Wildfire Across Agricultural Landscapes: Farmer and Rancher Experiences and Perceptions in the Southern Great Plains.

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Abstract

Wildfire frequency and intensity has increased across the Southern Great Plains of the United States and other similar landscapes worldwide in part due to climate change. It is important that policymakers, practitioners, and the agricultural community better understand the impact from increased wildfire incidence and severity across different agricultural landscapes. The purpose of this study is to examine the impact of wildfires across an agricultural landscape of the Southern Great Plains. Using primary data collected from semi-structured interviews of farmers and ranchers in the study region, we quantitatively explore farmers' and ranchers' perceptions and experiences about wildfires in the Southern Great Plains of the U.S using survey data. About 80% of the producers interviewed had directly experienced wildfire on their property, including significant losses to farmer livelihoods, food stocks (crops and livestock), forages, native grasslands, and structures (building and fencing). Many producers perceived wildfire frequency had increased and another megafire event was very likely. To help reduce wildfire risk for producers in the Southern Great Plains more timely education and outreach efforts about wildfire mitigation, organization of local fire associations, more timely disaster assistance, and innovative insurance solutions would be useful.

Keywords: Megafire, Risk, Wildfire Frequency, Wildfire Preparedness

Key Policy Highlights:

1) Farmers and ranchers face significant wildfire risk in the Southern Great Plains, a grassland dominated landscape, where public and pooled resources for wildfire mitigation and suppression are scarcer.
2) Policymakers and emergency planners need to be aware of the impacts from wildfires on grassland dominated agricultural landscapes, including losses to farmer livelihoods, food stocks (crops and livestock), forages, native grasslands, structures (building and fencing), amongst other that may occur.
3) More research and education concerning wildfire impacts and mitigation on agricultural landscapes needs to be conducted, such as organizing local fire associations, more effectively pooling local resources, and innovative insurance solutions.

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1. Introduction

Fire plays an important role in the development and shaping of ecosystems in the Southern Great Plains (SGP) of the United States (He et al., 2019; Cochrane, 2019). Dominated by grasslands, fire in the SGP region can reduce woody encroachment, positively influence growth of perennial herbaceous plants, increase plant species diversity and richness, and support native and endangered species (Deák et al., 2014; He et al., 2019; Stavi, 2019; Twidwell et al., 2013; Zavala et al., 2014). Recognizing the benefits of controlled or prescribed fire in the SGP, agricultural communities have used it as a land management tool to control invasive species, manage woody encroachment, manage crop residues, enhance grazing for livestock (Stavi, 2019; McCarty et al., 2009; Powell et al., 2018; Tidwell et al., 2013).

These practices, and human use of fire as a tool, however, may result in wildfires or a fire that was unplanned or escapes control (Tedim and Leone, 2020). In the states of the Southern Great Plains, as much as 84% of wildfires are a result of human ignitions, ranging across states from about 40 to 95% of wildfires (Balch et al., 2017). Research on wildfires in the Southern Great Plains indicates that large wildfire events are increasing in frequency (Lindley et al., 2019). Between 1992 and 2015 there were 1,698,835 wildfires in the U.S., of which 175,222 were wildfires averaging over 200+ hectares within the Southern Great Plains (Nagy et al., 2018). Furthermore, 50% of all wildfires in the continental U.S. occurred in the Southern Great Plains region over the past couple of decades (Donovan et al., 2017). The increased frequency and severity of fires, especially human induced wildfires, can result in adverse ecosystem changes, such as an increased likelihood of invasive plant and woody species infestations, adverse soil impacts, adverse effects on insect and bird species, and decreased plant species richness (Deák et al., 2014; Gordjin and O'Connor, 2021; Stavi, 2019; Zavala et al., 2014).

The growing impacts of wildfire due to land use and climate change and the resulting financial consequences have been well highlighted and described in the popular media. However, a majority of the media attention has focused predominately on the wildland-urban interface (WUI) in forested and mountainous regions of the U.S., which accounts for 50 to 95% of firefighting costs (Gude et al., 2008; Steelman, 2016). Nevertheless, an increase in wildfire frequency and intensity has threatened the safety of rural and agricultural communities in the Southern Great Plains (Steiner et al. 2018), where many states in this region lack adequate resources to deal with increased wildfire risk (Donavan et al., 2017). Agricultural communities, including farmers and ranchers, face production, property, health, environmental and economic risks from wildfires (Corrieri et al., 2019; Kabeshita et al., 2023). Studies of wildfire examining impacts on agriculture and agricultural communities is growing, including examinations of rangeland impacts, effects on livestock, health risks to farmers and ranchers, impacts on agricultural food production, and land management aspects (e.g. Corrieri et al., 2019; Kabeshita et al., 2023; Rethorst et al., 2018; Tidwell et al, 2013). However, there still exists a need for more studies examining farmers' and ranchers' wildfire experiences, perceptions and impacts on their operations to better understand the agricultural impacts across the U.S. in different environments.

The goal of our paper is to examine farmers' and ranchers' experiences and perceptions about wildfire in the Southern Great Plains. More specifically, we examine farmer and rancher experiences and perceptions about wildfires in southwest Kansas, western Oklahoma and the Panhandle of Texas. We collected primary data using semi-structured interviews of farmers and ranchers in the study region. We provide a quantitative descriptive assessment of the semi-structured interviews and statistically examine farmers' perceptions about wildfire frequency and intensity. The information and findings here can help guide outreach, extension and educational efforts targeted to policymakers, rural municipalities, and outreach organizations, helping them to better understand the challenges and issues facing agricultural producers due to increased fire incidence and severity in the U.S. and more broadly in similar prairie and savannah agricultural landscapes around the world.

