THESIS

DROUGHT & CONSERVATION: EXPLORING THE RELATIONSHIP BETWEEN DROUGHT AND GRAZING LAND CONSERVATION PROGRAM ENROLLMENT

Submitted by

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ABSTRACT

DROUGHT & CONSERVATION: EXPLORING THE RELATIONSHIP BETWEEN DROUGHT AND GRAZING LAND CONSERVATION PROGRAM ENROLLMENT

Financial loss from drought can have devastating impacts on the livelihoods of land and livestock managers. Conservation practices are one of the drought adaptation strategies for mitigating the damage of drought and are particularly useful for long-term adaptation. Using the largest known database of grazing conservation practice implementation, this study analyzes the effect of drought conditions on enrollment into the USDA Environmental Quality Incentives Program (EQIP) at the national scale. Specifically, we explore the impacts of drought on the number of EQIP grazing practices implemented in a given county from 2009-2018. We exploit exogenous variation in drought exposure at the county level to estimate the effect of drought conditions on grazing practice implementation. We find that severe drought increases drought-related conservation practice implementation for up to two years. Additionally, we find that following a severe drought, there is a meaningful increase in practices related to long-term drought adaptation such as ponds, livestock pipelines, and range planting. When analyzed by agricultural region, our findings suggest that each region uniquely uses conservation practices to respond to drought. We complement our national econometric model with a brief analysis of a 2013 survey of Colorado and Wyoming ranchers. We use results from the survey to examine management and drought adaptation differences in producers who had enrolled in EQIP and those who had not. We find that ranches enrolled in EQIP are more likely to add alternative on-farm enterprises and incorporate pasture rest into their grazing system as part of their drought

adaptation strategy. Results from both data sources work in concert to provide insight into the relationship between drought, EQIP, and livestock management.

ACKNOWLEDGMENTS

Thanks to my friends, family, and partner for all their support. Many thanks to my committee for their willingness to hear my wild ideas for the past two years. I have gotten to know and work with each of them in various ways and feel honored to have been able to learn so much from them. The DARE faculty have been incredible in facilitating my understanding of agricultural economics and I’m very thankful for their passion and energy.

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INTRODUCTION

Financial losses over the past 40 years associated to drought are estimated to be roughly $236.6 billion (in 2020 dollars), making drought the second most financially impactful weather phenomenon in the last 40 years (Smith, 2020). The increase in both the frequency and variability of drought is reshaping the agricultural industry as we know it. While definitions vary, most simply, drought is defined by sustained below average precipitation and above average temperatures. Furthermore, drought has unique implications in rangeland, pastureland, and non-irrigated agricultural systems that do not have the ability to supplement water delivery. Because the American livestock industry is incredibly dependent on the conditions of these range conditions, drought can have both short and long run, costly implications for the livestock industry (Briske et al., 2015; Countryman et al., 2016).

Livestock producers and grazing land managers have several tools for managing drought risk at their disposal. They include de-stocking their pastures, grass-banking, purchasing alternative feed, seeking government assistance or participating in conservation programming (Shrum et al., 2018). While the adoption of grazing conservation practices may serve as one drought management tool, research on this topic is limited. One approach is to analyze observed grazing conservation decisions to look for empirical evidence that producers and land managers adopt grazing conservation practices in response to drought. An investigation of this topic should distinguish grazing practices based on their expected risk management benefits to livestock producers and grazing land managers. In a research study similar to this thesis, Wallander et al. (2013) investigated this question for irrigation and tillage practices but did not include an in-depth analysis of conservation grazing practices. They find that drought risk in a county does impact the decision to enroll in tillage and irrigation practices, but do not conclude anything for grazing related practices.

Conservation practices provide unique options for producers in managing for drought. Conservation practices are implemented by individuals for a variety of reasons, but often, there are financial benefits through government cost-share programming, increased resilience and yields of range/pastureland, and payments for ecosystem services. These benefits make conservation grazing practices a uniquely positioned tool to aid producers in their navigation of climate and market uncertainty. The largest funding agent for conservation grazing practices in the United States is the National Resource Conservation Service (NRCS). The NRCS administers conservation programming and U.S. Farm bill conservation subsidies to hundreds of thousands of producers each year.

The objective of this research is to examine whether conservation grazing practices have increased in their use after drought events, and if so which ones. To accomplish this, we employ data from the USDA Environmental Quality Incentives Program (EQIP) which is administered by the NRCS and is the largest Working Lands Conservation Program (WLCP) in the U.S. We use these data, in concert with drought index data, to identify (i) whether the number of conservation grazing practice implementations increase after drought events, and is so, (ii) the marginal effect of decreases in growing conditions on practice implementation. We test the effect of drought on the implementation of all grazing-related EQIP practices, the subset of grazing-related EQIP practices identified by Wallander et al. (2013) as being drought related, as well as each grazing practice individually. We subsequently disaggregate the analysis by agricultural region as identified by Heimlich et al. (2000) to understand regional effects of drought on conservation practice adoption. Finally, we supplement the national-level analysis of program data with survey data from 39 counties in Colorado and Wyoming. The survey data provides the advantage that we can compare producers who do and do not enroll in the EQIP program, and explore whether drought, ranch characteristics, and/or management practices correlate with EQIP program enrollment.

There is limited prior research that asks whether this program is being used as a tool to facilitate changes in land and livestock management after major drought events. Prior academic work shows that livestock production risk can be minimized through agricultural insurance programs (Ifft et al., 2014; Lybbert & Sumner, 2012), but there is less evidence on the effectiveness of conservation programs in mitigating risk for land and livestock managers. Wallander et al. (2013) show that various federally funded working lands conservation programs can mitigate drought risk for agricultural producers who participate in irrigation and tillage practices. A recent meta-analysis of the adoption of conservation practices show that conservation practices and insurance programs can serve similar roles in buffering against negative impacts of weather on profits (Prokopy et al., 2019). Wilmer et al. (2016) interview various ranches and find that drought is always on the mind of producers, and that if managers change their practices after a drought, it often is in order to facilitate a buffer against future disruption. However, these changes in management practices towards more resilient systems can be costly and difficult to implement. EQIP is a potentially useful tool in aiding with this transition to new practices, as it provides technical advice and funding for the implementation of specific practices.

Our research contributes to existing literature in the three ways. First, we update prior work by implementing a current analysis of administrative data to represent more recent policy, climate, and economic conditions. We analyze a set of practices related to grazing, which has not yet been empirically analyzed by other authors. While we understand that EQIP is just one program working towards ensuring sustainable agricultural practices, because of its size and scale, we believe it holds representative power for other WLCPs. We use the Economic Research Service agricultural regions to identify practices that are implemented in each region after severe drought events, a first of its kind analysis for these data. Lastly, prior work on this area tends to rely on either administrative program data (Wallander et al., 2013) or survey data (Lubell et al., 2013). We use both to provide a more nuanced analysis into drought response behavior. In particular, we use the full population of program participants from EQIP administrative data to identify the determinants of specific conservation practice adoption while simultaneously providing insight into underlying mechanisms and outcomes by using a representative sample survey.

The paper is organized as follows. First, we first provide a literature review that explores the livestock management, conservation practice adoption, and drought response literature to provide context and direction for the present work. Next, we provide an overview of the EQIP program and background on history of the program, as well as its future direction as determined by the 2018 Farm Bill. In this section we also will explain in detail the types of practices of that exist in the program and their significance in management. The third section provides an overview of all of our data that we will employ in this study. We then expand prior work to identify this paper's conceptual framework and research methodology in analyzing EQIP enrollments at the national level. Section six presents and interprets results of this analysis. Finally, we provide a brief analysis of a Colorado and Wyoming randomized survey that asked ranchers questions with respect to their enrollments in federal assistance programs as well as various drought response and management practice questions. We conclude the paper with a discussion of these results, limitations of our analysis, and recommendations for future work.

LITERATURE REVIEW

This section summarizes the most relevant academic literature that contributes to the understanding of the relationship between conservation program enrollment and drought exposure. In doing so, the academic work we summarize stems from three major areas. First, the technology adoption and innovation literature explore motivations behind the use and spread of conservation practices. Secondly, literature from ecology, rangeland, and animal sciences provides useful background on livestock production and insights as to why and how WLCPs can be used as risk-mitigation strategies. Lastly, we call on literature with similar empirical strategies to introduce our methodology, shedding light on multiple identification challenges that we explicitly address in our empirical framework.

Conservation Practice Adoption

Understanding the adoption of various practices and protocols of landowners and ranchers is well studied in prior literature. This research is relevant to the present project in informing the narrative and understanding the reasons why producers change their management strategies in the face of changing environmental conditions. The following presents key research and meta-analyses that inform our understanding of the relationship between drought and conservation program enrollment.

Pannell et al. (2006) provide a useful framework for how the conservation practice adoption process takes place. The authors articulate the adoption sequence in the following steps: awareness of the problem or opportunity, non-trial evaluation, trial evaluation, adoption, review and adoption modification. For the present study, we present drought as the problem, and hypothesize that drought related conservation practices are adopted and reviewed by managers through enrollment in the EQIP program, and if useful, will remain adopted after the modification stage. Pannell and colleagues describe that relative advantage of a practice is the key factor in determining long-run adoption. Adjustment costs, possible short-run foregone profitability, and profit risk involved in the adoption of a practice all are important factors in determining the adoption of a practice (Cross et al., 2011; Pannell et al., 2006; Yu & Belcher, 2011). Therefore, we hypothesize that if EQIP's cost share is set to a rate that mitigates the financial burden of adoption and the manager believes there is long-term benefit to the practice, then adoption is more likely, so long as the practice is compatible with existing technology (Pannell et al., 2006).

Additional needs for conservation practice adoption may stem from climate change impacts, though adoption is not without barriers. Rickards & Howden (2012) describe how difficult management transitions to conservation practices can be when practice benefits may not be realized long after initial costs are paid. The authors describe the need for agricultural producers to begin the climate change adaptation process given the mounting ecological, social, and political pressures on agriculture. EQIP, then, provides a useful method for producers to engage in practices that situate them to navigate these mounting pressures without paying the full cost of their implementation. This benefit holds, so long as program design is not prohibitive. One study in the northeast finds that administrative and transactional costs represent a barrier to entry into EQIP for many producers (Del Rossi et al., 2021). Their finding suggest that overall, EQIP is well designed to meet the literature reccomended structure for payment for ecosystem service programs. The authors do, however, find that EQIP fails to provide financial incentive greater than the opportunity cost of the land (i.e., compared to alternative uses of the land) and has high transaction costs. Importantly for our work, these barriers could prove big enough to attenuate the effect of drought on enrollment in practices. Other factors affecting EQIP enrollment include public sector information use, cost share proportions, total program payment, total land area of the farm, and current farming practices (Ma et al., 2010; McCann & Nunez, 2005). Overall, if the cost-share represents enough payment to overcome program barriers and practice costs, managers are hypothesized to enroll in the program.

A recent meta-analysis of 93 studies on conservation practice adoption sheds light on the most prominent and consistent factors affecting agricultural conservation practice adoption (Prokopy et al., 2019). After analyzing and grouping the variables researched in each individual study, this study identifies key factors affecting the likelihood of conservation practice adoption. The authors find adoption related to producer characteristics such as: environmental and program/practice attitudes, formal education, awareness of a program/practice, and financial status/dependency. They find adoption related to land characteristics such as: farm size, vulnerability of the land, other conservation practice adoption, value-added product marketing, and practice effects on product yield. While the producer attributes underpinning EQIP adoption are beyond the scope of this paper, we build on this literature on mechanisms by examining the role of environmental conditions, i.e. drought, on program adoption. We have covered ideas behind overall conservation practice adoption, and we now present a few key insights from the literature around drought management adoption.

Drought Adaptation Literature

Conservation practices are one tool for land and livestock managers identified in the drought management literature. The following will present prior research into drought management and further draw the connection between conservation practice adoption and drought adaptation. Before describing drought management, we briefly define drought. Drought is both a quantifiable phenomenon of prolonged deviation from normal precipitation and a social-ecological belief about the state of moisture within specific context (Mishra & Singh, 2010). For example, agricultural producers may perceive that they are experiencing a drought long before those in an urban setting feel the effects. Given the breadth of definitions of drought and the social contexts that define it, there is much debate on how to measure drought. Most often, it is a measured by analyzing increased temperature, decreased precipitation, increased evapotranspiration rates, and some measure of the length of these changes. In this paper, we will use a common drought index known as the Palmer Drought Severity Index (PDSI) to operationally define drought conditions and mark an index value of less than -3 as indicating severe drought. Further information on this index will be provided in the Data section.

One 2009 paper surveying graziers in the Burkedin Region of Australia writes that "severe drought is the one risk that graziers…fear most" (Greiner et al., 2009). Severe drought is often on the minds of land and livestock producers and they respond to it in a variety of ways. Many ranchers navigate drought through planning for its impacts, and there is evidence than most ranches in the western region of the U.S. create drought contingency plans as a part of their overall planning efforts (Haigh et al., 2021; Coppock, 2011). The plans can be effective tools to mitigate the impacts of drought, though the specific responses *to* and impacts *of* drought depend on the manager's social, economic, and ecological system. (Briske et al., 2015; Haigh et al., 2021; Wilmer et al., 2016). In light of their importance and effectiveness, drought contingency plans are incorporated in multiple EQIP practice guidelines (for example, see NRCS conservation practice standards for practice 528). Finally, there is evidence that thoughtful stocking rates relative to temperature and precipitation can help optimize gains in beef production and help mitigate the effects of major drought (Reeves et al., 2013). The suite of tools that these drought planning efforts employ, however, is less understood. Our research aims to fill this gap in knowledge on drought mitigation, by shedding light on the specific tools and practices most frequently used for drought management.

Shrum et al. (2018) describe livestock ranching on semi-arid landscapes as among the most complex decision-making paradigms in land management and livestock management. The decisions made on the land, working in concert with environmental factors, can either improve or degrade rangelands conditions. The authors summarize four major strategies for drought management in livestock producers: (1) increasing the supply of forage to the herd (i.e., buying feed or renting pasture), (2) decreasing the demand for forage (i.e., selling animals to destock pasture), (3) financial risk management measures (i.e., seeking government aid and earning off-farm income), and (4) long-term preparation measures (i.e., reserve forage, conservative stocking, and drought insurance). The effectiveness of these strategies, however, depends on timing of implementation and specific ecological context (Derner & Augustine, 2016). For example, in the Colorado and Wyoming region, if selling livestock (strategy 2) is done too far into the drought, it can lead to worse overall outcomes (Hamilton et al., 2016; Ritten et al., 2010). Water development projects, conservative stocking rates, and rotational grazing efforts (all part of strategy 4) can be funded by EQIP and all show some promise in reducing the effect of drought on rancher livelihoods (Coppock, 2011; Wilmer et al., 2019).

We hypothesize that producers will self-select into the set of practices they perceive as utility maximizing, given their expectations of future drought, though information on both practice outcomes and future drought is imperfect. A large body of literature explores the outcomes of the practices recommended by conservation programs, which is key to understanding how producers perceive benefits of these practices. There have been various efforts to measure ecosystem service benefits associated with specific grazing conservation practices on rangelands, but there is not agreement on the effects in the academic literature (see Briske et al., 2017; Fletcher et al., 2020; Sanderson et al., 2020; Tanaka et al., 2011). Ultimately, spatial and temporal heterogeneity amongst producers can lead to varying resource outcomes of the practices (Fletcher et al., 2020). Drawing a direct relationship between conservation practices and conservation outcomes proves difficult, as varying management styles can lead to similar ecological outcomes (Wilmer et al., 2018).

Agricultural Decision-Making Theory

Early economic theory on producer decision-making relies on the fundamental assumption that a firm's main objective is profit maximization (Walras, Jevons, and Marshall). However, beginning in the 1920's many researchers have sought to provide a more accurate depiction of firm decision making. For ranching in the arid west, Smith & Martin (1972) were the first to propose that cattle ranchers might not be profit-maximizing, but rather, working in the business because of a love of the land, and a love of rural values. They develop a model where ranchers make decisions to maximize utility, rather than profits, that encompasses these values.

