometimes do not fit neatly within the categories of dryland farming, irrigated farming, and ranching. Rather, there are many mixed operations that fit multiple categories. Nonetheless, the sample includes a range of operations and thus supports the goal to understand a variety of perspectives.

To populate the sample, we contacted county extension agents, federal agency staff, agriculture–focused NGOs, and other community members to elicit referrals. Thirty-four individuals participated in this study across the five focus groups in the following communities: Chester (*n*=3), Choteau (*n*=8), Fairfield (*n*=6), Harlowton (*n*=10), St. Ignatius (*n*=7). Not all producers who were contacted participated in the focus groups. It is unclear if there are any distinct differences between those who participated in this study and those who did not.

Chester was the only focus group consisting of exclusively one category of producer, dryland farmers. The rest of the focus groups were composed of a diversity of producers, many of whom had mixed operations (i.e. ranching and dryland farming, irrigated and dryland farming, irrigated farming and ranching, or all three). Nearly 90% of participants reported raising livestock (cattle or sheep). About 44% of the sample reported practicing some dryland farming (not including rainfed rangelands). Seventy percent of the sample reported having some irrigated farmland or pastures.

Participants were asked a series of questions, such as: *What is your previous experience with drought*? *How did you know what to do in periods of drought? What information did you rely on to make decisions in periods of drought*? Participants were also asked to reflect on newsletters that provided a variety of types of climate information, such as descriptions of recent conditions, three-month seasonal climate forecasts, and mid-century climate projections. An interview guide allowed for comparability across groups while also allowing participants provide the rich, descriptive narratives that they determine to be the most salient relative to the research topic (Hesse-Biber, 2006). Focus group conversations were recorded, transcribed verbatim, and coded using NVivo 9. The data was analyzed by extracting dominant themes. These themes informed a larger narrative and the development of theory through an iterative process focused on comparing data, interpretation, and existing research (Hesse-Biber, 2006). Once 14 themes were identified, we returned to the data to examine how well these themes represented the data. The data excerpts included below provide evidence to support specific interpretations and conclusions.

5 RESULTS

In the following section, we describe how farmers and ranchers experience risk, and how they use knowledge to address this risk. Specifically, we discuss the role of risk, previous experiences, experimentation, and trust to understand what knowledge producers use.

5.1 Building Knowledge through Experience

Producers stated that "*years of experience*" and observations are *"some of our best knowledge"* to adapt operations to accommodate for adverse conditions, such as drought. They also suggested that the "*experience of neighbors*", "*friends*" and "*predecessors"* informed their personal knowledge. Consistent with previous literature (Kloppenburg, 1991; Feldmen & Welsh, 1995; Hassanein, 1999; Knapp & Fernandez-Gimenez, 2008; Ingram, 2008; Davis & Wagner, 2017; Sumane et al., 2018), producers focused on two components of experience: practice and place. Through experience with a practice and a place, producers developed knowledge of a unique biophysical context.

Experience appeared to build trust that if something worked on their farm or ranch in the past, it would work again.

For many producers, they "*grew up watching*" or have "*been helping farm*" from a young age. When a producer reflected on "*being around farming their whole life*" or their *"lifetime"* of experience in the field, they pointed to their long tenure of farming or ranching as key to their knowledge. A few producers also pointed out that their family's agricultural legacy contributed to their accumulated agricultural knowledge. They noted that, *"I'll be a fourth-generation farmer,"* that their family has *"farmed those same acres, some of them, for literally 100 years now,"* or "*Grandpa was out there in 1909 when he homesteaded, so that knowledge has been passed down."* Producers indicated this family history provided them access to a trusted cache of knowledge passed down from generation to generation.

Producers also argued that their history within a specific area, farm, or ranch provides them with an intimate knowledge of the unique features of those places and allows them to learn "*what works and what doesn't work."* Several producers talked about how they grew up on the land that they continue to work today. In addition, producers also described knowledge that they shared with other producers, built through common experiences on the same landscape. Some pointed to their shared histories in Montana, saying *"we were born and raised here,*" signifying their in-depth knowledge of the local area. Several producers discussed how they've come to understand the ways that natural systems can indicate changes in weather and climate across their shared landscapes. A group of dryland farmers said that they watch the grass in the ditch along the highway for indication of drought, because *"when it starts to turn brown, things are* *headed a wrong direction in a hurry."* In another focus group, several producers agreed that weather is best known by simply observing conditions outside. As one producer explained, *"I could step outside my door, look at the mountains, and it depends on how many clouds coming up over the mountains. It tells me if it's gonna be windy, if it's gonna rain."* Meanwhile, other producers talked about how *"you can tell by watching the animals"* when the weather is about to change and "*if the cows are crowded up in the corner of the corral, you might as well stay in the house that day*." These natural indicators supply producers with a means of anticipating weather within their landscapes. Across all five focus groups, producers repeatedly emphasized the importance of their experiences.

5.2 Trust in Local Knowledge

Producers looked to personal experiences and the experiences of close family, friends, and neighbors to provide knowledge they trusted. Many producers based the trustworthiness of information on "*what's already happened.*" Consistent with the results outlined above, producers often cited themselves or their "*inner person*" as one of their most trusted sources of knowledge for making decisions on their farm or ranch. Many explained *"just through experience you learn"* what to do in periods of drought. When asked about where they receive trusted information a rancher pointed to their "*gray hair"* to imply that *"from the years"* they have gained relevant *"expertise."* Producers often trusted themselves as their *"own touchstone"* because through *"their life's experience of living here*" they have witnessed "*what works*" on the landscape and what doesn't.

Producers also identified close friends, family, and peers to be trusted sources of information. Specifically, producers acknowledged trusting people who "*you know or are associated with and have confidence in"* or others who "*you start to know them, and you start to build some confidence in them."* One producer suggested that it is "*human nature to trust people that you have confidence in."* Producer contrasted their trust in people they know to "*data or statistics from some scientist that might be an expert that's somewhere else who you don't really know*." This producer suggests that "*outside-no-face-information*" is often more difficult to trust than what "*your neighbor tells you or what Johnny or Jim or Joe tells you.*" Several producers indicated that they were unlikely to trust knowledge that they were unfamiliar with or had no previous experience with.

