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Agricultural Adaptation to Climate Change: How Montana Farmers Make Proactive Changes Despite Unpredictable Conditions

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How Montana Farmers Make Proactive Changes Despite Unpredictable Conditions

By

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Abstract

In Montana, climate change is projected to increase interannual variability and the severity of weather events like drought. To sustain agricultural production, farmers must adapt to climate change within a complex decision-making process responsive to a range of climate and non-climate stressors. This study explores how Montana farmers approach proactive and long-term adaptation, two types of adaptation which are not well studied, but are expected to be increasingly important for adapting to the impacts of climate change. To understand Montana farmers' approaches to adaptation, I conducted 30 in-depth interviews with farmers across the state. Farmers explained how unpredictability in weather and markets fostered a lack of agency and the sense that proactive decisions were gambles. When asked about the utility of two forms of climate information designed to help make proactive decisions, three-month forecasts and mid-century projections, most farmers thought they lacked reliability and relevance. Instead, to buffer against short-term fluctuations and overcome a lack of agency, farmers prioritized long-term adaptations with short-term benefits. These findings suggest that improvements in climate information and agricultural policy could support farmers in pursuing proactive, long-term adaptations.

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1. INTRODUCTION

In Montana's climate, drought is common, and scientists predict that it will become more frequent and severe due to climate change (Whitlock et al. 2017). To adapt to climate change, including increasing impacts from drought and other weather events, Montana's farmers will need to employ a range of strategies from short- to long-term and reactive to proactive. This study aims to better understand how Montana farmers are making proactive decisions and enacting long-term adaptations to climate change, including investigating the role of climate information in informing farmers' decision-making processes. In the context of climate adaptation, more proactive and long-term adaptation is widely presumed to be necessary, with three-month forecasts and mid-century projections assumed to be two tools that will support farmers in this adaptation.

This study was conducted as part of a larger interdisciplinary project, "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 goal of this study within this larger project is to examine what adaptations farmers are pursuing and how they are using climate information to do so. The following questions guide this study: What proactive adaptations do farmers pursue and what kind of agency to they have to implement those adaptations? And how does climate information enter into proactive adaptation decisions? To explore these questions, I interviewed a total of 31 Montana farmers across 18 counties. Interviews were recorded, transcribed, and analyzed using an iterative process that compared data to existing theory and literature, with a focus on implications for farmers, policymakers, and future research.

This thesis is organized as follows: the next chapter is a land acknowledgement and personal statement of positionality. Next, a short glossary intended as a quick guide for differentiating terms. The fourth chapter is a draft manuscript, which includes relevant literature, methods, results, and discussion. The following chapter provides further results that did not fit into the manuscript results due to space constraints. The final chapter provides a detailed description of the study methods. Appendix 1 is the interview guide used in interviews for this study. Appendix 2 is the climate information provided to farmers to aid the interview process. Appendix 3 is the coding scheme used to initially organize interview analysis.

2. Land Acknowledgement and Positionality

I was born in northern California on the lands of the Wintu Tribe and grew up in western Washington on Muckleshoot and Coast Salish lands. I live and work on Salish and Kalispell lands at the University of Montana. I am a young white man of European descent, whose ancestors in the United States participated in settler-colonial perpetuated genocide, not only in the abstract but as documented participants. One of my most infamous ancestors is Captain Underhill, a once-heralded orchestrator of mass murders, including a tragic massacre of Pequot men, women, and children during a corn ceremony in 1636. (Afterwards, the Governor of Massachusetts Bay Colony declared the next day one of "Thanksgiving.") Underhill rampaged in Massachusetts, Connecticut, New York, and other colonies, potentially killing thousands of Indigenous people in religiously fueled violence funded by Britain, the Netherlands, and other European colonizing powers.[1] In the 1800s, my more recent ancestors moved to what is now western Washington at a time when settlers regularly used their power to displace and war against Indigenous tribes. These ancestors were pioneers of colonial politics and industry, building the soon-to-be state government and the first sawmill in the Washington territory. Subsequent generations did not rise into great prominence, but homesteaded, milled logs, and integrated into the modern economies of a growing Pacific Northwest. I long viewed this more recent family history as hardscrabble but productive and relatively unimportant to understanding my place in the fields of human ecology or resource conservation. Not until I lived in Montana

[1] Walters, Karina L., and Danica Brown. n.d. "Invasion from All Directions—Stolen Lands, Stolen Peoples 1600-1699." *Native Americans in Philanthropy.* Retrieved February 25, 2022. (https://nativephilanthropy.candid.org /timeline/era/invasion-from-all-directions-stolen-lands-stolen-peoples/page/2/)

did teachers and friends help me understand the true extent of the violence inherent in this legacy.

Research is a form of power. As a researcher, it is my responsibility to reflect on how my status, life, and family history actively shapes my worldview, approach to research, data analysis, and presentations of findings. I must take stock of my capacity to shape systems of power and consciously and unconsciously reproduce them. Too often, researchers—of all fields—who look like me and come from similar backgrounds have easily achieved in academia and professions without reckoning with those structures of power that pave multigenerational paths. Buoyed by a system designed for my success, my status as a white cisgender man, able-bodied and born into a well-educated middle-class family, easily integrated into dominant culture and education gives me immense privileges. This status also makes me complicit in innumerable forms of historic and ongoing oppression. How these forms of oppression surface in a master's thesis focused on agriculture in Montana may be less clear because these systems often exist outside the realms of narrow academic inquiry. For one, traditional agricultural research (and other forms of farming-related education, such as through land-grant colleges and universities) protected and reified the white hetero-male privilege to land derived from a European aristocracy and deeply embedded in the racist settler-colonial core of the United States. Thus, farming as a profession was designed so white men could accumulate wealth and power. Despite now living in a time when people of any race and sex can own land; throughout the United States, land ownership, farm ownership, and wealth is still starkly divided by race, class, and gender. [2] Farming (and land ownership broadly) in the United States today requires gobs of wealth, especially in this post-pandemic

[2] Horst, Megan, and Amy Marion. 2019. "Racial, Ethnic and Gender Inequities in Farmland Ownership and Farming in the U.S." *Agriculture and Human Values* 36:1–16.

moment of an exploding real estate market. Increasingly, minorities who wish to enter agriculture have two choices: "inherit it or marry it,"[3] which re-produces significant race, gender, and income inequality. This problem shows few signs of improving. In the U.S., Black ownership of farmland has shrunk over the past 100 years.[2] In Montana today, 95% of farmers are white and two-thirds are men.[4] Structural racism, sexism, and classism is built into our institutions of private land ownership, capitalism, and governance. Legacies live on.

We often face the temptation in research—as in life—to assume that the places we observe are more or less as they have always been. Yet in Montana and across the country, landscapes were lived (and farmed) under completely different social, cultural, and economic systems than they are today. Although I have no personal background in the site of my research, my family history and the settlement of the western frontier show many similarities to the development of Montana's landscapes. These landscapes were once governed by different relationships, including kinships with local ecology. These lands were utilized in vastly different ways. And they were stewarded by diverse, abundant, and interconnected communities of Indigenous peoples who were unjustly removed from their homelands. Across the Great Plains, this deliberate and deadly displacement stained the soil, soil which was supposedly destined to be "improved" by white men, soil that industry then systematically fertilized with the ground up bones of millions of slaughtered buffalo.[5] These events are part of the vast genocide of

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[3] Pilgeram, Ryanne, and Bryan Amos. 2015. "Beyond 'Inherit It or Marry It': Exploring How Women Engaged in Sustainable Agriculture Access Farmland." *Rural Sociology* 80(1):16–38.

[4] Due to income reporting through jointly-held corporations in each spouse's name, sometimes regardless of their level of involvement in the operation, I suspect that the true extent of gender inequality in agriculture may be higher.

USDA/NASS. 2017. "Census of Agriculture: Montana." Vol. 1, Chapter 2. Retrieved April 14, 2021 (https://www.nass.usda.gov/AgCensus/).

[5] Barnett, LeRoy. 1972. "The Buffalo Bone Commerce on the Northern Plains." *North Dakota History* 39(1):23–40.

Indigenous people and the near-extirpation of buffalo that were deliberate steps in creating the privatized agricultural landscapes we know today. As descendant of white settlers, I frequently disregard that this transition to the current land regime was rapid, intentional, and incredibly cruel. I believe that researchers must always reiterate that these acts shaped our current systems and will never be ameliorated. As Gosnell et al. (2021) state in a recent paper on ranching in the west, "achieving equity and inclusion requires a deep reckoning with discriminatory histories and systems…"[6] Academics must bring this reckoning to all aspects of their work. A settler-colonial legacy dating back to the very inception of the nation not only produced the lack of diversity within the modern agricultural industry today, but also the enormous power that agricultural symbols continue to wield. For an industry dependent on ecology and weather, its power is often complicit in spreading misinformation and stalling progress on one of the most pressing issues of our time, and one that is central to this research, addressing human-caused climate change. Despite a history of oppression and continuing injustices, agriculture is central to our economies, our communities, and our global food security, and increasingly vulnerable to global disturbances like climate change.

My background and my upbringing are in many ways tied to the histories of colonial settlement in the United States that facilitated a privatized agricultural system that favors white men. Yet I came to Montana and its conventional agricultural community as an outsider, a well-educated liberal consumer, not a producer of food. My livelihood is not vulnerable to the whims of weather and markets like those farmers who graciously engaged in my research. Researchers like me can elevate certain voices and narratives, and I have a responsibility to ensure that my

[6] Gosnell, Hannah, Kelsey Emard, Elizabeth Hyde, Leslie A. Duram, and Giacomo Falcone. 2021. "Taking Stock of Social Sustainability and the U.S. Beef Industry." *Sustainability* 13:11860.

research acknowledges past injustices and meets the needs of future generations. Thus, my positionality must consciously and deliberately counter the prevailing assumptions of a society dominated by people like myself—privileged white men who benefit from the pastoral patriarchal-capitalist hegemony. Researchers have an obligation to dismantle these structures. Even if my specific research topic has little potential for addressing these inequalities, I can use the status and privilege gained from this research to do so. As an individual, I am entangled in the research I conduct. Therefore, my responsibilities as a person—not just a researcher—are to use my advantages to *not* perpetuate destructive racist-colonial processes, instead to attempt to do what I can to rectify these injustices.

GLOSSARY

This glossary is not intended to provide technical or comprehensive definitions, but rather to help quickly distinguish between similar terms. However, the exact meanings of these terms can vary by context, please see the full text with cited literature for further information.

Accuracy: measured likelihood of a correct prediction.

Adaptation: strategy for acting in anticipation of or reaction to a long-term stimuli or stress such as climate change. However, adaptation is widely considered a complex process with nuances that escape simple definitions like these—see the text for further detail.

Certainty: measured likelihood of a future event.

Climate: long-term trends considering a historical period of reference over decades.

Predictability: likelihood of a future event informed by subjective experience.

Proactive: acting in anticipation of a stimuli or stress.

Reactive: acting after a stimuli or stress.

Reliability: likelihood of a correct prediction informed by subjective experience.

Variability: tendency to move from one state to another.

Weather: short-term events like hailstorm and drought.

3. Draft Manuscript

Agricultural Adaptation to Climate Change: How Montana Farmers Make Proactive Changes Despite Unpredictable Conditions

Target Journal: Weather, Climate, and Society

Introduction

Farmers in Montana must constantly adapt to extreme weather events and a variable climate (Lacey, Wight, and Workman 1985; Whitlock et al. 2017). In Montana, climate change will raise temperatures, lengthen growing seasons, favor different crop varieties, and aid the spread of pests, weeds, and disease (Whitlock et al. 2017). More extreme temperatures and more variable precipitation will also exacerbate plant stress, decrease yields, and increase the potential of more severe droughts (Whitlock et al. 2017; Wienhold et al. 2018). These impacts are simultaneously similar to those farmers are already adapting to and entirely new, outside of the historical range of climate variability and atypical to farmers' lived experiences (Anderson, Bayer, and Edwards 2020; Crane, Roncoli, and Hoogenboom 2011; Findlater et al. 2019; Howden et al. 2007). Therefore, how farmers approach adaptation carries broad implications for an industry highly vulnerable to the effects of climate change (Lal et al. 2011). Furthermore, farmers must adapt not only to unprecedented biophysical changes but also to shifting social, cultural, and economic conditions (Crane et al. 2011; O'Brien et al. 2007). A better understanding of how farmers adapt is needed because new kinds of adaptation will be required to protect livelihoods and maintain production of food (Lawrence et al. 2018). In this study, I examined how famers in Montana make adaptation decisions and how climate information fits into this process.

LITERATURE

Adaptation can be defined as a process of deliberate behavioral and/or technological change in anticipation of or in reaction to external stimuli and stress (Nelson, Adger, and Brown 2007; see e.g., IPCC 2014; Parker et al. 2017; Taylor 2015). Adaptation can take many forms in agriculture, including practices implemented by individual farmers (e.g., earlier seeding or planting different or more drought tolerant varieties) (Doll, Petersen, and Bode 2017; Howden et al. 2007; Whitlock et al. 2017). Yet even when individual farmers change practices, these potential adaptations occur across multiple scales. For instance, planting drought-tolerant seeds often occurs in dialogue with other farmers and experts like extension agents, is enabled by state or corporate breeding programs, and the harvested crop must be in demand on an often global market (Moser and Ekstrom 2010; Müller, Johnson, and Kreuer 2017; Thornton and Manasfi 2011). Thus, to make sense of the complexity of adaptation to climate change, decisions are often characterized on several scales. First, adaptation decisions can be either proactive decisions made in anticipation of events or reactive decisions made in response to events. They can also range from decisions made by individuals such as farmers to decisions made by international treaty-making bodies. Changes made to adapt to climate change can also range from the short-term (e.g., a change made for a growing season) to the long-term (e.g., a change that lasts for multiple years), and from incremental adaptations which are small and gradual to transformative adaptations which represent a change to a fundamentally new system (Park et al. 2012). Although the adaptation literature is generally conceptual or focused on adaptation in institutionally or technologically driven ways (Moser and Ekstrom 2010; Thornton and Manasfi 2011), adaptation is increasingly envisioned as enabled by and nested within specific social, cultural, political, and economic structures across many scales (Eriksen, Nightingale, and Eakin 2015; Moser and Ekstrom 2010; Thornton and Manasfi 2011; Wyborn et al. 2015).

As a result, farmers make changes to their operations based on many different interacting factors. For example, farmers may change their practices to respond to markets with the goal of increasing profits (e.g., by implementing no-till or growing pulse crops), yet these changes might also make their operations better adapted to climate change, even if farmers did not intend it. Therefore, adaptation on the farm is not always intentionally in response to climate change. Further, changes which make a farm better adapted to climate change in the short-term may become maladaptive overtime or at larger spatial scales (Eriksen et al. 2015; Moser and Ekstrom 2010). For example, some changes may reduce short-term losses but lead to increased long-term financial risks (e.g., taking out large loans to install more efficient irrigation systems) (Holzkämper 2017; Kates, Travis, and Wilbanks 2012; Thornton and Manasfi 2011). Thus, evaluating farming practices in terms of their climate adaptiveness is a subjective process that will vary by scale (geographic and temporal) and such analyses may only be possible retroactively and with long-term hindsight (Shrum et al. 2018; Thornton and Manasfi 2011).

Many studies have examined farmers' attitudes, beliefs, and behaviors to better understand their individual adaptation decision-making (for example: Arbuckle, Morton, and Hobbs 2013, 2015; Mase, Gramig, and Prokopy 2017). This research suggests that farmers tend to discount the long-term effects of a changing climate, and, like most Americans, their views on climate change are associated with their political beliefs (Dunn, Lindesay, and Howden 2015; Grimberg et al. 2018). For instance, midwestern farmers who do not believe in human-caused climate change are less likely to report intentions to adapt to climate impacts (Arbuckle et al. 2013). Further, many farmers do not make decisions in response to climate specifically, describing climate change as "the least of my worries," focusing instead on immediate priorities related to operations and economics, and stating that only multiple years of severe climate-related losses could spur decisions specifically in response to climate (Bitterman, Bennett, and Secchi 2019; Fleming et al. 2015).

Despite evidence that many farmers do not frame their decisions as adaptations to climate change, farmers describe local climatic changes and acknowledge that climate is intertwined with their decisions (Doll et al. 2017; Smit and Wandel 2006). As one study noted, “climate is a widely acknowledged risk factor for most agricultural activities, but without being the sole or even dominant driver for most of them” (Meinke et al. 2009:73). At a surface level, there is an apparent contradiction between farmers’ lack of belief in climate change and their decisions that make them better adapted to climate change, summed up by one researcher as “skeptical but adapting” (Doll et al. 2017). To explain this contradiction, the adaptation that is already occurring has been described as “reactive” to events already happening and informed more by gut-feeling, rather than the thorough analysis and planning for the future presumed to be needed to adapt to the worsening effects of climate change (Fankhauser, Smith, and Tol 1999; Lawrence et al. 2018; Meinke et al. 2009). Thus, many farmers are not yet widely employing the types of proactive and long-term approaches that researchers believe will be necessary to adapt to climate change (Grothmann and Patt 2005; Nelson et al. 2007; Robert, Thomas, and Bergez 2016; Thornton and Manasfi 2011; Wise et al. 2014). However, while there is widespread agreement about the need for proactive and long-term adaptation, these terms are often conflated and not well defined. Further, the specific ways that individual adaptation decision-makers envision and make proactive and long-term decisions and their agency to do so within cross-scale influences has not been well studied. Understanding how farmers make proactive and long-term adaptation decisions is important because farmers’ adaptation is not simply deliberate change in response to stimuli, but a continual and dynamic process without an end point and with both planned and unplanned decisions influenced by a range of factors across scales (Crane et al. 2011; Meinke et al. 2009; Wyborn et al. 2015).

Climate information is presumed to enable farmers to adapt to climate change in the more proactive ways that are needed (Brasseur and Gallardo 2016; Rickards, Howden, and Crimp 2014). Climate information can feature a variety of past and current conditions, but it often includes two tools that project future conditions crucial for making proactive adjustments: three-month forecasts (also called seasonal climate forecasts) and mid-century climate projections. Model studies have indicated that three-month forecasts can help agricultural producers prepare for favorable and variable conditions, improve short-term coping, and increase profits (Ash et al. 2007; Meza, Hansen, and Osgood 2008). Additionally, three-month forecasts may not require that farmers subscribe to human-caused climate change and thus can be communicated without specific political connotations (Prokopy et al. 2015; Rickards et al. 2014).