In addition to incorporating decision-maker values into firm decision modeling, utility maximization provides a framework to incorporate risk preferences into the model. Land and livestock management typically provides low returns on investment, high levels of risk, and high opportunity cost of capital. As shown from the above review, drought only works to exacerbate the risk and increase the difficulty of running a profitable and sustainable ranch. Chavas et al. (2019) provide a useful theoretical framework for decision-making under uncertainty in the agricultural sector. The authors find that variable inputs are risk-increasing, livestock is risk-reducing, and that off-farm income contributes to reducing the cost of risk (Chavas et al., 2019). This is releavent to our work as it provides theory and evidence that the effects of management decisions impacts the on the cost of risk to producers. We know that EQIP impacts management decisions, and therefore draw the line that changing practices that are risk minimizing can minimize the cost of risk to producers.

Wallander el at. (2013) draw on similar theory to employ an econometric estimation of drought impacts on conservation program enrollment. They define a set of hypothesized EQIP grazing practices, used in our study, that are likely to increase after in areas with higher drought risk (found in table 1). Their paper concludes that total irrigation and tillage practices from 2002 to 2010 increase in counties that have higher drought risk. They refrain from the same detailed analysis for grazing related practices. However, the authors write about grazing practices and conservation programs, concluding that "conservation programs already serve a role in facilitation drought risk adaptation for livestock producers" (Wallander et al., 2013).

One group of researchers acknowledge the utility maximization framework as applicable to questions around practice adoption, but choose to employ a profit maximization framework to derive estimates of the effects of employing EQIP prescribed grazing practices in Montana (Ashwell et al., 2019). The authors find evidence that enrollment can have positive profitability and production impacts, but the effect is much greater for ranches with large tracts of deeded land and large distances between watering locations. (Ashwell et al., 2019). We expand on this prior work to provide futher empirical analysis of EQIP for more practices than just prescribed grazing, as well as better identify which practices are used for drought management.

Methodoligcally, several papers have studied the effects of drought on agriculutral production through the use of drought indexes and panel data methods. A few recent papers use drought indicators as independent variables and study the effects on crop production yields and planting acreage (Cui, 2020; Kuwayama et al., 2019). Both papers employ panel data methodologies such as time and observation fixed effects which can control for a variety of confounding factors that cannot be addressed in cross-sectional or time series analyses. Simiarly, Timar & Apatov (2020) examine the effects of droughts for grazing operations in New Zealand using time and firm level fixed effects in a panel data regression model to estimate the economic impacts of drought on profitability. The authors find that larger farms are less likely to be impacted by drought but that drought decreases revenue and spending. We conclude that the use of a drought index combined with time and spatially variant outcomes is a useful methodology to approach our research questions.

Despite the vast literature on the role of conservation programs in drought management, we find gaps in existing literature that this paper will aim to fill in the emprical examination of our research question. The remainder of this paper will present data, methods, analysis and conclusions around our research questions. First, as prior work has yet to focus specifcally on grazing related practices, we ask whether an increase in severe drought exposure increases engagement with EQIP grazing practices, and if so, which ones. Next, we identify regional differences of the impact of drought on grazing practice enrollment, as regions vary greatly in their exposure to drought, and their response methodologies. Lastly, prior survey literature has yet to include EQIP enrollment as a factor in self-reported impacts of drought. Therefore, we will additionally provide a brief analysis of 2013 survey data to ask how EQIP enrollment is specifically related to drought management and drought impacts.

BACKGROUND ON THE ENVIRONMENTAL QUALITY INCENTIVES PROGRAMS

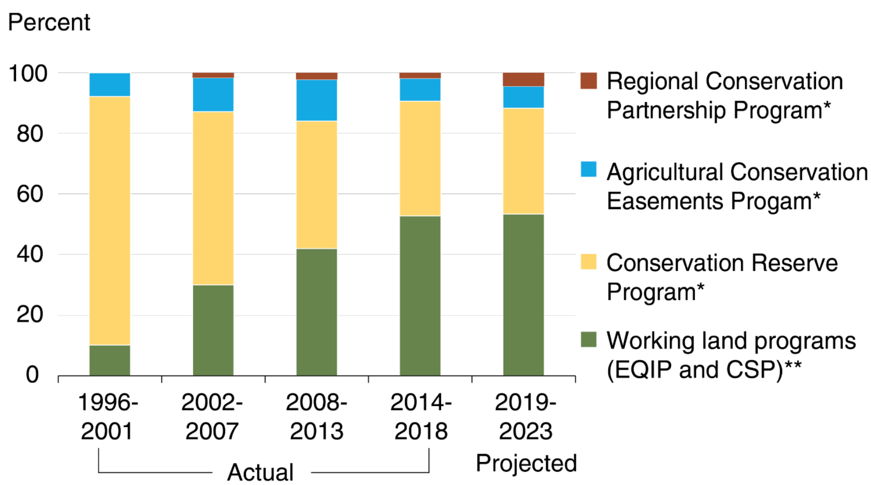
EQIP serves as a long-standing working lands conservation program that aids producers in changing management strategies. Analyzing the program not only provides useful insight into the largest working lands conservation program in the U.S., but also provides insight into how producers, in concert with conservation planners and service providers, are responding to various exogenous climate shocks. Additionally, the fact that EQIP collects and stores a national database on specific practice implementation offers researchers the opportunity to understand management behaviors as a response to exogenous conditions or shocks. The Conservation Stewardship Program (CSP) provides similar practice-based funding, but typically funds existing efforts, rather than the adoption of new management practices. Because of the funding strategy, and variety of practices that exist in EQIP over CSP, this project will primarily focus on the EQIP program. The following will provide background on the program and important program details that help to define our empirical strategy.

Funding and Legislation Overview

The present research uses the enrollments into EQIP as a useful metric of overall conservation program enrollment. Because of its size and scope, we believe the program can serve as a useful representation of conservation program enrollment generally. This section provides an overview of federally funded conservation programs, the history and future of EQIP, and a detailed explanation of EQIP practices and protocols. The goal of this section is to demonstrate the relative importance of EQIP for agricultural producers, in terms of funding, compared with other federally funded options.

The U.S. government funds a variety of conservation programs targeting agricultural producers, but the relative allocation to EQIP has risen dramatically in recent years. Other U.S. Farm Bill conservation programs include the Conservation Reserve Program (CRP), Regional Conservation Partnership Program (RCPP), Agricultural Conservation Easement Program (ACEP), and the Conservation Stewardship Program (CSP). CRP and ACEP are land retirement programs, RCPP provides funding to non-government organizations' conservation efforts, and EQIP and CSP are working lands programs.

Working lands programs comprise a significant amount of aid dollars to producers and they are growing in scale and scope. Figure 1 provides insight into the share of funds attributed to these programs from 1996 to 2023 and Figure 2 demonstrated the national funding amounts across time as well as authorized funding for FY 2019 to 2023. These changes demonstrate that EQIP is quickly rising in importance (in terms of funding dollars) among the suite of conservation programs that the U.S. Farm bills funds.



*Includes predecessor programs

**Includes the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) and predecessor programs. The programs are shown together because they are combined in the CBO estimates.

Sources: ERS analysis of Office of Budget and Policy Analysis data for 1996-2017 and Congressional Budget Office Estimates for 2018-2023.

Figure 1: Share of conservation spending by major U.S. Farm Bill programs and predecessors in the 2018 and previous farm acts

EQIP was first introduced and authorized in the 1996 U.S. Farm Bill, providing $130 million in funding and replacing 4 prior conservation programs: Great Plains Conservation Program, the Agricultural Conservation Program, the Water Quality Incentives Program, and the Colorado River Basin Salinity Control Program. It has been funded in each subsequent farm bill, though the practices, funding amounts, and initiatives within the program have changed over its 23-year history. In total, since EQIP's inception, hundreds of thousands of contracts and over $15 billion has gone into funding conservation contracts (US RULE 84 FR 69272).

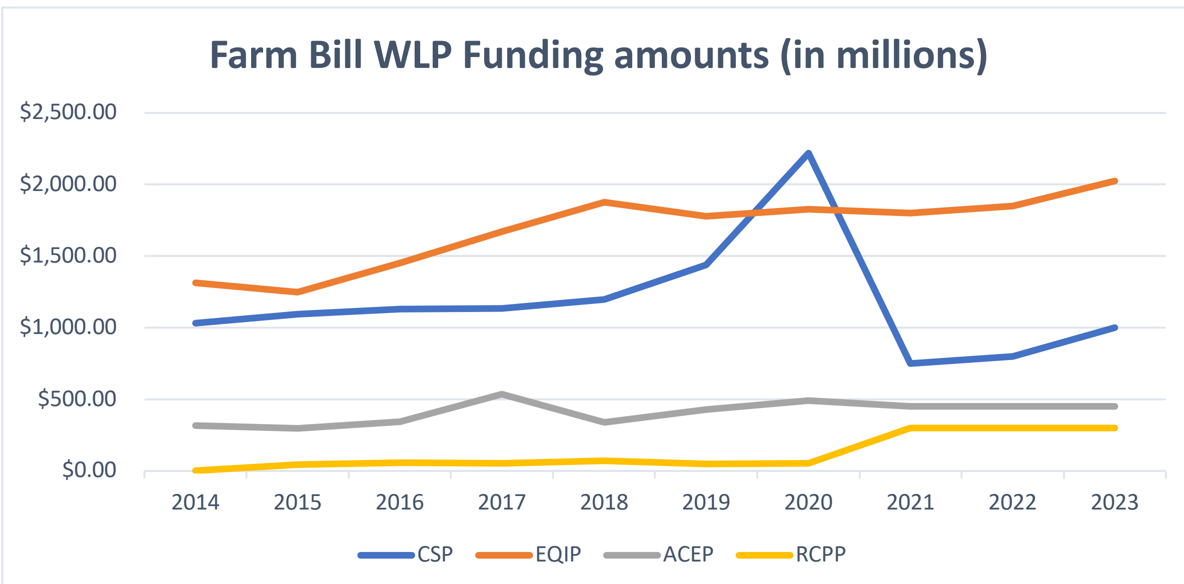


Figure 2: U.S. Working Lands Conservation Program funding levels from 2014 to 2018

Notes: Data come from USDA NRCS and the 2018 U.S. farm bill

To enroll in EQIP, agricultural producers must reach out to their local NRCS office (or a non-government conservation organization may facilitate this relationship) and apply for funding. Typically, a certified Technical Service Provider (TSP) will work together with the producer to collectively determine the best practices to implement on the producer's private land given NRCS federal, state, and local office conservation benefit objectives, funding availability, and resource concerns (Wallander et al., 2013). Once the practices to implement and duration of implementation are agreed upon, the producer and the NRCS enter into a contract, which can span from one to three years.

Nationally, EQIP has a few key mandates articulated in the U.S. Farm Bill that recently changed in 2018. Most relevant for the present study, livestock related practices were previously required to receive 60% of total annual funds, but this was reduced to 50% for Fiscal Years (FY) 2019-2023 (US RULE 84 FR 69272). Furthermore, 5% of funds were historically slated for wildlife related practices, which has now increased to 10% for FY 2019-2023. This is important as many of the practices that relate to grazing habitat also relate to wildlife. Lastly, the 2018 Rule provided for the expansion of the "EQIP purpose to include new or expected resource concerns, adapting to, and mitigating against, increasing weather volatility, and addressing drought resiliency measures" (US RULE 84 FR 69272). The present study aims to provide evidence that even before the explicit purpose of EQIP changed, the program was being employed as a response tool to severe drought. We focus specifically on grazing practices as articulated by the NRCS, as the focus of this paper is aimed specifically at land and livestock managers. The following section will explore the composition of these practices in detail.

EQIP Practices

EQIP has over 200 defined conservation practices standards, all of which come with their own set of strategies, guidelines, costs, and benefits. In this study we focus on the 32 practices categorized as grazing land conservation practices[1], one of six major EQIP practice groupings.

[1] Some practice codes fall into multiple categories due to the wide scope of these topic areas. Our study includes these practices so long as they are categorized as grazing.

The other major categories are cropland and soil conservation, fish and wildlife habitat conservation, forest land conservation, wetland and water quality, and irrigation efficiency.

Table 1 provides information on the 32 implemented EQIP grazing land conservation practices at the national level. Each state sets their own conservation objectives and while there is some state level heterogeneity in how practices are implemented, each practice has its own guiding standards (set at the national level) that must be met. Often times, a contract will include multiple practices to accomplish an overall goal. For instance, the same contract may include prescribed grazing (practice code 528), and to complement the grazing plan, the contract may also implement fence and watering facility practices in the same contract to reach the overall goal of more conservation-oriented grazing. Prescribed grazing guidelines specify that grazing plans should include a drought contingency plan.

Grazing practices accounted for over $2.7 billion (nominal) of EQIP funding from 2009 to 2018, a substantial portion of allocated funds (roughly 35% in our study period). We provide Figure 3 to give insight into how funds are distributed at the national level for grazing practices. We see that the large counties in the West receive the most funding in our study period. While we do not analyze the funding levels in our econometric modeling, it is important to note that Western States are much more likely to experience drought events and are also receiving a substantial amount of the total EQIP funding.

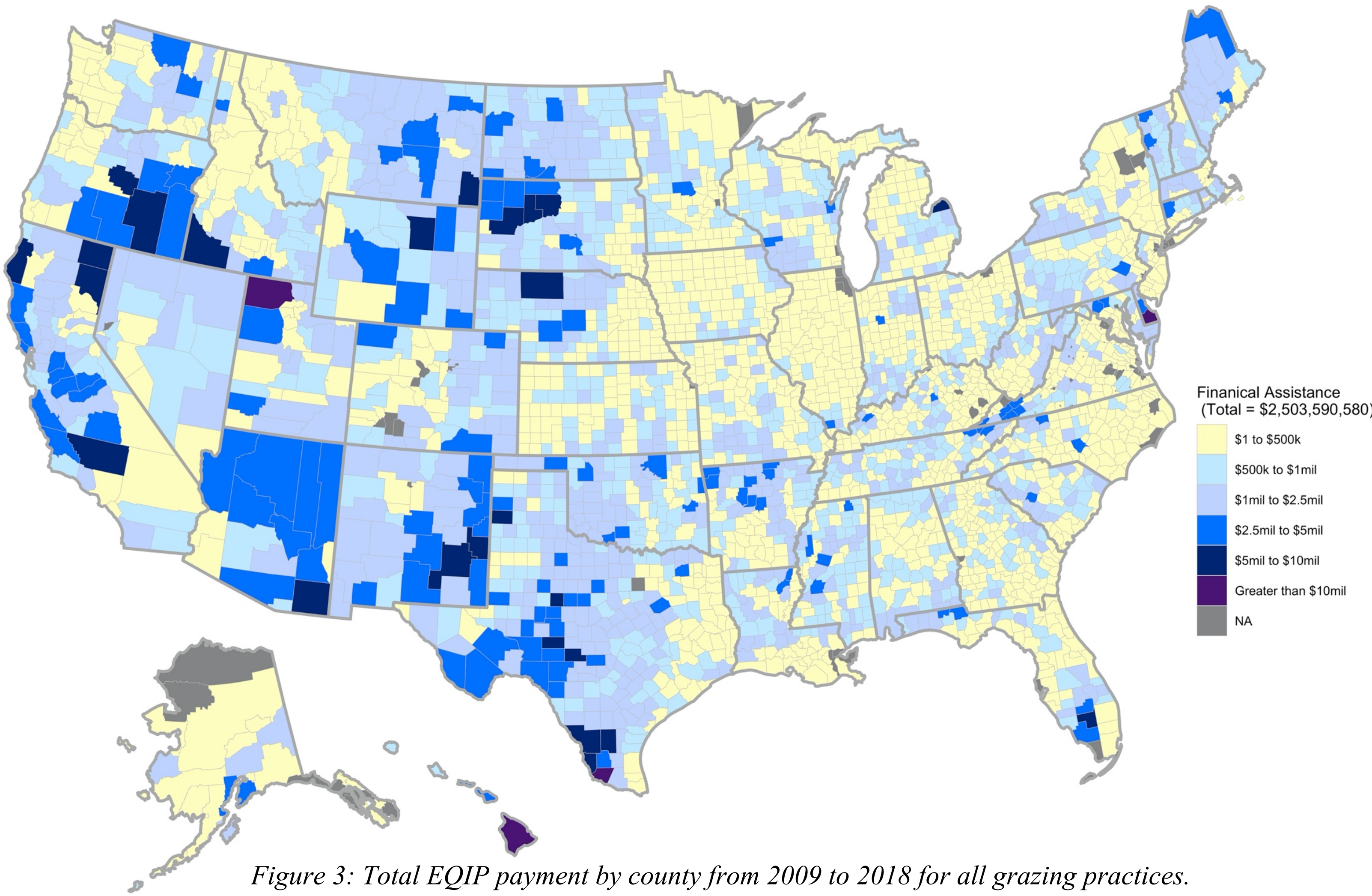


Figure 3: Total EQIP payment by county from 2009 to 2018 for all grazing practices.