2. Background on Wildfire and Agriculture Landscapes

Wildfires on agricultural landscapes can have a myriad of impacts across the landscape, on ranches and farming operations, and in the rural communities impacted by them. In agriculture, wildfires are most often associated with impacting ranching and livestock operations, particularly in the U.S. Brunson and Tanaka (2011) explain that a significant impact on ranchers and livestock producers from wildfire is loss of forage, feed opportunities, and livestock. Wildfire may also result in an increase in invasive species on rangeland, pasture and grasslands used for grazing, but ranchers have learned to adapt production systems to utilize some of these in their forage mix (e.g. cheatgrass). When additional forage opportunities are not available due to wildfire, economic impacts on ranching and livestock production are likely to be more severe (Brunson and Tanaka, 2011). This situation can be exacerbated if federal regulations further restrict foraging opportunities through restricted use of public lands after a wildfire or limits are placed on emergency grazing opportunities (McCormick and Wuerzer, 2016).

Animal losses can be significant too. Cowled et al. (2022) report that unprecedented bushfires in 2019 and 2020 in Australia resulted in the loss of between 56,000 and 69,000 head of livestock in New South Wales, Victoria and South Australia. While this was a small percentage of total livestock in the region at the time of the fires, it heavily impacted the economic livelihood of a small number of producers. Losses for operations that experienced fire during this period ranged from $200,000 to $725,000 compared to about $30,000 to $130,000 for operations that were not directly impacted by the fires. Wildfire can further influence decision-making related to livestock and ranch management. Kobayashi et al. (2010) find that expanding herd sizes with increased risk of wildfire that makes production less favorable may not be economically warranted, especially for smaller producers. In addition, they find in their model that ranchers and livestock producers facing less favorable production conditions may not be privately incentivized to reduce fuel loads on their land.

Other impacts to consider on ranchers, livestock producers, and local agricultural communities include lost animals, damage to fencing, damage to local infrastructure (e.g. power poles), property damage, rehabilitation and firefighting costs, lost wildlife, recreational impacts, loss of human life and health impacts, increase in invasive plant species, amongst others (Brunson and Tanaka, 2011; Kabeshita et al., 2023). Invasive species and woody encroachment (e.g. eastern red cedar) can further increase the risk of wildfire spread and its impacts (Cahill, 2022; Twidwell et al., 2013).

Wildfire can have an impact on farmers and crop producers. Kabeshita et al. (2023) found that crop losses due to wildfires were highest in California, Oregon and Washington, with the indemnity amount being over $250 million for crops in these states in 2020 alone. In crop production systems, farmers use fire to manage crop residues. This practice can result in wildfires if burning of crop residue becomes uncontrolled, which may damage other crops under production or reduce soil productivity (Stavi, 2019; Tedim and Leone, 2020). In Galicia, Spain, Calviño-Cancela et al. (2017) found that the majority of wildfires on agricultural lands were the result of agricultural and vegetative management (55 to 63%), followed by arson and similar activities (12 to 18%). Wildfires can impact crop productivity. Behrer and Wang (2022) find that low density smoke from wildfires can enhance crop yields, but increased smoke density as a result of more intense wildfires can actually be detrimental to crop yields. In Ghana, wildfires have changed local landscapes, resulting in shifts by small producers from perennial to annual crop production systems. Small farmers indicated they had experienced a decrease in crop yield, especially for perennial crops due to wildfires (Amissah et al., 2011). Kpienbaareh and Luginaah (2019) find that wildfires can result in food insecurity for small farmers in Ghana and long-term productivity losses due to soil degradation.

The overall impact on agricultural communities can be significant. This was apparent with the unprecedented wildfires in Australia in 2019 and 2020. During this time, bushfires burned over 3 million hectares of land, of which 820,000 hectares was agricultural land. The fires resulted in losses of over 3000 homes, 63,000 sheep and 8400 cattle. In addition, over 67,000 kilometers of fencing valued at over $600 million dollars and 3000 pieces of farm machinery valued at $180 million were lost (Wittwer and Washcik, 2021). Wittwer and Washcik (2021) found that wildfires in 2019-2020 had a significant impact on farm output in New South Wales, Australia, resulting in about $10 billion in welfare losses due to the bushfires.

Perceptions about wildfire frequency, risk and impacts vary across agricultural landscapes and rural communities. Ranchers in a Rangeland Fire Protection Association in Oregon had a high perception of wildfire risk due to significant investments in their operations and the significant history of wildfire across the state (McCormick and Wuerzer, 2016). Similar results were found for livestock producers surveyed in South Australia in 2014 (Smith and

Thompson, 2015). Property owners surveyed at the wildland urban interface in Flathead County, Montana perceived a 14 to 16% likelihood that wildfire would damage their property, including vegetation and structures on the property, within the next ten years (Paveglio et al., 2016). A survey of residents in rural communities in Pend Oreille County, Washington, found that residents perceived negative impacts from wildfire in the county and that wildfire was not seen as a healthy component of the local landscape. In addition, on average, there was a low level of perceived support among residents for regulation of local property owners to manage lands in ways that would help mitigate wildfires (Paveglio et al., 2021). Saengawut et al. (2015) found that rural residents surveyed in three fire-prone counties across Arizona, California and New Mexico perceived wildfire risk (measured as the likelihood of fire occurrence) was very low, with the level of risk varying by resident age, length of residency, risk attitudes, level of preparedness and place attachment (Saengawut et al., 2015). Wolters et al. (2017) surveying residents in rural Washington found that direct experience with wildfire events, knowledge about wildfire preparedness, perceived risk of wildfire to their neighborhood, and proximity to a wildland area increased likelihood of participating in Firewise behaviors (e.g. general planning, community activities, property preparedness, etc.). Understanding these perceptions provides a potential indication of the perceived risk that producers may have, which has been shown to be a significant predictor of wildfire preparedness (McNeill et al., 2013).

International studies about perceptions and behaviors provide additional insight. A study in the Croatian Mediterranean focused on drivers of wildfire occurrence. In this study, farmers indicated that abandoned and overgrown agricultural land, including crop fields, was a significant wildfire risk in the area. They indicated the need for regulations to manage abandoned and overgrown crop land in order to reduce fuel loads and wildfire risk (Jajtić et al., 2019). A study of farmers in Côte d'Ivoire found that 79% of farmers correctly perceived the upward trend in wildfire frequency that confirmed by remote sensing in the norther part of the country. Perceived causes of fires were from the use of fire used for hunting, farm establishment and development of fire breaks. In addition, perceived impacts from wildfires included burning of crops, adverse effects on crop yields, property damage, and loss of human life (Kouassi et al., 2022).