However, three-month forecasts are not widely used by agricultural producers (Lemos, Kirchhoff, and Ramprasad 2012; Mase and Prokopy 2014; McCrea, Dalgleish, and Coventry 2005). Limited use of three-month forecasts is sometimes explained in terms of shortfalls related to how forecasts are communicated and the technical limits in the information itself, such as inconsistent forecast accuracy (Cash et al. 2003; Cash, Borck, and Patt 2006). However, it is not clear whether communication or even technical improvements would lead to higher uptake of three-month forecasts among producers. Although some improvements in communicating climate information can increase their utility to individual farmers already using this information (Cash et al. 2006; Dunn et al. 2015; Wyborn et al. 2015), such improvements may not expand agricultural producers' uptake of climate information more broadly (Marshall, Gordon, and Ash 2011). In addition, increasing the level of detail in this information may increase utility for short-term decisions but not for long-term decisions (Dunn et al. 2015). Although several studies examine the utility of three-month forecasts, measurements of these tools' value (i.e., risks and benefits of use to farmers and society) varies widely and often does not include farmers' input (Bruno Soares, Daly, and Dessai 2018). By some metrics, farmers are "correct" not to use three-month forecasts in changing their practices due in part to far from perfect forecast accuracy (Kusunose and Mahmood 2016:106). There is evidence that in addition to more accurate forecasts, farmers want climate information to be framed within specific decisions contexts, for example connecting forecasts to agricultural advice regarding how specific types of operations might respond to future conditions (Ash et al. 2007; Dessai et al. 2009; Dunn et al. 2015; Lemos et al. 2012). Contextualizing climate information in this way may be especially important for mid-century projections, which have been shown to be of less use to producers unless connected to specific decisions (Cradock-Henry et al. 2020; Crane et al. 2010; Lemos et al. 2012; Prokopy et al. 2015)

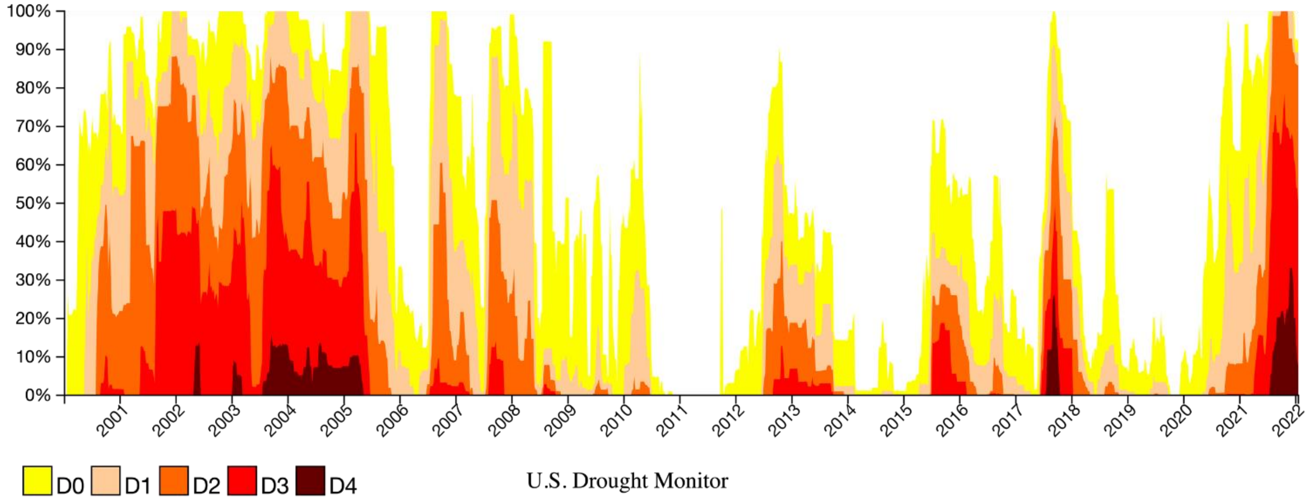
The emphasis on climate information also assumes that farmers have the agency and resources to act proactively, an assumption that may not fully recognize the myriad factors that influence adaptation decisions across scales. While a number of studies document farmers' limited use of seasonal climate information (Lemos et al. 2012; Mase and Prokopy 2014; McCrea et al. 2005), none examine farmers' perceptions regarding how to integrate imperfect forecasts into decision-making in ways that would allow for proactive changes to future conditions. Even though farmers do not always envision their decisions as adaptations to climate change and may not believe in anthropogenic climate change, their decisions may in fact make their operations better adapted to climate (Doll et al. 2017). An improved understanding of how farmers view and enact proactive and long-term changes today (and their opposites, reactive and short-term adaptation, respectively) should indicate how farmers might adapt to future climate conditions overtime and what factors must be in place to do so. For farm advisors or policymakers who want to help individuals like farmers adapt to climate change, understanding the conditions that lead to proactive and long-term decision-making is critical for not only tailoring tools like climate information to farmer needs, but also for examining the reasons why farmers pursue some proactive decisions and not others. To this end, this research asks: What proactive adaptations do farmers pursue and what kind of agency do they have to implement those adaptations? And how does climate information enter into proactive adaptation decisions?

Study Site and Methods

This research was conducted in Montana because the state has an economically important agricultural sector and extensive experience with drought. The state is home to over 27,000 farm and ranch operations, contributing $4 billion to Montana's economy and making agriculture one of the state's leading industries (NASS 2020). In Montana, 62% of land is in farms or ranches, totaling over 58 million acres (NASS 2020). Of that agricultural land, 66% is pasture and rangeland and 17% is harvested cropland (NASS 2020). This research focuses on crop farms or mixed operations (operations with crops and livestock). Crop production in Montana is often in large-scale export-oriented monocultures that rely on inputs like fertilizers and herbicides (Lawrence et al. 2018). This system is exemplified by wheat production, Montana's most important crop by both acres and value, accounting for about a quarter of the state's agricultural production in dollars (NASS 2020). However, many farms incorporate more diverse crop rotations, and Montana is also among the nation's leading producers of barley, lentils, peas, chickpeas, and oil seeds like canola and flaxseed (NASS 2020).

Drought is a regular occurrence in Montana. In 2017, over a quarter of the state experienced exceptional drought conditions (as defined by the U.S. Drought Monitor), which resulted in widespread crop and pasture loses, and water emergencies (NIDIS 2021). At the beginning of this study, Montana declared a statewide drought emergency, citing moderate to extreme drought conditions in nearly 70% of the state (State of Montana 2021; see Figure 1).

Figure 1: Drought in Montana from 2000 to Present by Percentage of Land Area



D0: abnormally dry; D1: moderate drought; D2: severe drought; D3: extreme drought; D4 exceptional drought (U.S. Drought Monitor; NIDIS 2022).

Irrigation is particularly important in Montana, but 80% of cropped acreage in the state is non-irrigated (NASS 2020). Non-irrigated operations depend on rainfall and soil moisture, while irrigators depend on summer streamflow, making all of these operations extremely vulnerable to weather and climate impacts.

To better understand how farmers view and enact adaptation, I conducted in-depth semi-structured interviews with 31 farmers across 18 Montana counties (25 interviews by phone, 1 by Zoom, and 4 in-person) (Table 1). The interview sample consisted primarily of farmers recommended by Montana State University (MSU) Extension and Natural Resource Conservation Service (NRCS) offices across Montana. The remaining participants opted into an interview via a mail survey, were on the Board of the Montana Grain Growers Association, or were recommended by research collaborators. I also interviewed two participants who were recommended by other farmers.

Table 1: Interview Sample Characteristics

	Operations (n = 30)	***Size, acres* (n = 20)***	***Irrigation (n = 30)***	***Organic (n = 30)***	***Gender† (n = 31)***
Farmers (all crops)	16	4,539 (ave.) 10 (min.) 16,000 (max.) (n = 10)	10 dryland, 3 majority dryland, 3 irrigated	3	14 male, 2 female
Mixed (crops and livestock)	11	9,413 (ave.) 800 (min.) 50,000 (max.) (n = 8)	5 dryland, 2 majority dryland, 4 irrigated	2	10 male, 2 female
Ranchers (all livestock)	3	4,680 (ave.) 1,360 (min.) 8,000 (max.) (n = 2)	2 dryland, 1 majority dryland	0	3 female
Total	**30 operations**	**6,503 acres (average)**	**17 dryland, 6 majority dryland, 7 irrigated**	**5 organic**	**24 male, 7 female**

Interviews included 30 operations and one interview of two participants.
*Size of operation was not a direct interview question; however, 20 farmers volunteered the size of their operation.
†Assumed, not self-identified.

I used a purposive sampling strategy with the goal of interviewing a range of farmers who represented the primary types of farming operations in Montana. Farmers were selected based on different types of crops and irrigation systems (e.g. non-irrigated dryland, and irrigated by flood, pivot, or drip) (see Table 2), and based on a diversity of adaptive practices (e.g. no-till). I also interviewed farmers from different parts of the state to capture different types of operations and climatic conditions. Of 31 participants, 16 resided in the Golden Triangle, a region with some of the most concentrated cropping in the state, where each county is 98% or more dryland by acreage and includes the highest rates of no-till agriculture in the state (Haynes et al. 2020; USDA/NASS 2017). This area is characterized by dryland wheat cultivation which may not have much tolerance to withstand further heat and drought stress and could serve as an early warning signal for climate change impacts to agriculture (Lawrence et al. 2018). The Golden Triangle also leads the state in pulse crops and barley, with crop rotations that are increasingly diversified in comparison to the rest of the state (USDA/NASS 2017). Outside of the Golden Triangle, 15 farmers resided in 12 counties across the central and southern span of the state.

Table 2: Sample Grain Farmers' Crop Diversity (By Number of Farms)

	Farms	***Wheat****	***Oilseeds†***	***Barley***	***Lentils***	***Peas***	***Chickpeas***	***Other‡***
1-2 crops	9	9	0	3	2	1	0	1
3-4 crops	7	7	5	4	1	3	2	3
5 or more crops	5	5	5	2	4	3	3	3
Total	**21**	**21**	**10**	**9**	**7**	**7**	**5**	**7**

In each column, the number of grain farms growing each crop by their total number of crops. The "Farms" column lists the number of farms in each category of total number of crops the operation grew, from monocultures growing one or two crops to diversified operations growing 5 or more crops.

*Wheat: spring wheat, winter wheat, or durum
† Oilseeds: flaxseed, mustard, safflower, canola, sunflower
‡ Other: corn, spelt, camelina, or unspecified

In-depth semi-structured interviews offered insight into producers' perspectives and practices while providing detail on both past and future decisions (Carlisle 2014). Interviews also allowed for comparing the discursive strategies that farmers use to underly these decisions and perceptions. An interview guide focused on understanding farmers' experiences with weather and climate impacts, their agency to adapt reactively or proactively to past and future impacts, and the factors that influence their decision-making process and use of climate information. Interview guides provides flexibility, allowing the interviewer to go into detail in the areas most salient to participants, and comparability, by ensuring that the same topics were discussed by each

participant (Hesse-Biber and Leavy 2017). Each interview included a section on climate information where most farmers were given examples of recent snowpack, soil moisture, three-month forecasts for temperature and precipitation, and mid-century projections in the form of spatial climate analogs (n = 23; some participants had technical issues and were unable to view the climate information but were asked the same questions without the visual examples) (see examples, Figures 2 and 3). This paper focuses on farmers' responses to three-month forecasts and mid-century projections.

Figure 2: Three-Month Forecast for Precipitation

Three-Month Forecast for Precipitation

Most Montanans experienced drier than normal conditions this summer, but the NOAA's Climate Prediction Center is projecting more normal conditions going into the fall, with somewhat likely wetter than normal conditions in northwestern Montana. While the return to normalcy is welcome, much wetter conditions will be necessary this winter in order to recharge soil moisture across the state.

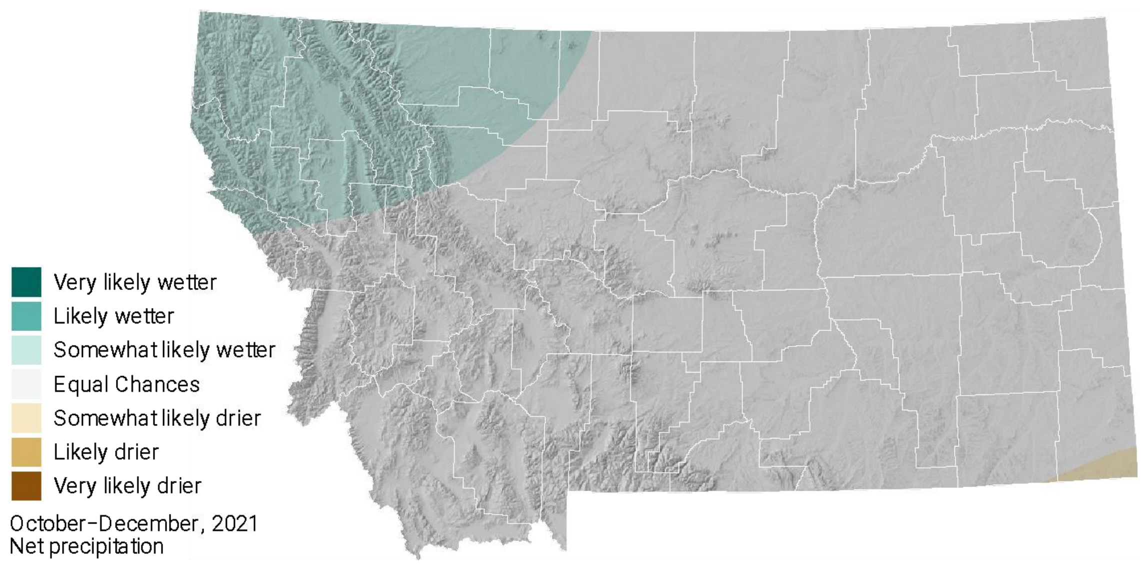
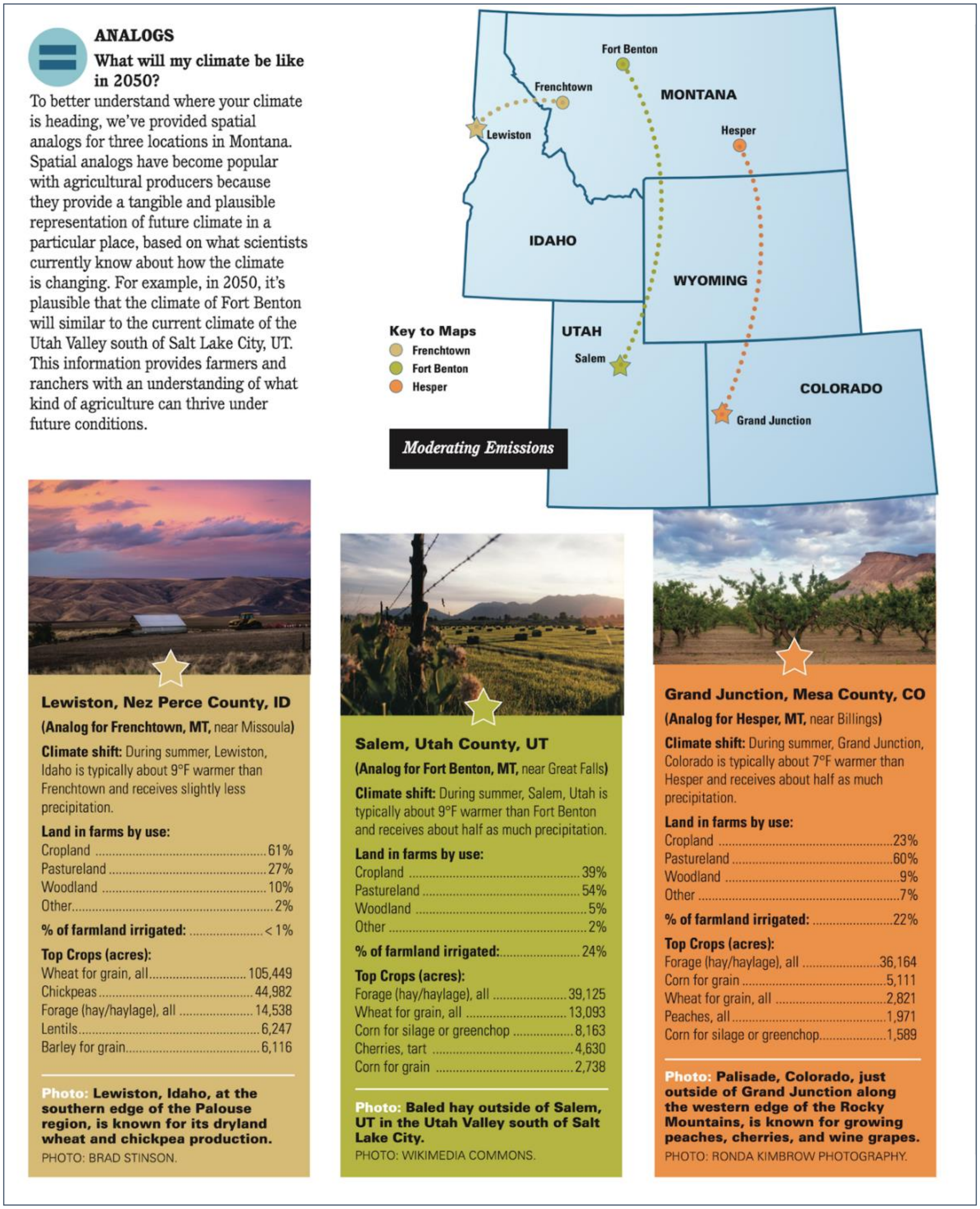


Figure 3: Mid-Century Projection as Spatial Climate Analog



ANALOGS

What will my climate be like in 2050?

To better understand where your climate is heading, we've provided spatial analogs for three locations in Montana. Spatial analogs have become popular with agricultural producers because they provide a tangible and plausible representation of future climate in a particular place, based on what scientists currently know about how the climate is changing. For example, in 2050, it's plausible that the climate of Fort Benton will similar to the current climate of the Utah Valley south of Salt Lake City, UT. This information provides farmers and ranchers with an understanding of what kind of agriculture can thrive under future conditions.

Lewiston, Nez Perce County, ID

(Analog for Frenchtown, MT, near Missoula)

Climate shift: During summer, Lewiston, Idaho is typically about 9°F warmer than Frenchtown and receives slightly less precipitation.

Land in farms by use:	
Cropland	61%
Pastureland	27%
Woodland	10%
Other	2%
% of farmland irrigated:	< 1%

Top Crops (acres):	
Wheat for grain, all	105,449
Chickpeas	44,982
Forage (hay/haylage), all	14,538
Lentils	6,247
Barley for grain	6,116

Photo: Lewiston, Idaho, at the southern edge of the Palouse region, is known for its dryland wheat and chickpea production.

PHOTO: BRAD STINSON.

Salem, Utah County, UT

(Analog for Fort Benton, MT, near Great Falls)

Climate shift: During summer, Salem, Utah is typically about 9°F warmer than Fort Benton and receives about half as much precipitation.

Land in farms by use:	
Cropland	39%
Pastureland	54%
Woodland	5%
Other	2%
% of farmland irrigated:	24%

Top Crops (acres):	
Forage (hay/haylage), all	39,125
Wheat for grain, all	13,093
Corn for silage or greenchop	8,163
Cherries, tart	4,630
Corn for grain	2,738

Photo: Baled hay outside of Salem, UT in the Utah Valley south of Salt Lake City.

PHOTO: WIKIMEDIA COMMONS.

Grand Junction, Mesa County, CO

(Analog for Hesper, MT, near Billings)

Climate shift: During summer, Grand Junction, Colorado is typically about 7°F warmer than Hesper and receives about half as much precipitation.

Land in farms by use:	
Cropland	23%
Pastureland	60%
Woodland	9%
Other	7%
% of farmland irrigated:	22%

Top Crops (acres):	
Forage (hay/haylage), all	36,164
Corn for grain	5,111
Wheat for grain, all	2,821
Peaches, all	1,971
Corn for silage or greenchop	1,589

Photo: Palisade, Colorado, just outside of Grand Junction along the western edge of the Rocky Mountains, is known for growing peaches, cherries, and wine grapes.

PHOTO: RONDA KIMBROW PHOTOGRAPHY.