Note: Data come from our administrative data and help to show the distribution of practices and funding across the country

DATA

Our research questions, and the respective data sources, are broken up into two broad categories. We answer our primary research questions around drought impacts on EQIP enrollment by compiling a panel dataset that varies across year and county that includes measures of drought, EQIP enrollment, and various control variables. We then analyze survey data in an auxiliary analysis to provide an example of context and narrative around the role of EQIP can play in drought management. Because it is not the primary analysis of this paper, survey data, analysis, and discussion will be presented in its own section.

Panel data and their respective methods are shown to be a useful method in analyzing climate impacts on economic outcomes (Dell et al., 2014). For this study, we compile a panel dataset with primary data coming from 4 major sources. Drought index data come from the modified Palmer Severity Drought Index (sc-PSDI), EQIP administrative data were retrieved directly from the NRCS, and control variable data come from the Cropland Data Layer and National Agricultural Statistics Service. We compile these datasets for every county in the continental U.S. from years 2009 to 2018. The following section will present detailed information on these data sources and the process by which it was aggregated.

EQIP data

Our EQIP administrative data come from a request to the NRCS for program contract and practice data. For this study, we use NRCS EQIP administrative data that includes the practice name, conservation practice standard code, fiscal year when the practice was initiated, county where the practice was implemented, the status of implementation, certification date[2] (if applicable), fiscal obligation of the practice, and the associated administrative office. Our data include all EQIP administered practices (including cancelled or terminated practices) to producers in the U.S. from fiscal year (FY) 2009 to 2018.[3] This dataset contains nearly 2 million unique observations of contracted practices and is the largest database of conservation practice implementation in the United States. While EQIP does not represent all conservation practices implemented, we believe, due to its scope and size, it provides a useful measure of practices implemented across the United States.

Relevant to our analysis, we present an important detail on the practice status variable. These data show whether the practice was "Cancelled", "Terminated", "Planned", "Draft", "Certified", "Partial Cert", or "Deleted". Because it is not possible to determine the reason why a practice was cancelled or terminated, we decide to confine our dataset to those practices whose status is "Draft", "Certified", "Partial Cert", or “Planned”. For example, if a producer backs out of the program, this could mean they changed their mind on the benefits after learning more about the practice, program, or environmental conditions and no longer sees the practice benefits as outweighing the costs. Please refer to the Appendix A Table 10 for an analysis of the results for all practices, rather than our subset for a reference comparison.

We use the described dataset to construct aggregate measures of the number of practices enrolled for each county and FY by practice group. We consider two groups of practices, all grazing practices and all drought related grazing practices (as identified by Wallander et al.

[2] This is the official completion date of the practice for the associated contract, which may include various practices. EQIP contracts last 1 to 3 years but the included practices can be completed at various dates and may differ from the contract completion date. Our data contains practice completion, not contract completion dates.
[3] The year that is tied to each practice initiation is the federal fiscal year (October of previous year to September of Calendar year). This is the year when payment and contractual obligation was made with producers but does not mean that the practice was implemented in that year.

2013), as well as individual practices in our subsequent analyses. Figure 3 shows trends in our hypothesized set of drought related practices (from Wallander et al. 2013) in terms of number of implementations over the span of our dataset. This graph helps align the relevant Farm Bills that take place during our study period as well as seeing that these practices are on the whole, being implemented more over time. The question we then ask is if this increase is just due to funding, or if increases in drought exposure plays a role in this increase. Table 1 provides information on the 32 implemented EQIP grazing land conservation practices at the national level. All practices associated with grazing are enumerated in Table 1 along with the number of implementations and average contract length (elapse) in our study period at the national level. Practices identified by Wallander et al. (2013) as drought related livestock practices are also enumerated.

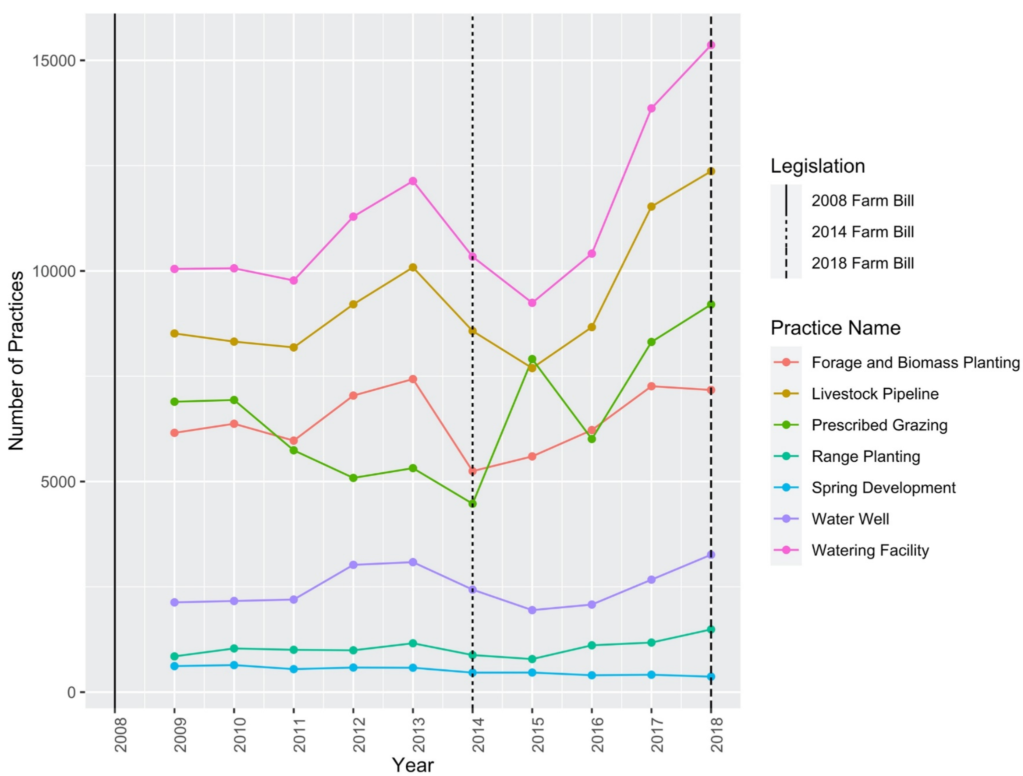


Figure 4: This graph helps demonstrate the national trends of our hypothesized set of drought related practices when compared to Farm Bill legislation.

Note: These data come from our EQIP administrative data set

Table 1- EQIP Grazing Practices and their drought relation, elapsed time from payment to completion, and number of practice implementations from 2009 to 2018

Practice Code	Practice Name	Drought Related*	Elapse (years)	Number of Practices
382	Fence	No	1.193	104420
314	Brush Management	No	1.2311	66240
516	Livestock Pipeline	Yes	1.1654	65244
561	Heavy Use Area Protection	No	1.0715	49050
512	Forage and Biomass Planting	Yes	1.0825	46915
533	Pumping Plant	No	1.0358	32100
614	Watering Facility	Yes	1.232	77907
590	Nutrient Management	No	1.8844	60293
528	Prescribed Grazing	Yes	1.963	40006
642	Water Well	Yes	0.818	18722
595	Pest Management Conservation System	No	1.7659	27287
580	Streambank and Shoreline Protection	No	0.9373	3366
550	Range Planting	Yes	1.3064	6945
378	Pond	No	0.7442	10615
560	Access Road	No	1.1064	6205
638	Water and Sediment Control Basin	No	0.9336	9583
315	Herbaceous Weed Treatment	No	1.1152	20368
338	Prescribed Burning	No	1.5418	16006
578	Stream Crossing	No	1.0691	5558
575	Trails and Walkways	No	1.2283	2431
342	Critical Area Planting	No	1.0309	33484
380	Windbreak/Shelterbelt Establishment	No	1.2793	7690
633	Waste Recycling	No	1.8072	2329
650	Windbreak/Shelterbelt Renovation	No	1.1401	2763
574	Spring Development	Yes	1.4258	3020
584	Channel Bed Stabilization	No	1.1462	301
511	Forage Harvest Management	No	1.7986	2284
576	Livestock Shelter Structure	No	0.9076	487
548	Grazing Land Mechanical Treatment	No	1.2674	273
610	Salinity and Sodic Soil Management	No	1.9427	419
381	Silvopasture Establishment	No	1.7931	174
322	Channel Bank Vegetation	No	1.6345	145

*As identified by Wallander et al. (2013).

Data come from the EQIP administrative dataset that we describe in detail in the Data section and represent values at the national level from 2009 to 2018. Elapse is the average time (in years) from payment to completion of the practice. N is the number of times that practice was implemented.

Drought Measure

Drought is both a quantifiable phenomenon of prolonged deviation from normal precipitation and a social-ecological sentiment about the state of moisture within specific context (Mishra & Singh, 2010). For example, agricultural producers may perceive that they are experiencing a drought long before those in an urban setting feel the effects. Given the breadth of definitions of drought and the social contexts that define it, there is much debate on how to measure drought. We operationally define it quantitatively for this paper using the Palmer Drought Severity Index (PDSI) [4].

We use an adapted version of the PDSI that is interpolated at the county level rather than the standard Hydrological Unit Code level (Abatzoglou et al., in press). The self-calibrated PDSI (sc-PDSI) interpolate weather station precipitation and temperature measures to determine accumulated deficits or surpluses at the county level for each month. This process creates a number ranging from approximately -10 to 10, where approximately only 4% of the data fall outside of -4 to 4. The value is determined on a monthly temporal scale and is affected by prior months values (i.e. prior drought conditions increase the severity of the current drought conditions). According to Wells et al. (2004), the sc-PDSI is more spatially comparable across interpolated regions than the standard PDSI. All palmer derived indexes have a threshold value that classifies regions as being in drought; when we refer to "severe" drought this refers to sc-PDSI value < -3.

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[4] Wallander et al. (2013) review the major drought indices available in the U.S. and determine that the Palmer Severity Drought Index (PDSI) is the most accurate index for measuring drought risk. The primary rationale behind this argument is that the PDSI tracks more than simply precipitation and groundwater but also "the stock of soil moisture over time based on a hydrologic model of recharge from precipitation and losses to evapotranspiration, infiltration, and runoff" (Wallander et al., 2013).

For this study, we explore various transformations of this index in understanding drought effects on EQIP enrollment. These include a dummy variable that is equal to 1 if the year average sc-PDSI < -3, the average sc-PDSI for the year, and the number of months classified as severe drought for the year. We present the econometric model estimates used with these various transformations in Appendix A.

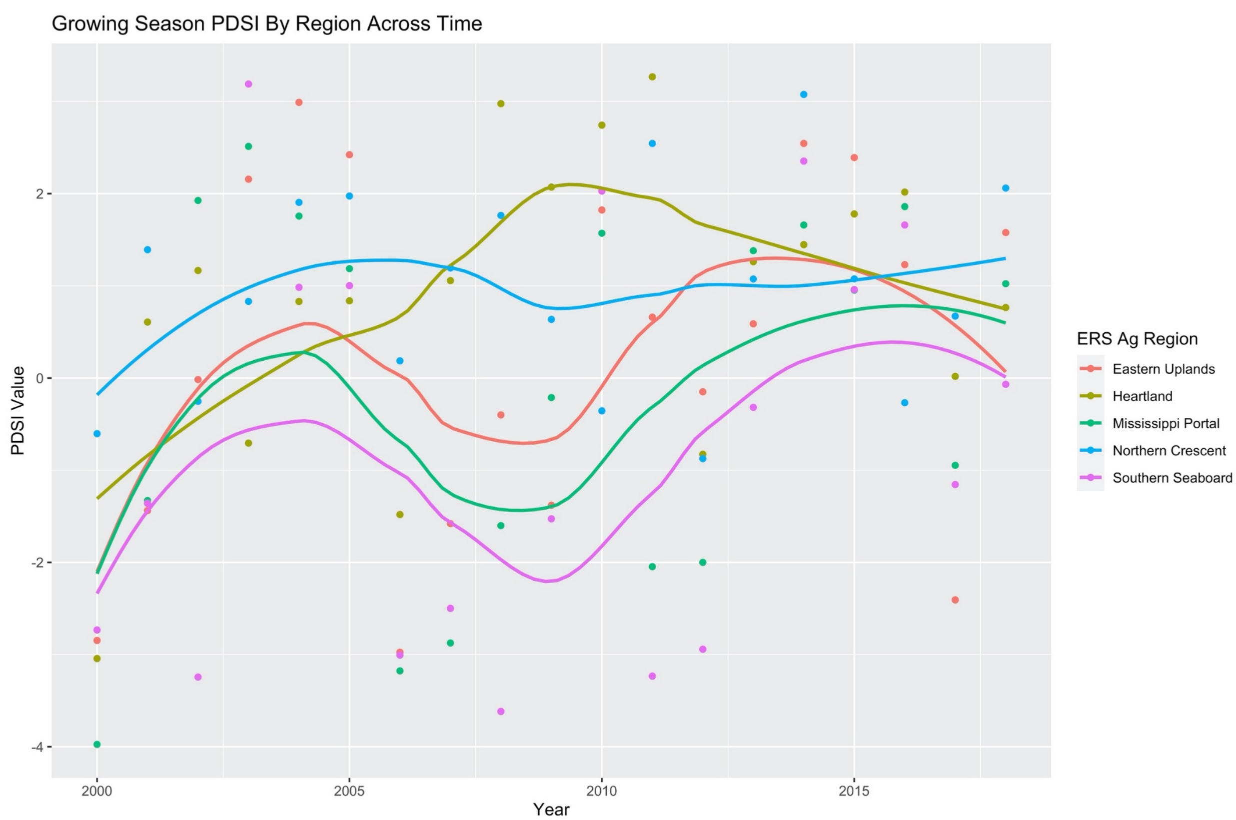

Figure 5 : A smoothed (loess) mean annual sc-PDSI by agricultural region (Eastern Regions)

Notes: Data come from the sc-PDSI and help to illustrate the temporal and spatial heterogeneity of drought.