Producers trust knowledge and information from family, friends, and peers because of their experiences. One farmer described trusting his father based on his past experiences with drought, *"because he went through a drought in the 80s.*" Since "*he's been through it. He knows the land and he knows all that*," this farmer uses their father's knowledge generated from his experience with drought for insight into crucial decisions for similar biophysical conditions. More generally, other producers expressed great confidence in the "*advice"* they received or what they "*learned*" from "*those who are around us…that have that experience"* or what "*the old timers told us they did.*" Another producer referred to the accumulated knowledge from their community as a "*collective past experience"* and identified it as a big part of the knowledge they trust and rely on.

In addition, some producers also talked about scientific information that they *"have confidence in,"* or as one producer described it as "*solid information."* This information often describes "*what's already happened*" and is typically based in scientific measurement, such as "*snowpack/snow water equivalent*," *"what the soil moisture is,"* or "*research on seeds and fertilizers.*" A producer confidently referred to snowpack measurements as "*good data*." Meanwhile, another farmer strongly proclaimed "*I'm a firm believer in El Nino. If we've got an El Nino in the ocean, we've got a drought in Montana."* Unlike other knowledge gained from their own experiences, the scientific information that some producers trusted was created and communicated by external sources.

5.3 Assessing the Trustworthiness of Climate Information

Producers described how past experience and observations sometimes led to distrust and skepticism, specifically in climate information. Some producers stated that they *"don't trust the forecast at all*" or that, "*weather people just do not know what they're talking about."* Producers pointed to times when weather and seasonal climate forecasts did not match their on-the-ground observations as reasons to not trust the accuracy and reliability of climate information. Additionally, producers discussed how differences between forecasts as well as forecasts that changed over time increased their distrust and skepticism.

While some producers described scientific information as "*solid information,*" a few participants indicated they were more skeptical. For example, one participant explained that "*There's the cold, hard facts of previous research that has been done on different seeds, different fertilizers, and those kinds of things"* but they go on to concede, "*Even those, ultimately, I don't believe them."* An irrigator described data reported from

Snow Telemetry (SNOTEL) sites, calling it "*fairly solid information,*" but they also expressed some skepticism, saying:

> *Once you know how much snowpack, you can kind of count on how your water is going to come out. Not really, I mean, you can—because of temperature differences, it could come out real quick but at least you know what your potential is.*

Producers argued that sometimes assessments of past conditions don't match their own observations. For example, one producer argued that a map depicting observed accumulated precipitation showed more moisture than he experienced on his farm during that period, saying *"there's a little heavy green spot right where I live…it's actually showing wetter. The problem with radar. It doesn't know the difference between a rain cloud and a wind turbine."* Another producer complained that the county weather station will measure 100th of an inch of rain *"just out of the clear blue sky*." One farmer noted that satellite radar records "*almost a tenth of rain on a couple of my fields every day because I'm underneath them wind towers and there isn't a cloud in the sky."* A few other producers suggested that satellites are "*reading bugs or ground clutter*" when they falsely record rainfall on clear days. These inaccurate records lead some producers to view seasonal climate forecasts and other climate information as less trustworthy and potentially risky.

In addition to concerns about reported conditions not matching what they observed; producers also talked about instances when weather forecasts didn't match their observations. Some participants recalled specific examples of inaccurate predictions, saying *"lately it'll show nothing and then it'll just dump rain*." Repeated differences between forecasts and observed conditions led one participant to proclaim "*AccuWeather, you might as well throw that in the garbage…They aren't even close."*

Producers who observed conditions that did not match weather records or forecasts said that they became more skeptical of this information.

Many producers also agreed that "*you cannot rely on*" weather forecasts because "*they're all different.*" Producers recounted viewing multiple forecasts with different predictions, saying "*you can look at three different ones and they'll never be three the same.*" One participant even recalled the same source producing different forecasts, saying:

> *My wife has the Weather Channel on her iPad, and I have it on my computer. Her iPad is always accurate, and the one on my computer, I might as well throw it out the window, and it's from the Weather Channel.*

For many producers, diverging forecasts signaled uncertainty, which reduced their confidence in such forecasts.

Several producers recalled weather forecasts changing over time. One producer noted, "*even ten days out, it seems to change*." Another producer agreed, saying *"out there seven, eight, ten days, and you can see the models change."* Changing weather forecasts can make it difficult for producers to make plans, such as when to plant, irrigate, or harvest.

It is important to note that producers were not explicitly asked about weather records or weather forecasts; however, they described their experiences with weather information to explain their distrust in seasonal climate forecasts and midcentury climate projections. By connecting their views on weather forecasts to their views on seasonal climate forecasts, they were questioning the utility and trustworthiness of climate information.

Forecasts that cover longer temporal scales, such as seasonal climate forecasts, were also noted to be susceptible to change over time. Some producers indicated that they would be unlikely to use seasonal climate forecasts because of expectations that "*it changes so fast.*" A rancher pointed to recent seasonal forecasts as evidence of forecast uncertainty, saying

> *It changes from week-to-week, so I might look at the three-month outlook for southcentral Montana in March, and it says hot and dry. So I think, "Okay," keep that in the back of my mind. Be ready to dump cows. Then, in late March it says, "Well, near normal."…and then three weeks later, it says wet and cold. That's actually this year. That's what it was saying. So I don't really look at the long-range forecast anymore…*

Changing seasonal climate forecasts can complicate producers' longer-term decisions, such as what to plant, when to calf, or how much additional land to lease.

Producers did not perceive particular sources of seasonal forecasts as consistently more accurate than others. Instead, they suggested that a particular forecast would be more accurate for a while and then less accurate, or vice versa. A rancher recalled noticing that "*one time, this one is perfect. Everything is right on and doing good, but then, all of a sudden, they start missing everything, and this one over here is good.*" Another producer explained "*you can't just stay with one thing because it may work for a month, two months, maybe all summer. The next year, it's out in left field.*" Forecasts that "*flip and flop*" led to decreased trust in the forecast accuracy of the seasonal forecasts that producers consumed. Overall, lack of confidence in the accuracy of climate information meant that producers did not necessarily integrate such information into drought decisions.

5.4 Local Diversity and the Utility of Climate Information

In assessing the utility of climate information, producers drew heavily on their understanding and experience that every operation is different, based on local biophysical conditions, micro-climates, and agricultural practices. They argued these variations meant that coarse scale climate information was not always useful and often risky. Producers drew on their personal observations, concluding that "*the country differs so much in the way a crow flies of ten miles."* They pointed to a combination of biophysical conditions such as weather, climate, and soils, which create a diverse landscape. Farmers and ranchers explained how this diversity creates unique local conditions for each agricultural operation, as one rancher proclaimed *"the biggest thing in agriculture, his place is different. J.R.'s is different…Every operation is different."* They pointed out that landscape diversity influences whether climate information is useful or not. In addition, producers indicated that coarse scaled information could also be risky because they were uncertain if this information could accurately describe their site-specific conditions.