Throughout the interview, participants were encouraged to bring up topics and ideas that were not covered in the interview guide. I used probes drawing on farmer's own language to clarify and elicit additional detail, or to explore connections between farmer's experiences and the literature. Most interviews were conducted by phone, due to the size of the study area, the ongoing COVID-19 pandemic, and the demands of farmers' growing seasons. Multiple farmers spoke to me on the phone from the cab of their tractor or late in the evening after a full day of work.

Interviews were audio recorded, professionally transcribed, coded in NVivo 12, and analyzed and interpreted through an iterative process comparing existing theory and empirical data. This dialectic process was attentive to emergent phenomena from the interviews through post-interview memos and an analysis process that identified emerging themes and unanticipated results. These memos also helped to identify divergent responses to interview questions to elucidate the differences among participants. I developed both topical codes to categorize practices and types of climate information (e.g. "cropping practices" or "three-month forecasts") and analytical codes to categorize themes relevant to the literature (e.g. "reactive adaptation" or "climate information relevance and utility"). After each interview was coded, data from each code was organized and re-organized into a series of documents to enable cross-interview comparison.

RESULTS

Interviews with farmers revealed the importance of understanding the influence of weather and climate on adaptation, including proactive decisions. Farmers described how proactive decisions are (and are not) informed by two forms of climate information, three-month forecasts and mid-century projections. Farmers also discussed their approaches to short-term responses and long-term adaptations.

Unpredictability and Variability Make Planning Difficult

Farmers described both short-term weather unpredictability and long-term climate variability that made it difficult to plan ahead and thus stymied efforts to be proactive to certain weather events. Drought was the weather event discussed most often. The potential for future drought loomed large for farmers and a few shared that multiple bad drought years in a row would put them out of business. Like hail and rainstorms, many farmers argued that drought was unpredictable, such as this farmer: "drought, you don't have any idea when it's coming, how long it's going to be here, or how bad it's going to be when it comes." Interestingly, although farmers emphasized the unpredictability of future weather, many also discussed the inevitability of drought, saying "in Montana we're always in a drought and sometimes it rains." Farmers met the looming and inevitability of drought with sometimes opposing mindsets, from "I always farm with a thought there could be drought" to "you farm for a wreck [drought] and you'll get a wreck." As the latter quote illustrates, many farmers chose to remain optimistic about future weather because they viewed drought as inherently unpredictable and believed that farming for a drought year—for instance, relying on crop insurance to cover a portion of losses while raising a less productive crop—would be the equivalent of admitting defeat. Because they perceived these weather events to be unpredictable, farmers often conveyed that to act in anticipation of specific events like drought would be a "fool's errand."

Dryland grain farmers also emphasized unpredictability in the form of interannual climate variability. As one farmer recounted, "No year is the same as another year. And I knew I was going to be in a place that was pretty variable to start with, but it's significantly more," and another said, "You don't have a clue what's coming. I mean, it's either feast or famine. There's very few years in between." Many farmers suggested that climate variability made it difficult to plan, as illustrated by this farmer, who said, "I think the seasons are a lot more just erratic. Every season's kind of different. It's hard to kind of plan." Interannual climate variability made farmers unsure about whether they would get enough moisture during the winter or over the growing season to sustain a crop. Together, farmers' experiences of unpredictable weather events and a climate with interannual variability frustrated their attempts to plan proactively for future conditions.

Table 1: Additional data on Farmers' Perceptions of Weather and Climate

Perception	Farmer responses
Weather as unpredictable	"The cold snap, I just didn't even see coming." "This little stint [drought] came more of a shock just because I had had like three or four really, really good years and so the grass was really lovely." "It'll stop raining at some point, and you don't know when it's going to turn back on."
Impacts to livelihood	"Our operation has all become a little more marginal in the floor so every weather event, I tend to notice it more."

	"We haven't been profitable since 2017, was the last profitable year we've had, and it's because of hail storms and droughts. So, it's had a pretty solid impact." "I always remember when I was younger, a guy once said that the amount of money I make just depends on how much it rains." "Because that, like a hail storm, flood, drought, they can affect you for at least four more years down the road, and they can cause you major problems, major headaches, and cost you a lot of money that far down the road."
Inevitability of drought	"This is Montana now, so in Montana, 'we're always in a drought, and sometimes it rains.'" "I always want to know what that plant's going to do in a drought because inevitably it's going to happen." "The saying in our area is no matter how much it rains, you're always two weeks away from the next drought."

Climate Information as Too Unreliable to Influence Proactive Decisions

Perceptions of unreliability in all timescales of weather forecasts and climate information reinforced the feeling of unpredictability that hindered farmers' proactive planning. According to one farmer, "In eastern Montana, we're flying blind as weather goes." Although a few farmers described recent improvements in the accuracy of weather forecasts, especially for forecasts up to 48 hours, most farmers argued that the accuracy of forecasts decreased over longer timescales, saying that forecasts beyond 7 days were rarely accurate. For some dryland farmers, the unpredictability of the weather and unreliability of forecasts reinforced a kind of blind optimism, a belief that their fortunes could improve any day with one storm that could turn things around and lead to a good harvest. As one farmer said "…one storm system that they were wrong about and we're going to have a nice crop." Because weather forecasts were seen as too unreliable to use in planning, farmers suggested that acting in anticipation of certain weather events could be pointless or even counterproductive.

While nearly all farmers were interested in three-month forecasts (paying attention to them in agricultural magazines and online), their perceptions varied widely, with a majority of farmers asserting that three-month forecasts were not useful because no forecast can accurately predict the weather. Farmers' views on the unreliability of weather forecasts colored their perceptions of three-month forecasts. For example, farmers stated: "the farther out you get, the less reliable," "I don't really believe any of it more than a couple days out," that longer than 10 days "usually lies to me," and "I don't even look at anything over a month. It's useless to me." One farmer shared, "…those bozos don't have an idea what's going to happen 15 days from now. How in the hell are they going to project out 90 days?" Farmers also described their experiences with past errors in three-month forecasts which influenced their perceptions of unreliability, saying "Complete hit or miss…. I have so little faith in any of it," "they've all been wrong," and they're "pretty much bullshit." As one farmer explained:

> Whether it be a 30-day or a 90-day forecast, I always tell people, I think they have about a 33% chance of getting it right, above or normal or below. Last winter, there was a lot of mixed forecast. A lot of them were saying, "yep, we're going to have a really tough winter." And it turned out it was flat dry, whole winter long. So, they're not reliable enough that I could change my farming practices based upon on those forecasts.

Farmers perceptions of unreliability meant that, for most farmers, these forecasts did not inform decision-making. As one farmer stated: "I look at them [three-month forecasts] and I don't make any decisions based on them." Other farmers said they might consider three-month forecasts in the future for specific short-term responses like holding back fertilizer, but that those forecasts are not reliable enough to do so currently. The widespread perception that predicting the weather was pointless meant that most farmers did not use short-term weather or climate information (in the range of 7-90 days) to make proactive decisions. However, some farmers already used or intended to use three-month forecasts. This group of farmers said three-month forecasts could influence their short-term responses if presented in specific time windows at least one month ahead of seeding for spring and fall growing seasons. These farmers described three-month forecasts as boosting their confidence, saying they make "your fall decision-making a lot easier." Alternatively, they also suggested that three-month forecasts help them "question our current practices." Yet, most of the farmers who used or intended to use three-month forecasts still viewed them as somewhat unreliable and thus regarded them as one piece of useful information but not "the primary factor" in decision-making.

Very few farmers were familiar with mid-century climate projections and many hesitated to even think 30 years in advance, often due to concerns about the accuracy of these projections. As one farmer argued:

> I respect the fact that their [mid-century] projection is based on scientific data and mine is on my gut, but I guess I have a hard time buying into guaranteeing that we're going to have significant change in the next 30 years. It will change. I don't doubt that, but how, which way, and what I think is pretty bold to say.

Most farmers agreed with the premise that Montana's climate would change by the year 2050. For example, one farmer suggested that "[climate] is changing…it has been since the last Ice Age. So I think it's our job to change with that." However, most farmers also dismissed the idea that climatic changes could be modeled or predicted. Many farmers perceived climate information to be less accurate the further in the future it projected. As one farmer quipped: "I'd believe [mid-century projections] more if they could get three months from now accurate, let alone 2050." When thinking about long timescales, most farmers argued that they needed to remain cautious and emphasized the inherent uncertainty in predicting future conditions. As one farmer stated, "I don't make really any major plans based on [mid-century projections]…. I still have to be a little hesitant." One diversified dryland farmer who believed that mid-century projections were accurate said they had to remain cautious in their decision-making because of long-term uncertainty: "It's hard to really like fully embrace it, you know what I mean? And it's not that I don't believe it, it's just like such an unknown." Farmers also discounted mid-century projections based on what they perceived to be an irrelevant timescale. One farmer asked, "how's that going to change what I do right now?" another stated, "a 30-year projection, I don't think affects many of us." Many farmers, even those who perceived the mid-century projections to be accurate, questioned how and at what timescales they could change their operations to account for 30-year projections. As one farmer noted, "I find them interesting, but I wouldn't say useful." Therefore, whether they perceived mid-century projections as accurate or not, most farmers struggled to perceive mid-century projections as a tool that would be relevant to their day-to-day decision-making.

Although most farmers did not find mid-century projections useful, many described their emotional responses to these predictions. Some farmers, especially older farmers, reflected soberly on how projections would make farming as they knew it nearly impossible. One farmer seemed to grasp for words before responding: "It's pretty sad." As another farmer explained:

> I hope that isn't the case because that's not good. That does scare me a little bit. Hopefully it's not that extreme, but if it is, we're looking at what I would consider now crop failure every year. It wouldn't be a complete failure, but the yields would be considerably less. Scary stuff, if it's true, if it pans out.

However, other farmers, especially younger farmers, expressed more optimism about future conditions and more faith in adaptation. For example, farmers used phrases such as "the American farmer is just pretty darn resilient" to describe their belief that farmers will adapt to the climate no matter how it changes. A few farmers who found mid-century projections to be accurate described the specific ways they might adapt, including shifting to new crop varieties, such as corn or sweet potatoes, to take advantage of a longer growing season, or even shifting to more cattle and less cropping. While a few farmers believed that the changes depicted in the mid-century projections were already happening, others envisioned them as occurring in the distant future, which influenced whether they thought they needed to change their operations sooner than later. None of the farmers who only grew crops discussed making cropping changes in response to mid-century projections in the near future. However, the mixed operators were already using mid-century projections to change watering and grazing patterns and invest in new pivot irrigation. Only a few farmers spoke of potentially using mid-century projections to inform other types of decisions, including buying more land, expanding irrigation capacity, and investing in more no-till equipment to help retain soil moisture. Based on their experiences with weather forecasts and three-month forecasts, farmers' perceptions of unreliability affected their willingness to use predictive climate information to plan proactively for future conditions.

Table 2: Additional Data on Farmers' Perceptions of Three-Month Forecasts and Mid-Century Projections

Perception	Farmer responses
One storm as an unpredictable savior	"It could turnaround tomorrow. Like I said, one storm system, and we're back in the driver's seat." "One rain will change everything in 24 hours if you had a big rain." "It doesn't take much. The 1/10th of an inch or a quarter of an inch at the right time can take you from 10 bushel to 20 bushel."
Three-month forecasts as unreliable	"No, because I don't trust long range. I mean, I don't trust long range projections." "I was reading in July it's going to stay hot and dry until November, there's not much I can do with that because I don't believe long-term projections." "And so as this weather's getting crazier, for them to try to tell me what's going to happen three months from now, I don't believe they can do it, and so it's not going to affect me. No." "Weather is such that you just can't go much more than two weeks out in the future. Things can change so much in that time that overwhelms any forecasting ability they have." "End of the day, all that matters is what actually ends up happening, whether they think it's going to be hotter and drier or cooler and wetter, it doesn't mean diddly unless it actually comes true." "How accurate is that? Is this like flipping the coin and going to Vegas?"
Three-month forecasts as not influencing farm decisions	"But as far as our cropping plans and that kind of stuff, I just go forward with it because I just don't put any faith in any long-term weather forecast." "I can't predicate my activity on three months worth of data."

	"I think the ability to make some informed decisions based on the climate could just be paramount to any ag operation. I don't feel like I have the ability right now, and maybe I'm wrong."
Mid-century projections as uncertain	"But it's just kind of a wait and see if that actually happens. Some of those long-term forecasts just aren't quite there for what's really going to happen." "The other thing you have to keep in mind is the future's really hard to predict. And maybe it'll happen like that, but maybe not. A lot can happen." "And so it's just kind of all over the place, it's hard to follow religiously, I guess you could say."
Mid-century projections as irrelevant	"I don't know that it's really going to matter to me in 2050. How's that going to change what I do right now? It might change what [my son] does.... But in 2050, I don't even know if I'll be alive." "Even if I was a young farmer, even if I was 30 years old, I don't think that would affect be much to say here's what's going to happen 30 years from now. Because you'd just be saying, well, I mean, I'm not looking to put in orange groves or pecan groves or grapes which are longer term crops. Those guys, I can see we're going to, if I want to put in a plant pecan trees or not. But when we're raising wheat and barley, a 30-year projection, I don't think affects many of us." "So, if you think 2050, now, I'm going to be 80. I will have transitioned our farm and our ranch, so what does that look like? What are things I need to be preparing for?" "I don't think I'll have to worry about 2050, but I think my great grandson might."
Pessimism about mid-century projections	"That's not good…. Hell, just forget the temperatures and half as much water is a problem. I'm barely getting by with what I got." "I don't want to be doomsayer, but I'd say that it's looking that way. I've said for a long time, probably for at least 40 years, that things can't keep getting better for everybody." "I try not to worry about it too much, but at the same time, it is a reality I think that's going to become, I think things are going to get worse and worse."

Optimism about mid-century projections	"I mean, I just think, I guess my final thought on the whole climate thing and farming in general is that the American farmer is just pretty darn resilient. And I learn rather rapidly to change with our environment and find a way to make it work." "So if Salem, Utah, is going to be similar to our climate, that's not a lot of downside for us. That means a longer growing season. That'd be all right. I can adjust crops and practices but if everything was saying that I were going to turn into Antarctica then we'd start questioning whether or not I really want to be investing in land and a place that at the time I want to retire our land might be worthless."

In the Short-term, Responses are either Impossible or Gambles

Whether making changes to weather proactively or reactively, many farmers mentioned a lack of agency—that their options were limited or nonexistent—or that short-term events were so unpredictable that any decision was a gamble. A lack of agency was common when farmers were asked about their responses to past weather events, arguing "there's just not much you can do ahead of time, and there's not much you can do while it's dry...Okay, I cut a poor crop. Now what do I do?" One farmer described the extreme drought that was affecting much of eastern Montana, saying "There's some things you just can't adapt to." Many farmers argued there was no way to respond to weather once the growing season had started, as one farmer quoted another "'I've done everything I can do to produce a crop. It's out of my hands and in someone else's now.'" Even when farmers were asked about preparing for a future weather event, like drought, many farmers maintained a lack of agency. Another farmer, when discussing proactive decisions based on a dry three-month forecast, said "there's not a whole heck of lot I can do about it." Farmers must invest significant time, labor, and money to get a crop in the ground, but after seeding they described the feeling that they often have no control over what occurs. Overall, many farmers described operations that were largely fixed or pre-determined, or in other words, they had very few if any opportunities with which to use their agency to change their practices reactively or proactively.

However, a few farmers described very specific but limited reactive responses. For example, farmers stated that rain and hailstorms can damage crops and must be inspected for fungal infection and treated immediately. Farmers with mixed operations also discussed grazing livestock on an old or failed crop. Often, farmers retain some flexibility for short-term decisions within the bounds of their pre-determined cropping plan. For example, one diversified grain farmer described how they adjust their crop rotation over the short-term: “We don’t do much different, for if it’s too dry to seed winter wheat, you don’t seed winter wheat, you just seed it in the spring. Well, it gets to the spring, if it’s still too dry you just seed it anyway... It’s all you can do, and then hope it rains.” Delaying certain crops like spring wheat in favor of winter wheat (or vice versa, for either wet or dry conditions) is one of the most common responses in these types of systems, where farmers can use short-term flexibility of certain crops to balance current soil moisture conditions without sacrificing their long-term cropping rotation. Yet even this approach has its limits. As this farmer added, farmers cannot wait for certain conditions and delay planting indefinitely. Instead, farmers must plant and hope for good weather. Many farmers relied on this kind of optimism in the face of weather unpredictability, as two farmers added: “I’ve been much more focused on establishing my crop and hoping that it rains.” On the other hand, one diversified crop and livestock farmer worried about drought becoming more frequent and when it would force a transformative change in their operation, saying “At what point do you say like, ‘Man, I just can’t adapt anymore?’ And am I going to end up being 100% grazing?”

Many farmers asserted that short-term proactive decisions were gambles because of the unpredictability of weather and markets. When discussing proactive decisions ahead of the growing season, farmers said, “I took a gamble” and “you’ve got to have a lot of luck.” Farmers also compared their livelihood to gambling, saying “you’re professionally a gambler” and “…anybody in agriculture’s a gambler.” Farmers often used terms like “bet” or “coin toss” to convey a sense of unpredictability regarding the efficacy of their proactive decisions. Farmer’s most common gambles happened in advance of a growing season: selecting crops, timing seeding, and deciding when and how much fertilizer to purchase and apply. Withholding fertilizer until there is sufficient moisture to ensure a good crop was a response to unpredictable weather that was discussed by most farmers. As one dryland farmer put it, it’s “the only thing you can do.” Another common example farmers discussed as a short-term proactive decision is to pre-purchase inputs like fertilizer. Due to recent rising commodity costs, pre-purchasing inputs can save farmers money if costs continue to rise, but farmers also perceived this decision as a gamble. As pre-purchasing fertilizer illustrates, most if not all short-term cropping decisions are based on both weather/climate and market conditions, both of which are regarded as unpredictable. But market conditions were often weighed more heavily in decisions. As one farmer responded to a dry and warm three-month forecast through crop selection: “Maybe you wouldn’t plant as much canola unless the price is high, but everything’s driven by price. I mean, it truly is.” In this example, even if a farmer thinks a dry summer is likely, if the price of a drought-vulnerable crop was high before the growing season, they may still plant the crop because the payoff might be worth the risk, an example of farmers’ need to play the odds. The unpredictability of both weather and markets made farmers feel like short-term proactive decisions were always risky even if they had thoughtfully planned ahead. As one farmer described, “if I spent all winter preparing for a drought next year, it’s entirely possible I would have floods next year, and I would’ve gone the exact wrong direction.” As noted earlier, many farmers perceive the weather to be so unpredictable that any day could bring the “one storm” that delivers enough moisture for a bumper crop that will pay off a gamble. Furthermore, their perception of interannual variability in climate makes it difficult for farmers to prepare in anticipation of any specific weather conditions during the growing season. In short, famers described very limited agency in the face of unpredictable weather and climate and envisioned the few proactive adaptations available to them as gambles subject to the whims of weather and markets.