Knowledge and community factors may impact perceptions and preparation for wildfires. In Australia, studies have focused on how social factors influenced preparedness within rural communities, as well as residents' wildfire awareness and knowledge of wildfire risk (McGee and Russell, 2003). These studies found that agricultural communities and residents with long standing associations and history in rural areas were better prepared than newer residents and those with smaller properties, due to a culture of self-resilience, previous experience with fire during farming, and social cohesion (McGee and Russell, 2003). Bates et al. (2009) found that knowledge about wildfires and associated mitigation measures increased resident's perceived behavior control, or ability to feel they can help mitigate impacts of wildfires at the wildland-urban interface (WUI). In addition, focusing on perceived behavior control to help control and mitigate wildfires in a community and for your own home was a strong predictor of behavioral intentions to actually do so (Bates et al., 2009). Integrating local knowledge and experience to help take account of the complex nature of wildfire risks can result in local efforts such as Rangeland Fire Protection Associations, which are partnerships between local ranchers and land management agencies, to help mitigate, adapt and increase resilience to wildfire across agricultural landscapes (Essen et al., 2023). These associations though are highly dependent on a build-up of social capital and cohesion in the local community (McCormick and Wuerzer., 2016).

Public support for mitigation practices to reduce wildfire risk are important for effective regulation and social capital development (McCormick and Wuerzer, 2016; Twidwell et al., 2013). There is some public support for using prescribed burning, livestock grazing, thinning, and mowing of rangelands to help mitigate wildfire risk (Brunson, 2008), but acceptability and support for these practices will likely be location and environment specific (Brunson and Schindler, 2004; Brunson and Tanaka, 2011). Adoption and use of fire as a management tool (e.g. prescribed burn) though can be strongly impacted by perceptions of legal liability for a fire that burns a neighbor's property, which is positively mediated by being part of a prescribed-burning association (Kreuter et al., 2021)

This study contributes to this growing literature by providing insight and knowledge about farmers' and ranchers' perceptions and experiences with wildfires in the Southern Great Plains. It provides new information about farmers' perceptions and experiences with wildfire and crop production, as well as perceptions of farmers and ranchers about increased frequency of wildfires in this region and the risk of another megafire event.

3. Data and Methods

3.1 Study Area and Sample

The Southern Great Plains encompasses Kansas, eastern Colorado, Oklahoma, eastern New Mexico and Texas. It is an area dominated by grasslands with dry and windy weather that provides a conducive environment for the spread of wildfires. Over time, the introduction of invasive species, woodier biomass, changing precipitation patterns, and extreme events such as higher regional temperatures have contributed to exacerbating the frequency and intensity of wildfires in this region (McKenzie et al. 2004; Brenkert-Smith et al., 2012; Steiner et al., 2018; Donovan et al., 2020; Harmoney, 2020; Agovino et al., 2021). A number of studies predict that the length of wildfire seasons will increase in the region and the overall frequency of wildfires will increase by as much as 150% (Donovan et al., 2017; Stambaugh et al., 2018; Edwards et al., 2019). In this context, 16 megafires, or fires over 42,600 hectares, have occurred in this region between 2006 and 2018, burning over 800,000 hectares in Kansas and in the panhandles of Oklahoma and Texas between 2016 and 2017 (Lindley et al 2019). For instance, on March 6, 2017, a wildfire burned over 485,000 hectares in Kansas, Oklahoma and Texas, resulting in the loss of thousands of head of cattle, thousands of kilometers of fencing, and homes (Rethorst et al., 2018). In Oklahoma alone, wildfires have burned an area of 301,530 hectares in 2018, making this state the 4th largest state in area burned by wildfires in the U.S. (Smith et al., 2022).

For this research, our study region (see Figure 1) is located in the Southern Great Plains (SGP) of the U.S., and consists of 14 counties in southwestern Kansas, 14 counties located in the western part and panhandle of Oklahoma, and 15 counties in the northern panhandle of Texas.[1] This region is a mosaic of grasslands with significant amounts of agricultural production that include dryland and irrigated crop production as well as livestock and rangeland production (Boryan et al., 2011). The three states represented account for 30% of U.S. cattle production, with the value of agricultural activity exceeding $60 billion (of which roughly 60% is from livestock production) (USDA-NASS, 2017). The study region also has the highest amount of land enrolled in the Conservation Reserve Program (USDA-FSA, 2020). On average, agricultural

[1] Counties included Barber, Clark, Commanche, Ford, Grant, Gray, Haskell, Kiowa, Meade, Morton, Pratt, Seward, Stanton and Stevens in Kansas; Alfalfa, Beaver, Beckham, Cimarron, Custer, Dewey, Ellis, Harper, Major, Roger Mills, Texas, Washita, Woods and Woodward in Oklahoma; and Carson, Dallam, Gray, Hansford, Hartley, Hemphill, Hutchison, Lipscomb, Moore, Ochiltree, Oldham, Potter, Roberts, Sherman and Wheeler in Texas.

producers in the study region have farmed for 25 years, have 316 hectares of cropland, raise 463 head of cattle, and are 59 years of age. Thirty-five percent of producers and operators are female, and approximately 58% have employment off-farm (USDA-NASS, 2020). There does exist significant heterogeneity across agricultural operations examined with respect to these and other characteristics, as well.