Many producers suggested that useful climate information must be presented at a scale that captures the diversity they observe on the landscape. When producers discussed seasonal climate forecasts, they adamantly called for site-specificity, suggesting that spatial diversity makes locally specific information more valuable than general information. One farmer stated, *"for it to be useful for us, it has to be site-specific."* A producer explained that, *"if you're planning on a trend that includes the whole state of Montana, well, you might just be way off base in the end because that trend isn't what's happening on your place."*

As an example, some producers indicated that there was too much diversity within their county for aggregated county level data to be useful. One rancher explained that within their county, *"living here, it's not the same…You've got almost three different worlds.*" To this producer, these three different worlds represented stark geographical boundaries where weather and climate differ dramatically from one area to the next. Another producer stated "*you can actually almost scratch a line, most the time, on the way the showers come through."* In one case, a producer noted that the highway was a clear division between two distinct metrological areas during a recent drought, saying *"everything west of the highway, they were extremely dry, on the eastern side of the county, so same county, but it was completely different."* Producers contrasted "*the bigger Montana picture,"* with "*three miles down the road,"* and what is happening on *"just my farm."* Ultimately, a rancher explains *"what everyone's looking for in the end… you're focused on your bubble."*

Producers pointed to specific ranges, mountains, hills, or ridges as influential on weather and climate conditions across the landscape. They used these physical features to emphasize the importance of locally specific information. A rancher pointed to a specific example, saying "*If there's a mountain—the Bearpaw sitting here versus Turner, there's a hell of a lotta difference."* Meanwhile, a farmer stated that the *"the Sweet Grass Hills definitely affects our moisture here."* Another rancher explained that *"the change in elevation makes quite a difference. I'm 900 feet higher than Choteau, and that temperature is cooler up there."*

Producers also noted that small-scale variations in soil type meant that information from coarse resolution soil moisture maps was not always useful. A farmer drew on personal experience monitoring his own soils to conclude that "*every field is different*." Meanwhile, other producers acknowledged that all "*soils are different.*" According to producers, "*a difference in soil type*" can determine *"how it holds the moisture. No matter how you manage it, there's a difference*." Therefore, a rancher noted that decisions *"have to take the soil conditions into account whether it's got clay in it or sand"* or any other type of soil. A producer with high concentrations of gravel in their soil pointed out how wind can deplete soil moisture *"in a week from adequate to none."* These smaller-scale biophysical differences reinforced producers' perceptions that information at larger spatial resolutions may not be particularly useful.

5.5 How Risk Perceptions Influence Use of Climate Information

Consistent with the literature, producers discussed the interacting risks that make agriculture challenging, including risks associated with adverse weather and climate conditions. Interestingly, some producers suggested that relying on seasonal climate forecasts increased risk, and that risk was compounded by financial vulnerability.

Many producers described rapid changes in weather as particularly problematic. Producers reflected on the times when the "*weather turned so quickly"* as though someone had just "*flipped a switch.*" When these transitions "*happen in a hurry,*" some producers felt that there was nothing they could do. When asked how they responded to the 2017 drought, one farmer stated *"it came on so quickly, that there was not a lot you could do. There were no warning signs."* Other producers recalled other droughts that came on so quickly that "*the rain just shut off,*" or high temperatures and "*three or four days of wind*" depleted soil moisture "*in about a week.*"

Many producers also described the financial risks that they encounter. A farmer noted that because "*the margin is so thin in agriculture,*" producers are exposed to substantial financial risks. They explained,

> "*for a lot of us…just corn seed, it's like $16, $17,000 just for seed, just let alone all the extra costs. And, if you screw up on that, and you have a crop failure, that could make the difference whether you survive or not long-term.*"

Another farmer stated, *"I'm at close to a half a million dollars a year that goes into my ground...you throw that much money into the ground every year, and hope it gives you something back.'"* This farmer concluded that *"$100,000 is not all that far off*" for potential losses within a single season. One farmer said that it is critical to "*stay soluble financially. Being able to have enough money to plant that next crop is always your final, bottom line."* Often, financial risks are not isolated to economic damages alone but can also substantially impact a producers' lifestyle, social networks, and identity. A producer points out that "*economically, for most of us, if we make a big mistake, it can cost everything. It can cost you your livelihood, your home, your operation, your whole whatever*." Several producers stressed that losses can be "*your way of life that's on the line."* They illustrated how these risks create a financial vulnerability that is omnipresent in their operations, which led to several producers discussing a basic need to "*survive*".

Financial vulnerability increased risk aversion and, for some producers, led to a reluctance to rely on seasonal climate forecasts, to the extent that that information was perceived as inaccurate, uncertain, and not trustworthy. They framed their reluctance to use seasonal climate forecasts in terms of the overall uncertainty that they face as producers, saying "*you can predict and you can guess and you can hope, but until it happens, you don't know."* One rancher warned that "*you never really know if things are* *going to pan out. Don't count your chickens before they're hatched."* Producers acknowledged that their decisions can determine whether they *"make it or break it."* One producer noted that *"if you make some big mistakes…you might not be there very long. It's risky."* A farmer also advised that even "*on a good looking year…you have to just plan for the best, and financially prepare for the worst."*

As a result, some producers suggested that their uncertainty in seasonal climate forecasts might increase risk. As one producer put it *"I'm not going to stake my life on it, which was ultimately what we're talking about. We're staking our way of life on that information."* Another producer stated that *"You trust stuff just so far, no matter where it comes from. Because until it's proven and in front of you, it's your livelihood and your way of life that's on the line."* Thus, financial risk made producers reluctant to utilize seasonal climate forecasts that they perceived as uncertain. Rather than seeing seasonal climate forecasts as a potential way to reduce risk from adverse climate and weather conditions, many producers saw that information itself as risky. Instead, many producers sought more certain information they felt they could trust.