Long-Term Adaptations Created Both Short-Term and Long-term Buffers and Benefits

Farmers implemented many long-term adaptations incrementally in ways that allowed them to weather short-term fluctuations and benefit from immediate improvements. As one farmer described these adaptations: “We’re trying to maintain soil health and soil moisture consistently so we’re not as subject to weather variation.” To another farmer, this approach meant that “we plant what we’re going to plant almost disregarding what weather is coming.” These adaptations reduced the importance of short-term responses altogether, thus farmers expressed confidence in their ability to make decisions without needing information like three-month forecasts. As one dryland farmer shared, “we spend a year conserving and developing a moisture profile on our fallow ground and that dictates what we’re going to do rather than the three-month forecast.” For many dryland farmers, their own measurements of local soil moisture and trust in their experience of how much soil moisture they need to grow a good crop took precedence over the “not reliable” potential moisture that three-month forecasts predicted for the growing season.

This long-term approach was more common for diversified operations with established crop rotations and also served as an adaptation to unpredictable markets. One farmer recounted how a diverse rotation buffered against short-term market volatility, saying "I felt if I was diversified enough with five different crops, that [the price of] winter wheat could be sky high and spring wheat's probably going to go with it, and the pulse crops could be absolutely junky and I'd even myself out between the two." Despite the temptation to "bet" on the highest paying crops or the chance of good weather, diversified rotations were seen as spreading out a farmer's short-term risk to both weather and markets. These farmers argued that investments in long-term adaptations reduced the need for short-term gambles in the context of unpredictable weather and markets, instead planning for the crops and practices that provide consistent returns over multiple years, avoiding the temptation to go all in on a certain crop when the price is high or the weather looks favorable. Many of these farmers still attempted to maintain flexibility for short-term adaptations (e.g., delaying seeding of certain crops and withholding fertilizer) while remaining generally focusing on long-term strategies like a diversified crop rotation and no-till. Therefore, farmers' short-term and long-term approaches are not mutually exclusive, though farmers emphasized that their long-term adaptations reduced the need to win short-term "gambles."

Farmers with a long-term approach mentioned the need for incremental change and short-term benefits. As one farmer said, "we want to just kind of have marginal changes to what we're doing and trying to keep the curve going upwards on yields and crop quality." Many of the diversified dryland farmers described no-till as incremental, noting that no-till sometimes requires stepwise investments in expensive and specialized equipment. They also described the ways in which the benefits begin to accrue soon after no-till is adopted and build up in the soil over multiple seasons, and so investments pay off over short- and long-terms. One farmer explained how no-till is a long-term adaptation to unpredictable weather:

> Long-term wise, that's why we're doing what we're doing. We're trying to get the organic matter up. So it holds more water. So when I do get a three-inch rain or a four-inch rain or a time period where it does rain, we're holding more of that water in the top 6, 8, 10 inches than I ever had before. And so that's, sometimes, is holding on to the next rain event, which might be two days away, two weeks away, two months away, I don't know.

Although it is a long-term adaptation, the short-term benefits of no-till influenced some farmers' decisions to adopt the practice. Many farmers spoke of how the widespread adoption of no-till immediately stopped severe soil erosion in the Golden Triangle in the 1980s and '90s. Some farmers emphasized immediate economic benefits of no-till, as one farmer described: "[My dad] was probably one of the first people in the area to go to the no-till style of farming. We actually got audited, I think it was four years in a row because the government couldn't believe that his yields were climbing so fast." Another farmer connected that their no-till approach to a range of short-term results, saying "Weather's certainly changing, but yet my moisture's up and my yield's a bit up. And we've been more profitable than we've ever been. I guess we've adapted somewhat."

Although many dryland grain farmers have adopted no-till practices, fewer farmers had adopted a related strategy, cover cropping. Some farmers said that cover cropping was impossible due to low rainfall and that cover crops' soil benefits could be replicated in a harvestable crop like chickpeas. However, unlike no-till, some farmers described that cover cropping provided fewer short-term benefits and some farmers cited policy barriers, like specific plant material requirements in crop insurance, that make cover cropping more difficult to implement compared to no-till. Yet some farmers named a factor they thought was more important that kept farmers from adopting cover cropping, a lack of short-term benefits. A few farmers experimenting with cover cropping described how other farmers may not be able or willing to wait three years for the benefits to show on their farm, saying "…there are a lot of guys that won't wait that long. They want something sooner." A few farmers also expressed discomfort in enrolling in multi-year cost-share assistance for practices that they perceived to be risky, especially cover cropping. They feared government programs would lock them into cover cropping, reducing the acreage available to shift cropping to respond to weather, markets, finances, or other potentially unforeseen factors, thus further reducing their agency to respond to short-term fluctuations. Farmers' reluctance to adopt cover cropping may indicate that even long-term adaptations that seem to align with a diversified approach may require consideration of short-term costs and benefits to be more widely adopted by farmers.

Even when farmers have established long-term plans, they often sacrifice short-term flexibility. For most decisions, farmers only have limited periods of time within which they can act, time windows that are often related to weather. For example, seeding must occur early enough in the spring to allow the crop to mature but not too early to have soggy fields or risk a sudden frost. In the late summer and fall, harvesting crops and managing fields may overlap with seeding winter crops. One farmer described how unpredictable weather events can shorten the already slim time windows available to farmers:

> You have to be ready [for] timely management in your fields. Absolutely. Whenever the window is there, you utilize the windows, wherever, cultivating, harvest, all these different things, haying, whatever it is. You better be ready because things can change.

Farmers discussed how operational characteristics such as farm size, equipment, crop storage, the type and diversity of crops, and availability of labor interact to effectively shorten or lengthen these time windows, and, like the weather, these characteristics can vary within and across seasons. Farmers described the most acute impacts as occurring when unpredictable weather forces short-term reactive decisions that conflicted and overlapped with other limited time windows (e.g., when harvesting or sowing a crop was forced into the same window as responding to fungal disease or repairing equipment).

Farmers asserted that recognizing the time windows within which weather, labor, finances, and other conditions must align is important because farmers are under pressure to act within limited timeframes which can be further limited by unexpected weather events or other time-sensitive reactive responses. For example, adaptations like no-till and diversifying rotations with pulse crops may require more time overall than previous conventional practices (i.e., the management of plant material in the field is more complicated and time-consuming in a diverse no-till operation than in a monoculture tilled operation). Farmers noted that these practices also require a certain amount of lead time for planning, specific moisture conditions before implementing, and additional labor which may be involved in other practices like harvesting, hauling, or storing crops. Furthermore, time windows are not exclusive to short-term decisions. Buying land is a long-term adaptation, but a few farmers described the challenge of being ready to purchase land when a parcel adjacent to their operation went for sale. Thus, in addition to long-term adaptations that enable farmers to handle unpredictable weather and markets, farmers may also need flexibility to respond in nimble ways to changing conditions and emerging opportunities. Cultivating this flexibility is particularly challenging in the context of already limited time and resources. While farmers described themselves as unable to adapt in the context of variable and unpredictable weather/climate and markets, they either explained how long-term adaptations limited short-term agency or served to liberate them from short-term fluctuations.

Farmers also described decisions that spanned short- and long-term responses and required reactive and proactive decision-making. For example, farmers with livestock described reducing herd size as a reactive response to drought. However, adapting to drought involved both long-term proactive planning (e.g. investing in watering infrastructure and writing drought plans) and recovering from drought required long-term efforts to recoup losses and rebuild herd size. In this way, some long-term responses may take the form of a series of short-term decisions, some of which can be proactive and some reactive. In addition, drought may take the form of a short-term event or a prolonged multi-year trend, and farmers spoke of the difficulty of deciphering between the two. Short-term decisions in response to weather may seem an insignificant strategy to adapt to climate change; however, since certain weather events will become more frequent or severe—which some farmers observed—how farmers react to these weather events to reduce their impacts is an important piece of long-term climate adaptation. In addition, short-term decisions may have long-term cumulative effects, such as the potential to affect farmer’s long-term livelihoods.

Table 4: Additional Data on Farmers' Proactive and Reactive Adaptations

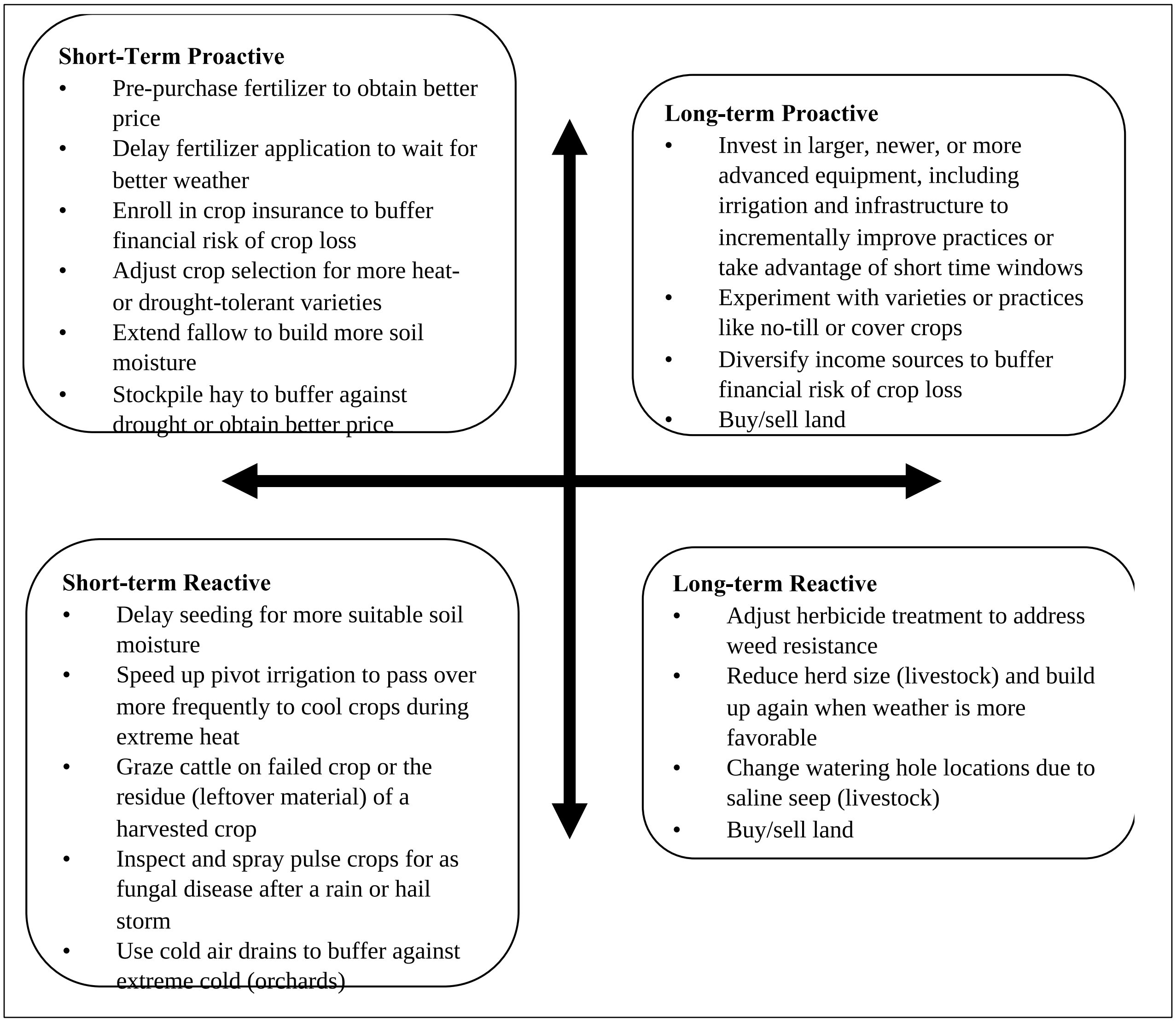
Adaptations	Farmer responses
Limited Agency	"I can't take fertilizer back out, the diesel's burned, the seed is in the ground. There's just not much you can do." "There's no drastic changes I can make that I see." "I think you just do the best job you can every year and hope Mother Nature cooperates and gives time and moisture and everything usually turns out."
Reactive	"…you have to go out there and mow them, or swath them, or something just to handle the residue. Chop them, something, because it could be a pain in the neck a year or two later to deal with it." "After it rains like that, you have to go out there and inspect [pulse crops] and make sure that you don't have [ascochyta]. If you do, you need to spray for it immediately." "I think, let's see, one, two, three, four, five, six, seven times I moved our cows that summer, to try and keep them fed. I hauled water everywhere for them and I cut the herd in half and I still couldn't keep them fed that year."
Proactive fertilizer purchases	"I mean, right now we're having a super large increase in fertilizer price and chemical prices and stuff. And so I proactively went ahead and purchased a month ago a whole bunch of those inputs that. And price kept going up. And right now it looks like a great idea, but by spring it might be the opposite and I wonder why I did that." "So I can shift those and pre-buy those at more appropriate times if I know what we're growing ahead of time. Also can budget, that's a good way to budget. And typically our input, our chemical and fertilizer costs follow our commodity price cost rather than having supply demand market."
Proactive withholding inputs due to weather	"I tried to plan last year when I was waiting until I knew I was going to have a crop or I thought I was going to have a crop and then I put my inputs into it. So that's about the only thing you can do there. Make sure that you're have a crop. You're always gambling, to a certain degree. But you do have a floor with your insurance…" "Back in '15 and '16, one year, I put a million dollars' worth of chicken manure on our fields and I droughted out the next year. And after that, I was

	like, 'We are not doing this again because ...' Yeah, it's still there, some of it, for the following year, but you're putting a lot of chips into that crop year that ended up being just a grazing year for us." "I went ahead and fertilized and sprayed and you know, literally spent tens of thousands of dollars and I got nothing out of it. And so that money was all wasted. So this next year going into it dry, I'll probably be a lot more cautious about it." "If you try to anticipate weather conditions in this country with the way you do your inputs, you're just going to shoot yourself in the foot." "Maybe sometimes if we're feeling lucky, you go like, 'oh, let's fertilize for even bit better than average in case the rain comes.'"
Proactive incremental	"I think little by little, we can kind of make adjustments ourselves." "We don't do them in reaction to drought, you try and reduce your long-term risk and that's the best way I do it." "If this is the world that we're in now with highly variable climate more than ever, I have to figure out how to share risk because you can't build soil on quarterly profit reporting cycles. I mean this doesn't happen instantly."

DISCUSSION

In this study of Montana farmers, unpredictable weather and a variable climate influenced farmers' decisions about adaptation, and in particular made proactive decision-making and long-term adaptations challenges (see Figure 1 for examples of different types of adaptation decisions). For some farmers, three-month forecasts weighed into decision-making as "one factor" in a complex process; however, for most farmers three-month forecasts were not reliable enough to influence decisions. While most farmers were unfamiliar with mid-century climate projections and did not see them as accurate or relevant, some farmers discussed that by 2050 they would essentially experiment with short-term adaptations that could become permanent. For example, farmers envisioned—but had not started—adopting new crop varieties to adapt to longer growing seasons, a low-risk adaptation which "fit" with their current efforts to diversify rotations. In the short-term, unpredictable weather and unreliable forecasts resulted in farmers' viewing proactive adaptations as risky "gambles," a risk that was compounded by unpredictable markets. And farmers' decisions about how to handle uncertainty in weather and markets were often informed by an optimism that "one storm" would make farmers' time, labor, and financial investments pay off with a good crop. In this context, many farmers expressed a profound lack of agency to adapt proactively to variable and unpredictable conditions. However, while farmers viewed weather and markets as largely out of their control, they envisioned longer-term adaptations, such as diverse crop rotations and no-till practices, as providing buffers against the impacts of fluctuations in markets, weather, and climate. But importantly, the long-term adaptations that were widely adopted also provided more immediate short-term benefits.

Figure 1: Examples of Farmers' Responses to Weather and Adaptations to Climate



Similar to previous studies, in this study farmers' decision-making responded to and anticipated a range of stressors—not just climate—in a holistic process where farmers prioritized short-term economic concerns (Doll et al. 2017; Lawrence et al. 2018; Meinke et al. 2009:69; Wyborn et al. 2015; Karimi et al. 2020; Lawrence et al. 2018; Schewe and Stuart 2017; Borlu and Leland 2020; Roesch-McNally et al. 2018). While I found that most farmers paid attention to three-month forecasts even though they did not use them, they also wanted more accurate weather and climate forecasts; in line with Dessai et al.'s (2009) findings, farmers' decision-making is complex and must account for this range of stressors, including economic and social stressors, that cannot simply be addressed with more accurate predictions of weather and climate conditions. Crucially, in the study described in this paper, most farmers did not see climate information (three-month forecasts and mid-century projects) as resources for their proactive adaptation.

Therefore, similar to other studies (e.g., Lemos et al. 2012; Mase and Prokopy 2014), I found that for the most part farmers' approached adaptation without utilizing climate information. Collaboration among climate forecasters, advisors, and farmers (including participatory approaches where climate information is tailored to users' needs) could make climate information more relevant to farmers and connect them to specific adaptations (Cliffe et al. 2016; Cradock-Henry et al. 2020; Howden et al. 2007; Mase and Prokopy 2014), which may be especially important for mid-century projections which farmers in this study viewed as less relevant than three-month forecasts. Importantly, most farmers in this study did not perceive three-month forecasts or mid-century projections as reliable enough to help them overcome the unpredictability they face in weather and climate. Instead of utilizing climate information to navigate this uncertainty, farmers choose adaptations, such as no-till and diversified rotations, that buffered against a range of unpredictable stressors (i.e., weather and markets) thus rendering short-term climate information irrelevant. Because climatologists expect more interannual variability and severe and unpredictable weather as climate change intensifies (Whitlock et al. 2017), farming practices that work under a range of conditions and thus buffer farmers from unpredictability will be increasingly important. However, because climate change is presenting new and increasingly extreme conditions, farmers cannot simply rely on their past experiences of climate to decide which adaptations will work in the future, highlighting the urgent need for proactive adaptations that are effective under novel conditions (Findlater et al. 2019; Whitlock et al. 2017).

In addition, farmers may be more likely to adopt proactive adaptations if they have short-term benefits. In this study, farmers implemented strategies that provided benefits over shorter and longer timescales, and that provided economic benefits early on (e.g., no till practices) which may make farmers more likely to continue these practices overtime. Farmers also preferred strategies that helped them retain flexibility, such as experimenting with introducing new varieties in crop rotations. Similarly, Cradock-Henry et al. (2020) found that farmers in New Zealand incrementally and autonomously improved existing practices to provide short-term buffers to interannual variability and retain future flexibility, but these actions, such as adjusting stocking rates for operations with livestock, were in response to conditions like drought, not in anticipation of future events. Ash et al. (2012) also found that producers incrementally adapted to climate variability while preserving their flexibility to respond to short-term fluctuations. As long as taxes, loans, and most crops "mature" annually, farmer decision-making may remain focused on short-term, incremental changes as seen in the literature (e.g., Ash et al. 2012; Bitterman et al. 2019; Wise et al. 2014). Similar approaches in different parts of the world provide further evidence of the importance of identifying adaptations that are proactive but also have short-term benefits and retain long-term flexibility.

But do farmers ultimately need to believe in anthropocentric climate change or intend to adapt to climate change to proactively adapt to climate change? While a farmer's belief in anthropocentric climate change may predict their climate adaptation (Arbuckle et al. 2013, 2015), these beliefs are not the only factors driving decision-making on the farm (Robert, Thomas, and Bergez 2016; Crane et al. 2011). In this study, whether or not farmers believed in anthropogenic climate change had little connection to current on-farm adaptations. For example, farmers who perceived mid-century projections as accurate models of climate change did not always adopt more proactive adaptations. Thus, even though farmers' climate beliefs might suggest some alignment with climate science and even an intent to adapt, these farmers still struggled with the uncertainty of longer timescales and of making climate change relevant to their day-to-day operations. Further, it is difficult to predict which adaptations will be most effective in the long-term, in part because the impacts of climate change at the local scale are still somewhat uncertain (Shrum et al. 2008; Thornton and Manasfi 2011). The most beneficial climate adaptations will also vary by a farmers' crops, equipment, size, local weather patterns, and myriad other factors (Eriksen et al. 2015).