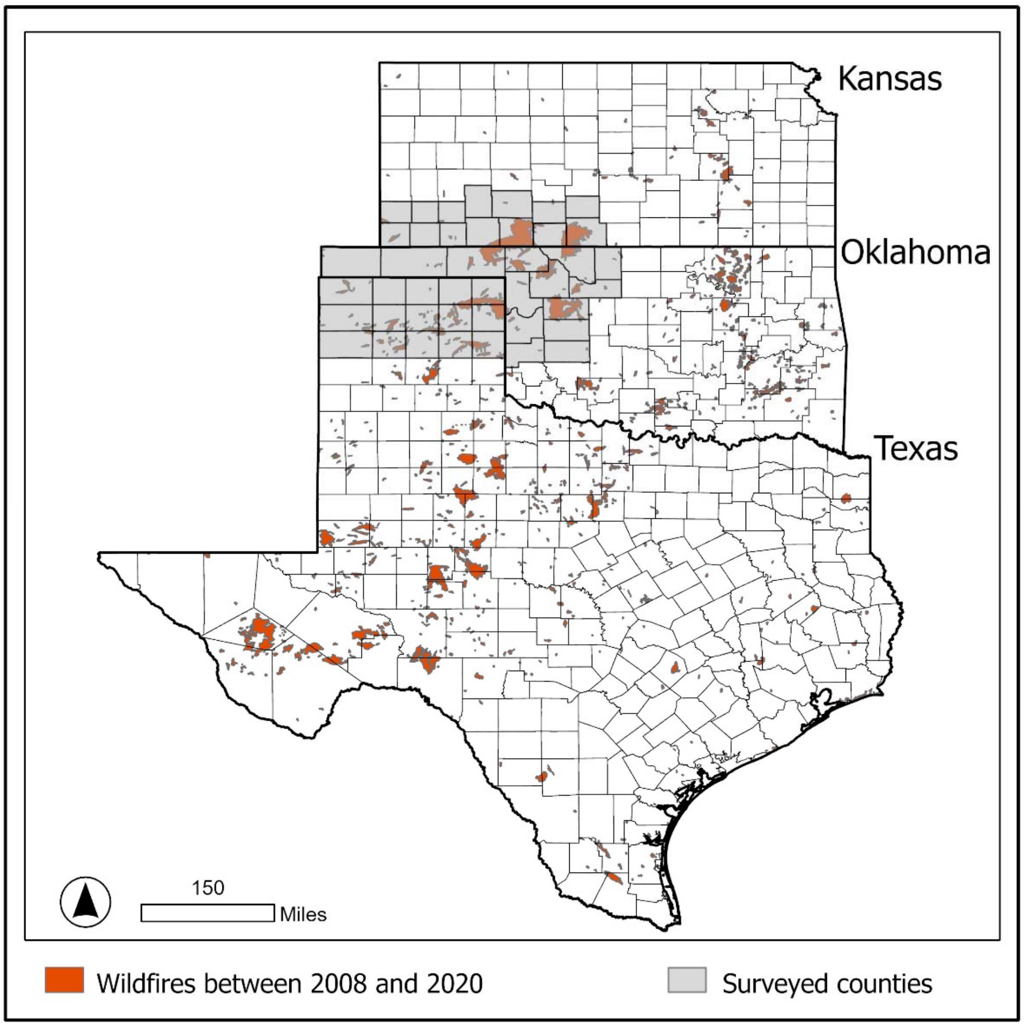

Figure 1: Study Region, Surveyed Counties and Wildfires in the Study Region from 2008 to 2020. (Wildfire Data Source: MTBS, 2022)

3.2 Semi-Structured Interviews

This paper draws upon data collected from semi-structured interviews conducted in March 2020 in and around 8 counties within the study region (Barber, Clark, Seward counties in KS; Beaver, Texas and Woods counties in OK; and Ochiltree and Lipscomb counties in TX). Local Extension personnel working directly with a variety of agricultural producers in each county provided initial assistance in identifying potential participants. The research team then contacted the producers directly by phone to arrange interviews and obtained additional participants for the study through snow-ball sampling (Kirchherr and Charles, 2018). Producers had operations that usually spanned multiple counties across those indicated within the study region above.

Teams of two researchers interviewed farmers and ranchers at a centralized location in each county listed above (e.g. a hotel conference room, public library), at the farm, or over the phone. We offered each participant $50 for completing the interview to help cover travel costs and to compensate them for their time. Using a semi-structured interview questionnaire that included both closed and open-ended questions in sequential order, our research team aimed to ensure that we covered the topics of interest during the interview, had sufficient comparability of responses across our participant interviews; and to provide flexibility that would allow for dialogue during the interview (Brinkmann, 2014; Kallio et al., 2016; Longhust, 2016; Starr, 2014). We conducted all interviews following protocol approved by the Human Subjects Institutional Review Board at Kansas State University.

The interview questions asked about farm characteristics, engagement in conservation programs and practices, general perceptions about wildfire occurrences, and experiences with wildfire on their operations, including frequency, damages, resources available to combat and recover from wildfires, and land management practices they use to mitigate wildfire risk. Participants were invited to clarify, explain, or provide further detail when appropriate following each question. Researchers maintained notes of participant responses for all interviews and recorded and transcribed interviews with participant permission. The data collection effort yielded 78 completed interviews, of which 72 were usable for the analyses and assessments conducted here. Six of the interviews were not used because the respondents had not owned land within the past 10 years, the interviews were incomplete (e.g. due to time constraints imposed by the participant), or the participant was not involved in agricultural production in the area (e.g. fire chief, or just moved to the area). Notes from all completed interviews were compiled into a central data matrix.