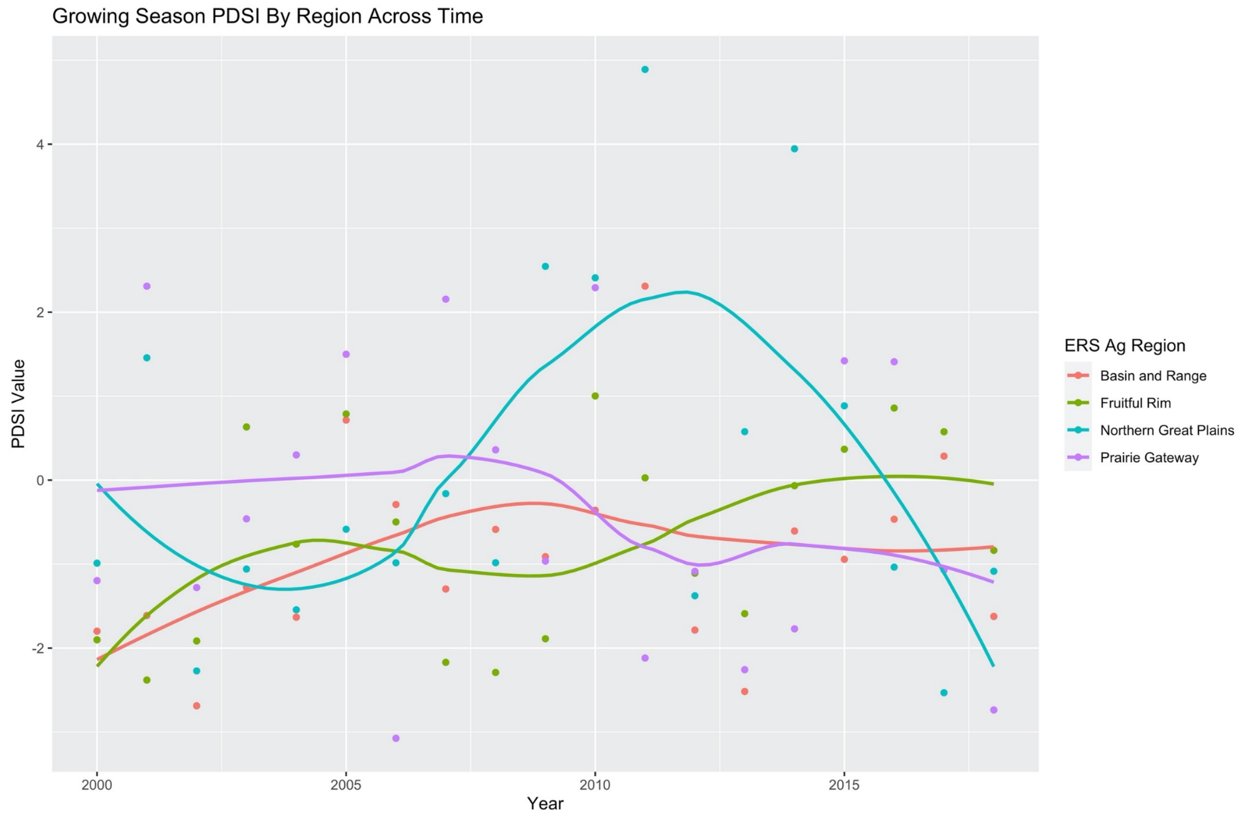

Figure 6: A smoothed (loess) mean annual sc-PDSI by agricultural region (Western Regions)

Notes: Data come from the sc-PDSI and help to illustrate the temporal and spatial heterogeneity of drought.

Because of our interest in the lagged effects on enrollment, we include 3 lagged variables and excluded the year of indicator. This was done to avoid issues associated with simultaneity because of the inability to determine when the enrollment happens relative to drought within a given year. The lag for each of the growing season PDSI values, and for the dummy variables, is the mean value for the months of April to July in the year(s) prior to the enrollment fiscal year. For example, if in county x, we calculate the mean growing season PDSI value for the year 2006, we then associate that with the enrollments in that county for FY 2008 and classify it as lag 2.

Figures 4 and 5 show the average sc-PDSI value by year and ERS agricultural region and helps demonstrate the trends across our study period. Climate is a complex issue that involves decade, century, and millennium long trends. We see that the mean value changes in what appears to be a cyclical pattern over time. These long-term timelines of drought cycles can make drought a difficult variable to use as an exogenous shock within a given region. However, we find rich spatial heterogeneity over 10 years, and across 3024 counties, and we are therefore able to exploit both spatial and temporal heterogeneity in drought impacts to understand its impacts on grazing land conservation practice adoption.

Control Variables

We draw from two additional data sources to construct variables that control for potentially confounding effects: a change in the number of producers in the area or a change in the land base available to enroll in these programs. To controls for these effects, we calculate for the number of pastureland operators and percent of the county that is rangeland/pastureland in each county in each year. We find that, while relatively stable, both of these variables change temporally and spatially in a way that would not be captured by our fixed effects.

County-level information on the annual number of pastureland operators comes from the National Agricultural Statistics Service (NASS) U.S. Census of Agriculture. We combine data from the 2007, 2012, and 2017 Census of Agriculture reports on the number of pastureland operators in each county in those years and then linearly interpolate in the intermediate years where data is not available. For example, if county x had 20 operators in 2007, and 25 operators in 2012, we assume a linear step for each year between data such that in 2008 there are 21 operators, 2009 has 22, 2010 has 23, and 2011 would be 24.

County-level information on the percent of rangeland and pastureland in a county for each year in our study period is calculated using remote sensing data retrieved from the USDA Cropland Data Layer (CDL). These data are raster data with 30-meter pixel resolution that use a variety of data sources to compile their estimates of land including the National Land Cover Database and NASS agricultural census data. To construct yearly, county level estimates of pasture and rangeland, we use all land type cover categories that include pasture or rangeland, such as grassland, pasture, hay land, shrubland, and wetlands and calculate the percent of each county that is covered by these land cover classifications. This does include land that hypothetically could not be grazed, such as land inside of a national park, but because that land will not change in and out of the classification through cropland conversion through time, it does not affect our results. Other studies have examined the efficacy of these data and while accuracy in the technology has much room for improvement, we find that it can act as a useful control variable when aggregating cover types into one category (Hendricks & Er, 2018; Lark et al., 2017).

Summary

Table 2 provides the summary statistics for each of the above variables used in our model and the various drought index interpolations we articulated.

Table 2- Summary statistics of national data

Variable Name	min	max	mean	Std. Dev	n
# operators	1.400	3945.600	438	381	28820
% County in Range	0.94%	99.87%	36.48%	22.66%	28820
Growing Season PDSI	-7.79	8.54	0.29	2.57	28820
Growing Season PDSI Lag 1	-7.79	8.54	0.28	2.65	28820
Growing Season PDSI Lag 2	-7.79	8.54	0.34	2.66	28820
Growing Season PDSI Lag 3	-7.79	8.54	0.04	2.72	28820
Dummy (Mean PSDI < -3, Lag 0)	0	1	0.10	0.30	28820
Dummy (Mean PSDI < -3, Lag 1)	0	1	0.11	0.32	28820
Dummy (Mean PSDI < -3, Lag 2)	0	1	0.11	0.31	28820
Dummy (Mean PSDI < -3, Lag 3)	0	1	0.14	0.35	28820
# Drought Graze Practices	0	620	10.65	18.65	28820
# All Graze Practices	0	989	28.69	39.93	28820
Non-Drought Grazing Practices	0	447	18.79	25.81	28820

Notes: There are 3,242 counties or county equivalents in the U.S. but we keep only those where there is at least 1 drought related grazing practice in at least 1 of our study years (2009 – 2018).

RESEARCH METHODOLOGY

This section describes the conceptual and empirical frameworks used for our national analysis of EQIP administrative data and drought. The conceptual model serves to motivate our empirical approach, shedding light on the mechanisms that can lead to EQIP participation. The conceptual model is framed around producer decision making and utility maximization theory. The empirical model then expands on this conceptual framework of the producer, to identify the impacts, through a fixed-effects Poisson regression, of drought on EQIP practice implementation.

Conceptual Framework

Here we outline a conceptual framework that motivates our empirical analysis and introduces the identification concerns that we address. Consider a utility maximizing producer who chooses a set of practices, p, to implement on their operation subject to their budget constraint. We denote the universe of possible practices as $P = (p_1, p_2, \dots p_N)$ and define the producer's choice set as a subset of this set, $p \subset P$. For simplicity, we define practices in the set P such that EQIP-funded practices are distinct from the same practices implemented without EQIP. For example, a producer can choose to install a fence on their own, $p_{fence} \in p$, or they can choose to install a fence through an EQIP contract, $p_{fence}^{EQIP} \in p$, or they can do both[5]. Producers choose their practices at time t based on their expectations of drought, D, at time $t + 1$. Producers derive utility from profits, $\pi(p, D)$, and non-market benefits, $B(p, D)$, that are realized at time $t + 1$. Non-market benefits are those that accrue based on a produce's preferences for many possible

[5] For instance, a producer could use EQIP funding to help implement one new fence line, but may also choose to implement another fence line that is not subsidized through the EQIP program.

non-monetary outcomes. In other words, $B(p, D)$ might include preferences for conserving soil quality for future generations or more broadly stated by Smith & Martin (1972), a love of land. We define benefits as a function of both the practice choice set and the realization of drought because the benefits of implementing conservation practices, for example, will be influenced by the degree of drought experienced. For example, take EQIP practice 516, livestock pipeline. This practice helps pay for producers to lay pipeline to create livestock watering structures where there is not a natural source of water. This practice may help the producer utilize forage in a part of the property is typically not grazed, therefore improving profitability. In addition, it also creates resilience to drought by allowing additional feed resource and water resource to be accessed in times of scarcity due to drought. Following this logic, the producer's optimization problem at time t can be written as:

$$\max_{\mathrm{p}} \mathrm{EU}[\pi(\mathrm{p}, \mathrm{D}), \mathrm{B}(\mathrm{p}, \mathrm{D})],$$

where EU denotes the producer's expected utility. Profits are determined from sales revenues, fixed and variable costs, and subsidy payments. Profits can be written as:

$$\pi(p, D) = r \cdot q(p, D) - c(p) + s(p),$$

where r is the per-unit price the producer receives for their agricultural product, $q(p, D)$ is the quantity of agricultural product they produce which is a function of the practices they implement and their expectations of drought, $c(p)$ includes the fixed and variable costs associated with implementing each practice, and $s(p)$ is the (fixed) subsidy amount the producer receives if their practice choice set includes at least one EQIP practice. Written in this way, the producer optimization problem yields a straightforward prediction regarding the decision to enroll in EQIP:

$$\text{Enroll} = \begin{cases} 1 & \text{if } EU[\pi(p^{*,EQIP}, D), B(p^{*,EQIP}, D)] > EU[\pi(p^{*,0}, D), B(p^{*,0}, D)] \\ 0 & \text{otherwise} \end{cases},$$

where $p^{*,EQIP}$ denotes a set of practices that includes at least one EQIP-funded practice, and $p^{*,0}$ denotes a set of practices that does not include any EQIP-funded practices. If the expected utility from enrolling in the program is less than all other outside options, the producer will not enroll in EQIP. This type of economic model is supported in the literature with respect to drought adaption behavior (Hall & Leng, 2019). In regard to drought in particular, we present that the expected utility associated to EQIP practices will change after major drought events if the practices increase the ability of producers to manage for future droughts or help restore productivity post drought.

While the behavioral model helps us understand how drought expectations can lead to EQIP enrollment, uncertainty remains in two key areas. First, there is not a consensus on how producers form these expectations around drought. We address this uncertainty by testing multiple transformations of the drought index and determining which functional form best fits our data. The second uncertainty is around the magnitude of the effect that expected drought (D) plays the total utility of the producer. While we can measure the effects of drought on quantity produced, the effects on non-monetary benefits is not immediately clear. The results from our econometric model will also shed light on this, as we identify the effect of severe drought on the choice to enroll in the program. The following with provide an in-depth look at our methods to identify an answer to our research question given the data we have.

Empirical Strategy

Our empirical strategy to answering our primary research question is informed by econometric and applied economics literature, data availability, and our conceptual framework. We note that, given the above framework, producers are only going to opt in when they perceive some benefits to the program. We first have deducted that if producers perceive a high enough benefit to cost ratio, they will enroll in EQIP. We now can identify the relationship between an exogenous shock (i.e. drought) and the number of enrollments into the program to conclude whether the benefits to cost ratio, and therefore the number of choices to enroll, shifts due to the shock.

In doing this, we follow methods of recent economics literature that used heterogenous exposure to drought across time and space to identify the effects of drought on an outcome variable (Kuwayama et al., 2019). Using variability across time and space lets us control for unobservable heterogeneity using fixed effects, which has been shown to be a useful identification strategy in climate related inquiries (Dell et al., 2014).

Our dependent variable of interest is the enrollment into the program, which presents empirical challenges as states administer enrollment in different ways, depending on the leadership and resources concerns for the state and region offices. Many state NRCS offices operate in a way such that any producer can walk into the office and apply for the program and then their applications will be ranked based resource concerns and program objectives. One NRCS employee[6] calls this the random acts of conservation method. However, some states have created targeted implementation plans that focus on a resource concern and then try to enroll all relevant parties into practices that will lead to successfully managing the concern area.

[6] Comes from an informal interview about EQIP programming with a state conservationist from the NRCS.

This variation in state management styles make it difficult to derive a cohesive framework for the access that a producer might have in their process of enrolling in the program. However, we employ a suite of fixed effects to help. First, we use county level fixed effects, which lets us control for unobservable time-invariant county level differences across the continental United States. Second, we use year fixed effects to account for unobservable temporal changes across our study period. Lastly, we incorporate state-by-year fixed effects to account for state differences in administering the program, such as the scenario described above. Ultimately, the incorporation of our control variables (percent of land that is rangeland and number of pastureland operators in each county, each year) in combination with our various fixed effects lets us accurately identify the effects of drought exposure on program enrollment.

Given the discrete construction of our outcome variable, the count of the number of implementations of a category of practices by county and year, we present the need to use a non-linear estimation methodology. Prior work has demonstrated the use Poisson regression models as for discrete panel count data (Hausman et al., 1984). In particular, the Poisson models where the exogenous variable (drought in our case) is not completely independent across time and space or if the number of zeros appear to be inflated present some unique challenges (Blundell et al., 1995). In our work, we choose to exclude counties where 0 drought related practices take place in all 10 years. For example, as we count the number of enrollments in a particular county, there may counties where there are no years between 2009-2018 where $p^{eqip} > 0$. This means that that this county will not be included in the analysis. The data will contain many zero, as there will be cases when a county on has 1 or two years with any enrollments, making all other years' counts equal to 0 for that county. The cause of these zeros is relevant to our conceptual framework and ultimately the model specification we employ. A zero in our data under this method indicates that the benefits associated to the program did not outweigh the costs, as articulated in our conceptual framework. It also, however, could be the result of an exogenous factor such as NRCS employee turnover or a change in the way EQIP contracts are ranked, but we believe that in eliminating counties where there were no enrollments, we control for these barriers. We therefore choose to employ a standard Poisson model to analyze our data and answer our research question.

Our main estimated model (a fixed-effects Poisson model) can be written as:

$$d\left(y_{ijt} \mid X\right) = \mathcal{L}\left(y_{ijt}, \alpha_i^{\text{county}} + \alpha_t^{\text{year}} + (\alpha_j^{\text{state}} * \alpha_j^{\text{year}}) + \beta' x_{ijt}\right)$$

where X represents the N × K matrix of all explanatory variables, x_{ijt} is one row-vector of this matrix, β is the vector of parameters of interest and $\mathcal{L}$ a likelihood function. The subscripts i, j and t refer to the county, state, and the year, respectively. α_i^{county} represents county fixed-effects (which standard error are clustered on), α_t^{year} represents year fixed-effects, and $\alpha_j^{\text{state}} * \alpha_j^{\text{year}}$ represents the state-by-year fixed-effects that we use in the model. Our set of β parameters that we estimate are the coefficients on the sc-PDSI in the year prior to enrollment, PDSI in 2 year prior to enrollment, and sc-PDSI in 3 years prior to enrollment, as well as our control variables of percent rangeland cover and number of operators. In this model, because sc-PDSI ranges from -10 to 10, where a more negative value indicating higher drought severity, a negative β estimate indicates that for a decrease in the sc-PDSI value (i.e. closer to -10) there will be an increase in EQIP enrollments for the specified category (i.e. drought related grazing practices).

Because this model specification is based around the marginal increase/decrease in the sc-PDSI value, we cannot deduce with this specification the effects of severe drought on enrollment. For this we also present a model that employs the same strategy but instead of the sc-PDSI values, the β parameters estimate the coefficients for a dummy variable, where:

$$\text{Dummy} = \begin{cases} 1 & \text{if mean growing season PDSI for a given year is } < -3 \\ 0 & \text{otherwise} \end{cases}$$

We hypothesize that if there is no statistical difference in y_{ijt} (number of practice implementations for drought-related practices) conditional on severe drought having occurred, then severe drought does not explain, in part, the observed increase in program enrollments. Rejection of the hypothesis would offer evidence in support of the argument that severe drought leads to increased implementation of drought-related grazing conservation practices in subsequent years. Using our regression specification, this hypothesis can be shown mathematically as:

$$H_0: \hat{\beta}_{drought} = 0$$

$$H_1: \hat{\beta}_{drought} \neq 0$$

$$H_2: \hat{\beta}_{non-drought} = 0$$

We additionally test whether there is any statistical difference in coefficient estimates from 0 for non-drought related practices, indicating whether or not the effect is being driven by the practice set or some other factor. Rejection of these hypotheses offers support that the number of practice implementations may also be explained, in part, by observable factors included in $\hat{\beta}_{don-drought}$:

$$H_0: \hat{\beta}_{don-drought} = 0$$

$$H_1: \hat{\beta}_{non-drought} \neq 0$$

This model, because of our state-by-year and county fixed effects is deemed to provide evidence for the causal role of drought on EQIP practice enrollment changes. While we acknowledge that omitted variable bias is a possibility, we believe that our selection of fixed effects and control variables account for this bias. State-by-year fixed effects account for time and state level variations in the data that could bias results such as funding and enrollment ranking criteria that change at the state level each year. Our county fixed effects account for all other time-invariant county characteristics such as average production levels, county demographics, etc. Our control variables, percent of rangeland and number of producers, were deemed to vary enough through time at the county level to be included as control variables. It is through exploiting the stochastic nature of drought shocks through time and space over our study period that we are able to make the argument around causality. There do remain some variables that our model is unable to account for, such as the size of ranching operations, operator characteristics, and specific NRCS agents, that all might impact a producer's likelihood to enroll in the program.