In contrast, a handful of producers found seasonal climate forecasts useful and embraced them despite the uncertainty or risk. A rancher explained that "*there's a lot of things I could do—even if it was a forecast that said 80 percent chance of it being this way. Or, we're 60 percent sure. Then I can gamble on the other 40 percent."* This rancher recognized that forecasts are "*never going to be right all the time"* but still it "*just helps us plan."* Other producers suggested that they continually seek out a variety of weather and climate forecasts. For one producer, they referred to weather and seasonal climate forecasts as "*a tool in your toolbox*." However, this rancher continued on to say, "*I don't say you can rely on them*." Meanwhile, another rancher stated that *"I compulsively check the weather…it's not always accurate, but I can't help myself but to keep looking."* Several producers discussed how they could not trust that forecasts would be accurate, however, they could accept that forecasts are uncertain and continued to seek them out.

5.6 Managing Risk

Given these challenges, some producers were cautious and focused on practices that they perceived as less risky. A farmer stated that producers are often *"pretty cautious on what they trust and what they don't. Or how far they trust."* For example, a dryland farmer identified himself and other dryland farmers as "*cautious"* when making management decisions. He reflected that dryland farmers have learned to be cautious *"because those who weren't cautious aren't here*." Other producers also described their approach as "*cautious,"* or *"conservative."* As this irrigator explained:

> *It's more of a mindset of. Are you on the conservative side of this, or are you more progressive in thinking that you could outsmart it? Enough of us get burned that we end up being conservative.*

This producer suggested that their use of a conservative mindset, or caution, enables them to survive in agriculture. He asserted that to be *"progressive in thinking that you could outsmart it"* referring to uncertainty about future conditions which involves a level of risk that may lead to being "*burned*." By witnessing or personally incurring the costs of "*getting burned*," producers are compelled to implement strategies that are not "*progressive in thinking"* but that they are confident will be successful. "*Progressive,"* as used in this context, indicates something, new, foreign, or unfamiliar, like new technology, ideas, or information. One rancher argued that *"technology takes a long time* *to go through everybody, or get everybody on board before everybody's committed [because] you make one mistake, and like I say, it's make it or break it."* Similarly, another rancher discussed how they must be "*selective on where we get our information,"* feeling they must be selective *"because the risks are big.*" Producers discussed utilizing caution, having a conservative mindset, or being risk averse in their approach to managing risk.

Producers defined a cautious approach in different ways. A dryland farmer described "*easing into*" a new crop rotation strategy. This farmer identified their "*comfort zone*" to "*only grow pulse crops on fallow at this point*". Due to the high "*input cost with the pulse crops,"* he managed the financial risk by slowly transitioning to a pulse crop rotation. Similarly, a rancher admitted that they had become "*gun shy,*" explaining that they're, "*pretty careful on not overstocking a little bit. You're kind of, I would call it, gun shy. You don't know what every year is going to bring here."* These producers described being cautious by minimizing risks they could control, for example through decisions about planting times and stocking rates.

Many producers suggested that managing risk is not only necessary during bad years. One producer noted that with drought, *"there is that possibility every single year*". Many producers were similarly cautious and described adjusting their operations to make them better prepared for the uncertainty of what each season brings. *"You had to adapt because for us it was, 'We're not going to make it…doing things the same way we are, we're screwed,'"* one rancher explained. This producer also highlighted how uncertainty created risks to their operation. Although producers described a need to adapt their operations to *"almost be prepared for"* drier, drought-like conditions, they discussed different ways to accomplish this.

Some producers made adjustments to achieve a "*consistent"* operation in order to *"survive the disasters."* Over the course of nearly a decade, a dryland farmer adjusted his operation so that even in dry conditions he "*doesn't change much in the operation*," because he's "*not putting as much into it, but because of that, expectations are lower."* Instead, "*if it did get good …You make that decision to go a little bit more,*" by applying more inputs, like fertilizer. With fewer inputs and expectations of lower yields, this farmer sustains a consistent yet modest yield and financial return with the possibility of capitalizing on wet years. Similarly, a rancher described efforts to adapt to changing conditions, such as variable water regimes, stating that they cannot keep "*trying to chase it all the time."* They went on to explain, *"we've pretty much adjusted our stocking rate so that we can survive a drought like last year, and we don't increase."* In contrast to the farmer above, this rancher does not take advantage of the wet years to increase production. Another farmer explained how he reduced inputs on dryland crops, saying *"On the dryland…We fertilize for a drought. The last few years, we just go to the bare minimum and try to make malt barley."* Notably, this farmer made these adjustments to his dryland barley but on his irrigated crops, "*we do plant and we do fertilize for having a good year."* Interestingly, most of the irrigators did not minimize their inputs in anticipation of drought, likely because they have water rights that enable them to buffer drought conditions. For example, as described above, in 2017, despite above normal snowpack, Montana experienced a flash drought due to limited summer precipitation. Multiple irrigators recounted being unaffected by the 2017 drought*, saying "I'm almost* *all irrigated, so we had water here…The drought this particular time did not affect us."* Another irrigator stated, *"last year, drought didn't affect me at all."* Meanwhile, many dryland farmers and ranchers suffered throughout the dry summer months. But again, many irrigators did not face the same uncertain conditions as dryland farmers.

In the previous examples, producers highlighted different ways that they have or have not adapted their operations to meet adverse climate and weather conditions, such as drought. Some producers reduced their inputs (stock, fertilizer) to obtain dependable yet modest yields, while others reduced inputs only to increase to meet favorably wet day-to-day and seasonal conditions. Meanwhile, some irrigators didn't feel a need to adapt their operations to meet adverse conditions at all, as their rights to irrigated water allowed them to weather the drought conditions.