3.3 Sample Make-Up and Representativeness

Descriptive Statistics of interview respondents are provided in Table 1. In addition, these statistics are compared with population level statistics for the study region (see footnote 1 for counties included) based on the 2017 Agricultural U.S. Census. As seen, the interviewees had been farming for about 28 years on average, about 13 years longer, on average, than farmers in the region. Farm size is much larger than the average, but this is not unexpected, as many of the respondents operated large commercial size operations, a primary interest in developing our sample. In addition, given the large standard deviation there is a large range in the sizes of farms within our sample. About 40% of the farms had less than about 200 hectares of crop land. Overall, our sample of respondents is more likely representative of medium to large agricultural operations in the region. The Agricultural Census includes very small producers, hobby farmers, and retirees, which can make up a considerable percentage of farmers in the region, given the broad definition of farmers used by the U.S. Department of Agriculture. In addition, it should be recognized that many farmers had farmland that they operated in other counties and other states in the study region. Our sample had about 1.6 times as many head of cattle than the average agricultural operation and was less representative of female owners and operators (7% in our sample vs. 35% in the population). The average age of farmers was similar (61 years of age in ours ample vs. 59 years of age in the population), with the interviewees being slightly older. On average, interviewees more often did not work off the farm (42% in our sample vs. 59% in the population). Finally, 72% of the interviewees had a college education, which is contrasted with 28% in the general population of farmers in KS, OK and TX. Again, some of these differences are likely reflective of our sample being more representative of larger commercial operations, which tend to have a smaller number of female owner and operators, as well as having a relatively lower percentage being employed off-farm. Results from this study should be interpreted in light of these differences.

Table 1. Descriptive Statistics and Comparison with 2017 Agricultural Census Data (*n* = 72)

Variable	Description	Mean	Standard Deviation[a]	2017 Ag Census[b]
Experience	Years of farming experience	38.4	16.0	25.0
Crop Acreage	Total crop hectares	1188	1931	317
Head of Cattle	Total number of cattle owned	742	1959	464
Female	Binary (=1 if female and 0 otherwise)	0.07	0.06	0.35
Age	Years of age	61.5	10.8	58.7
Off-Farm Work	Binary (=1 if employed any time off the farm, 0 if none)	0.42	0.24	0.59
College	Binary (=1 if college education or higher, 0 otherwise)	0.72	0.20	0.28[c]

[a] For binary variables, the standard error is calculated as $p(1-p)$, where p is the mean of the binary variable.
[b] Source: USDA-NASS, 2020.
[c] Source: USDA-ERS, 2019.

3.4 Descriptive Statistics and Regression Analysis

While many of the close-ended questions yielded numeric data (e.g. age, number of acres under production, number of cattle), we also analyzed and coded participant open-ended responses to identify patterns and to generate binary variables to assess the presence of specific items or themes in the responses. A value of "1" indicates a threshold for defining that binary variable was met, while a value of "0" indicates the threshold was not met or that information was not present in the data for the given interviewee (de Block and Vis, 2019). We provide descriptive statistics for the binary and other variables used in the analysis in Table 2. This article focuses mainly on examining the quantitative data generated from our interviews to explore producer wildfire experiences and perceptions of wildfire activity in the study region through descriptive statistics and regression methods. We provide additional qualitative insights through selected quotes from interviewees to provide additional depth.

Table 2. Descriptive Statistics for Binary and Other Explanatory Variables

Variable	Definition	Mean[b]
	Wildfire Risk Perceptions	
Frequency	Binary variable equal to 1 if interviewee had indicated they had perceived an increase in wildfire activity over the past 30 years. (*N = 71*)	0.63 (0.23)
Megafire	Binary variable equal to 1 if interview had indicated it would be very likely that a megafire would occur in their area in the next 10 years. (*N* = 62).	0.63 (0.23)
	Perceptions of Factors Influencing Wildfire Risk	
No-Tillage	Binary variable equal to 1 if interviewee indicated that they perceived no-till farming increased risk of wildfires in their local area. (*N* = 70)	0.11 (0.10)
Poor Grazing	Binary variable equal to 1 if interviewee indicated that they perceived poor or inadequate grazing of land increased risk of wildfires in their local area. (*N* = 70)	0.11 (0.10)
Biomass on CRP	Binary variable equal to 1 if interviewee indicated that they perceived fuel loads on Conservation Reserve Program (CRP) land increased risk of wildfires in their local area. (*N* = 70)	0.26 (0.19)

Drought	Binary variable equal to 1 if interviewee indicated that they perceived that drought conditions increased risk of wildfires in their local area. (*N* = 70)	0.49 (0.25)
Wind	Binary variable equal to 1 if interviewee indicated that they perceived that high winds increased risk of wildfires in their local area. (*N* = 70)	0.36 (0.23)
Human Causes	Binary variable equal to 1 if interviewee indicated that they perceived causes related to human causes (e.g. chains on trucks, rail lines, welding of fences, etc.) increased risk of wildfires in their local area. (*N* = 70)	0.49 (0.25)
Invasive Plants	Binary variable equal to 1 if interviewee indicated that they perceived that invasive plant species increased risk of wildfires in their local area. (*N* = 70)	0.17 (0.14)
Land Conversion	Binary variable equal to 1 if interviewee indicated that they perceived that conversion of land from cropland to grassland or rangeland increased risk of wildfires in their local area. (*N* = 70)	0.04 (0.04)
	Past Wildfire Experience	
Experience with Fire	Binary variable equal to 1 if interviewee indicated they have experienced fire on their property. (*N = 72*)	0.79 (0.16)
Frequency of Past Fires	Frequency of fire on the property during a 10-year period, reported as decimal between 0 and 1. A value of 0 indicates never and a value of 1 indicates every year. A value of 0.2 is once every 5 years. (*N = 66*)	0.22 (0.32)
Years Since Last Fire	Number of years since the owner last experienced a fire directly on their property. (*N = 58*)	9.3 (11.2)
Neighbor Had a Fire	Binary variable equal to 1 if interviewee indicate a neighbor had directly experienced a wildfire. (*N = 72*)	0.81 (0.16)
Fence Damage	Binary variable equal to 1 if a fencing was damaged due to a wildfire. Conditional on interviewee experiencing a wildfire (*N* = 57).	0.74 (0.19)
Crop Lost	Binary variable equal to 1 if cash crops were lost due to a wildfire. Conditional on interviewee experiencing a wildfire (*N* = 57).	0.18 (0.14)
Livestock Lost	Binary variable equal to 1 if livestock was lost due to a wildfire. Conditional on interviewee experiencing a wildfire (*N* = 57).	0.33 (0.22)
Forage Lost	Binary variable equal to 1 if forage or hay was lost due to a wildfire. Conditional on interviewee experiencing a wildfire (*N* = 57).	0.49 (0.25)
	Wildfire Preparation and Mitigation	
Remove Cedars	Binary variable equal to 1 if red cedars trees are removed to prevent wildfires. (*N = 72*)	0.11 (0.10)
Rely on Local Fire Department	Binary variable equal to 1 if heavily or strongly rely on local fire department to prevent and combat wildfires. (*N = 72*)	0.57 (0.25)
Use Fire Breaks	Binary variable equal to 1 if use fire breaks on their land to prevent and combat wildfires. (*N = 72*)	0.14 (0.12)
Use Prescribe Burns	Binary variable equal to 1 if use prescribe burning practices. (*N = 72*)	0.57 (0.25)
Use Preventative Prescribe Burns	Binary variable equal to 1 if use prescribe burning practices to prevent wildfire on their land. Conditional on interview experiencing a wildfire (*N* = 41)	0.29 (0.21)
Land Change	Binary variable equal to 1 if mentions they use disking, tillage, grading or other land preparations are used to prevent wildfires. (*N = 72*)	0.57 (0.25)
Fire Equipment	Binary variable equal to 1 if the interviewee has sprayers, water tanks, fire truck, or water tankers on-farm to help combat wildfires. (*N = 72*)	0.51 (0.25)