In implementing our regression analysis, we use the statistical coding software R and the *fixest* R package. We use the software to estimate the Poisson, fixed-effects maximum likelihood model with clustered standard errors (Bergé, 2018). We use the above specification to estimate the effects of drought on the counts associated to all grazing practices, drought specific grazing practices, and individual practices. We also run our analysis for different agricultural region as defined by the USDA Economic Research Service (Heimlich, 2000).

RESULTS AND DISCUSSION

Results and discussion are presented in three sections. We begin by presenting the results of our national estimation of the impacts of drought on grazing practice enrollment and drought related grazing practice enrollment. Next, we present and discuss results from the disaggregated model where we tease out results by agricultural region and by practice. Finally, we present an analysis and discussion of the robustness of these results.

Primary Specification Results

Results from the primary model specification are shown in Table 4. These results compare model results from analyzing severe drought impacts on all grazing practices, drought related grazing practices, and non-drought related practices (as articulated in Table 1). We see that in the years following severe drought, there is a positive and statistically significant coefficient in years 1 and 2 after the drought for drought related practices, but not for non-drought related practices. This provides us with our evidence to reject our null hypothesis that the effects are the same for both groups of practices. We see that for all grazing practices, there is an effect in year 1, but we hypothesize that this is due to a effect from the included drought related practices. At the national level, these results support the hypothesis of practices related to drought management originally presented by Wallander et al. (2013). The effect appears to hold for at least two years after a decrease in growing conditions, indicating that there may be a compounding effect, and/or an administrative lag in the enrollment process, that in turn forces the enrollment behavior. Standard errors are clustered at the county level, and county and state-by-year fixed effects are all included in both models.

Table 3 -Results from Poisson estimation of growing season drought impacts on EQIP grazing practice enrollment

	Count: All Grazing	Count: Drought Grazing	Count: Non-Drought Grazing
	Coefficient	Coefficient	Coefficient
PDSI lag 1	-0.0006	-0.0085	0.004
	(0.005)	(0.006)	(0.005)
PDSI lag 2	-0.0088*	-0.0110**	-0.0049
	(0.005)	(0.006)	(0.005)
PDSI lag 3	0.0021	-0.002	0.0033
	(0.005)	(0.006)	(0.005)
# (in thousands)	0.4404**	0.1165	0.6549***
of operators	(0.172)	(0.178)	(0.195)
% Rangeland	-0.3865	-0.3975	-0.4205
	(0.317)	(0.403)	(0.338)
Observations	28,820 [1]	28,820 [1]	28,820 [1]
Squared Corr.	0.6465	0.6442	0.6297
Pseudo R2	0.6024	0.5785	0.5675
BIC	510,410.5	306,608.6	381,221.5

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

[1] Only used observations where there was at least 1 year with at least 1 practice.

Coefficient standard errors are in parentheses and clustered at the county level

Fixed Effects for county, year, and state-by-year omitted for brevity

Table 4- Estimated model using dummy variable of growing season mean PDSI < -3 as the exogenous variable

	Count: All Grazing	Count: Drought Grazing	Count: Non-Drought Grazing
	Coefficient	Coefficient	Coefficient
Dummy lag 1	0.0584**	0.0931***	0.0284
	(0.025)	(0.030)	(0.026)
Dummy lag 2	0.0379	0.0483*	0.0233
	(0.024)	(0.028)	(0.028)
Dummy lag 3	0.0258	0.0438	0.0102
	(0.022)	(0.028)	(0.024)
# (in thousands) of operators	0.4365**	0.1197	0.6481***
	(0.173)	(0.181)	(0.196)
% Rangeland	-0.3222	-0.3471	-0.366
	(0.319)	(0.403)	(0.340)
Observations	28,820 [1]	28,820 [1]	28,820 [1]
Squared Corr.	0.6469	0.6445	0.6300
Pseudo R2	0.6025	0.5787	0.5675
BIC	510,296.40	306,503.20	381,216.6

*** p < 0.01; ** p < 0.05; * p < 0.1

[1] Only used observations where there was at least 1 year with at least 1 practice.

Coefficient standard errors are in parentheses and clustered at the county level

Fixed Effects for county, year, and state-by-year omitted for brevity

Table 4 then uses the same model specification (fixed-effects Poisson) but estimates the model using dummy variables indicating whether the mean PDSI for the year was less than -3, indicating severe drought conditions. This model provides evidence that severe drought increases (positive coefficient on the dummy) the drought related practices when controlling for the number of operators, % of land available for enrollment, and county, state, and year fixed effects. We do not see evidence of this effect for non-drought related practices, which supports rejection our null hypothesis that these drought related practices increase in use after severe drought events. The effect does not apply to non-drought related practices. What these results translate to in terms of elasticities is an estimated 9.75% increase in drought related practices in the year after a severe drought and a 4.94% increase in drought related practices two years after a severe drought.

A natural extension, then, is to break out the analysis by practice to see which practices are increasing and which are not across the country in the years after severe drought. The following section examine this issue using the dummy variable model specification, where we present which practices increase (positive coefficient) or decrease (negative coefficient) in the years following severe drought events.

Disaggregated Model Results

We disaggregate the above model in two ways. First, we use the dummy variable specification to identify the practices that have statistically meaningful ($P \leq 0.1$) coefficients on the dummy variable for each lag year. We find that in the aftermath of severe drought, practices that increase are related to delivering water to animals and managing forage. We then see that enrollment two years after a major drought changes are similar, with the addition of some long-term adaptation strategies possibly present, through the implementation of fence, prescribed burning, and range planting Three years after a severe growing season drought event leads to practice choices more closely related to long term drought solutions, such a more intensive management with practices such as fence, prescribed grazing, and weed/forage management. This methodology has let us update the set of practices that we previously identified as being used as drought management to see which practices increase or decrease in the years after drought events. Additionally, while prior understanding examined which practices would increase with an increase in drought risk, this methodology lets us understand which practices increase (or decrease) in the era after drought, helping to identify the effects of drought as a shock rather than a perceived risk.

We also disaggregate our results by ERS Agricultural Region to identify the effects that drought has on practice choices in each region. A map of these results can be seen in Figure 7. Grazing practices are implemented all over the country, but these practices can be used in varying ways and are more or less popular depending on the region. We therefore believe that breaking up the analysis by region helps to identify regional drought response differences. In this map, we identify practices in the year after severe drought for each region, as that year holds the strongest effects in our original model and could prove most useful to NRCS providers to know which practices are popular in the year after a drought.

Table 5- National practice implementation changes given severe drought & controls

Practice Code	Practice Name	Estimate	Std. Error	Pr(>|z|)	N
		Lag 1			
378	Pond	0.1597	0.0915	0.0810	8362
512	Forage and Biomass Planting	0.1476	0.0461	0.0014	24847
516	Livestock Pipeline	0.0830	0.0374	0.0266	27593
561	Heavy Use Area Protection	0.1095	0.0478	0.0218	22638
580	Streambank and Shoreline Protection	-0.4205	0.2391	0.0787	4252
614	Watering Facility	0.0588	0.0346	0.0887	27403
		Lag 2			
338	Prescribed Burning	0.1535	0.0741	0.0384	10836
342	Critical Area Planting	-0.1344	0.0537	0.0122	22017
378	Pond	0.1312	0.0673	0.0513	8362
382	Fence	0.0636	0.0335	0.0579	28290
516	Livestock Pipeline	0.0620	0.0355	0.0811	27593
528	Prescribed Grazing	-0.1152	0.0700	0.0998	23644
550	Range Planting	0.3049	0.1195	0.0107	6667
		Lag 3			
315	Herbaceous Weed Treatment	0.1232	0.0590	0.0368	12867
382	Fence	0.0593	0.0310	0.0560	28290
528	Prescribed Grazing	0.1081	0.0582	0.0633	23644
550	Range Planting	0.4146	0.1013	0.0000	6667
638	Water and Sediment Control Basin	0.6326	0.2041	0.0019	5462

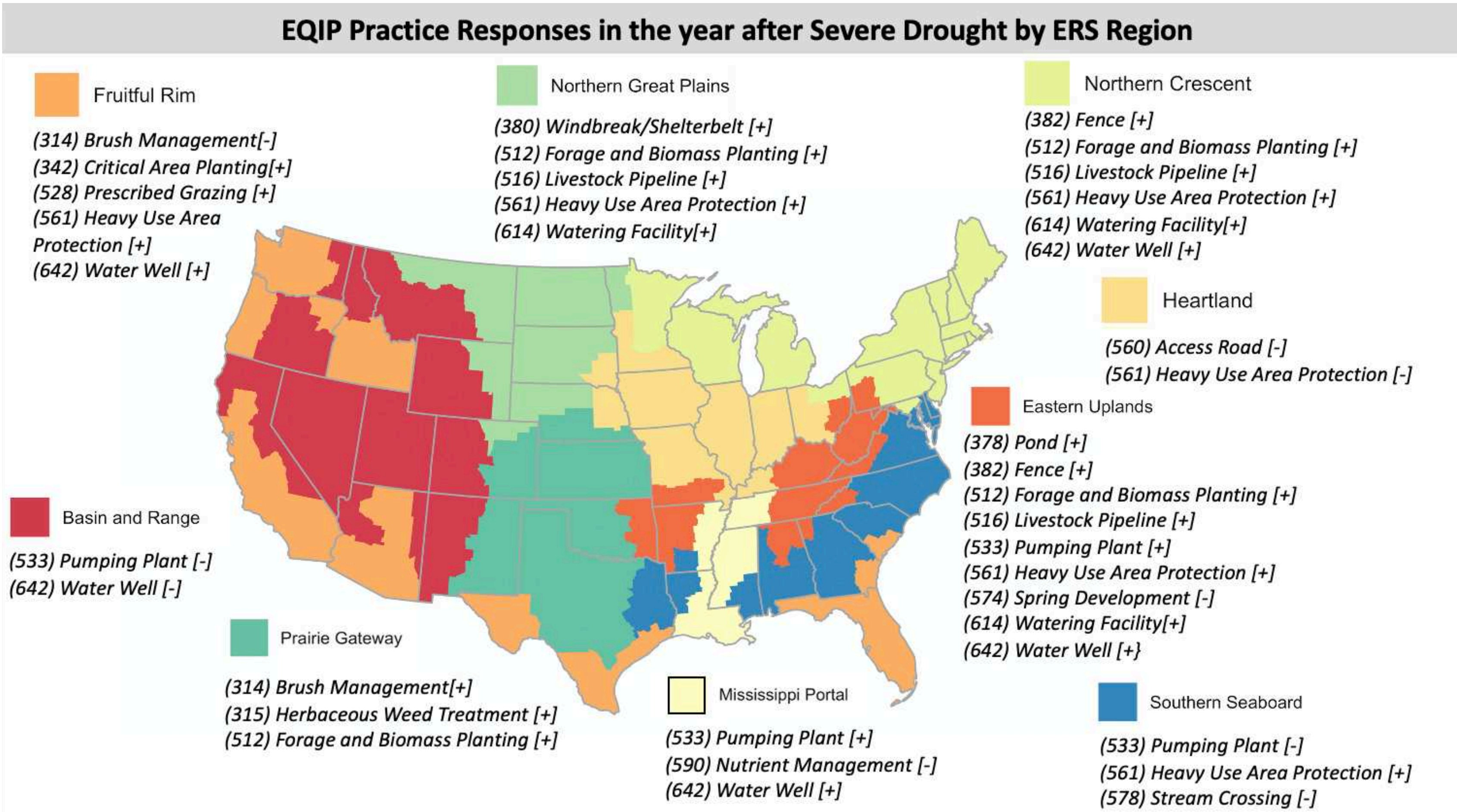

Figure 7: Drought response practices by ERS region

Robustness Checks

Our results demonstrate robustness to various specifications. In an effort to demonstrate the robustness of our model, we undertake three additional modeling tasks. First, we include various specifications for the drought grazing practice model (see Table 9 in Appendix A) that help articulate the differences in sign and significance in the models where we specify drought differently. From this we see that using the mean annual sc-PDSI value for a county is the most intuitive model that has the best model fit. The dummy variable model is also used because it can capture severe drought exposure rather than marginal decreases in growing conditions. We also run an OLS regression which provides similar results to our Poisson Regression (see Table 11 in Appendix A).

An important modeling decision that we make is what number to use for the dummy variable cutoff. The cutoff for "severe" drought in the sc-PDSI is -3, so it is an intuitive choice in our exploration of drought. However, it's important to test how this choice affects our results. Figure 3 analyzes how using different cutoff values for the drought dummy variable (rather than -3, which is used in this study) changes the regression coefficient, the p-value, and the standard errors. We change the cutoff to range from -4 to 4, seeing that in wetter years, drought related practice implementation declines. We also see that the non-drought related practices do not appear to relate to growing condition. For drought related practices, the effect size of a more severe drought conditions appears to relate to a larger regression coefficient, offering evidence in support of our hypothesis that practice implementation numbers for these practices is related to growing condition. We do see that for very wet conditions, there is a decrease in non-drought related practices, offering support that enrollment in the program overall decreases when conditions are good.