In summary, farmers in this study focused on proactive adaptations that: 1) buffered against risk related to unpredictable and fluctuating conditions in weather and markets; 2) provided short-term benefits, often financial; and 3) can be incrementally improved overtime, so that farmers can plan for good years and avoid the sense of path dependency or being "locked in" to practices that are unproductive. Agricultural advisors and policymakers can use this model to help farmers adapt to climate change in three ways. First, advisors can emphasize experimenting with practices that fit within the model to spur farmers new to adaptation to begin to change their practices in low-risk ways that emphasize short-term benefits across a range of conditions; second, the model recognizes the importance of improvements overtime, where advisors can encourage farmers already adapting their practices to continue to improve their strategies during good seasons (i.e., incrementally improve); and, finally, the model can help advisors better understand the underlying motivations so that new policies and programs fit within the model that farmers use for adaptation decisions, making these initiatives more likely to lead to widespread changes.

While most farmers' adaptation is autonomous (Ash et al. 2012; Cradock-Henry et al. 2020), programs and policies can support proactive adaptation. For example, crop insurance, a program focused on growing season outcomes (i.e., short timescales), could accommodate more of the strategies that farmers use to buffer short-term fluctuations in weather and markets. Crop insurance could encourage, rather than discourage, inter-seeding (planting more than one crop in the same field) and diversification in rotations which would help farmers buffer against both short- and long-term climate and market risks (Roesch-McNally et al. 2018). Similarly, for climate adaptations that require long-term investments and incremental improvements overtime, reducing the short-term burdens of USDA cost-shares (including better opt-out provisions to avoid farmers' being "locked-in") may increase farmers' likelihood of experimenting with different types of adaptations and increase their capacity for continuing to improve their existing adaptations. These cost-share programs could also focus on creating short-term incentives for adopting practices like cover crops that may take multiple years to show results but may have potential to help farmers adapt to climate change over the long-term. Finally, the already widespread participation in federally funded programs like extension and crop insurance, suggests the potential for effective structural changes that can move a large number of farmers toward more climate adaptive practices regardless of their climate beliefs or intent to adapt to climate change. For example, practices like no-till, long heralded by farm advisors to reduce soil erosion, also serve as a likely adaptation to climate change.

This study was limited by a relatively small sample of farms in Montana by size, crops, and other operational characteristics, which means that results might not include the full range of adaptations, especially among farmers who grow other specialty crops mixed vegetables, and mixed operations with livestock. Interestingly, mixed operations with livestock may pose especially interesting cases for future climate adaptation research, especially for transformative adaptation that might involve shifting systems from cropping to grazing. This study focused on farmers' responses to and actions in advance of weather events rather than a pre-determined list of adaptive practices, and future research could examine why farmers choose or do not choose specific adaptive practices. Future research may also benefit from interviewing farmers no longer in operation to better understand the challenges of adaptation.

Despite the adaptations that farmers are already pursuing and the potential to modify existing policies and programs, some researchers worry that existing approaches on the farm will be inadequate to adapt to climate change (Ash et al. 2012; Kates et al. 2012; Meinke et al. 2009; Nightingale et al. 2020). Because it seems unlikely that climate change adaptation alone will become a sole and primary motivating factor for farmers to change their practices, policymakers should enact wide-ranging land use or other political-economic changes to help spur more proactive climate adaptation in agriculture. Given the complex factors and interacting stressors that farmers must respond to within the inherent uncertainty of weather and markets, farmers' autonomous and incremental adaptation, even if proactively planning for the next drought, can only go so far to adapt their operation to climate change. Transformative changes to the agri-food system may be the best remaining levers to spur the level of proactive and transformative adaptation necessary to sustain agricultural production amidst a changing climate.

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ADDITIONAL RESULTS

These findings below did not fit into the manuscript due to length limitations, but they contribute to our understanding of how Montana farmers adapt to climate change and may integrate into future publications. Although each farmer's capacity to adapt to weather and climate is different, many farmers spoke of similar constraints to adaptation. Unsurprisingly, nearly every farmer mentioned both time and labor as general constraints to responding to weather events and adapting to a variable or changing climate. Yet constraints (at the individual scale) and barriers (impediments that cannot be overcome) are dependent on individual farmers' contexts and tied to specific adaptations. Two of the most common adaptations farmers spoke of were equipment and seeds.

5.1 Equipment as a Buffer if Financially Feasible

Nearly all farmers believed that equipment improvements would help their operation adapt to climate. The new (or upgraded used) equipment that farmers discussed ranged from items like fencing, pivots, hauling trucks, and storage bins to newer, higher-technology equipment like variable rate sprayers or advanced no-till implements such as air drill seeders and stripper headers. Farmers argued that investments in these types of equipment help them buffer against bad years, specifically the weather events and financial fluctuations that come as a result. Many farmers described how newer or larger equipment saved them money and allowed them to be more efficient with time and other resources like fuel. One weather-related benefit of newer and larger equipment that a few farmers explained is the ability to act more quickly in critical time windows by covering more ground or completing tasks more quickly. As one farmer described: "the only thing that I can think of to plan for weather delays as far as seeding is getting larger equipment… get the seed in the ground faster to put it in between weather delays."

Some farmers also spoke of purchasing equipment to avoid the delays associated with more frequent repairs of older equipment. For farmers with irrigation, most described an additional capacity to react to extreme heat events, yet these farmers expressed that they can only make minor adjustments to timing of irrigation or speed of pivots; however, farmers with both smaller and larger farms and a variety of crops discussed the importance of irrigating strategies to adapt to extreme heat.

When farmers spoke of using equipment to adapt to climate, the primary constraint was their immediate finances. When discussing air drill seeders that would improve a no-till operation by reducing soil disturbance and retaining more moisture, one farmer said "…to tell you the truth, that would be the only obstacle is the cost of it. Just being able to afford it," and another said "…cost is a factor that weighs on me, and if I can mitigate some of these costs by finding lower price no-till equipment, that's something that would maybe improve my operation." Farmers described that investments in this equipment must be planned around good years. As one farmer said, "whenever you have a good year, well, you make sure that you invest and use that money very wisely because you already know that the extremes might happen." As this farmer indicated and others discussed, equipment investments must be planned for good years because of cash flow constraints during most years. Farmers also gain tax advantages by delaying equipment purchases to good years to reduce their taxable income. The timing of equipment investments must be according to weather and markets, as a direct result of whether conditions allow for a good harvest. Some farmers expressed concerns that increasing bad years would lead their operation to fall behind in equipment upgrades and lose efficiency compared to other farmers, a kind of negative spiral where weather creates equipment backlogs which reduce a farmers' ability to react to weather which further reduces their ability to have good harvests to overcome the equipment backlogs. Farmers described how repair is another financial constraint of equipment. Farmers said that repairing newer equipment is more costly and takes more time because of proprietary technologies and fewer (if any) trained or certified third-party mechanics. Although farmers described the money saved with newer and more efficient technologies, including built-in GPS and data tracking, these systems came with headaches including less ability to repair the equipment themselves, greater difficulty finding repair technicians, and longer wait times for repairs. In addition, for some farmers, managing and making decisions from the data generated in this newer equipment represented an "information overload." A few farmers spoke of trying to find better data management software or services to maximize information gathered from their equipment, and some farmers believed that managing this data is constrained by brand propriety (e.g., John Deere data and equipment does not "talk to" New Holland data or equipment).

Farmers' used language that aligned with the treadmill of production, how farmers' financial constraints are indicative of the shifting economics of farming as a livelihood. As farmers explained: "It's difficult to make a living, a lot more difficult than it was," and "the biggest issue we have is machinery costs and input costs are so high that, to make enough money for a family to live off of, you got to keep growing." Many farmers said they felt a pressure to increase efficiency, production, or size to respond to financial constraints which seemed to worsen overtime with the increasing cost of inputs and equipment. Some farmers mentioned larger operators' better economies of scale, which some farmers spoke of struggling to compete with. One farmer called this trend of growing size and growing expenses a "vicious" cycle. Farmers discussed these constraints with phrases that emphasized the pressure of short-term economics such as "we're all just year-to-year." Many farmers mentioned that they rely on stable income from off the farm which usually comes from a spouse with a full-time job, but occasionally the primary operators of the farm also brought in significant off-farm income. In discussions with farmers, there seemed to be an overlap between those farmers who already used climate information in their decision-making and those who had the financial capacity to experiment with new practices and new forms of technology as a result of higher-earning off-farm jobs. This overlap seemed to coincide with a greater sense of agency to adapt for the future. For example, one rancher who invested in new pivots, diversified their ranch income with a camping bed-and-breakfast, planned to install solar panels, and directly marketed their beef said that an alternate income stream from an inheritance allowed them the capacity to expand their operation. Only a couple of other farmers spoke of such extensive adaptations and displayed such agency in proactively adapting for the future, and both of those farmers had dual off-farm incomes from advanced professional careers, including two lawyers.

5.2 Seeds: The Oldest Adaptation Technology, Out of Farmers' Hands

In contrast to the immediate financial constraints farmers faced in equipment, farmers' discussions of constraints to using seeds to adapt were less proximate. Many farmers were acutely aware of the importance of advancements in seed breeding to adapt to climate, but these seed technologies seemed out of their control. As one farmed described their concern:

> That's just scary to me. [Seeds are] the best way to meet climate change, but the problem is the ownership of the seed. That's really scary, 'cause they can have too much. The company that owns the seed has the control, not the guy that puts it in the ground.

In describing past adaptations in parts of Montana agriculture, farmers spoke of how improvements in seed genetics (and the herbicides that accompany those crops[7]) were central to driving widespread changes—such as no-till—and maintaining their competitiveness in global markets. One farmer recounted how advances in winter wheat varieties, led by a program at Montana State University, gave many farmers more flexibility to allow wheat rotations to respond to weather by adjusting the timing of crop rotations to take advantage of moisture, whether it occurred in the winter or spring. To expand on this type of adaptation to variability, a few farmers described the need for more investment in breeding "winter" crops, such as winter canola, to give them more capacity to make these adaptations with other parts of their crop rotations. A few farmers mentioned that perennial wheat varieties would be another potential advancement that would help them adapt. Farmers also spoke of recent advances in pulse varieties and their markets which allowed for more widespread adoption, but that pulse development in Montana still lags behind Canada or North Dakota, meaning the state was missing out on the full adaptive benefits of pulse crops that are bred for specific soils and climates. When discussing these types of seed genetic improvements as adaptations, some farmers worried that the public seed breeding program at Montana State University would see decreasing funding or even be shut down in the future due to loss of support from major seed companies, which now rely less on public seed breeding programs.

Farmers' concerns that public breeding was being undermined were underscored by descriptions of increasing constraints in purchasing and using seed. Farmers described how

[7] One farmer argued that the expansion of no-till in the Golden Triangle area was also made possible by a new, lower priced generic version of the herbicide RoundUp coming on the market due to patent expiration. If a lower priced chemical drove this widespread change which allowed many farmers to adopt an adaptive practice, it is an example of the importance of financial constraints on farmers' operations and how corporate-level changes can contribute to a widescale change in on-the-ground practices.

consolidation in seed and chemical companies (which are now often the same multi-national corporations) reduced their access to seed by closing nearby seed dealerships and increased their costs by controlling prices and making protected seed varieties the norm. As one farmer explained the prominence of protected variety seeds:

> The problem I have with it is that they charge an arm and leg for it and they make you buy it every single year. That's where the problem is, because now instead of buying seed one time in five years, you got to buy it five times in five years, and you never know where that price is going to be because it changes every single year.

Farmers also felt that the effects of related market consolidation when selling pulses, barley, and other crops, consolidation that limited their power to compete for the best prices for the crop they raised. Farmers also argued that the cropping systems in the Northern Great Plains receive less investment for seed breeding and chemicals advances than the Midwest's more lucrative corn and soybean crops.

Table 5.1: Additional Data on Farmers' Discussion of Constraints

Constraint	Farmer responses
Seed consolidation	"The breeding process shouldn't be expensive of enough to justify having to buy that seed over and over and over again." "Because they have too much control over your inputs, and over your product."
Data management	"I'm always a little frustrated with, I mean, you should be able to lump it and then have it spit out what you want to do a little easier. Honestly, I think we have too much information, more than we need, and that's part of the problem." "And one of our problems is getting the data out of our, we use John Deere so the type of equipment you use dictates the form of your data

	and it also keeps you inside that equipment if you want to use that data because these Jack Wagon manufacturers don’t let you merge data.” “I mean, this thing where if you’re red, the red company owns you. If you’re green, the green company owns you, because they’ve got not only your indebtedness to control you with, but they got your data. And that, to me, is scary.”
Treadmills of production	“There’s a scale of things here that I can meet a scale of a certain size, but if I go to another size, it costs more and more.” “Most farms have expanded significantly over the last 20 years also. And it’s economically driven. I mean, machinery is more expensive, but it’s also more efficient so you cover more acres with it and it’s bigger and all those things add up. And the way to combat those increased costs is to cover more acres with the same machines. Even though they cost more, it still per acre wise makes you more efficient. But if you’re going to be competitive, you have to [get larger]. That’s just the name of the game.” “We’ve been adopting and so fast and so furiously that I hope it slows down at some point [laughter].” “In 2012, when I started, a typical recipe and a typical prescription, if you will, on a guy’s farm, it was less than half of what it is now. That’s not just cost-wise, it was the amount of product needed to kill a [weed] was about half.”

6. METHODS

To better understand how farmers view and enact adaptation, I conducted in-depth semi-structured interviews with 31 farmers across 18 Montana counties. This study is part of a larger project in partnership with the Montana Climate Office funded by the US Department of Agriculture National Institute for Food and Agriculture. The larger project, Montana Drought and Climate, seeks to improve climate information to better meet the needs of agricultural producers. To do so, the project is designed to help understand how producers use climate information in their decision making. The general methodological approach was designed by the Montana Drought and Climate project team to be interdisciplinary, collaborative, mixed-methods, and experimental.

For the larger project, survey and interview instruments build on focus group interviews conducted in 2018 with producers (n = 34) in five sites across Montana to better inform the content and presentation of climate information to be distributed in newsletters and available online. Findings from these focus groups helped inform the design of survey and interview questions (Snitker 2019). In addition, the survey questionnaire (n = 3,000), mailed in May 2021, benefited from discussions with four agricultural experts across the state and pretests with a small number of producers to check the relevance of the survey to Montana producers. In-depth, semi-structured interviews with farmers (n = 31, the primary focus of this thesis) and ranchers across Montana (n ≈ 30) allowed for a more detailed understanding of the context, practices, and perceptions of climate information, risk, and decision-making. Climate information research has noted the need for more mixed methods approaches, which allow for both depth and generalizability (Mase and Prokopy 2014). Depth is achieved through semi-structured interviews, which generate rich contextual information. Generalizability is achieved through the large survey sample size, which allows for more comparisons of variables, and the survey sampling method, which allows for analyzing how well the pool of respondents represents the Montana agricultural community through databases such as the USDA’s National Agricultural Statistics Service (NASS). As a member of the Montana Drought and Climate project team, I co-developed the survey and interview guides with other project members to meet the objectives of the larger project and this thesis.

6.1 Study Site

This research was conducted in Montana because the state has an economically important agricultural sector and extensive experience with drought. The state is home to over 27,000 farm and ranch operations, contributing $4 billion to Montana’s economy and making agriculture one of the state’s leading industries (NASS 2020). In Montana, 62% of land is in farms or ranches, totaling over 58 million acres (NASS 2020). Of that agricultural land, 66% is pasture and rangeland and 17% is harvested cropland (NASS 2020). This research focuses on crop farms and mixed operations (farms with crops and livestock). Farms in Montana are often large-scale export-oriented monocultures that rely on inputs like fertilizers and herbicides (Lawrence et al. 2018). This system is exemplified by wheat production, Montana’s most important crop by both acres and value, accounting for about a quarter of the state’s agricultural production in dollars (NASS 2020). However, many farms incorporate more diverse crop rotations, and Montana is also among the nation’s leading producers of barley, lentils, peas, chickpeas, and oil seeds like canola and flaxseed (see Figure 6.1.1; Montana Field Guide 2017; NASS 2020).

Figure 6.1.1: Cultivated Crop Land Use Density in Montana

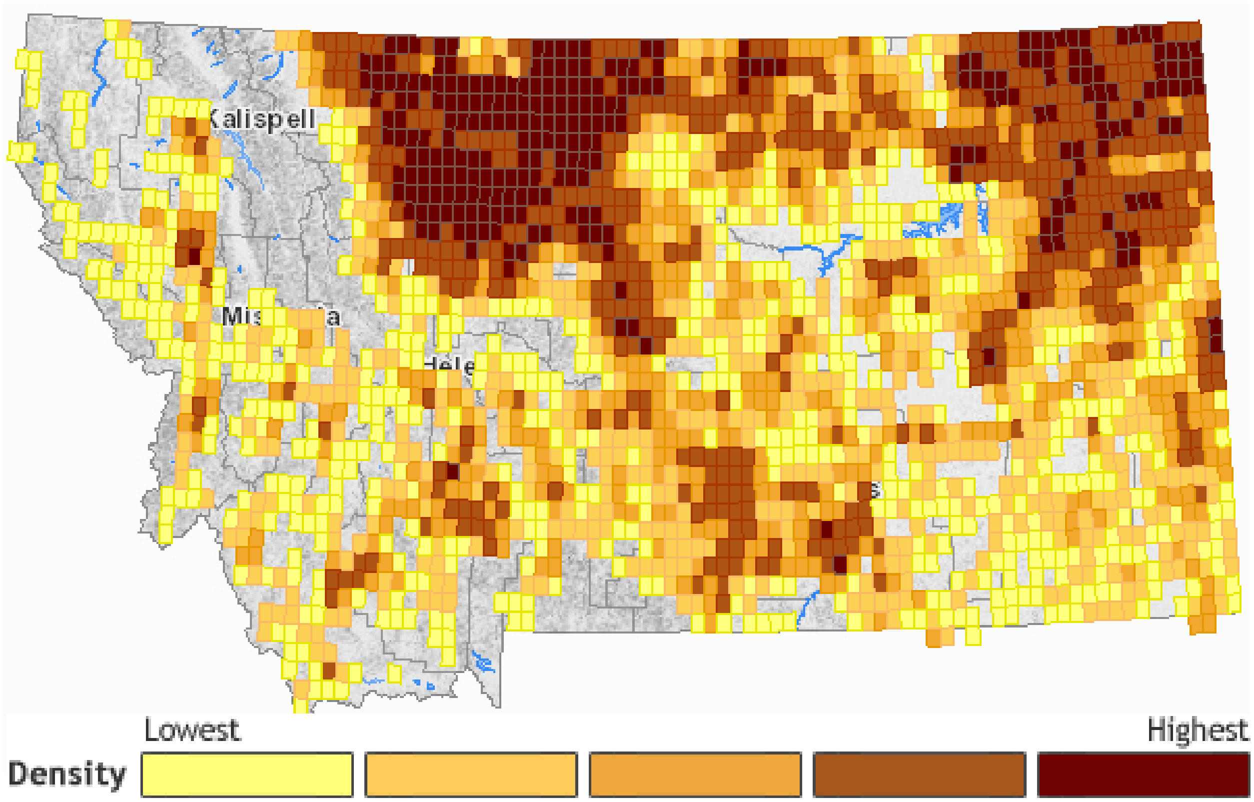
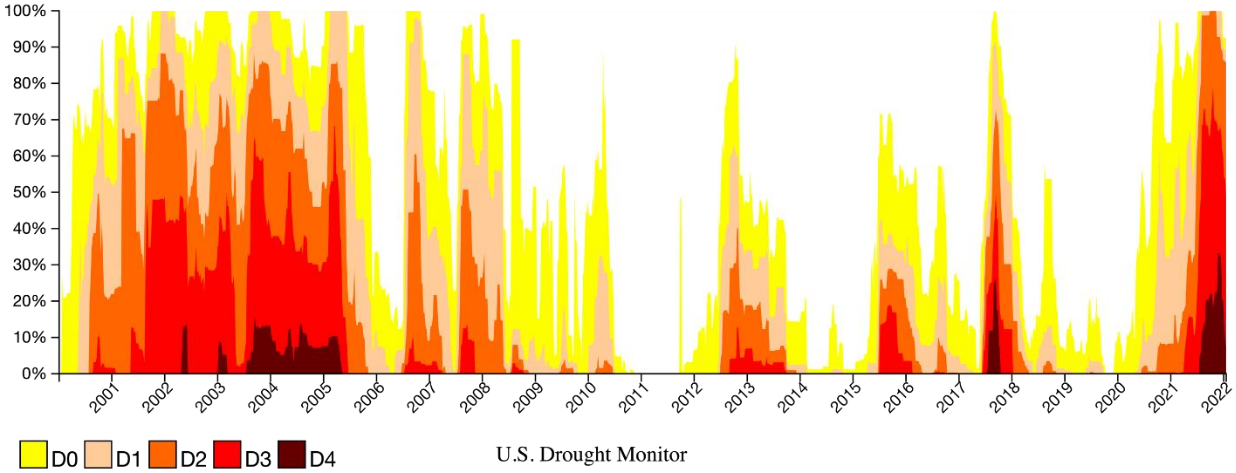


Figure data includes relative density of cultivated crops such as alfalfa, grains, vegetables, and orchard fruit. Approximately 61,596 square kilometers are classified as Cultivated Crops in the 2017 Montana Land Cover layers. Grid on map is based on USGS 7.5-minute quadrangle map boundaries (Montana Field Guide 2017).