In contrast to the caution described above, producers also discussed their willingness to *"get out there and you try stuff, and see what works, and have a disaster here or there."* One producer stated, *"You get out there and you try stuff, and see what works, and have a disaster here or there. Have successes and take those successes and try to expand upon them."* Experimentation was described by producers as a process to adapt new information to a specific context and determine "*is it good or not?"* or to see if "*real life either confirms it or doesn't*." While producers acknowledge that "*trying something new is really, really risky,"* they argued that they could explore uncertainty, and limit the impact of risk through initial small-scale, low-risk experimentation (i.e. a small number of acres planted of an experimental crop). Several producers stressed the importance of starting with a "*small sample*" or *"little test plot in a corner of a main field," "starting small, experimenting. Doing a little bit. Seeing how that worked,"* which can mitigate the risk of *"breaking the mold of what has worked for 100 years and why you're still here."* Described by one producer as a "*risk analysis,"* gaining beneficial knowledge on the effectiveness of a specific technique may outweigh the costs of a corner plot going unproductive for a season. These producers went on to suggest *"it depends on how interested you are in learning whatever you're trying to figure out."*

After initial tests, a few producers described scaling up for expanded testing, saying that they "*have successes and take those successes and try to expand upon them*." A dryland farmer recounted scaling their experiments up until expanding to their whole operation, *"you do that 100 acres, and then you turn around—I did 500 acres, and I did 1,000, and now for the last six or seven years, I've done it on everything."* Increased experimentation over time develops more certain outcomes associated with knowledge implemented through practices in that specific context. Exploring new practices through small scale experiments develops increased certainty while risking low initial costs. Based on increased certainty, producers are able to prove the effectiveness of new practices on their operation. Throughout this process, producers develop experience with a practice in a particular place, accumulating trusted experiential knowledge to later draw upon in future decision making. It is this process that makes one participant comment "*farmers and ranchers are probably the most innovative group of people who are involved in testing the limits of Ag or doing experimentation."* Importantly, producers did not describe engaging in this type of experimentation to test out the efficacy of climate information.

6 CONCLUSION

Montana is anticipated to experience increasingly challenging climate conditions, especially more frequent and intense drought conditions (Whitlock, 2017). These changes will introduce new risks as well as intensify existing risk for agricultural producers. This study has examined the role that risk and trust play in producers' perceptions of different types of knowledge.

Many of the risks described by producers in this study have also been described in previous studies, including risks related to adverse weather events, financial hardships, and new technologies (Hardaker et al., 2004; Hay, 2007; Menzie, 2007; USDA, 2018). Most notably, producers in this study characterized adverse weather and climate conditions, such as prolonged drought, as large risks to their operations. A single risk, such as drought, can be detrimental to an operation; however, multiple risks can compound to make producers more vulnerable. Leichenko & O'Brien (2002) suggest that multiple risks, such as fluctuating markets and climate impacts, can interact with one another to create "double exposures." They specify that double exposure occurs when individuals are "confronted by the impacts of both climate change and economic globalization." (p. 227). A double exposure could result from drought and high interest rates, making producers more susceptible to harm.

Producers in this study often equated uncertainty with risk, regarding uncertain climate information as risky. Climate information was regarded as risky because it was produced by experts from far away, not grounded in local knowledge and observations, and perceived as potentially inaccurate. Thus, relying on climate information to make decisions about drought was considered risky, since decisions based on inaccurate forecasts might result in financial loss. And without previous positive experience utilizing climate information, producers were unsure about the outcomes of decisions based on such information.

In contrast, producers trusted local knowledge and tried-and-true practices, regarding them as less risky given previous outcomes. Local knowledge was regarded as trustworthy because it was based on producer experience and grounded in the local context. Further, knowledge based on past actions that produced positive outcomes was regarded as less risky because producers assumed that what worked in the past was likely to work in the future.

Figure 1 illustrates the relationship between trust, risk/uncertainty, and different types of knowledge, as described by producers in this study.

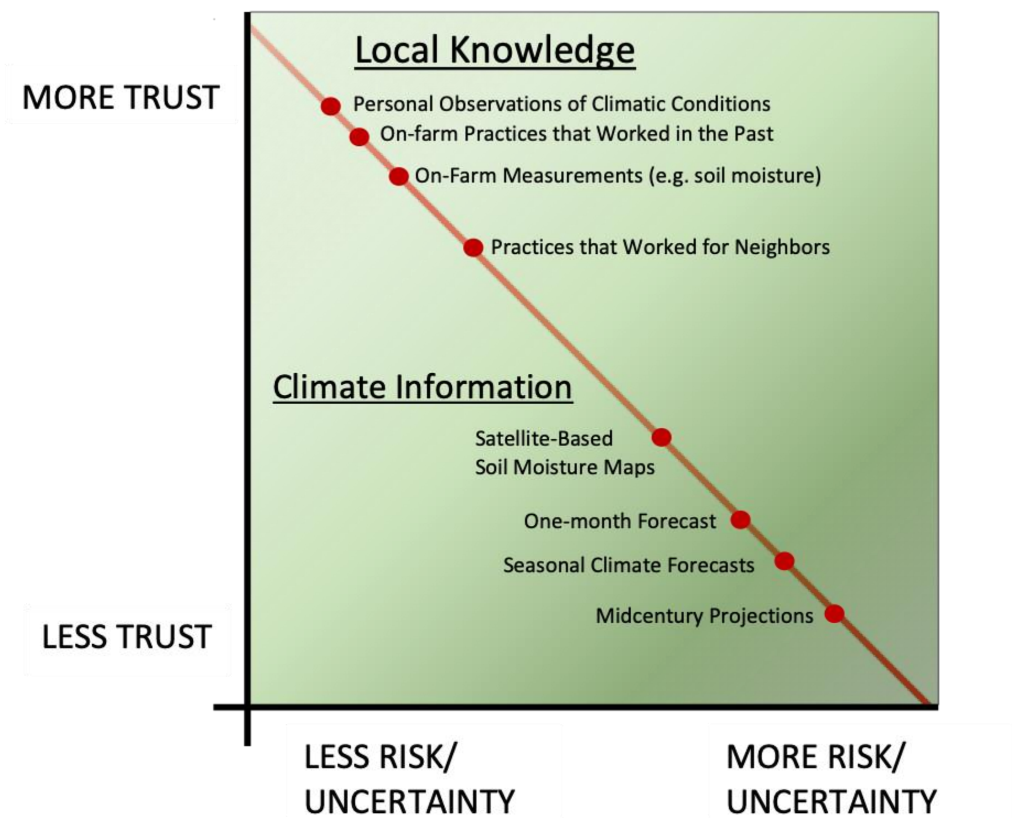

Figure 1. The relationship between risk, uncertainty, and trust in agricultural producers' perceptions of different types of knowledge, such as climate information and local

To

address this type of risk, agricultural producers in this study indicated they are "cautious" or risk averse and draw on their experiences for trusted knowledge that has been proven to work on their farms and ranches. These findings align with previous research on producers utilizing knowledge from trusted sources (Carolan, 2006a, 2006b; Knapp & Fernandez-Gimenez, 2009; Oreszczyn et al., 2010) and the role of past experiences in producer decision making (Kaup, 2008; Haigh et al., 2015; Wilke & Morton, 2017). Similarly, in this study, Montana producers described how they utilized knowledge gained from family and friends from past and present generations. Previous research has also found that family and friends are one of producers' most trusted sources of knowledge (Kloppenburg, 1991; Hassanein, 1999; Carolan, 2006a; Knapp & Fernandez-Gimenez, 2009; Chatrchyan, 2017). The producers in this study credited past generations as contributing to the knowledge they use to make decisions today. When producers recalled what "*the old timers told us they did,*" they bring the past into the present as historical narratives (Wilke & Morton, 2017). Wilke and Morton (2017) state that contemporary agricultural decisions are often "grounded in the farm's history, past activities and traditions*"* (p. 21).