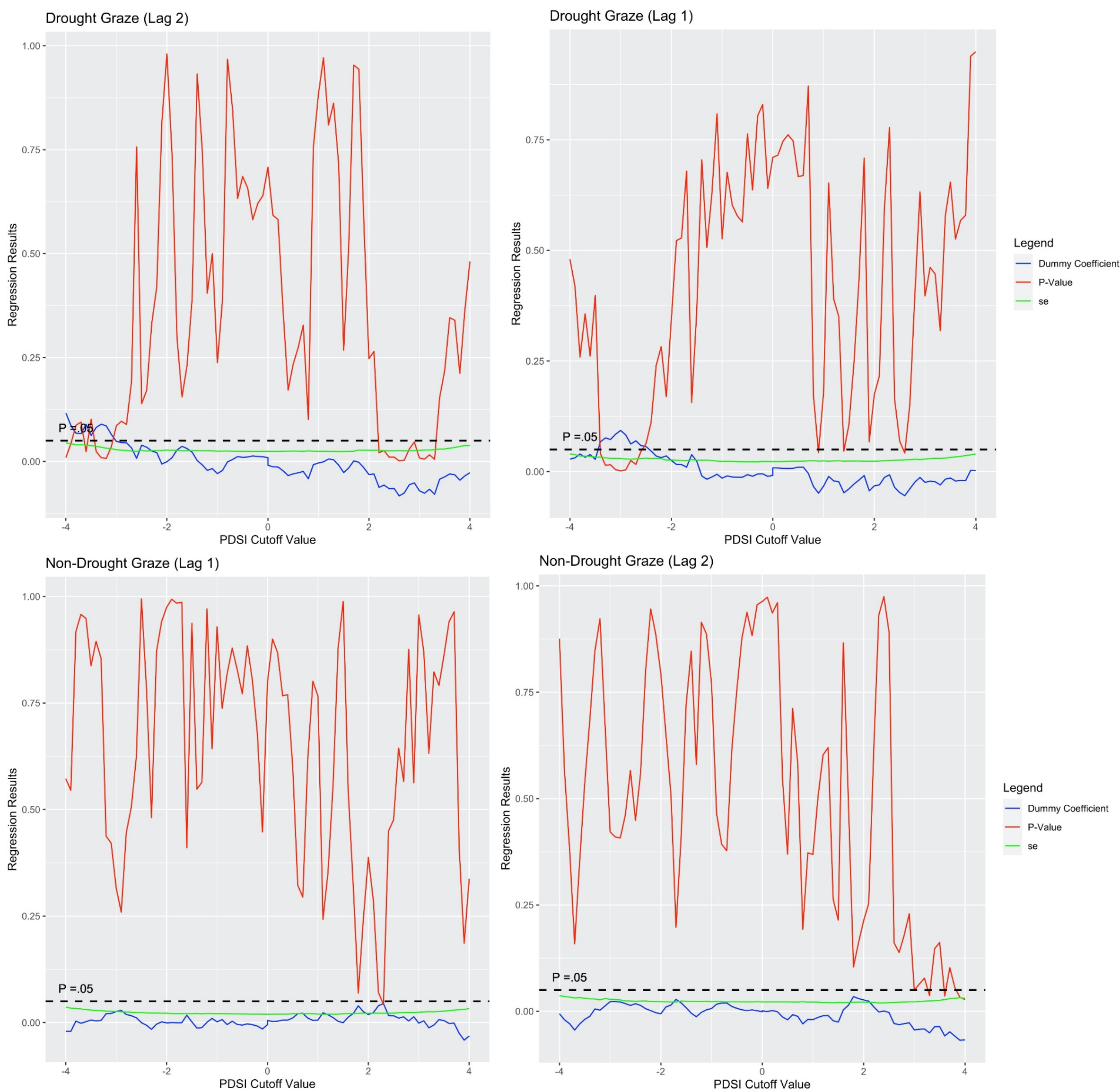

Figure 8: Robustness of the dummy variable PDSI cutoff selection for the drought grazing and non-drought grazing models

COLORADO AND WYOMING RANCHER SURVEY

While the national analysis of EQIP administrative data is useful to understand practice implementations that happen as a result of declining growing conditions and severe drought events, it cannot shed light on why some producers choose to enroll in the program and some do not. To this end, we turn to a 2013 randomized survey of Colorado and Wyoming ranchers[7] who were asked about their demographics, ranch characteristics, management strategies, the impacts of drought on their operation, and whether or not they have enrolled in EQIP. The aim of this section is to complement the above analysis and provide more detailed context into the relationship between EQIP and drought for a small subset of the total study area.

We believe that a brief inspection into the survey data results provides complimentary insights into our broader story of how EQIP enrollment relates to drought. The survey was administered in one year (2013) and in 39 counties, whereas our administrative data analysis spans 10 years and more than 3000 counties. We do not present these results and assume that they apply across our whole study area, nor do we presuppose that these results would hold across all ten years of our study timeline. We believe that these results do have explanatory power for ranchers the Colorado and Wyoming region.

[7] A copy of the survey is provided in Appendix B. These survey responses were initially collected and digitally entered for thesis work exploring ranchers' adoption and implementation of what the paper deemed as "progressive" management and business practices, as well as their use of government programs (Ghajar, 2013). Data were analyzed with the permission of Dr. Maria Fernandez-Gimenez, the advisor on the original project.

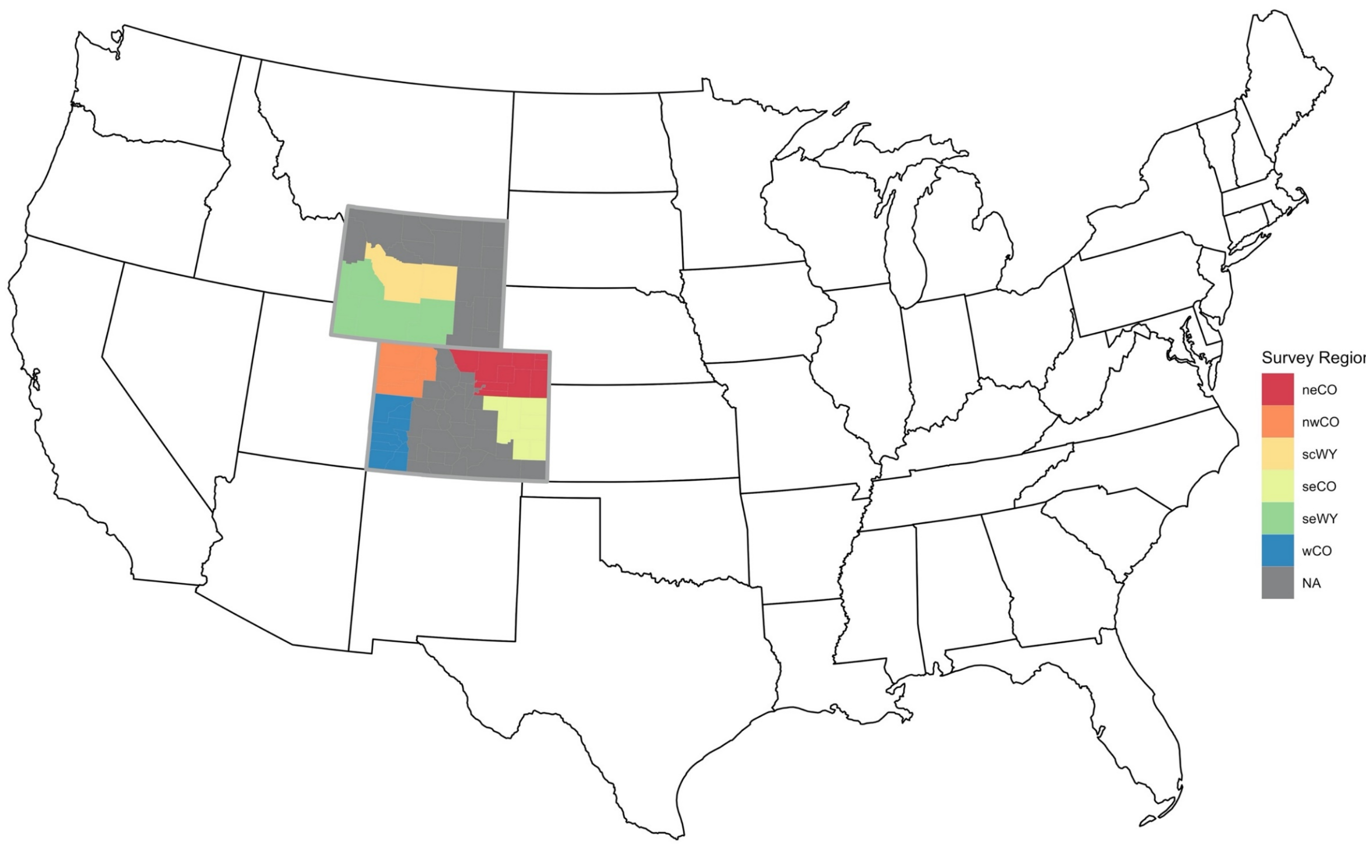

Figure 9: Survey study area

The following provides some key details and takeaways from the survey administration process from 2013[8]. The survey was sent to a randomly selected set of ranchers who are in the 6 regions presented in Figure 9. Ranchers were defined as individuals who own more than 20 animal units and manage at least 100 acres or more of private, public, or leased pastures. The national agricultural statistical service (NASS) assisted with survey implementation, with roughly 1200 surveys sent out across the 6 regions (200 in each). The original team also sent reminders and follow-up surveys. The adjusted response rate for the survey was 34%. To assess non-response bias NASS employees called ranchers who did not respond to the survey. This revealed that the sample may be over representative of older individuals and those with a lower adjusted gross income (AGI).

In the following section we introduce our empirical methods for analyzing these data, present our results, and offer a brief discussion of the takeaways and implications. We then weave these results into a cohesive narrative with the results from the administrative data analysis in the final discussion section.

Survey Data Methods

The survey data analysis provides insight into the context of ranches in Colorado and Wyoming who enroll in EQIP enrollment. We use a logit model to examine the extent to which ranch characteristics, management practices, and drought impacts predict participation in EQIP. We are not claiming causality, simply studying correlations in an effort to shed light on

[8] For a description of the survey methods and a detailed overview of survey results unrelated to EQIP, see Ghajar (2013).

mechanisms for a sample of the EQIP population. For the analysis of the 2013 survey data, we use the following logit specification of the relationship where:

$$Ln\left(\frac{P}{1-P}\right) = \alpha_0 + \beta_c X_c + \beta_d X_d$$

and P is the probability that they enroll in the EQIP[9], X_c is a vector of ranch characteristics including education level, acres owned and leased, adjusted gross income, and survey region, and X_d is a vector of the drought related variables of interest. We run multiple models and in each one X_d is specified slightly differently. In the first model, X_d is the vector of the self-reported impacts of drought on the operation. In the second model, X_d is the vector of self-reported drought response and drought preparedness practices. In the third model, X_d is a vector of self-reported general ranch management practices. In testing these models separately, we identify drought impacts that are associated with program enrollment and what (if any) management decisions are associated with program enrollment. We hypothesize that reported impacts of drought will predict the enrollment into EQIP when controlling for ranch characteristics. We also hypothesize that ranchers who enroll in EQIP are more likely to implement conservation grazing practices. We test these hypotheses by testing whether the beta coefficients in the above model are significantly different from zero. For a table of summary statistics for all the variables we use in the model, please refer to table 12 in Appendix A.

Survey Results

Results from these logit regression models are shown in Tables 6, 7, and 8. These tables only include the significant predictors of EQIP enrollments. Please refer to the table notes and Table 12 for a list of variables that we include in the models but were not included in these

[9] Survey participants marked a 1 or a 0 for their participation in the program.

tables. From Table 6 we see that people who experience an impact of drought on profits are more likely to enroll in EQIP. From Table 7 we see that ranches who engage in practices that are typically are funded through EQIP, like living fence, livestock pipeline, and fencing stream banks are more likely to enroll in the program, and multi-species graziers are less likely to enroll. Lastly, from Table 8, we see that ranches who are more likely to incorporate pasture rest into their drought preparation practices or add alternative enterprises as a response to drought are more likely to enroll in EQIP, while those who would let livestock condition decline during a drought, or use weather predictions as a drought planning tool, are less likely to enroll. All analysis involves controlling for ranch and rancher characteristics. Questions that were used as controls can be seen in the notes of each table. No rancher demographic or ranch characteristic variables were significant in our model results and are therefore not shown in the tables.

These results provide intuition into how EQIP has historically been used by ranchers in Colorado and Wyoming. In conversations with NRCS administrators during the course of this project, we anecdotally heard that people often come to apply for EQIP when they need a specific project funded. Maybe a spring dried up and they need money to pipe water from another spring, or they are hoping to add a cross fence in a pasture. These are the types of efforts associated with the EQIP program in general and with practice implementations. Survey results provide a useful narrative around the characteristics of ranches that are enrolling and not enrolling in EQIP. However, due to the phrasing of the questions asked, we cannot gather the timing of the relationship between the ranch drought adaptation or management practices and EQIP participation. For instance, a rancher could have suffered drought impacts on profits, and then enrolled in EQIP, or he/she could have enrolled in EQIP and then suffered drought impacts on profits.

Table 6: Results tables from logit model where X_d= drought impacts

Drought Impacts -> EQIP Enrollment	
Variable Name	$\mathbb{1}(Enrolled\ in\ EQIP)$
Profits	0.890 *
	(0.463)
N	175
logLik	-79.853
AIC	231.706

*** p < 0.01; ** p < 0.05; * p < 0.1
Standard Errors in Parenthesis

Note: Only Statistically Significant Results are shown. Questions from survey included in Logit model estimation are: Section 1: 1, 2, 3; Section 2: 11,17; Section 7: 1,2,5,7. These See Appendix B for a copy of the survey and Table 12 for all control variables. These included number of head, gender, education level, income, and land ownership characteristics.

Table 7: Results tables from logit model where X_d= management practices

Management Practices -> EQIP Enrollment	
Variable Name	$\mathbb{1}(Enrolled\ in\ EQIP)$
Fence Stream Banks	1.768 **
	(0.830)
Lay Livestock Pipeline	1.624 ***
	(0.542)
Multi Species Graze	-2.798 **
	(1.234)
Install a living Fence	2.224 **
	(1.086)
N	170
logLik	-56.621
AIC	215.243

*** p < 0.01; ** p < 0.05; * p < 0.1
Standard Errors in Parenthesis

Note: Only Statistically Significant Results are shown. Questions from survey included in Logit model estimation are: Section 1: 1, 2, 3; Section 2: 17,18; Section 7: 1,2,5,7. See Appendix B for a copy of the survey and Table 12 for all control variables. These included number of head, gender, education level, income, and land ownership characteristics.

Table 8: Results tables from logit model where X_d = drought practices

Drought Practices -> EQIP Enrollment

Variable Name	$\mathbb{1}(Enrolled\ in\ EQIP)$
% of land operated that is BLM	0.048*
	(0.025)
Add Alternative Enterprises	2.655***
	(0.963)
Let Livestock Condition Decline	-2.037 **
	(0.908)
Incorporate Pasture Rest	1.079 **
	(0.505)
Use Weather Predictions	-1.540*
	(0.807)
N	176
logLik	-69.111
AIC	226.223

*** p < 0.01; ** p < 0.05; * p < 0.1
Standard Errors in Parenthesis

Note: Only Statistically Significant Results are shown. Questions from survey included in Logit model estimation are: Section 1: 1, 2, 3; Section 2: 12,17; Section 7: 1,2,5,7. See Appendix B for a copy of the survey and Table 12 for all control variables. These included number of head, gender, education level, income, and land ownership characteristics.

Discussion

Our findings indicate a pattern of differences in ranchers in Colorado and Wyoming who enroll in EQIP and those who do not. These differences include management practices and drought impacts that could help articulate the relationship between EQIP and drought adaptation for this subset of land and livestock managers. For instance, a rancher who experiences drought, may be likely to use that event to catalyze change by adding enterprises and changing cattle management structure. This has implications as policymakers work to build programming to aid ranchers in times of drought, as they can tailor it to how they already are responding.

A similar Wyoming survey of drought impacts on ranchers reports that ranches that were large in scale and had ample resources, and/or ranches that had diverse income streams where some of them were not dependent on growing conditions were are two key strategies for reducing the impact of drought (Kachergis et al., 2014). Ranchers who had enrolled in EQIP in the survey study area were incorporating pasture rest and alternative enterprises more than those who did not enroll, when accounting for all other control variables. This is interesting, as both of these practices could aid in the economic and ecological resilience of a ranching operation to drought.

Our finding that those who report a higher impact of drought on profits were more likely to have enrolled in EQIP is an important addition to the story. A droughts' impacts on profits can really be a turning point for decision making and could be the measure where people decide they are going to seek additional services through programs such as EQIP. This is how we have modeled decision making in our conceptual model, and these results this type of association for this group of Colorado and Wyoming ranchers.

Overall, these results help provide context into the differences in producers who enroll in EQIP and those who do not for the Colorado and Wyoming region. While it's a small subset of our overall study area, we believe that these results provide helpful narrative in the story behind the decisions that we see in our analysis of the national, aggregated dataset. Our national dataset cannot identify those producers who do not enroll in the program, and this survey lets us understand some of the differences between producers who do enroll, and those who do not. We find evidence of drought adaptation in those who enroll in the program and next, will conclude this paper with final thoughts around the national administrative analysis, survey results, project limitations, and recommendations of future directions in the topic area.

DISCUSSION AND CONCLUSION

This paper explores the role that one federal conservation program can have on drought management for producers. We articulate the effects on enrollment from decreases in growing conditions, finding a statistically meaningful relationship in the increase of drought related practice implementation after severe drought. We identify practices that increased in the number of implementations in the years after drought, finding that in the years after a severe drought, the practices that are employed that appear to be oriented towards building resilience to future drought. In the year after a severe drought, practice changes appear to be mostly focused on response to drought, rather than a change towards mitigating the effect of future drought. Additionally, we complement the national analysis with a brief look into Colorado and Wyoming ranchers to see what differences exist in those who participate in EQIP and those who do not. We find that producers are more likely to enroll (though we don't know the sequence of these events) if they experience drought impacts on profits, add alternative enterprises as a response to drought, and incorporate pasture rest into their grazing systems. Together, these two analyses provide evidence that EQIP practices and EQIP funding has historically acted as a useful drought management and drought adaptation tool.