Drought is a regular occurrence in Montana. In 2017, over a quarter of the state experienced exceptional drought conditions (as defined by the U.S. Drought Monitor), which resulted in widespread crop and pasture loses, and water emergencies (NIDIS 2021). At the beginning of this study, Montana declared a statewide drought emergency, citing moderate to extreme drought conditions in nearly 70% of the state (State of Montana 2021; see Figure 6.1.2). Irrigation is particularly important in Montana, but 80% of cropped acreage in the state is non-irrigated (NASS 2020). Non-irrigated operations depend on rainfall and soil moisture, while irrigators depend on summer streamflow, making all of these operations extremely vulnerable to weather and climate impacts.

Figure 6.1.2: Drought in Montana from 2000 to Present by Percentage of Land Area



D0: abnormally dry; D1: moderate drought; D2: severe drought; D3: extreme drought; D4 exceptional drought (U.S. Drought Monitor; NIDIS 2022).

6.2 Sample

To better understand how farmers view and enact adaptation, I conducted in-depth semi-structured interviews with 31 farmers. I conducted 25 interviews by phone, 1 by Zoom, and 4 in-person. One phone interview included two farmers on one operation. Interview lengths averaged 1 hour 15 minutes, ranging from 45 minutes to 2 hours 10 minutes. I used a purposive sampling strategy with the goal of interviewing a range of farmers who represented the primary types of farming operations in Montana (see Table 6.2.1 for sample characteristics and Table 6.2.2 for comparison to Montana's primary crops, excluding hay). Farmers were selected based on different types of crops and irrigation systems (e.g. non-irrigated dryland, and irrigated by flood, pivot, or drip), and based on a diversity of adaptive practices (e.g. no-till). Most of the farmers in the sample primarily raised grain crops (e.g. wheat, barley), including rotations with pulses, oil seeds, or other crops (n = 13), many raised grain crops and cattle (mixed operators; n = 11), some raised cattle only (n = 3), and some raised primarily fruit or mixed vegetables (n = 3).

Table 6.2.1: Interview Sample Characteristics

	Operations (n=30)	Size, acres (n=20)	Irrigation (n=30)	Organic (n=30)	Gender (n=31)
Grain Farmers (all crops)	13	5,620 (ave.) 560 (min.) 16,000 (max.)	10 dryland, 3 majority dryland	2	12 male, 1 female
Mixed Operators (crops and livestock)	11	9,413 (ave.) 800 (min.) 50,000 (max.) (n=8)	5 dryland, 2 majority dryland, 4 irrigated	2	10 male, 2 female
Ranchers (all livestock)	3	4,680 (ave.) 1,360 (min.) 8,000 (max.) (n=2)	2 dryland, 1 majority dryland	0	3 female
Fruit and Vegetable Farmers	3	216.5 (ave.) 10 (min.) 423 (max.) (n=2)	3 irrigated	1	2 male, 1 female
Total	**30 operations**	**6,503 acres (average)**	**17 dryland, 6 majority dryland, 7 irrigated**	**5 organic**	**24 male, 7 female**

While the cattle ranchers do not fit the farmer label which is the focus of this sample, two of the cattle ranchers had experience with crop farming and explained why their operations transitioned out of raising grain crops in favor of cattle, making their interviews relevant to understanding crop farming in Montana. Most farmers in the sample did not have any irrigation (n = 17), while some were mostly irrigated (n = 7), and some only had a minor amount of irrigation (n = 6). When asked to describe their operation generally, most farmers volunteered the size of their operation with varying degrees of specificity (farm size, n = 20). Farm sizes averaged 6,503 acres, ranging from 10 acres to 50,000 acres.

Table 6.2.2 Sample Comparison to Montana's Crops (Rank by Acreage Harvested in 2019)

Crop (state rank)	Number of farmers (n)	Crop (state rank)	Number of farmers (n)
Wheat (all, 1)	21	Canola (6)	2
Barley (2)	9	Flaxseed (7)	4
Peas (3)	7	Corn (all, 8)	4
Lentils (4)	7	Safflower (9)	2
Chickpeas (5)	5	Sugarbeets (10)	1

**Excluding hay and alfalfa (NASS 2020)*

Of the grain farmers or mixed operators, wheat (including spring, winter, and durum) was grown by all farmers. The next most frequently grown crop, oilseeds, were only grown by farmers with diversified crop rotations (5 of 7 farmers who grew 3-4 crops raised oilseeds, and all 5 farmers who grew 5 or more crops raised oilseeds) (see Table 6.2.3 for information about crop diversity in the sample).

Table 6.2.3: Crop Diversity of Sample Grain Farmers (By Number of Farms)

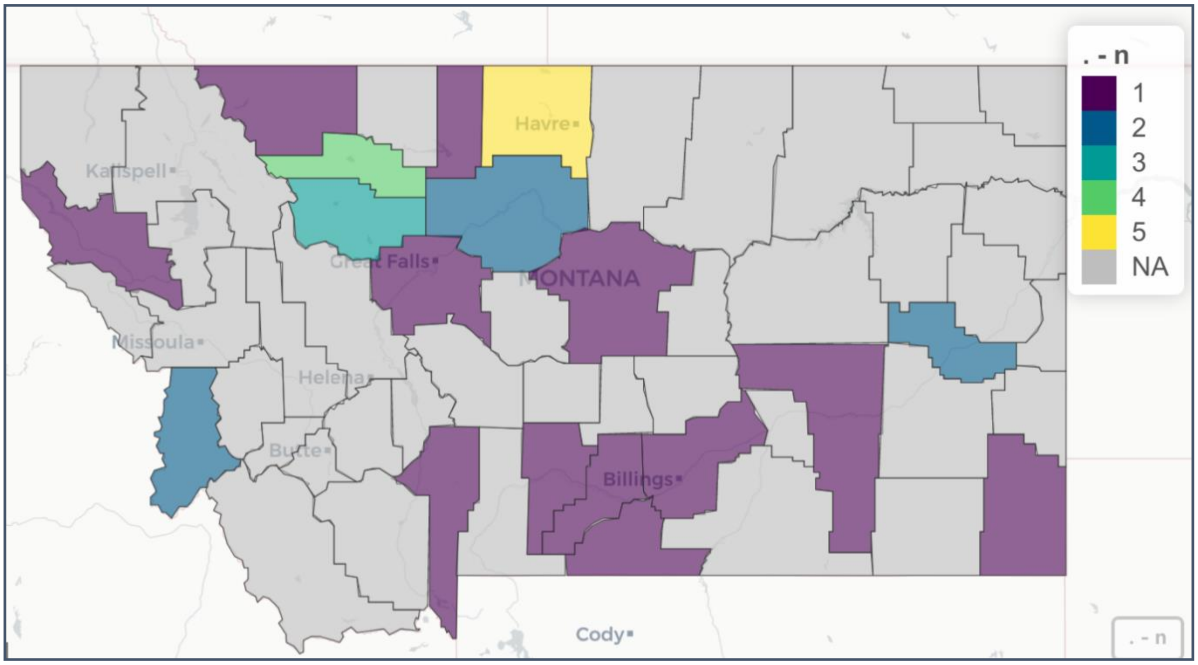
	Farms	Wheat*	Oilseeds†	Barley	Lentils	Peas	Chickpeas	Other‡
1-2 crops	*9*	9	0	3	2	1	0	1
3-4 crops	*7*	7	5	4	1	3	2	3
5 or more crops	*5*	5	5	2	4	3	3	3

Total	*21*	21	10	9	7	7	5	7

*Wheat: spring wheat, winter wheat, or durum
† Oilseeds**:** flaxseed**,** mustard, safflower, canola, sunflower
‡ Other: corn, spelt, camelina, or unspecified

The interview sample consisted primarily of farmers recommended by Montana State University (MSU) Extension and Natural Resource Conservation Service (NRCS) offices across Montana. The remaining participants opted into an interview via the Montana Drought and Climate mail survey, were on the Board of the Montana Grain Growers Association, or were recommended by research collaborators. I also interviewed two participants who were recommended by other farmers. I interviewed farmers from 18 Montana counties to capture different types of operations and climatic conditions (see Figure 6.2.1 for the geographic range of the sample). Of 31 participants, 16 resided in the Golden Triangle, a region with some of the most concentrated cropping activity, where each county is 98% or more dryland by acreage and includes the highest rates of no-till agriculture in the state (Haynes et al. 2020; USDA/NASS 2017). This area is characterized by dryland wheat cultivation which may not have much tolerance to withstand further heat and drought stress and could serve as an early warning signal for climate change impacts to agriculture (Lawrence et al. 2018). The Golden Triangle also leads the state in pulse crops and barley, with crop rotations that are increasingly diversified in comparison to the rest of the state (USDA/NASS 2017). Outside of the Golden Triangle, 15 farmers resided in 12 counties across the central and southern spans of the state.

Figure 6.2.1: Interview Participants by County



6.3 Instrumentation

In-depth semi-structured interviews offered insight into producers' perspectives and practices while providing detail about past and future decisions (Carlisle 2014). Interviews also allowed for comparing the discursive strategies that farmers use to underly these decisions and perceptions. An interview guide focused on understanding farmers' experiences with weather and climate impacts, their agency to adapt reactively or proactively to past and future impacts, and the factors that influence their decision-making process and use of climate information (see Appendix 1 for complete interview guide). Interview guides provides flexibility, allowing the interviewer to go into detail in the areas most salient to participants, and comparability, by ensuring that the same topics were discussed by each participant (Hesse-Biber and Leavy 2017). Each interview included a section on climate information where most farmers were given examples of recent snowpack, soil moisture, three-month forecasts for temperature and precipitation, and mid-century projections in the form of spatial climate analogs (n = 23; some participants had technical issues and were unable to view the climate information but were asked the same questions without the visual examples) (see Figures 6.3.1 and 6.3.2 for examples and Appendix 2 for the complete climate information provided to interview participants).

Figure 6.3.1: Three-Month Forecast for Precipitation

Three-Month Forecast for Precipitation

Most Montanans experienced drier than normal conditions this summer, but the NOAA's Climate Prediction Center is projecting more normal conditions going into the fall, with somewhat likely wetter than normal conditions in northwestern Montana. While the return to normalcy is welcome, much wetter conditions will be necessary this winter in order to recharge soil moisture across the state.

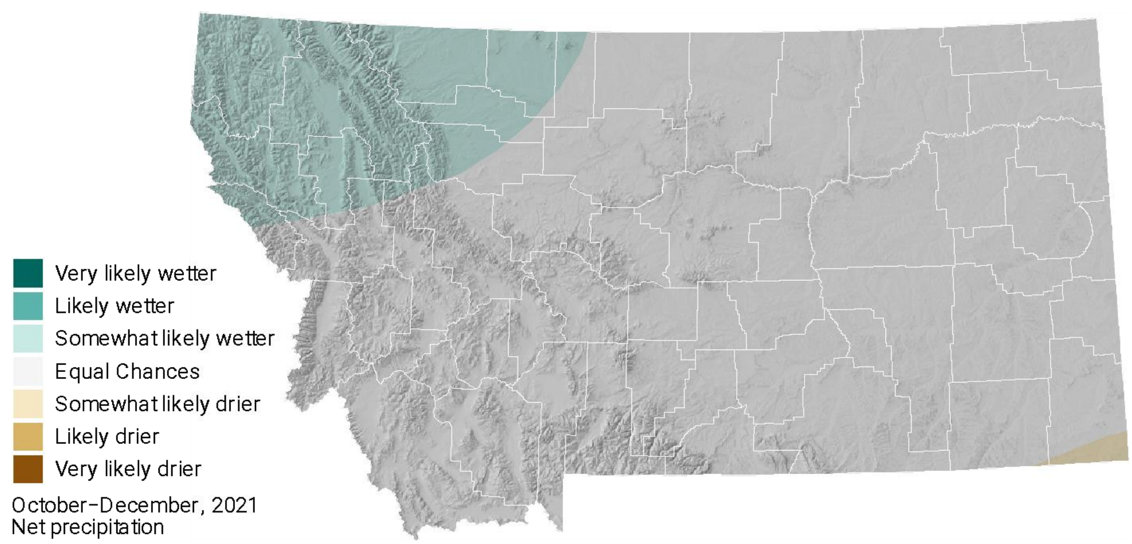
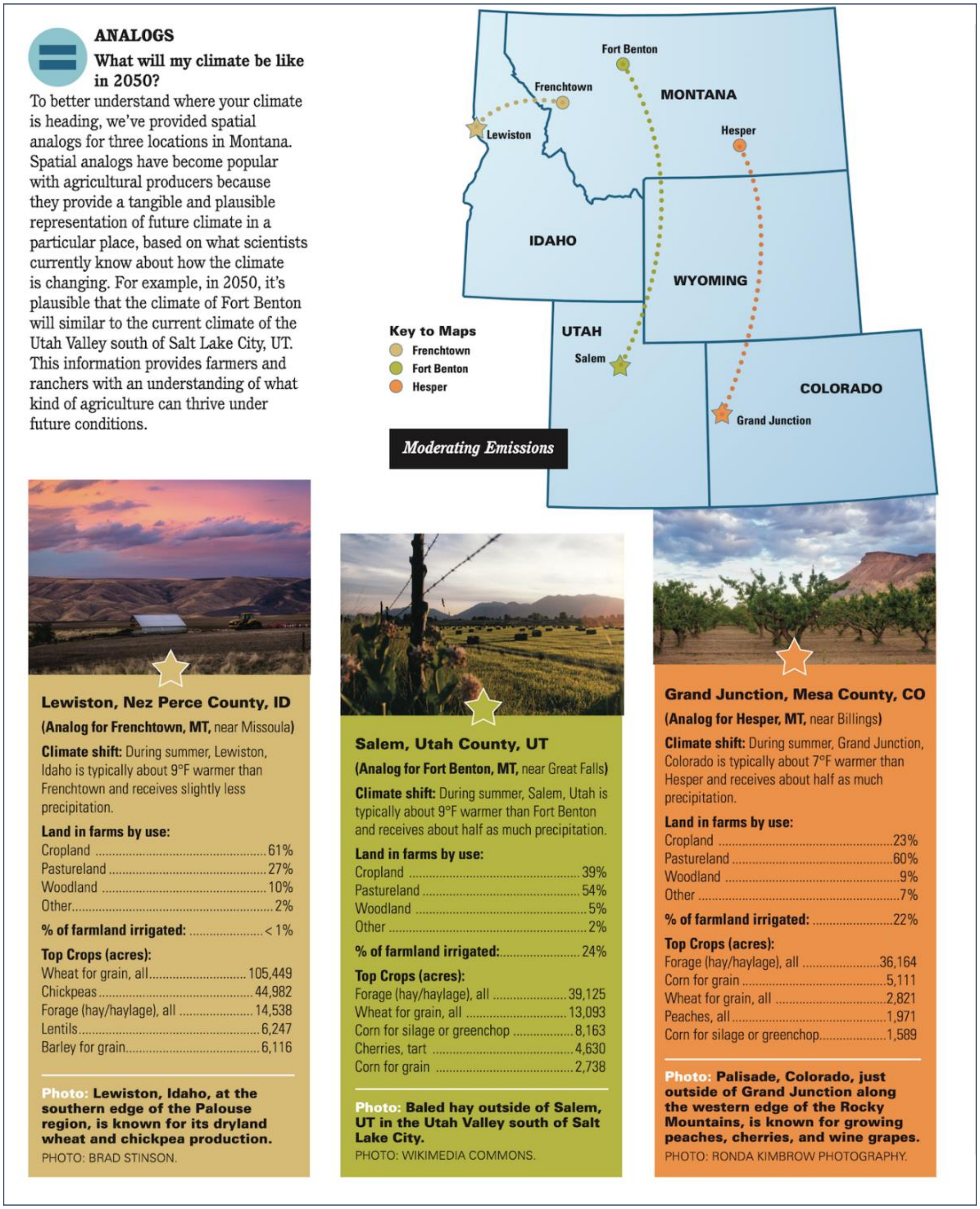


Figure 6.3.2: Mid-Century Projection as Spatial Climate Analog



ANALOGS

What will my climate be like in 2050?

To better understand where your climate is heading, we've provided spatial analogs for three locations in Montana. Spatial analogs have become popular with agricultural producers because they provide a tangible and plausible representation of future climate in a particular place, based on what scientists currently know about how the climate is changing. For example, in 2050, it's plausible that the climate of Fort Benton will similar to the current climate of the Utah Valley south of Salt Lake City, UT. This information provides farmers and ranchers with an understanding of what kind of agriculture can thrive under future conditions.

Lewiston, Nez Perce County, ID

(Analog for Frenchtown, MT, near Missoula**)**

Climate shift: During summer, Lewiston, Idaho is typically about 9°F warmer than Frenchtown and receives slightly less precipitation.