Mow to Prevent Fires	Binary variable equal to 1 if the farmer mentions they specifically mows their land to help prevent wildfires. (*N = 72*)	0.29 (0.21)
Graze to Prevent First	Binary variable equal to 1 if the farmer mentions they specifically grazes their land to help prevent wildfires. (*N = 72*)	0.25 (0.19)
	Other Operational Characteristics	
Grazing and Grass Acreage	Hectares of land dedicated to pasture, forage production, rangeland and grassland. (*N = 71*)	2161 (3385)
Amount of Land in CRP	Hectares of land currently enrolled in the CRP program. (*N = 72*)	172 (379)

[a] Only farm characteristics not reported in Table 1 are reported here.
[b] The standard deviation is provided in parentheses.

For wildfire perceptions, we also generate two binary variables (Frequency and Megafire in Table 2) to conduct regression analyses. During the interviews we asked agricultural producers two specific questions about their perceptions about wildfire events over time. The first question was: *Compared to 30 years ago, has the frequency of wildfires in the region changed?* This question was used to assess if producers have perceived an increase in wildfire activity (i.e. occurring more often) over the past 30 years or as long as they have lived in the study region. We coded responses to this question as a binary variable (Frequency), with a "1" indicating a farmer or rancher had perceived an increase in the frequency of wildfires over the past 30 years, and 0 otherwise. The second question asked was: *How likely is it that another major wildfire, such as the ones in 2016 and 2017, will occur in the region this year or up to the next ten years*. The wildfires in 2016 and 2017 where the Anderson Creek and Starbuck fires that burned over 162,000 and 290,000 hectares in the study region, respectively (Rethorst et al., 2018). We were interested in assessing if producers perceived that another megafire, similar to these two fires, would occur in the next 10 years. We coded responses to this question as a binary variable (Megafire), with a response of "very likely" as 1 and 0 for any other response.

Given the discrete coding of the perception questions asked, we estimate two binary logistic regression models to assess what factors help to predict farmers' perceptions of wildfire events in the study region. Logistic regression is a widely used statistical model for regression models with binary dependent variables (Bergtold et al., 2010; Greene, 2012). We examine a number of categories of factors, including operational characteristics (crop area, acreage devoted to grazing and grass, head of cattle, amount of land in the CRP program), producer characteristics (years of experience, sex, being employed off-farm, and having a college education), and wildfire experience (frequency of wildfire on their land and years since last wildfire event). The predictors are supported by literature on agricultural producer and wildfire risk perceptions (Alló and Loureiro, 2020; Meldrum et al., 2019; Ramsey et al., 2019). Producers at each interview location faced similar wildfire experiences and challenges due to the proximity between their agricultural operations. These factors would likely result in observations being correlated due to unobserved factors for interviewees at each location where interviews took place. To correct for this during estimation of the binary logistic regression models we utilized a cluster-robust variance matrix (Cameron and Trivedi,2005) during estimation to obtain asymptotic standard errors for the parameter estimates. Clusters were defined using the centralized interview locations in the study region. Finally, we estimated marginal effects for each explanatory factor following Greene (2012). Given the smaller sample size, marginal effects are relatively robust to small sample bias, as evidenced by Bergtold et al. (2018). Asymptotic standard errors for the marginal effects are estimated using the delta method (Greene, 2012).

4. Results

We first present results related to agricultural producer wildfire experiences, followed by an analysis of factors predicting agricultural wildfire perceptions. We then follow this with results on agricultural producer preparedness and wildfire mitigation.

4.1 Agricultural Producer Wildfire Experiences

We specifically asked farmers and ranchers about their experiences with wildfire on their lands, including the frequency with which they experienced wildfire, as well as the associated impact and damages they experienced from wildfire on their agricultural operations. Of the 72 agricultural producers interviewed, approximately 79% have directly experienced wildfire on their land, but the frequency with which they have experienced wildfires varies. Seventy-seven percent indicated that they had experienced a wildfire about every 1 to 5 years; 9 percent indicated they experienced a wildfire event about every 6 to 10 years, and the remaining 14 percent of producers experienced wildfire less often or never. On average, agricultural producers interviewed experienced a wildfire event within the past 4.3 years on their land. Of the 57 agricultural producers that had experienced wildfires on their land, the impacts on their agricultural operations varied. Seventy-four percent of these producers indicated that they had fencing that had been damaged due to the wildfire, while 49% indicated they had lost grass needed for foraging or hay used for livestock feed. In addition, 18% of the producers indicated they had crop damage from wildfire, and 33% had experienced loss of livestock due to a wildfire event (Table 2).