While it's not the only strategy that agricultural producers have in adapting to climate change and drought risk, EQIP proves a useful program in helping subsidize management shifts after drought events. These results have implications for NRCS agency personnel, land and livestock managers, and policymakers who are writing the legislation for these programs. While we cannot identify weather EQIP is in fact welfare increasing for producers who enroll or society at large through the above study, we can identify what practices are being used as a response to drought. These results can push policy towards providing additional funding for these practices in the years after a severe drought.

Drought risk management is something that anyone associated with land and livestock management is either already is thinking about or will soon be. Working lands conservation program practices can add to suite of options that land and livestock managers have in their drought management protocols. While the short-term response to a major drought event is likely still best served by de-stocking, finding supplemental feed, and seeking drought relief subsidies, the implementation of conservation practices could show promise is a long-term drought adaptation strategy. EQIP projects can diversify water sources, help with more intensive management of livestock, and help facilitate the creation of additional enterprises on the property, which in turn can build a more resilient system against drought impacts.

While the EQIP planning and implementation process does not typically involve conversations of land or livestock manager profitability, these results help articulate the importance of incorporating profitability into the practice decisions implemented on a parcel. Drought and variable conditions can have major impacts on rancher profitability and livestock performance (Hamilton et al., 2016; Irisarri et al., 2019) but there is evidence that the implementation of practices can positively impact economic outcomes (Ashwell et al., 2019). We recommend that further research into the relationship between economic outcomes and practice implementation is merited.

This study is not without limitations. First, in our administrative spatial analysis, we are limited to an aggregated county level analysis of behavior. Because of this we are not able to tease out parcel level effects of land use, soil type, and/or other land/landowner characteristic on EQIP enrollment. A second limitation of the study is the specification of drought. Drought, while a ubiquitous topic in land management, takes on a variety of operational definitions in research. While we employed a few empirical definitions to ensure our results were not solely a function of our definition, this is still a limitation. We cannot ascertain the “best” definition and continued research into the benefits and costs of various drought metrics is merited (for more on this, see: Hall & Leng, 2019). Lastly, the survey data we had was limited in scope; it is nearly 8 years old and covers a limited geographic area. These issues can create questions of the external validity of the results; however, we believe these results still hold merit in informing the relationship between EQIP and drought adaptation.

Based on our work, we recommend a few future directions of research into this topic area. First, we recommend that future work to develop a strategy to identify the causal relationship between EQIP enrollment and the specific impacts of drought, such as impacts on profitability. In addition, we also recommend that this work be applied more directly to the farmer level, rather than the aggregated county level, to ensure specific producer level heterogeneity is captured. Lastly, we recommend that this work be applied to conservation practice enrollment outside the EQIP program. While EQIP provides the largest comprehensive database of conservation practice enrollment, we recommend continued survey or interview data collection to understand the relationship between exogenous climate variables and land and livestock management decisions.

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APPENDIX A

Table 9: Comparing Poisson regressions including dropped practices

	Count: All Grazing		Count: Drought Grazing		Count: Non-Drought Grazing	
	Dropped Practices	All Practices	Dropped Practices	All Practices	Dropped Practices	All Practices
Dummy lag 1	0.0584**	0.0537**	0.0931***	0.0773***	0.0284	0.0296
	(0.025)	(0.024)	(0.030)	(0.028)	(0.026)	(0.025)
Dummy lag 2	0.0379	0.0477**	0.0483*	0.0544**	0.0233	0.0355
	(0.024)	(0.024)	(0.028)	(0.027)	(0.028)	(0.028)
Dummy lag 3	0.0258	0.0371*	0.0438	0.0593**	0.0102	0.0179
	(0.022)	(0.021)	(0.028)	(0.026)	(0.024)	(0.023)
# (in thousands) of operators	0.4365**	0.3661**	0.1197	0.015	0.6481***	0.6170***
	(0.173)	(0.165)	(0.181)	(0.158)	(0.196)	(0.191)
% Rangeland	-0.3222	-0.2402	-0.3471	-0.2421	-0.366	-0.3091
	(0.319)	(0.306)	(0.403)	(0.384)	(0.340)	(0.323)
Observations	28,820 [1]	29,040 [2]	28,820 [1]	29,040 [2]	28,820 [1]	29,040 [2]
Squared Corr.	0.6469	0.6410	0.6445	0.6358	0.6300	0.6264
Pseudo R2	0.6025	0.6068	0.5787	0.5807	0.5675	0.5743
BIC	510,296.40	558,579.20	306,503.20	333,791.40	381,216.6	414,053.10

*** p < 0.01; ** p < 0.05; * p < 0.1

[1] Only used observations where there was at least 1 year with at least 1 drought practice.

[2] There are more observations because some counties drop out of the study when not including dropped practices

Coefficient standard errors are in parentheses and clustered at the county level

Fixed Effects for county, year, and state-by-year omitted for brevity

Table 10: Comparing the drought grazing models with different uses of the PDSI

	Mean Growing Season PDSI	Growing Season Severe Drought Dummy	Mean Year PDSI	Year PDSI Severe Drought Dummy	June PDSI	June PDSI Severe Drought Dummy
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Variable lag 1	-0.0085	0.0931***	-0.0143*	-0.0247	-0.0154***	0.0055
	(0.006)	(0.030)	(0.008)	(0.039)	(0.006)	(0.038)
Variable lag 2	-0.0110**	0.0483*	0.0009	0.0120	0.0011	0.0387
	(0.006)	(0.028)	(0.007)	(0.035)	(0.005)	(0.037)
Variable lag 3	-0.002	0.0438	-0.0087	0.0457	-0.0025	0.0463
	(0.006)	(0.028)	(0.008)	(0.035)	(0.006)	(0.031)
# (in thousands) of operators	0.1165	0.1197	0.1213	0.138	0.1206	0.1147
	(0.178)	(0.181)	(0.178)	(0.178)	(0.180)	(0.179)
% Rangeland	-0.3975	-0.3471	-0.4056	-0.5108	-0.4523	-0.3949
	(0.403)	(0.403)	(0.403)	(0.407)	(0.412)	(0.404)
Observations	28,820 [1]	28,820 [1]	28,820 [1]	28,820 [1]	28,820 [1]	28,820 [1]
Squared Corr.	0.6442	0.6445	0.6442	0.6441	0.6443	0.6445
Pseudo R2	0.5785	0.5787	0.5785	0.5785	0.5785	0.5785
BIC	306,608.60	306,503.20	306,625.0	306,648.70	306,638.70	306,595.3

*** p < 0.01; ** p < 0.05; * p < 0.1

[1] Only used observations where there was at least 1 year with at least 1 drought practice.

Coefficient standard errors are in parentheses and clustered at the county level

Fixed Effects for county, year, and state-by-year omitted for brevity

Table 11- OLS version of our main model specification

	Count: All grazing	Count: Drought grazing	Count: Non-Drought grazing
	Coefficient	Coefficient	Coefficient
Growing Season PDSI lag 1	-0.1847	-0.1807***	-0.0039
	(0.137)	(0.062)	(0.095)
Growing Season PDSI lag 2	-0.2523*	-0.1995***	-0.0528
	(0.133)	(0.063)	(0.092)
Growing Season PDSI lag 3	0.2095	0.0558	0.1537
	(0.140)	(0.065)	(0.095)
# (in thousands) of operators	20.22**	1.069	19.15***
	(8.457)	(3.623)	(5.891)
% Rangeland	-18.64**	-8.521**	-10.12
	(9.475)	(3.919)	(6.980)
Observations	28,820 [1]	28,820 [1]	28,820 [1]
R2	0.5855	0.5663	0.5689

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

[1] Only used observations where there was at least 1 year with at least 1 practice.

Coefficient standard errors are in parentheses and clustered at the county level

Fixed Effects for county, year, and state-by-year omitted for brevity

Table 12- Summary statistics for survey

Variable Name	Min	Max	Mean	Std. Dev	N
Ranch/Rancher Characteristics					
EQIP Enrollment	0	1	0.27	0.45	168
Region	0	10	6.36	3.55	168
%Private Land	10	100	80.52	24.79	168
%USFS Land	0	75	5.54	13.65	168
%State Land	0	80	5.33	13.26	168
%BLM Land	0	80	7.50	16.57	168
% other land	0	70	1.60	8.23	168
Private Acres (Q2)	1	6	4.45	1.42	168
# of head (CowCalf)	0	1500	94.50	185.50	168
# of head (DryCows)	0	2900	58.29	272.93	168
# of head(Yearling)	0	5000	71.28	412.77	168
# of head (Sheep)	0	4400	74.55	460.71	168
# of head(Goats)	0	50	0.58	4.06	168
# of head(Horses)	0	95	5.94	11.47	168
# of head(Other)	0	495	9.88	47.71	168
AGI Livestock	0	100	45.72	33.49	168
AGI Wildlife	0	30	1.50	4.61	168
AGI Crops	0	100	15.28	25.49	168
AGI OtherRanch	0	95	1.52	9.41	168
AGI OffRanch	0	99	36.13	34.74	168
Education Level	1	6	4.25	1.07	168
Gender	1	2	1.15	0.36	168
Income Category	1	8	3.88	1.27	168
Drought Impacts					
Winter Feed	0	1	0.68	0.47	168
Profit	0	1	0.54	0.50	168
Grazing Capacity	0	1	0.82	0.39	168
Weaning Weight	0	1	0.38	0.49	168
Water Availability	0	1	0.41	0.49	168
Reproduction Rates	0	1	0.24	0.43	168
Other	0	1	0.05	0.21	168
Management Response to Drought					
Add alternative enterprises	0	1	0.07	0.25	168
Purchase feed	0	1	0.66	0.47	168
Let body condition decline	0	1	0.08	0.28	168
Reduce herd size	0	1	0.77	0.42	168
Earn off farm-income	0	1	0.30	0.46	168

Rent additional pasture	0	1	0.27	0.45	168
Apply for GOVT assistance	0	1	0.12	0.32	168
Sell retained yearlings	0	1	0.20	0.40	168
Move livestock to another location	0	1	0.28	0.45	168
Wean early	0	1	0.43	0.50	168
Place livestock in a feedlot	0	1	0.14	0.34	168
Management to prepare for drought					
Add stocker operation	0	1	0.09	0.29	168
Add other livestock types	0	1	0.02	0.15	168
Grass banking	0	1	0.20	0.40	168
Conservative Stocking	0	1	0.36	0.48	168
Pasture Rest	0	1	0.39	0.49	168
Use weather forecasting	0	1	0.11	0.32	168
General Management Practices					
Rotational grazing	0	1	0.83	0.37	168
Continuous grazing	0	1	0.12	0.32	168
Low moisture supplements	0	1	0.47	0.50	168
Manage sensitive species	0	1	0.11	0.32	168
Minimize riparian grazing	0	1	0.22	0.42	168
Spring development	0	1	0.23	0.42	168
Fence stream banks	0	1	0.12	0.32	168
Lay water pipeline	0	1	0.36	0.48	168
Prescribed burning	0	1	0.08	0.28	168
Mechanical brush removal	0	1	0.17	0.37	168
Wildlife Water Development	0	1	0.18	0.39	168
High intensity, short duration grazing	0	1	0.15	0.36	168
Install erosion control	0	1	0.12	0.32	168
Use a herder to manage livestock	0	1	0.08	0.27	168
Low-stress livestock management	0	1	0.42	0.49	168
Apply herbicide	0	1	0.43	0.50	168
Install wildlife friendly fence	0	1	0.20	0.40	168
Use a herding dog	0	1	0.08	0.28	168
Put in food plots	0	1	0.05	0.21	168
Multi-species graze	0	1	0.07	0.25	168
Install a living fence	0	1	0.05	0.23	168
Non use of the land	0	1	0.11	0.32	168
Other	0	1	0.01	0.08	168

APPENDIX B

I: OPERATION CHARACTERISTICS

In the first section, we ask you a few questions to gain a better understanding of the nature of your ranching operation.

1) Approximately, what percentage of your ranching operation falls into each of the following land ownership categories? ***Write in the estimated percent.***

Private	_______%
U.S. Forest Service	_______%
State Lands	_______%
Bureau of Land Management (BLM)	_______%
Other (please specify)___________	_______%
Total	**100%**

2) About how many private acres of land do you have in your ranching operation? ***Check one.***

☐ Less than 100 acres ☐ 250 – 499 acres ☐ 1,000 – 4,999 acres

☐ 100 – 249 acres ☐ 500 - 999 acres ☐ 5,000 acres or more

3) As of January 2013, about how many head of cattle, sheep, horses and other livestock did you have on your ranching operation? ***Please write in a number, write "0" if none.***

Cow-calf pairs_______ Sheep_______ Other (Please list.) _____________

Dry cows _______ Goats _______ _______________________________

Yearling (stocker) cattle _______ Horses _______ _______________________________

4) What percent of your ranching operation's annual labor is supplied by the family? _______ %

5) About how many years have you managed this ranching operation? _______ years

II: NATURAL RESOURCE MANAGEMENT GOALS Please tell us about your resource management goals.

1) **Grazing management involves balancing many goals. Below is a list of goals sometimes associated with grazing. Please rank the goals as they relate to the PRIORITIES you have in your operation.**

A. Livestock production	D. Invasive plant management	G. Soil health
B. Forage production	E. Recreation	H. Water quality
C. Carbon sequestration	F. Riparian and/or meadow health	I. Wildlife

Please rank the goals above as they relate to the priorities you have for your operation. (1 is the highest priority; 9 is the lowest priority. Write the letter associated with the goal on the line next to the appropriate ranking below. If a goal is not applicable to your operation, please do not include it in the ranking.)

1.__________________________ _	**4.**__________________________ _	**7.**__________________________ _
2.__________________________ _	**5.**__________________________ _	**8.**__________________________ _
3.__________________________ _	**6.**__________________________ _	**9.**__________________________ _

2) Are there any additional goals related to natural resource management that are important to you?

III. MANAGEMENT PRACTICES AND PROGRAMS

The next questions ask about your general approach to GRAZING the LARGEST are of PRIVATE land (owned or leased) that is NOT IRRIGATED, on which you control the management decisions. We recognize that grazing changes from year to year. Please answer for typical years.

1) **The NUMBER OF PASTURES (fenced areas) on the largest area of non-irrigated PRIVATE land is typically *(check one)*:**

☐ 1 ☐ 2-5 ☐ 6-10 ☐ More than 10

2) **The NUMBER OF HERDS or groups of livestock on the largest area of non-irrigated PRIVATE land is typically *(check one):***

☐ 1 ☐ 2-5 ☐ 6-10 ☐ More than 10

3) **In most pastures, the DURATION OF GRAZING in the largest area of non-irrigated PRIVATE land is typically *(check one):***

☐ Continuous in most pastures through the year
☐ Continuous through the growing season in most pastures, but not year-long
☐ Short in most pastures- lasting for a few days at a time
☐ Moderate in most pastures- lasting for a few weeks at a time
☐ Long, in most pastures- lasting for periods of 1-3 months but not the entire growing season
☐ Other (please list):_______________________________

4) **In most pastures, the GRAZING SEASON on the largest area of non-irrigated PRIVATE land is typically *(check one):***

☐ All seasons
☐ The dormant season
☐ Only in the middle of the growing season
☐ Only late in the growing season

☐ The entire growing season ☐ Intermittent through the growing season

☐ Only early in the growing season ☐ Other (please list): ______________________________

5) **In most pastures, the STOCK DENSITY on the largest area of non-irrigated PRIVATE land is typically *(check one):***

☐ 0-5 acres/animal unit ☐ 5-10 acres/animal unit ☐ 10-20 acres/animal unit

☐ 20-30 acres/animal unit ☐ 30-50 acres/animal unit ☐>50 acres/animal unit

6) **In most pastures, REST from grazing on the largest area of non-irrigated PRIVATE land is typically *(check one):***

☐ No rest ☐ All seasons ☐ The dormant season

☐ Only early in the growing season ☐ Only the middle of the growing season ☐ Only late in the growing season

☐ Intermittently in the growing season ☐ Other (please list): ____

7) **Which of the past SEVEN YEARS would you characterize as representative of your TYPICAL grazing management? C*heck all that apply.***

☐ 2006 ☐ 2007 ☐ 2008 ☐ 2009 ☐ 2010 ☐ 2011 ☐ 2012

8) **We recognize that grazing may differ from pasture to pasture within the same large area of land. Are there any other elements of your general grazing management strategy that are important to understand? *Please write your answer in the box[note: box deleted in this thesis due to required formatting of page numbers].***

Drought may change your management decisions and your ability to meet your management goals. Please tell us more about your approach to management with regard to drought events.