Land in farms by use:

Cropland	61%
Pastureland	27%
Woodland	10%
Other	2%
% of farmland irrigated:	< 1%

Top Crops (acres):

Wheat for grain, all	105,449
Chickpeas	44,982
Forage (hay/haylage), all	14,538
Lentils	6,247
Barley for grain	6,116

Photo: Lewiston, Idaho, at the southern edge of the Palouse region, is known for its dryland wheat and chickpea production.
PHOTO: BRAD STINSON.

Salem, Utah County, UT

(Analog for Fort Benton, MT, near Great Falls**)**

Climate shift: During summer, Salem, Utah is typically about 9°F warmer than Fort Benton and receives about half as much precipitation.

Land in farms by use:

Cropland	39%
Pastureland	54%
Woodland	5%
Other	2%
% of farmland irrigated:	24%

Top Crops (acres):

Forage (hay/haylage), all	39,125
Wheat for grain, all	13,093
Corn for silage or greenchop	8,163
Cherries, tart	4,630
Corn for grain	2,738

Photo: Baled hay outside of Salem, UT in the Utah Valley south of Salt Lake City.
PHOTO: WIKIMEDIA COMMONS.

Grand Junction, Mesa County, CO

(Analog for Hesper, MT, near Billings**)**

Climate shift: During summer, Grand Junction, Colorado is typically about 7°F warmer than Hesper and receives about half as much precipitation.

Land in farms by use:

Cropland	23%
Pastureland	60%
Woodland	9%
Other	7%
% of farmland irrigated:	22%

Top Crops (acres):

Forage (hay/haylage), all	36,164
Corn for grain	5,111
Wheat for grain, all	2,821
Peaches, all	1,971
Corn for silage or greenchop	1,589

Photo: Palisade, Colorado, just outside of Grand Junction along the western edge of the Rocky Mountains, is known for growing peaches, cherries, and wine grapes.
PHOTO: RONDA KIMBROW PHOTOGRAPHY.

Throughout the interview, participants were encouraged to bring up topics and ideas that were not covered in the interview guide. I used probes drawing on farmer's own language to clarify and elicit additional detail, or to explore connections between farmer's experiences and the literature. Most interviews were conducted by phone, due to the size of the study area, the ongoing COVID-19 pandemic, and the demands of farmers' growing seasons. Multiple farmers spoke to me on the phone from the cab of their tractor or late in the evening after a full day of work.

6.4 Analysis

I used a qualitative analysis that consulted relevant literature, generated theory, and examined the data. Interviews were audio recorded, professionally transcribed, coded in NVivo 12, and analyzed and interpreted through an iterative process comparing existing theory and empirical data. This dialectic process was attentive to emergent phenomena from the interviews through memos I wrote immediately after each interview. These memos also helped to identify divergent responses to interview questions, note connections to the literature, and elucidate the differences among participants. The memos were the first step of an analysis process which identified emerging themes and unanticipated results. After interviews, I listened to each interview audio recording while re-reading and correcting each interview transcript to ensure accuracy. This re-reading led to developing codes for transcripts, which represented a conceptual organization of recurring themes. I used topical codes to categorize practices and types of climate information (e.g., "cropping practices" or "three-month forecasts") and analytical codes to categorize themes relevant to the literature (e.g., "reactive adaptation" or "climate information relevance and utility") (see Appendix 3 for the full coding scheme). After each interview was coded, data from each code was organized and re-organized into a set of documents to enable cross-interview comparison. Each set of documents was progressively refined for the most prominent themes which answered research questions and the richest, most easily understandable, and most representative quotations from farmers interspersed with interpretation. Throughout this process, I returned to interviews to examine how well these codes and re-organized documents represented the data.

6.5 IRB and COVID Precautions

The University of Montana Institutional Review Board (IRB) approved interview protocol prior to data collection. Protocol included updated precautions due to the ongoing COVID-19 pandemic which meant that in-person activities had a heightened risk of harm to participants. I completed two doses of the COVID-19 vaccine prior to conducting any interviews. Prior to scheduling in-person interviews with participants, I confirmed that all parties involved agreed to follow guidelines issued by the University of Montana and other applicable local, state, or federal guidelines. When conducting in-person interviews, these guidelines included but were not limited to remaining outside, keeping at least a 6-foot separation, and ensuring that all parties wear face masks. Adequate safety equipment, personal health checks for researchers, and other precautions were used. In total, 26 out of 30 interviews were conducted remotely, eliminating the risk of in-person transmission. Before each interview, I informed participants that their responses are confidential and will be secured and destroyed with the completion of the research project. Participants gave their verbal consent at the beginning of each interview and I offered contact information for myself, the project director, and the institutional review board. Participants were reminded that they could withdraw their consent at any time. Introducing myself as a researcher from the College of Forestry and Conservation, I acknowledged my status as an outsider, but also as someone who cares about agricultural communities.

6.6 LIMITATIONS

Some limitations were encountered due to the mostly remote nature of data collection. Thus, the opportunity to build rapport with farmers was reduced by conducting a majority of interviews over the phone. However, remote interviews created more flexibility in conducting interviews with farmers during the growing season by allowing for interviews over the phone from the farmers' tractors or in the evening after their workday. In addition, some participants could not access the climate information due to remote interviews and limited internet service. Despite access limitations, many of these farmers were already familiar with similar snowpack, soil moisture, and three-month forecasts, enabling discussion of the utility of this information in decision-making. My analysis of climate adaptation may be limited by comparing crop-only farmers and mixed operators (farms that included both crops and livestock), which can employ different adaptations and respond to stressors in different ways. The same is true for the small sample of fruit and vegetable farmers, which helped identify cross-cutting similarities; yet vegetable farms represent fundamentally different operations with much smaller sizes and different capacities and adaptations. More in-depth research would be required of fruit or vegetable farmers to understand the full extent of their adaptations. While this sample does include farmers who grew the top ten crops in Montana (by harvested acres, see Table 6.2.2) because most farms in this sample are specialized to one or two crops (usually wheat), there is room for better understanding operations that were more diversified or grew less popular crops. The sample also only includes active farmers and does not include ex-farmers who may have shut down their operation, a population which could offer unique insight into the challenges of adaptation.

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Appendix 1: Interview Guide

Do you have any questions before we get started?

1. Can you tell me a little bit about your operation?
   Probe: specific crops, irrigation (type/extent), how do you sell your crops?
2. How long have you (been farming), want to visit owned and operated this farm?
3. In what ways have you changed your operation over time?
4. What goals are most important to you in terms of your farm and farming operation?

Thanks for telling me about your operation. As I mentioned, part of this research project is looking at how farmers like you respond to weather and climate events.

5. When you think about your farming operation over the years, what kinds of weather and climate events have impacted your farm?
   Probe on drought, flooding, extreme cold, extreme heat, year-to-year variability, hail, wind, pests.
   For each, ask: How did [climate stressor] impact you?
   For each, ask: How did you respond to that [climate stressor]?

6. What changes, if any, did you make to prepare your farm for future [climate stressor]?
   Probe: Are you usually able to make these changes? Why or why not?
   Probe: What barriers do you face [to name specific change]?
   Further probe, if necessary: economic and market barriers, barriers in obtaining private services, barriers in government programs, or other policies that might post barriers?
   Probe: How could those [name specific barriers] be addressed?

7. When you think about these sorts of climate and weather events [name the ones they named], do you feel like you're mostly reacting or also able to be proactive and plan for the next event?
8. When you look to the next 10 to 20 years, what kinds of weather and climate events worry you?

9. In a perfect world, what changes would you make to your operation to prepare for these events?
   (Ask this for each specific event they discuss)

Now I'd like to ask you some more specific questions about the factors that enable or constrain your ability to prepare for [name these types of events] that you might face in 10 years.

10. Is adopting new equipment or technologies necessary for making the changes you mentioned? I'm thinking of technology broadly.
    Probe: What are they?
    Probe: Why or why not?
    Probe: What changes or new private sector services would enable/constrain your ability to adopt this technology? (e.g. contracts, insurance, co-ops)
    Probe: What new government programs or changes to programs would enable/constrain your ability to adopt this technology? (e.g. funding programs, seed breeding)
    Probe: What new policies or reforms to policies would enable/constrain your ability to make this change? (e.g. Farm Bill to local policy)
    Probe: In terms of markets and financing, what changes or new programs would enable you to make this change?
11. Are there new sources of knowledge or information you need to make the changes you mentioned?
    Probe: What are they?
    Probe: Why or why not?
    Probe: Do you need new knowledge or information specifically from the private sector to make this change? (e.g. crop, chemical, or equipment advisors)
    Probe: Do you need new knowledge or information from state or federal agencies to make this change? (e.g. NRCS, extension, universities)
    Probe: Are there any policy changes that would enable you to get the information you need?
12. What else—<u>other</u> than equipment or information—do you need to make the changes you mentioned?

For the next questions, I'm interested in your thoughts on different types of climate information. I've brought some examples of climate information that I'll share as we talk. I'll take a moment so you can read these.

13. Here's an example of snowpack information (take a few moments and let me know when you're ready).
    a. Do you use snowpack information?
    b. If yes, how do you use snowpack information?
    Probe on specific climate stressors discussed above.
    c. What would make snowpack information more useful?
14. Here's an example of soil moisture information (take a few moments and let me know when you're ready).
    a. Do you use soil moisture information?
    b. If yes, how do you use soil moisture information?
    Probe on specific climate stressors discussed above.
    c. What would make soil moisture information more useful?
15. Here's an example of a three-month forecast (take a few moments and let me know when you're ready).
    a. Do you use 3-month forecasts?
    b. If yes, how do you use three-month forecasts?
    Probe on specific climate stressors discussed above.
    c. What would make three-month forecasts more useful?
    Probe on scale of information.
16. Here's an example of a projection of how conditions might change by 2050 (we call these analogs—you can take a few moments and let me know when you're ready).
    a. Do you use 2050 projections?
    b. If yes, how do you use 2050 projections?
    Probe on specific climate stressors discussed above.
    c. What would make them more useful?
    Probe on scale of information.
17. Aside from short-term weather forecasts, are there other types of climate information that you use?

18. When you think about the kinds of changes that you discussed making to your operation earlier *(give some examples here)*, does climate information help you make those changes?

    Probe: If so, how? If not, why not?
19. What other kinds of climate information would be helpful in achieving your goals?
20. How do you like to access climate information?

    Probe: Print, online, radio, phone app, or other forms?

21. Thanks for speaking with me today, is there anything else you'd like to share on these topics?
22. Are there other farmers in this area who you think I should talk with?

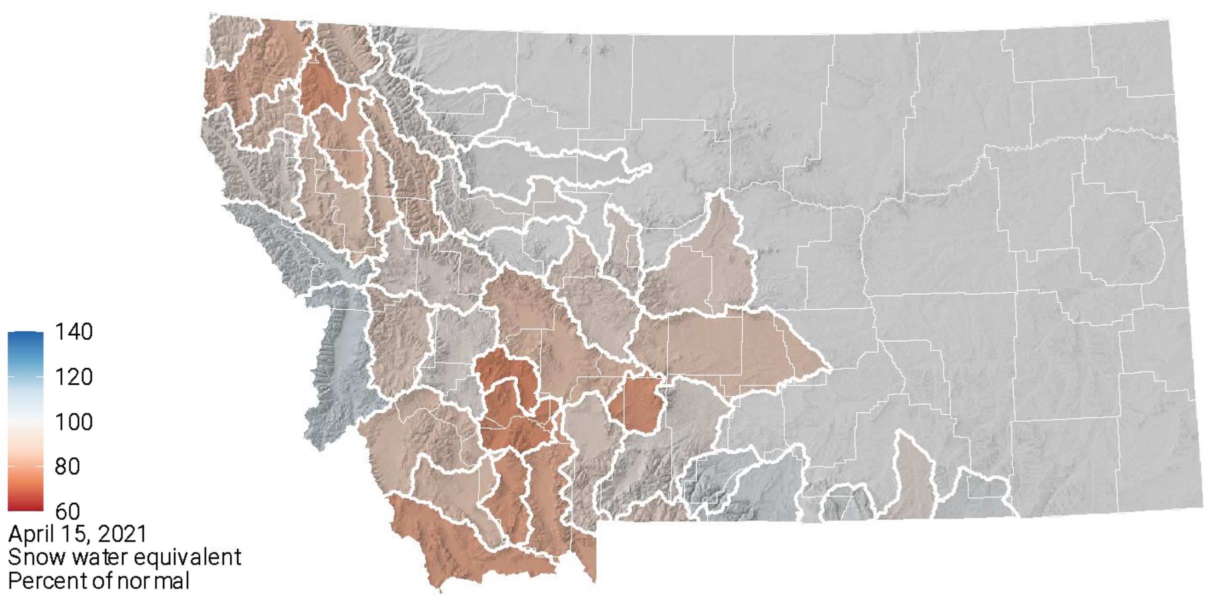
    Ask for farmers, crop types, irrigation systems that might be underrepresented in the sample.

APPENDIX 2: CLIMATE INFORMATION PROVIDED TO FARMERS

This summer climate information (shown below)—snowpack, soil moisture, and three-month forecasts—was provided to farmers from July 1 to September 8 (n = 6). All farmers received the same mid-century projections and definitions.

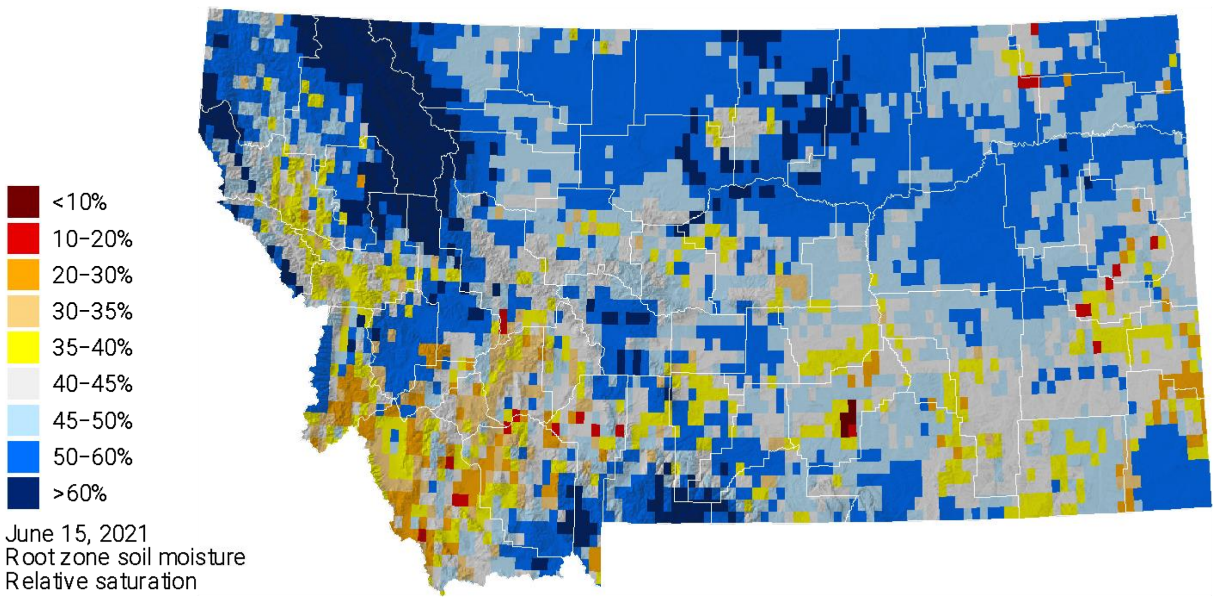
Snowpack

As of mid-April, snowpack was below normal across much of western Montana. Snow Water Equivalent (SWE) values range from 76% of normal in Boulder basin east of Butte to nearly 107% of normal in the Bitterroot basin. Due to several unusually warm periods, snowmelt progressed rapidly across the high country this spring, and only a few snow monitoring sites are still reporting snowpack as of mid-June.



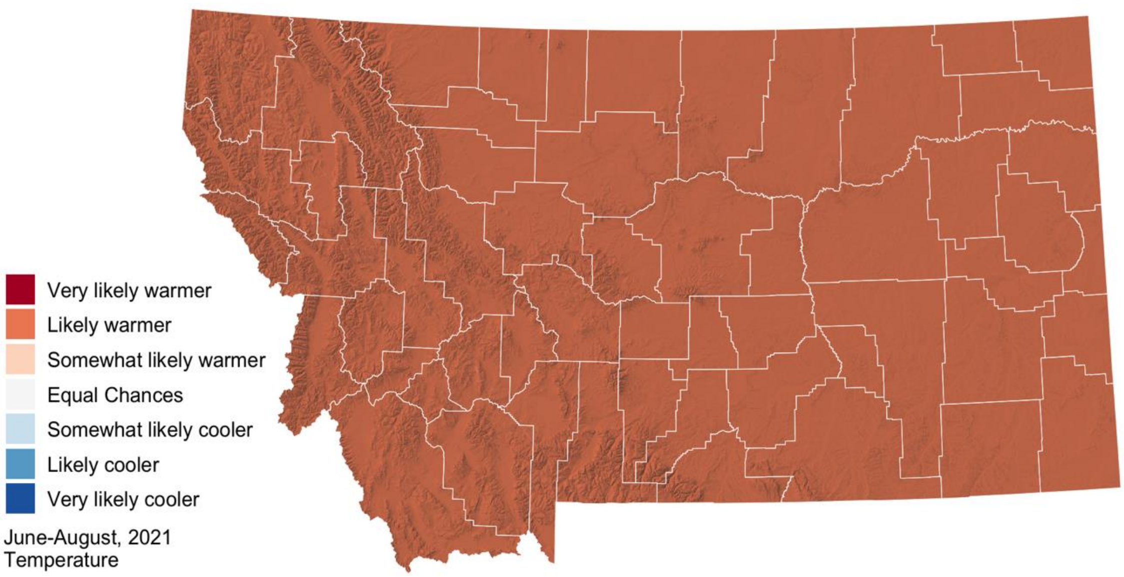
Soil Moisture

Satellite-derived estimates of soil moisture are very low for southwestern Montana (10–35% saturation) and generally below 50% across the rest of southern half of the state. Conditions in the northern Rockies and across much of northern Montana are relatively moist. Given the forecast for the rest of the summer, soils will continue to dry throughout the summer.



Three-Month Forecast for Temperature

In contrast to our cool temperatures across portions of the state this past spring, NOAA's Climate Prediction Center (CPC) is projecting conditions to be likely warmer than normal throughout the summer (June–August).



Three-Month Forecast for Precipitation

NOAA's Climate Prediction Center (CPC) is forecasting that June–August precipitation will be drier than normal across Montana, with more confidence in drier conditions for western Montana than eastern Montana. Dry conditions, combined with likely warmer temperatures across the state, could lead to expanding drought conditions and increased irrigation demand as we move into summer.

ANALOGS

What will my climate be like in 2050?

To better understand where your climate is heading, we've provided spatial analogs for three locations in Montana. Spatial analogs have become popular with agricultural producers because they provide a tangible and plausible representation of future climate in a particular place, based on what scientists currently know about how the climate is changing. For example, in 2050, it's plausible that the climate of Fort Benton will similar to the current climate of the Utah Valley south of Salt Lake City, UT. This information provides farmers and ranchers with an understanding of what kind of agriculture can thrive under future conditions.

Lewiston, Nez Perce County, ID

(Analog for Frenchtown, MT, near Missoula**)**

Climate shift: During summer, Lewiston, Idaho is typically about 9°F warmer than Frenchtown and receives slightly less precipitation.