Despite the relevance of the past, climate change might pose a problem for producers who rely upon previous experiences to make decisions about future drought. Rapid and dramatic changes to climate may create new conditions that do not resemble producers' past experiences. In Montana, expected climate changes are anticipated to impact precipitation, snowpack, and instream flows and increase the frequency and duration of drought.

Even though producers perceive new knowledge and practices, such as climate information, to be risky, many producers still experiment with new information and practices, despite the risks they associate with it.through small scale on-farm or ranch experimentation, producers described a process to develop first-hand experience to determine the effectiveness of new practices while limiting their exposure to harm. Experimentation can support local knowledge creation and increase trust in the knowledge and practices that work well. These findings have been supported by previous research as well (Feder and Slade, 1984; Leathers and Smale, 1991; Marra and Carlson, 2002). Specifically, Mase et al. (2017) also found that one of the primary ways that Midwest farmers manage risk is by adopting new technologies.

On-farm or ranch experimentation has been previously documented in Montana's Golden Triangle as well. Stephens (2015) found that both conventional and organic farmers used testing and experimentation to explore new crop varieties, technology, and techniques. However, they suggested that experimentation typically occurred among only a few "pioneers who are willing to experiment and risk failure, bear that risk for their community" (p. 98). In addition, they found that many other farmers felt it too risky to experiment with unproven technologies or techniques. However, pioneers provided the community with concrete examples of how such knowledge and practices would fare in an operation similar to theirs. Stephen's (2015) findings provide further evidence of the importance of experimentation for creating trustworthy local knowledge among Montana agricultural producers.

In this study, many producers described experimenting with new crops or grazing regimes, but only a handful of producers mentioned testing climate information in the same manner. One producer recounted how he "*planted 1,500 trees*" to intentionally "*push a little bit of the climate zone on them, because we knew things were warming*." Other producers who are interested in integrating climate information into their decision making, could begin by experimenting with seasonal climate forecasts. For example, to test out a seasonal forecast that calls for a hotter than usual growing season, a farmer might plant a more heat tolerant crop, such as corn, on a subsection of their land, instead of wheat. If planting corn was successful, the farmer could build from this experience and continue to utilize seasonal forecasts.

Meanwhile, a few producers indicated that they utilize climate information despite a lack of overall confidence in its accuracy. For these producers, seasonal climate forecasts may be one component within a "*toolkit"* of available resources for decision making. A rancher indicated that the "*blend*" helps him *"make an educated decision"* and acknowledged the inherent uncertainty of his knowledge. Balancing multiple factors in agricultural decision making has been examined by previous research as well (Kaup, 2008; Knapp & Fernandez-Gimenez, 2009; Raymond, 2010; Lehébel-Péron et al., 2016). Kaup (2008) calls this the "reflexive producer," a producer who negotiates among different types of knowledge to make a decision. The reflexive producer makes agricultural decisions within a complex environment with multiple types of knowledge and interacting risks and uncertainties.

Many of the findings described above build upon past research that has pointed out the importance of local knowledge to agricultural producers across the world (Leach & Fairhead, 2000; Naess, 2013; Goulet, 2013; Sumane et al., 2018). Since these findings are not new, why have scientists failed to effectively integrate local knowledge into agriculture or climate science? The agriculture industry's financial interest in advancing profitable science and innovation may be one explanation for why science has largely ignored local knowledge. Local knowledge, the knowledge gained from personal experiences doing an activity in a particular place, is not easily commoditized; whereas, new seed varieties, equipment, fertilizers, insecticides, and herbicides are profitable. The technology treadmill describes the pressure farmers and ranchers feel to continuallyinvest in new technologies with hopes of obtaining higher rewards. However, with increased production generated from more efficient technologies, farmers often end up receiving lower prices per unit due to the newly created surplus supply (Howard, 2016, Guptill, 2017). Meanwhile, companies that develop the next technological advancement are guaranteed a market that needs their product. While this model may increase the amount of annual production for an operation, these advancements may not support a resilient operation (e.g. monocropping). Due to the rapid pace of the technology treadmill, producers are unable to do anything besides try to keep up. Whether or not climate information is part of the technology treadmill or an accessible source of useful information remains to be seen.

These findings suggest several ways that agricultural producers could be supported while they navigate a variety of risks. Agencies, such as the United States Department of Agriculture, U.S. Department of the Interior, Natural Resource Conservation Service, County Extension, and others, could support producers in developing new practices, testing new technologies, and applying new information in decision making. To do so, these agencies must encourage producer-conducted experimentation. As outlined in this study, many producers experience financial risks, which can create barriers to engage in on-farm experimentation. Agricultural agencies can target financial barriers through programs that reduce financial risk and incentivize experimentation. This would complement current programs that respond after harm has occurred, such as the Federal Crop Insurance Program, disaster payments, and the Price Loss Coverage Program. Agency investment in on-farm and on-ranch experimentation can mitigate the impacts of financial risks by helping producers test the local relevance of non-local knowledge and information, increasing producer's capacity to respond to drought conditions.

Additionally, this study aims to inform how climate information providers' work could become more relevant to agricultural producers. Today, scientists create and disseminate climate science for broad audiences with a wide range of applications. Between policy makers, water managers, agricultural producers, and the general public, climate information is often intended for mass consumption. However, this one size fits all approach does not always meet the unique needs of agricultural producers. To make climate information more meaningful for producers, we need to figure out how it can be better tailored to producers' needs.