9) **What year was the last drought that affected your operation? *Please list year or years:* ____________**

10) **During the last drought, did you have a drought management plan in place? *Check one.***

☐ Yes ☐ No

11) **During the last drought, which of the following were impacted more severely than expected? *Check all that apply.***

☐ N/A–have not experienced drought ☐ Grazing capacity ☐ Irrigation water availability

☐ Winter feed availability ☐ Weaning weights ☐ Reproduction rates

☐ Profitability ☐ Other: (please fill in): ____

12) **How do you manage for drought impacts?** ***Check all that apply.***

☐ N/A–have not experienced drought

Management in response to drought	**Management to prepare for drought**
☐ Add alternative on-farm enterprise	☐ Increase flexibility by incorporating both cow-calf and stocker cattle
☐ Purchase feed	☐ Increase flexibility by adding other livestock types
☐ Allow livestock condition to decline; maintain herd size	☐ Add areas for grass banking (stockpile forage)
☐ Reduce herd size	☐ Employ conservative stocking rate to allow full grazing even in drought years
☐ Earn off-farm income	☐ Incorporate pasture rest into grazing system
☐ Rent additional pasture	☐ Use 1-3 month weather predictions to adjust stocking rate
☐ Apply for government assistance program	
☐ Sell retained yearlings	
☐ Move livestock to another location	
☐ Wean early	
☐ Place livestock in a feedlot	

13) **Do you think drought will be more influential in your management plans/operations in the next ten years than it has been in the past ten years?** ***Check one.***

☐ Yes ☐ No

14) **If another drought were to begin right now, how severely would this impact the economic viability of your operation?** ***Check one.***

☐ No differently than the last drought ☐ Less severely than the last drought ☐ More severely than the last drought ☐ N/A–have not experienced drought

Monitoring may provide additional information on which to base management decisions. Please tell us more about your approach to monitoring on your operation.

15) **What types of informal monitoring do you do on your ranch?** ***Check all that apply.***

☐ Observe grass height, density or ☐ Observe amount of forage ☐ Observe the condition of my

☐ Observe erosion ☐ Observe wildlife ☐ Observe weather

☐ I do NO informal monitoring ☐ Other informal monitoring (describe): ______________________________

16) **In the <u>last 10 years</u>, what types of formal monitoring have you done on your private land, Forest Service and BLM allotments, or state lands grazing leases?** ***For each land status on your ranch, please <u>circle</u> all that apply. If you are not familiar with the method circle NF.***

☐ I do NO formal monitoring (***Check box***) (SKIP TO QUESTION 17)

	Private Land	**Forest Service, BLM or State Land**	**Not Familiar with this Method**
Measure rainfall	1	2	NF
Photo points	1	2	NF

Vegetation measurements			
Step point	1	2	NF
Nested frequency	1	2	NF
Cover (ocular estimate)	1	2	NF
Cover (line point intercept)	1	2	NF
Cover—other method	1	2	NF
Density of key species	1	2	NF
Clip biomass or residual	1	2	NF
Grazing response index	1	2	NF
Herbaceous utilization	1	2	NF
Browse utilization	1	2	NF
Riparian utilization	1	2	NF
Stubble height	1	2	NF
Proper functioning condition	1	2	NF
Streambank stability	1	2	NF
Water quality	1	2	NF
Wildlife habitat surveys	1	2	NF
Wildlife counts	1	2	NF

Management practices vary greatly from one operation to another. Please tell us more about your management practices on your operation.

17) **In the <u>last 5 years</u> have you participated in any of the following programs with your ranching operation? *Check one for each program.***

Land retirement conservation programs, for example, Conservation Reserve Program (CRP) or Wetland Reserve Program (WRP)	☐ Yes	☐ No
Working land conservation programs, for example, Environmental Quality Incentives Program (EQIP) or Conservation Security Program (CSP)	☐ Yes	☐ No
Wildlife habitat programs, for example, Landowner Incentive Program (LIP), or Ranching for Wildlife (RFW)	☐ Yes	☐ No
Agricultural land and grassland preservation programs, for example, Farm and Ranchlands Protection Program (FRPP), or Grassland Reserve Program (GRP)	☐ Yes	☐ No
Conservation easements	☐ Yes	☐ No

18) **In the <u>last 5 years</u> have you carried out any of the following management practices on your ranching operation? *Check <u>all</u> that apply.***

☐ Rotational grazing	☐ Prescribed burning	☐ Reseeding

☐	Continuous, year-round grazing	☐	Mechanical brush removal	☐	Put in wildlife-friendly fencing
☐	Low moisture supplements to distribute livestock, for example, Crystalyx	☐	Installed wildlife water development	☐	Used herd guard dog or other companion animal to deter predators
☐	Managed for sensitive plant or animal species (including threatened or endangered species)	☐	Holistic Resource Management, Savory grazing, or high intensity-short duration grazing	☐	Put in food plots (plant desirable plant species to distribute foraging)
☐	Grazed riparian areas for 30 days or less during the year	☐	Put in erosion control structures	☐	Multiple species grazing
☐	Spring development	☐	Used a herder to manage livestock distribution	☐	Put in living fences
☐	Fenced stream banks or riparian areas	☐	Low-stress stock management	☐	Non-use of land (other than related to drought)
☐	Laid water pipeline	☐	Applied herbicides	☐	Other (please list) ______________________

19) In the <u>last 5 years</u> have you participated in or implemented any of the following business practices with your ranching operation? *Check one for each practice.*

Direct marketing of livestock products, for example, meat, wool, milk or cheese	☐ Yes	☐ No
Oil or gas leasing or extraction	☐ Yes	☐ No
Guiding services for hunting and fishing	☐ Yes	☐ No
Guiding services for bird watching and other types of wildlife viewing	☐ Yes	☐ No
Charged access fee for hunting, fishing, or wildlife viewing	☐ Yes	☐ No
Agri-tourism including rural tourism, such as a dude ranch	☐ Yes	☐ No
Received carbon off-set or carbon sequestration payments	☐ Yes	☐ No
Wind energy development	☐ Yes	☐ No
Geothermal energy development	☐ Yes	☐ No
Grass-fed or grass-finished beef, lamb, or goat	☐ Yes	☐ No
Certified organic beef, lamb, or goat	☐ Yes	☐ No
Bed & breakfast or other accommodations, for example, retreat facilities	☐ Yes	☐ No

Other (Please list.)

____

20) A person's decisions about whether to engage in new activities are usually based on many factors. We would like to know what influences <u>your</u> decision to <u>implement a new management tool or practice for your ranching operation.</u> Please indicate below to what degree each of the following factors influences your decision. ***Circle one number for each factor.***

	Does Not Influence	Slightly Influences	Moderately Influences	Strongly Influences
Environmental benefits of the management practice	1	2	3	4
Potential for the management practice to benefit the local economy	1	2	3	4
Management practice will help reduce the spread of invasive weeds	1	2	3	4
Reliable scientific information exists to support the use of the management practice	1	2	3	4
Amount of time it takes for desired results from the management practice to be achieved	1	2	3	4
Amount of time desired results from the management practice will last	1	2	3	4
Impacts of the management practice on grazing capacity	1	2	3	4
Impacts of the management practice on wildlife habitat	1	2	3	4
Potential for direct financial gain from implementing the management practice	1	2	3	4

21) In general, which of the following statements best describes your approach to engaging in new management practices or programs with your ranching operation? ***Check one.***

- ☐ I actively seek new management practices/programs beyond my local resources and I am willing to take financial risks to try these new practices/programs
- ☐ I seek new management practices/programs from my local resources and in general I am asked by members of the community for my opinion regarding new practices/programs
- ☐ I like to watch others and see how they do before adopting a new management practice/program, but I adopt before the average person
- ☐ Cautious, I adopt new management practices/programs after the majority of people have, generally due to economic necessity or increasing pressure from peers
- ☐ I tend to avoid new management practices/programs if possible, preferring to continue with what's worked in the past

NRCS, USFS, BLM						
Conferences or workshops	1	2	3	4	5	6
Internet websites	1	2	3	4	5	6
Advice from family, friends, and peers	1	2	3	4	5	6
Agricultural organizations, for example, Cattlemen's Association	1	2	3	4	5	6
Professional association, for example, Society for Range Management	1	2	3	4	5	6
Other (Please list): ____________________	1	2	3	4	5	

3) **What is your preferred method for receiving information about rangeland management? *Check one.***

☐ Websites ☐ Email ☐ Word of mouth or face-to-face ☐ Print publications ☐ Other (please list): ____________________

4) **How do you access the internet? *Check <u>all</u> that apply.***

☐ A dial-up connection ☐ A high-speed connection ☐ A smartphone ☐ N/A – I do not use the internet

5) **About how often do you access the internet? *Circle one.***

Never	Very Rarely	Monthly	Weekly	Daily
1	2	3	4	5

6) **How would you rate the importance of the internet for the day-to-day management of your operation? *Circle one.***

Not at All Important	Slightly Important	Moderately Important	Very Important	Extremely Important
1	2	3	4	5

7) **What are the biggest barriers to using information from the internet to augment your operation? *Check <u>all</u> that apply.***

☐ No internet access
☐ Slow internet speed
☐ Intermittent or unreliable internet connection
☐ Lack of time to find information online
☐ Difficulty of determining which online sources are trustworthy
☐ Lack of experience with using the internet to find information
☐ Difficulty finding information that is specifically applicable to my operation
☐ All my informational needs are filled by sources other than the internet
☐ There are no barriers to using information from the internet to augment my operation.
☐ Other (please specify): ____

Of the barriers listed above, which is the single biggest barrier to using information from the internet to augment your operation? ***Single biggest barrier:*** ____

8) **When learning about rangeland management on the internet, which media formats do you or would you prefer?** ***Check all that apply.***

☐ Text ☐ Downloadable documents (e.g. .pdf files, Word files) ☐ Video

☐ Audio files ☐ Pictures ☐ Games

☐ Slideshows ☐ Other (please specify):________________

Of the media formats listed above, which is your first preference? ***My first preference:*** ________________

9) **When making a choice that will affect the management of your operation, to what degree does information you find on the internet influence your decisions in each of the following management areas?** ***Circle the number that applies.***

Management area	Not at All	Slight Degree	Moderate Degree	High Degree	Very High Degree	Not Applicable
Ranch Business Management						
Livestock purchasing	1	2	3	4	5	6
Livestock marketing	1	2	3	4	5	6
Buying/selling equipment	1	2	3	4	5	6
Buying/selling feed or hay	1	2	3	4	5	6
Infrastructure development (fences, wells, buildings etc.)	1	2	3	4	5	6
Energy development	1	2	3	4	5	6
Tourism/Hunting	1	2	3	4	5	6
Participation in government programs (e.g. EQIP, WHIP, CRP)	1	2	3	4	5	6
Conservation easements	1	2	3	4	5	6
Estate planning	1	2	3	4	5	6
Resource Management						
Weather forecast/prediction	1	2	3	4	5	6
Rangeland assessment or monitoring	1	2	3	4	5	6
Invasive species or weed management	1	2	3	4	5	6
Grazing management	1	2	3	4	5	6
Rangeland seeding	1	2	3	4	5	6
Prescribed fire	1	2	3	4	5	6
Wildlife or habitat management	1	2	3	4	5	6
Drought management	1	2	3	4	5	6

Wildfire or other natural disaster preparedness/recovery	1	2	3	4	5	6
Predator control	1	2	3	4	5	6
Livestock Herd Management						
Livestock genetics/breeding	1	2	3	4	5	6
Livestock health/veterinary care	1	2	3	4	5	6
Feeding/nutrition/forage quality	1	2	3	4	5	6
Low stress livestock handling	1	2	3	4	5	6

10) **Please indicate how reliable you find you find the information on rangeland management from these sources to be. *Circle the number that applies.***

Information Source	Not at All	Slight Degree	Moderate Degree	High Degree	Very High Degree	Not Applicable
☐ County Extension office or agent	1	2	3	4	5	6
☐ Private companies or consultants	1	2	3	4	5	6
☐ Industry magazine(s), for example, Progressive Cattleman	1	2	3	4	5	6
☐ Scientific Journal(s)	1	2	3	4	5	6
☐ Environmental organization(s)	1	2	3	4	5	6
☐ County or city weed authority	1	2	3	4	5	6
☐ Local or regional newspaper	1	2	3	4	5	6
☐ State government agency, for example State Forest Service or Wyoming Game & Fish	1	2	3	4	5	6
☐ Federal agency, for example, NRCS, BLM, USFS	1	2	3	4	5	6
☐ Conferences or workshops	1	2	3	4	5	6
☐ Family, friends, or peers	1	2	3	4	5	6
☐ Agricultural organizations, for example, Cattlemen's Association	1	2	3	4	5	6
☐ Professional association, for example, Society for Range management	1	2	3	4	5	6

11) **Of the information sources listed in question 10, which sources do you use the internet to access? *Check all that apply, using the checkboxes next to the information sources in the table above.***

VII: BACKGROUND

In this last section, we would like to know more about your ranching operation and your background. This information will only be used in making comparisons and will remain strictly confidential.

1) Of your annual gross income, what percent comes from (*write in your best estimate):*

Income from livestock	_______ %
Income from wildlife	_______ %
Income from crops	_______ %
Income from other on-ranch sources e.g. dude ranch)	_______ %
Income from off-ranch sources	_______ %
Total	**100%**

2) What was the last year of school you completed? *Check one.*

- ☐ Grade school
- ☐ Some high school
- ☐ Completed high school or GED
- ☐ Some college or vocational/technical school
- ☐ Completed 4 year college degree — Major ________________
- ☐ Completed a graduate or professional degree (MS, PhD, MD, JD, DVM, etc.) — Major ________________

3) When you are no longer operating your farm or ranch, which of the following best describes what you expect will happen to the operation? *Check one.*

- ☐ It will be operated by my spouse
- ☐ It will be operated by my children
- ☐ It will be operated by other relatives
- ☐ It will be operated by a non-relative who is currently involved with the ranch
- ☐ It will be operated by individuals not involved with the current operation
- ☐ It will be converted to a non-farm use
- ☐ Don't know

4) Not including the generations after you, how many generations of ranchers have there been in your family? *Check one* (*if you have a spouse, please answer for the longer heritage*).

- ☐ 1- I am a first generation rancher
- ☐ 2-my parents were ranchers
- ☐ 3-my grandparents were ranchers
- ☐ 4-my great grandparents were ranchers
- ☐ 5-my great great grandparents were ranchers
- ☐ I don't know
- ☐ Other (please list)____________

5) What is your gender? *Check one.*

☐ Male ☐ Female

6) In which year were you born? __________

7) What is your approximate gross annual income? *Check one.*

☐ Less than $19,999 ☐ $80,000 - $199,999 ☐ $800,000 - $999,999

☐ $20,000 - $49,999	☐ $200,000 - $499,999	☐ Between $1 million & $5 million
☐ $50,000 - $79,999	☐ $500,000 - $799,999	☐ Over $5 million

Thank you for your help with this important study! Your participation is greatly appreciated. Please feel free to use the remaining space for any additional comments.

Please return your completed questionnaire in the enclosed envelope to:

Dept. of Forest and Rangeland Stewardship
Colorado State University
Attn. Shayan Ghajar
P.O. Box 150969
Lakewood, CO 80215

Phone: (970) 329-4175
Email: Shayan.Ghajar@colostate.edu

Thank you for your time in completing this survey.
Your input is valuable and appreciated.
Thank you again.

If you have any questions about your rights as a survey respondent, you may contact Janell Barker of the CSU Institutional Review Board at (970) 491-1655.

Cover photo courtesy of the Bureau of Land Management