Land in farms by use:

Cropland	61%
Pastureland	27%
Woodland	10%
Other	2%
% of farmland irrigated:	< 1%

Top Crops (acres):

Wheat for grain, all	105,449
Chickpeas	44,982
Forage (hay/haylage), all	14,538
Lentils	6,247
Barley for grain	6,116

Photo: Lewiston, Idaho, at the southern edge of the Palouse region, is known for its dryland wheat and chickpea production.
PHOTO: BRAD STINSON.

Salem, Utah County, UT

(Analog for Fort Benton, MT, near Great Falls**)**

Climate shift: During summer, Salem, Utah is typically about 9°F warmer than Fort Benton and receives about half as much precipitation.

Land in farms by use:

Cropland	39%
Pastureland	54%
Woodland	5%
Other	2%
% of farmland irrigated:	24%

Top Crops (acres):

Forage (hay/haylage), all	39,125
Wheat for grain, all	13,093
Corn for silage or greenchop	8,163
Cherries, tart	4,630
Corn for grain	2,738

Photo: Baled hay outside of Salem, UT in the Utah Valley south of Salt Lake City.
PHOTO: WIKIMEDIA COMMONS.

Grand Junction, Mesa County, CO

(Analog for Hesper, MT, near Billings**)**

Climate shift: During summer, Grand Junction, Colorado is typically about 7°F warmer than Hesper and receives about half as much precipitation.

Land in farms by use:

Cropland	23%
Pastureland	60%
Woodland	9%
Other	7%
% of farmland irrigated:	22%

Top Crops (acres):

Forage (hay/haylage), all	36,164
Corn for grain	5,111
Wheat for grain, all	2,821
Peaches, all	1,971
Corn for silage or greenchop	1,589

Photo: Palisade, Colorado, just outside of Grand Junction along the western edge of the Rocky Mountains, is known for growing peaches, cherries, and wine grapes.
PHOTO: RONDA KIMBROW PHOTOGRAPHY.

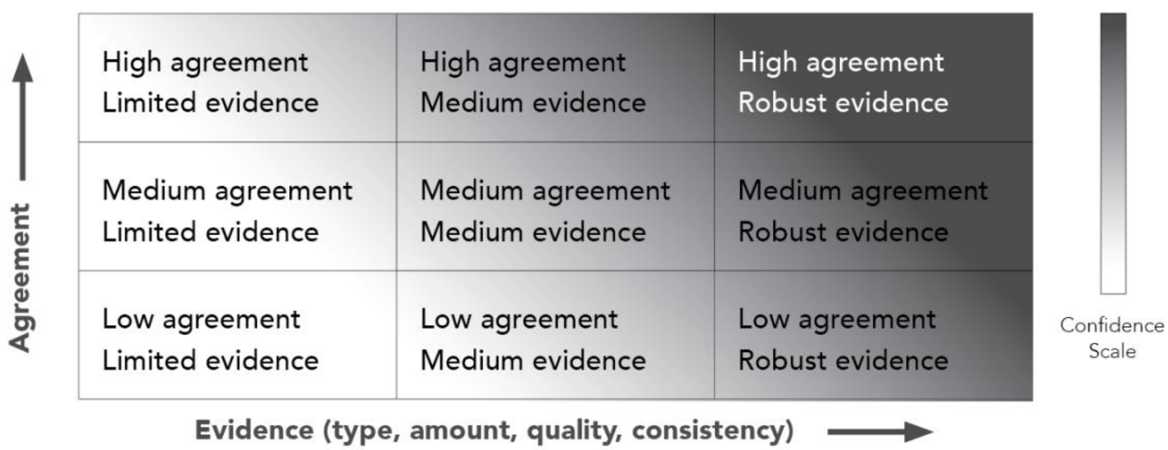
Temperature and Precipitation — Our three-month temperature and precipitation forecasts come from NOAA’s Climate Prediction Center.

Normal(s) — Climatologists use the term “normal” to compare current conditions or forecasts, such as temperature or precipitation, to the past. Here, the normal value is the statistical mean (the average) for a given measurement in a specific place during a specific period of time. Climatologists use the most recent 30-year period, rounded to the nearest decade, to define normal in North America: 1981–2010. The goal is to look far enough back in time to capture variation in weather patterns, but not so far as to be irrelevant to recent conditions. In 2021, we will start using the 1991–2020 period.

Drought — The US Drought Monitor identifies general areas of drought and labels them by intensity. Maps of drought intensity are used by policy-makers, resource managers, and agricultural producers to make decisions. More information about the US Drought Monitor can be found at the US Drought Monitor website.

La Niña/El Niño — El Niño and La Niña are the warm and cool phases of a recurring climate pattern across the tropical Pacific, the ***El Niño Southern Oscillation (ENSO)***. When ENSO is between warm and cool phases, conditions are called ENSO Neutral. ENSO is one of several global climate phenomena that affect Montana’s weather patterns, and ENSO conditions often guide seasonal climate projections for Montana. Current ENSO conditions and up-to-date projections are available on NOAA’s ENSO website.

Mid-century Projections — We present summaries of mid-century (AD 2040–2069) climate change impacts from the Montana Climate Assessment(MCA). The MCA findings are derived from careful analysis of many global climate projections that were run as part of the Coupled Model Intercomparison Project Phase 5 (CMIP5), and how those projections will likely affect people in Montana. **Climate change projections and impacts are uncertain.** Each key message provided here is followed by an expression of confidence that assesses a) the level of agreement among experts with relevant knowledge used to craft the message, and b) the quality of the evidence supporting the message.



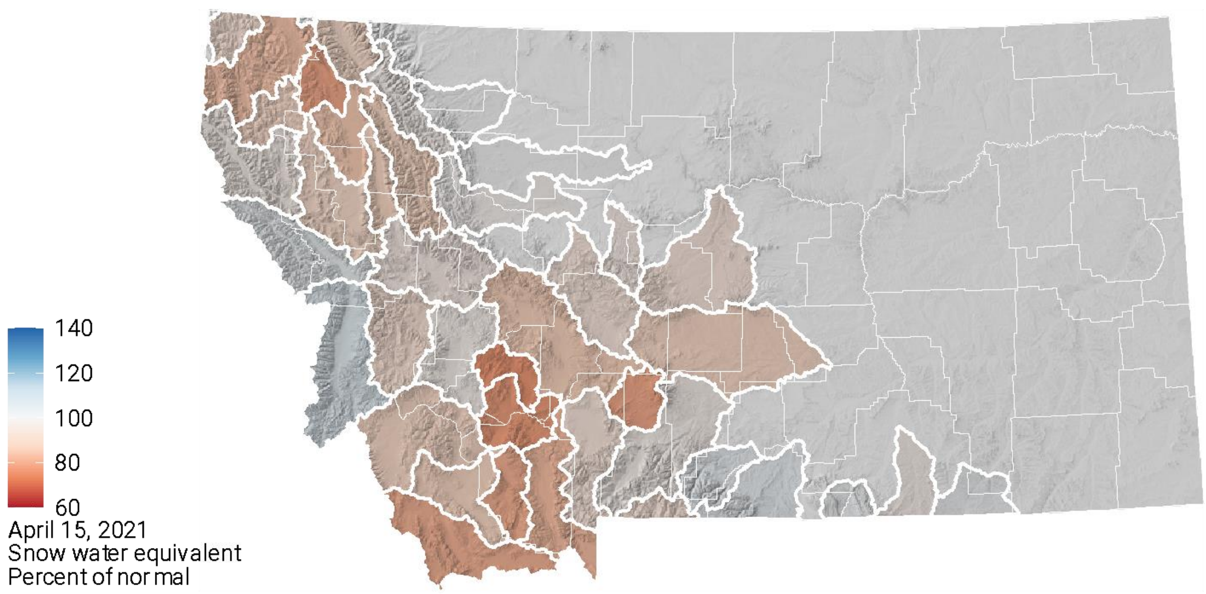
Root Zone Soil Wetness — Root Zone Soil Wetness is a measure of how much water has saturated the soil. More specifically, it’s the relative saturation between completely dry (indicated by a 0) and completely saturated (indicated by a 1) between 0 and 100 cm depth. In the maps in this newsletter, soil saturation comes from NASA’s Soil Moisture Active Passive (SMAP) satellite program “SPL4SMGP” data product. Soil moisture is mapped using a combination of radar and radiometer measurements from space and surface observations at an approximately 9-km spatial resolution.

Fall Climate Information Update

Because summer climate information became irrelevant, the following updated snowpack, soil moisture, and three-month forecasts were provided to interviews from September 10 to November 11 (n = 16).

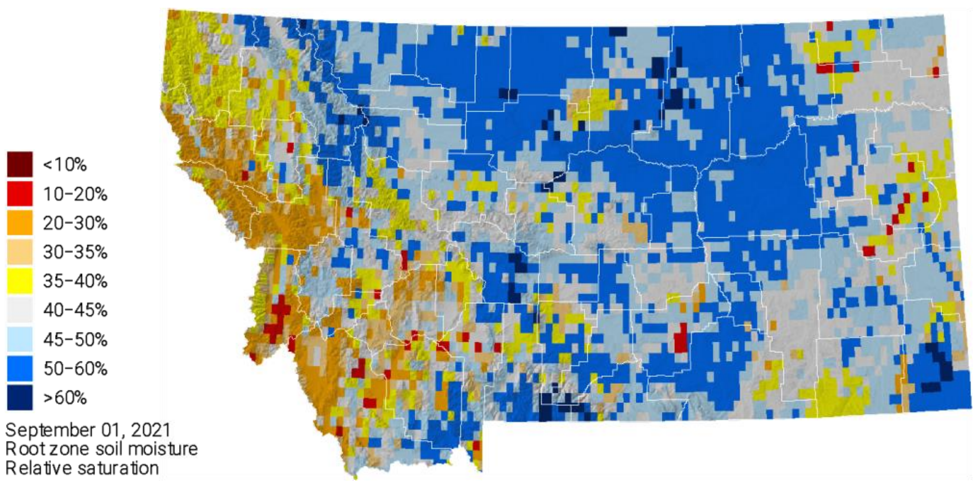
Snowpack

As of mid-April, snowpack was below normal across much of western Montana. Snow Water Equivalent (SWE) values range from 76% of normal in Boulder basin east of Butte to nearly 107% of normal in the Bitterroot basin. Due to several unusually warm periods, snowmelt progressed rapidly across the high country this spring, and only a few snow monitoring sites are still reporting snowpack as of mid-June.



Soil Moisture

Satellite-derived estimates of soil moisture are very low for western Montana (10–35% saturation) and below 50% along the eastern edge of the state. Soils in north-central Montana have maintained moisture levels since the spring and early summer, though most of Montana remains drier than normal for this time of year. Fall soil moisture recharge and winter snowpack will largely determine moisture going into the 2022 growing season.

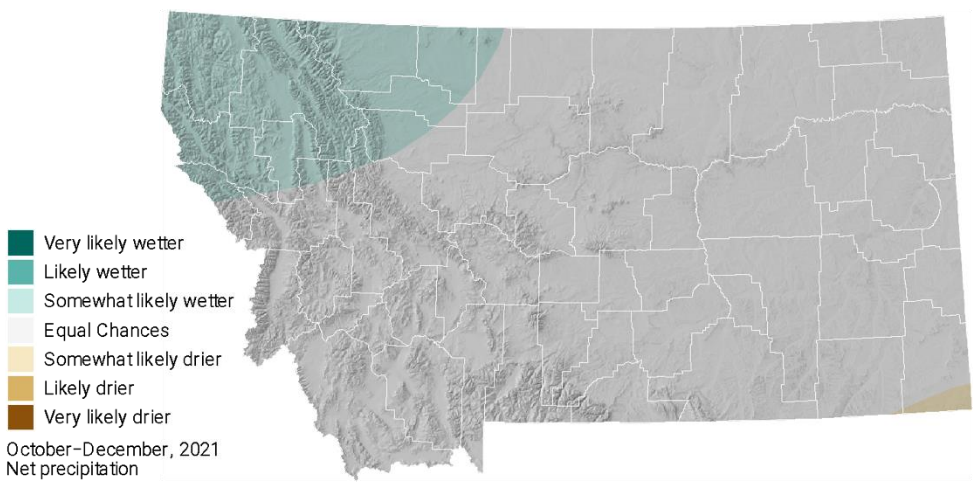


Three-Month Forecast for Temperature

After a much warmer than normal summer across Montana, NOAA's Climate Prediction Center is predicting equal chances of warmer or cooler conditions for most of Montana this fall, meaning that conditions are likely to be relatively normal across the state. Southwestern Montana is forecast to experience somewhat likely warmer conditions this fall.

Three-Month Forecast for Precipitation

Most Montanans experienced drier than normal conditions this summer, but the NOAA's Climate Prediction Center is projecting more normal conditions going into the fall, with somewhat likely wetter than normal conditions in northwestern Montana. While the return to normalcy is welcome, much wetter conditions will be necessary this winter in order to recharge soil moisture across the state.



APPENDIX 3: CODING SCHEME

Adaptations, Topics		*These code specific practices, decisions, or adaptations. Each factor code includes constraints/barriers and enablers/opportunities, so both positive and negative aspects are included under the same code*
"On farm" factors	Vegetation, cropping	Specific practices including rotations, diversity, cover cropping, use of drought tolerant varieties
	Income diversification	Specific practices include selling products from different farm/ranch enterprises, income from services beyond growing/raising (e.g., tourism, outfitting/guiding), the use of certifications to get a higher premium on products (e.g., organic, humane handling)
	Grazing management	Specific practices including grazing strategies and management (i.d. intensive, moderate, extensive, rotational, planned, holistic, etc.), grazing planning, and stocking rate
	Machinery & infrastructure	Specific machinery and infrastructure, referring to iron, metal, and concrete. This includes irrigation, storage, and implements like tractors, seeders, tilling implements, and other mechanics
	Marketing	Specific decisions about marketing crops or livestock, contracts, buyers, and wholesale/consumers
	Time or labor	General discussion of on-farm/ranch time or labor capacity, changes, or constraints
"Off farm" factors	Economic	General discussion of external economic conditions like markets, supply chains, processing plants, or corporate consolidation and *not* including labor or cash flow which should be included under other codes
	Policy, crops	General and specific policy or practice of trading, exporting, importing, governing grains and other crops
	Policy, livestock	General and specific policy focused on beef and other livestock (or crops for Ada), includes hay and feed and other animal products, includes country of origin labeling, import/export policy

	Insurance	Includes hail, multi-peril, and other types of crop insurance as well as pasture, rangeland, and forage insurance
Technology and information factors	Chemicals	Specific chemical inputs like herbicide and fertilizer, use when discussing a specific product or when cropping, precision, or machinery are *not* the primary focus
	Seeds	Specific varieties or genetics of seeds, whether from public or private sources discussed as a technology in itself and not a cropping practice
	Precision & data	Includes GPS, variable rate, sensors, data software, DNA testing, and other technology that is electronic in nature and *not* primarily iron or concrete
Government programs and services	EQIP, CSP, CRP, cost shares	Specific enrollment-based federal programs
	NRCS, DNRC, MSU Extensions	Separate from info & knowledge, this is information specifically provided by federal and state government programs and services like NRCS, Extension, research stations, and universities and *not* including climate information
	Other gov.	General and specific discussion of programs and services not covered above.
Climate Information		*The topical climate information codes largely align with the questions in the interview to delineate based on what kind of climate information is being addressed; the topics and the meanings codes will likely overlap*
Climate information topics	Snowpack	Specific to snowpack information and the snowpack map provided
	Soil moisture	Specific to soil moisture and the soil moisture map provided
	3-month forecast	Specific to three-month forecasts and the three-month temperature and precipitation forecasts provided
	2050 projection	Specific to 2050 or multi-decade projections and the 2050 analogs provided
	Other climate information	Specific other types of climate information like historical information, wind forecasts, etc.
	Climate change	General and specific observations of how the climate has changed overtime, opinions on climate change

		and climate science, and rants about climate change political correctness and other beliefs
Climate information meanings	Weather and climate impacts	Specific weather and climate events and the material impacts they had on an operation, including the effects of drought, flooding, extreme weather, wildlife, insects, pests, disease, and other events; while one interview question focused on impacts, these impacts are often mentioned throughout conversations as the cause of enacting specific factors/adaptations above and should be used when the impact is the focus with some potential overlap with adaptations codes above
	Access & format	General ease of finding climate information, the medium or format it is presented and preferred, and paying for climate information
	Trust & credibility	General trust in the entity providing climate information, either when evaluating the trustworthiness of scientists and meteorologists in general or specific institutions like UM, *not* including specific forecasts which refers to accuracy and reliability below
	Accuracy & reliability	General accuracy or reliability of the climate or weather information itself, including specific forecasts and projections and both short- and long-term
	Relevance & utility	Specifically referring to how climate information is useful on the farming or ranching operation, including discussion of how the information could or could not inform specific practices and decisions in which cases it may overlap with adaptation codes above
	Temporal scale	General timing of climate information including specific decision-making windows, lead times, length of projections and forecasts
	Spatial scale	General usefulness of geographic scale in climate information, including how "zoomed in" producers want climate information and the ways that weather can vary across a single operation
Adaptation, Decision-Making		*These codes refer **not** to tangible or material barriers and factors which should be coded with adaptations above, but to discussion that indicates how farmers*

		and ranchers conceptualize adaptation; may often overlap with other codes, but not always
Adaptive decision-making	Management goals	Specific goals and objectives of the operation, usually answered in the beginning but sometimes goals or objectives are revised or revealed later in discussions
	Operator/Operation Characteristics	Includes how long the operation has been in business, process of inheriting or acquiring land, passing land to the next generation and transition plans
	Information & knowledge	Separate from information provided by government programs or services, includes attending conferences, learning from neighbors, using social media, and private crop/chemical/rangeland management advisors
	Weighing	General discussion of weighing multiple factors to make a decision, including market information, climate information, local knowledge, etc. including information overload, difficulty choosing /using information, and when climate and market uncertainty play hand-in-hand
	Reaction	General sentiment of reacting to stressors, either weather/climate related or other stressors, including the reasoning behind how and what an operation can do to react to events as they happen, often incremental and short-term ways to reduce risk but not always
	Proaction	General ability to foresee stressors, either weather/climate related or other like economic, and take steps in advance to reduce risk before these events happen or seem likely to occur, often longer-term ways to reduce risk but not always
Attitudes	Weather and climate attitudes	General framing of how an operation can or cannot respond to weather and climate, including how to deal with uncertainty, a blind optimism or pessimism or stubbornness, or ways of understanding inherent weather/climate uncertainty
	Treadmill and technology attitudes	General discussion of increasing size of operation, cost of inputs or equipment, advancing economic pressures and technological progress—and whether that will allow for more adaptations to climate/weather, like techno-optimism, or push operations out of business, techno-pessimism

	Other, efficacy & agency	General expressions of capacity and ability (and also expressions of lack of agency) to overcome barriers, when not covered by other codes
	Money	Specific discussion of cash flow constraints, lending and financing from the private sector, off-farm income, healthcare, retirement
Misc.	Good & funny	Quotes that you don't want to forget
	Misc. important	Includes things that are important but may not fit in any of the above categories (e.g. family or community history that might help provide context)
	Misc. not important	Includes things that are not important and don't fit anywhere—unrelated anecdotes, travel stories, etc.