In this study, producers pointed out that forecasts were often presented at spatial or temporal scales not useful for their decisions. However, many producers also highlighted the need for highly accurate forecasts that they can trust. As previously discussed, downscaling climate information, specifically seasonal climate forecasts, to finer spatial scales most useful for producers (i.e. "*just my farm")* introduces different kinds of uncertainties and could inadvertently increase producers' distrust in climate information. To address these issues, climate information providers must direct research efforts to develop accurate forecasts that meet the spatial and temporal needs of producers. In the meantime, climate information providers need to increase trust by better communicating the relationship between spatial scale, uncertainty, and accuracy. To accomplish this, they can package downscaled forecasts alongside coarse-scale forecasts. Delivering forecasts at multiple scales and clearly communicating differences in confidence may provide producers a better understanding of the relationship between spatial scale and forecast certainty and increase trust among agricultural producers.

These findings suggest that climate information providers must work to create and disseminate information that considers how producers make agricultural decisions, including local knowledge created through experience and experimentation. The Drought Impact Reporter is a promising platform where producers and scientists can view local observations of drought impacts from producers and other stakeholders. In fact, these on-the-ground perspectives became an important early indicator of the 2017 drought in Montana. A recent report found that "early decisions of ranchers and producers, such as destocking, provided the "early warning" of the ensuing drought for many who work on providing drought and climate information" (Jensco et al., 2019, p. 68). The report concluded that producers' "early warning indicators" can help scientists recognize signs of drought earlier. Therefore, greater investment in communication channels that convey producer observations to scientists can help increase drought response (Jensco et al., 2019).

Currently leading the production of climate information within the United States, the National Oceanic and Atmospheric Administration (NOAA) could provide leadership within the science community to develop better communication with local farmers, ranchers, and agricultural organizations. More specifically, agencies with local representatives such as Extension and the Natural Resources Conservation Service could partner with NOAA to serve as a communication corridor from farmers and ranchers to NOAA and other climate information producers. By bringing both climate scientists and agricultural producers to the loading dock, as described by Cash et al. (2006), climate scientists can learn what information is used or not and why, as well as what information will best serve agriculture producers.

To further ensure that these agencies integrate local perspectives and knowledge into climate information, the U.S. Congress should supply adequate legislative direction and resources to accomplish these efforts. Policy that supports the creation of climate information relevant to agricultural producer should be integrated into future farm bills. If climate information is going to be useful for agricultural producers, it must be integrated into a wholistic national policy that governs the majority of American agricultural policy. Allocating resources for climate science within the farm bill will enable further development of climate science innovation that is created and disseminated for the specific needs of agriculture producers.

Experimentation is likely to be an important way that agricultural producers will adapt their operations to changing climate conditions. In addition, on farm/ranch experimentation is one way that producers can effectively utilize climate information within their agriculture decision making. While researchers have sought ways to develop better on-farm experimental methods (Ashby, 1987) or integrate new tools (Luschei, 2001), little research has examined the ways that producers engage in experimentation. More specifically, future research should explore how producers are experimenting with seasonal forecasts and longer-term climate projections in their management decisions. Further, research should explore the long-term economic advantages that on-farm experimentation may provide producers amidst changing climate conditions, particularly in the context drought.

Future research should also attempt to address some of the limitations of this study. Topics such as risk or on-farm and ranch experimentation were identified as important aspects to how producers perceive existing knowledge and create new knowledge. However, the focus groups in this study did not explicitly ask about risk and experimentation. Future research can expand on these findings through a more in-depth focus on the relationship between climate information, risk, and uncertainty, as well as how producers use (or could use) experimentation to integrate climate information into management decisions. In addition, in-depth interviews with individual producers would provide an opportunity to examine these topics in more detail, as compared with focus groups.

Montana agricultural producers explained that they experience diverse conditions across the landscapes and operations in which they work. Government agencies can help protect the livelihoods of producers and rural communities by supporting the creation and communication of knowledge that matches the diverse needs of individual agricultural operations, especially within the context of a changing climate.

Additional Concluding Thoughts

1.1 Limitations and Considerations

Focus groups create a social environment that resemble how individuals often interact in the real world. Although this format can provide valuable insight into social interactions and shared experiences, some of those same social processes can limit a producers' full participation in focus group dialogue. In this study, moderators deliberately encouraged all producers to be open in sharing their thoughts and opinions, however, participation across producers was varied. Each focus group consisted of producers who dominated conversations and others who shared their perspectives less often. In the practical sense, there are limitations on how much each producer could realistically share given the limited duration of each session. Meanwhile, the social dynamics of groups can also prohibit some producers from sharing as much as others, as some producers may not feel comfortable sharing alternative opinions to their peers. Asch's (1951) groundbreaking study provides an excellent example of how actors can have strong power and influence over an individual's ability to express opinions opposite of the group consensus. Peer influence may pressure a producer not to share their opinions or to adopt the group consensus over their own. Due to the strong social dynamics present at focus groups, this data represents a collective understanding of the group in a specific time and place, not individual opinions (Berg, 2007; Hesse-Biber, 2006).

In addition, the social nature of focus groups can be valuable for exploring shared resources, such as knowledge, however, it may be inappropriate for other topics.

Producers indicated that some aspects of their management happen in isolation from others. A couple of producers emphasized how their management decisions were solely their responsibility. One farmer stated, *"In the end, it's ultimately my decision what I want to do."* A rancher also said that they "*have to filter [information], and the filter that it goes through is me…in the end."* Considering the isolated position from which some producers make decisions, one-on-one semi-structured interviews may be the more appropriate setting to further explore how individual producers "filter" such information relevant to their own specific needs.

While the sample for this study sought to include a diversity of producers, the sample did not have representation from all types of Montana producers. For example, orchardists, corn farmers, and sugar beet farmers were not represented in this sample. There were only a few women and no non-white farmers who participated to our knowledge. Thus, this study is limited in its ability to describe the full range of agricultural producers in Montana.

1.2 Implications for Practice

The Natural Resource Conservation Service (NRCS) provides financial support to agricultural producers to complete farm and ranch development projects. The Agricultural Management Assistance (AMA) is an NRCS program that provides financial coverage for up to 75% of costs (not to exceed $50,000 annually) for water development projects, soil conservation projects and to "mitigate risk through production diversification or resource conservation practices, including soil erosion control, integrated pest management, or transition to organic farming" (NCRS, 2019). This program assists producers by partially relieving financial burdens associated with implementing or developing a new aspect of their operation. The AMA is different than other federal agricultural financial programs because it provides financial assistance for preventative risk management, as opposed to other programs that respond after harm or injury has hit, such as the Federal Crop Insurance Program, disaster payments, and the Price Loss Coverage Program. Available funds like these can help producers find and test locally relevant knowledge and information. Not only can state and federal government agencies support producers to create new knowledge, agencies can help facilitate the communication of locally relevant knowledge through locally embedded staff, including Extension agents, NRSC staff and Montana Department of Agriculture employees. These staff can best support knowledge transfer by facilitating farmer-to-farmer communications through conferences, field tours, workshops, and community social events.

1.3 Future Research

While the purposive sample used in this study sought to represent a diversity of opinions and provide insights into the knowledge that producers utilize in periods of drought, these findings cannot be generalized to the population of Montana agriculture producers. A next step in this research is to develop a representative sample of Montana agricultural producers. Future research should to develop a statewide survey that is able to draw from statistically conclusive findings.

Appendix 1

2 INTERVIEW GUIDE

Welcome people as they come in the door and ask them to fill out the short form about their operation and the informed consent form.

Thanks everyone for coming today. I'm Laurie Yung from the University of Montana College of Forestry and Conservation. This project is funded by a USDA program called Water for Agriculture. The goal of the project is to take seasonal forecasts and other climate information and put that information into a format that will be relevant and useful to agricultural producers all across the state of Montana, especially in the context of drought and other issues related to water availability.

Let's do introductions before we get started, please tell us a bit about your ag operation and any other role you play relative to agriculture (introductions all around, including USDA team members). We also need to complete the informed consent (pass out and briefly explain informed consent, remind them we'll be recording).

Today we'll be asking you some questions about last summer's drought and some questions about the draft climate information that we've put together. I'll be asking most of the questions, but Adam and Libby will also ask some questions. Kyle and Carly are available if you have questions about the information in the newsletter. We'll break at about Noon to eat lunch. I think it's worth noting that there are no wrong answers. In fact we fully expect that you will have different answers to some of our questions, so please let us know if you disagree or think differently than someone else in the room. It's important for us to hear all views. Make room for different people to speak up. To make sure we finish in 2 hours, I may nudge us along at times so we can stay on schedule.

1. So we'd like to start by talking about the drought last summer. Did you do anything differently on your farm or ranch to deal with the drought?
2. How or where did you learn to do that (reference the specific things they discussed doing differently)?
3. We're interested in what you think about the utility of different sources of information. When you think about your own knowledge as a farmer and what you learn from friends and family, as compared with information from scientists, extension agents, or other so-called experts, what did you find most useful during the drought? (probe on why)
4. How do you share and exchange ideas and information with other farmers regarding how to respond to the drought?

5. Now we'd like to ask you to read a draft newsletter we've pulled together. The goal of this newsletter is to provide information that will be useful to producers. But since

none of us are producers, we need your help understanding which parts are useful, what needs to be improved, and what isn't helpful. We plan to produce this newsletter four times a year and content will change based on the season. So, this is actually the April 1st newsletter, so you'll need to think back a little bit to decide if think would have been helpful in early April. As you read through the newsletter, please mark anything really useful with the green highlighter and anything confusing with the yellow highlighter. After you read through the newsletter, we'll have a chance to discuss it in detail. Please feel free to take notes on your copy.

6. As you know, this is our first attempt to develop something that we hope will be relevant and useful to farmers and ranchers, but we're certain it can be improved upon, so we're looking forward to your feedback.
7. Do you think this information would be useful to you as a farmer or rancher?
    - Probe: How do you think you would use this information?
8. Now we'd like to ask you about the maps and the scale of the information provided. There are two scales at which we can provide this information. Here they are on a paper together. The top map is what you just saw in the newsletter and the bottom map shows information at the county level instead. Which one is more useful to you and why? (<u>handraising vote</u>)
9. As you know, all of the future projections are somewhat uncertain (because we can't predict the future with complete accuracy). Looking at page 6, what do you think about the certainty or uncertainty of the summer forecast?
    - Probe: Is this information be useful to you even though it's somewhat uncertain?
10. We're also trying to figure out how to compare this year's conditions to normal conditions. Here are two ways to show how this year's temperatures differ from normal temperatures. Which one works better for you? (<u>handraising vote</u>)
11. Shifting to the mid-century projections on page 7. What did you think about these longer-term projections? Would they be useful to you?
12. A lot of research has shown the ag producers don't find the forecasts on pages 6 and 7 very useful. Why do you think that's the case and how can we make this information more useful to you?
13. What additional climate information would be helpful?
14. Now thinking about the newsletter as a whole (not just the mid-century projections), some people have asked us to add a short section with recommendations for farmers and ranchers to consider. Would this information be useful to you? Who would you want to provide this information?
15. We're thinking of publishing this newsletter on January 1st, April 1st, June 1st, and September 1st. Would that timing be useful to you?

16. Here's an outline of the information we plan to provide in each newsletter. Please spend a few minutes looking this over. Cross out what you don't need, star what's most important, and add anything additional that you want.

17. Is there anything else you'd like to share about the newsletter? Are these other ways we can make this information more useful to you? Or things that need to be clarified?
18. We have a few additional questions about what kind of information you trust. In thinking about how you would deal with a drought and the different kinds of knowledge or information you would rely on, what are your most trusted sources of information?
19. Probe on how knowledge you have from experience/friend/family compares to scientific information or other types of knowledge (e.g. ag advisors)
20. What about the newsletter? Do you trust the information presented in the newsletter?
21. What would make the newsletter more trustworthy?
22. Is there anything else you'd like to share with regard to this project?

We're official finished, but you're welcome to stay and provide any additional ideas or feedback. Please leave your handouts and newsletters so we have your notes, but feel free to take additional copies if you'd like. And if you think of anything later, please be in touch.

Again, we greatly appreciate your time. Thanks so much for coming today.

Appendix 2

3 QUESTIONAIRE

Please tell us a little bit about your operation (e.g. if you have livestock, what kind, if you grow crops, which kind, if you have an irrigated or rainfed operation or both).

When you think about making decisions for your operation relative to water (e.g. drought, flooding, etc.), what sources of information are most important to you? Please rank the top three, with 1 being the most important, 2 being the second most important, and 3 being the third most important.

___ My family
___ My own experience
___ Friends and neighbors
___ Agricultural science
___ Agricultural advisors
___ MSU Extension
___ Agencies (e.g. DNRC, DOA, NRCS)
___ Conferences and trade shows
___ Other. Please specify: ____

Age ______________

Gender _______________

How many years have you been in agriculture? _____________ years

Did you grow up on a farm/ranch? (please circle one) Yes No

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