The most often cited impact from wildfires was loss of forage and feeding opportunities for livestock. Lost forage can have a significant economic impact, reducing weight gain of livestock, increasing feed expenses, and a need to sell livestock early and/or at a lower weight, reducing revenue earned from livestock sales. Some producers indicated that when grass used for forage, feed and hay was lost, the land took several months to a year to become productive again due to soil erosion problems, re-emergence competition from weeds, and impacts from the fire on soil productivity, which can prolong the impact from the wildfire. Producers told us about these impact on their livestock operations:

> *"Well, I've only had one* [wildfire] *burn the entire ranch. I didn't even think that was possible, but it happened at the start of the wildfire* [in] *2017. … Cost me 30 miles of fence. And we lost all the grass at the time of the year were we needed grass. That all had to be shipped. And so it had several thousand dollars worth of damage just to us. Overall, to the county, is around $50 million."* (Interview, Clark County, Kansas)

> *"Well, I'd say we lost 90 to 95% of our grass, our home and everything in it, my writing office and everything in it and our guest house and everything in it*." (Interview, Ochiltree County, Texas).

This last producer had approximately 2331 hectares of grassland. Other producers told us:

> "*Well, for me, it burned 12 sections, which is 7000 acres and killed 68 cows. … Four buildings. Four trailers. Almost burned our house down."* (Interview, Lipscomb County, Texas)

> *"So consequently, the heat, wildfire damage is caused strictly by heat. And what it does to grass is heat. So that was a day of 9% humidity and it was really dry, so it burns down into the ground. … Plus we had grass coming, but it was weak because it had come out of a drought, so we killed a lot of grass out. That was our biggest damage*" (Interview, Clark County, Kansas)

Another significant economic cost from wildfires experienced by many farmers interviewed was damage to or loss of fences. Farmers indicated that it cost $4700 to $7500 to replace a kilometer of lost fence. Very few producers indicated they had insurance to cover lost fence directly, and one producer indicated many producers were not likely aware of insurance to cover losses of fencing due to wildfires. Across producers interviewed, producers mentioned the kilometers of fences lost to wildfires ranged from 15.3 to over 219 kilometers (over $1.5 million in loss) for a given operation. Two producers who talked about fencing losses, indicated:

> *"We had, maybe five, or six years ago, we had an excess of like 380,000 acres burned in multiple counties down here,... And the ironic thing on that is, what people really don't realize, what's the really killer on a grass fire, outside of if you lose livestock, yeah, that's big, but fences are the major killer. Here, fences cost $10,000 to $12,000 a mile. We've had producers that lost 50 miles worth of fence. Which, you're talking 50, you're talking a half million dollars to replace fences. People don't have that. Plus, you say, "Well, I could put in new fence." Well, you only got so many, when you had that huge acreage that burned, there aren't that many people that build fence.*" (Interview, Ochiltree County, Texas)

In some of our interviews, farmers and ranchers experienced heavy losses due to megafire events in the study region. One producer, who was particularly impacted by the Starbuck Fire in 2017, indicated that over 95% of their approximately 3300-hectare ranch burned, which was primarily grazing land for the livestock. The producer lost over 100 registered red angus cows, 40 replacement heifers, and wooden livestock corrals, as well. Another farmer impacted by the Starbuck fire in Kansas in 2017, indicated all but 10 hectares of their ranch burned. The fire killed all grasses for forage and feed and even clean burned all the wheat stubble on the operation, resulting in greater water erosion on those fields. In addition, the farmer lost 153 kilometers of fence and had to repair an additional 32 kilometers of fence. The producer also lost over 1200 head of livestock and those that did survive were traumatized and stunted, having to be sold at a discount at market. It took over 3 years for the farmer to rebuild their herd. Another farmer commented about the economic impact of loss of their registered herd and genetic stock built up in that herd.

> *" We had a registered herd of Red Angus and we lost pretty much all of our registered cattle. We didn't lose our bulls, thank goodness. ... we opted not to restock. At my age... It had taken us 10 years to get that registered herd going ... On cattle losses and grazing losses and we recovered some value there, ... And, on a commercial herd, they paid 70% of market value on a cow. And it was good but when you're running a registered herd, those values are just... We had a lot of*

> *money invested in that registered herd and so that recovery was just a drop in the bucket compared to the value we had. But that's the way the program goes."* (Interview, Lipscomb County, Texas)

Another producer commented on the impact of the wildfire to their crops.

> *" I've got some land up Northwest of town here, and of course I didn't really go look at it because it was in green wheat. So I didn't think anything about it. And I was focused trying to get fences and things put up. And so I didn't look at it until later on in the spring, and I went to spray it because we had a rust problem. ... But when I got out there on the sprayer and I was like, "There isn't anything here." It was just extremely thin ... But I am no-till. And so I had all that wheat stubble on there. And so I think that fire burnt across that field. It didn't kill everything, but it killed enough of it. ... You wouldn't normally think of green wheat as being susceptible to fire. But it was because I had so much stubble there that burnt."* (Interview, Clark County, Kansas)

4.2. Perceptions of Wildfire Frequency

Of the 71 producers who responded to the question about wildfire increasing in frequency in the region over the past 30 years, approximately 63% indicated that they did perceive an increase in wildfire frequency (Table 2). We asked interviewees what factors may be contributing to this increase in frequency and risk of wildfires. As reported in Table 2, the two most common factors cited by 49% of producers interviewed were drought conditions and human causes (e.g. escaped fires used for land management, such as prescribed burns, welding of fences, downed power lines, use of chains on trucks, cigarettes, and railroads). Thirty-six percent of producers indicated that high winds increased wildfire risk, while 26% identified an increase in fuel loads on agricultural lands, including land enrolled in the Conservation Reserve Program, as a contributing factor. Other causes that resulted in an increased perception of frequency and risk included invasive plant species (17%), especially woody species, no-tillage practices (i.e. leaving crop residues on the soil surface of crop fields) (11%), poor grazing practices (11%), and land conversion (e.g. from cropland to grassland) (4%). Some of the farmers' comments on these factors included:

> "*Oh, a higher population. More people using cutting torches, cigarettes, campfires, fireworks, dragging chains, more miles of electrical line is under stress all the time and can malfunction in a 60-mile-an-hour wind. … Increase in feral brush, primarily juniper and cedar. … Then an increase in CRP acres. The final cause, in my estimation, is an increase, or a change, in climate or weather or both. I know that there's a lot of argument about whether that's man-caused global warming or just a natural climate variation, but there has definitely been a change in weather and climate in the last 30 years it seems to me*." (Interview, Ochiltree County, Texas)
>
> *"All these fields that are CRP were wheat and they would have had some firebreaks. We don't have no firebreaks anymore.... We had a wildfire, well it was kind of a wildfire, a week or so ago and the only kind of break they get* [is] *the county comes out there with the road grader and makes two or three passes in a pasture that's got grass three foot tall. And if the wind's blowing 60 miles an hour, it's pretty hard to stop it. … I would say that's what's causing most of our fires is there's just no breaks."* (Interview, Woods County, Oklahoma)
>
> *"Well, to me mother nature has a way of resetting itself and we've had a lack of fire since people have moved into this area, built fences, put cattle in here. The old prairie fires that we used to have when we had the buffalo, I'm sure there were large scale fires back then and they were able to burn and they would burn to a point and when they ran out of fuel and then they quit. And so that was pretty common. We've taken fire out of the ecosystem. And the '17 fire that's out here, the Starbuck, the 283 fire, we had a lot of grass and some cedar and things like that, eastern red cedar and then the fire they had down in Dewey County, I believe it was in '18, I mean that land was covered with cedar, a lot of it so you're adding a lot of fuel. I think, the lack of management, particularly prescribed burning over the last 50 years has played into this, in my opinion."* (Interview, Beaver County, Oklahoma).

Estimation results for the binary logistic regression models examining producer wildfire perceptions (Frequency Model) are reported in Table 3. The McFadden Pseudo R^2 for the regression was 0.19. Of the factors examined in the regression, two of the factors had a statistically significant effect that was different from zero. The marginal effect for the variable, Years Since the Last Fire, was – 0.0060, indicating for each year that passes without a wildfire occurring on a farmer's or rancher's property, the likelihood they perceive an increase in the frequency of wildfires decreases by 0.60%. Thus, a farmer who has experienced a wildfire more recently on their land, more likely perceives that the frequency of wildfires has increased. On the other hand, given the frequency of actual wildfire events experienced by producers was not a statistically significant predictor, it may be the case that producers who have just experienced an event more recently may be more likely to potentially overstate their perception of the frequency of wildfire events.

Table 3: Binary Logistic Regression Model Results for Examination of an Increase in Past Wildfire Frequency (Frequency) and Likelihood of another Major Wildfire Event (Megafire) with estimated marginal effects.

	Frequency Model		Megafire Model	
Variable (Predictor)	**Parameter Estimate[a]**	**Marginal Effect[b]**	**Parameter Estimate[a]**	**Marginal Effect[b]**
Constant (Intercept)	0.83 (1.64)	---	-0.45 (0.72)	---
Kanas Resident[c]	0.091 (0.86)	0.016 (0.15)	-1.88** (0.78)	-0.33** (0.13)
Oklahoma Resident[c]	1.16 (0.98)	0.20 (0.17)	-0.67 (0.50)	-0.11 (0.078)
Past Wildfire Experience				
Frequency of Past Fires	-0.56 (1.33)	-0.10 (0.24)	6.05** (2.80)	1.08** (0.49)
Years Since Last Fire	-0.034* (0.019)	-0.0060* (0.0034)	0.013 (0.031)	0.0023 (0.0056)
Operational Characteristics				
Crop Acreage	-0.00040 (0.00018)	-0.000072 (0.00032)	-0.00062 (0.00059)	-0.000095 (0.00013)
Grazing and Grass Acreage	0.00040 (0.00069)	0.000072 (0.00012)	-0.00022* (0.00011)	-0.00039** (0.00020)
Amount of Land in CRP	0.0013** (0.00063)	0.00023** (0.00011)	-0.00062 (0.00059)	-0.00011 (0.00011)
Head of Cattle	-0.0020 (0.00017)	-0.00035 (0.00031)	0.0021 (0.0014)	0.00037 (0.00025)
Producer Characteristics				
Experience	-0.021 (0.018)	-0.0037 (0.0032)	0.029** (0.014)	0.0052** (0.0025)
Off-Farm Work	1.53 (1.06)	0.28 (0.19)	0.60 (0.80)	0.11 (0.14)
College	-0.44 (1.05)	-0.078 (0.19)	0.41 (0.56)	0.073 (0.096)
Fit Statistics				
Log-Likelihood	-33.87		-30.49	
McFadden R^2	0.19		0.22	
N^d	64		59	

Note: ***,** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

[a] Robust standard errors are presented in parentheses. Estimates represent robust standard errors estimated using a cluster-robust variance matrix approach following Cameron and Trivedi (2005). Clusters are defined using centralized interview locations identified in Figure 1.

[b] Marginal effects are estimated as partial average effects following Greene (2012). Asymptotic standard errors were estimated following Greene (2012) are presented in parentheses.

[c] Kansas Resident and Oklahoma Resident are binary variables equal to 1 if the interviewee resides in that state.

[d] The number of observations for the two regression models differ due to missing data.

The other statistically significant predictor in the Frequency Model in Table 2 was the Amount of Land in CRP. The marginal effect of this factor was 0.00023, indicating for each hectare (acre) of land an interviewee has enrolled in CRP, the likelihood of a producer perceiving an increase in wildfire frequency was higher by 0.057% (0.023%). While the result is statistically significant it is relatively small. The significance of the effect could be due to a myriad of factors associated with CRP lands, including increased biomass production and fuel loads, as well as management restrictions potentially imposed by CRP contracts limiting grazing, mowing, and prescribed burning (Anderson and Stubbendieck, 2006). Concern with both of these factors, for example, was expressed by a rancher in Oklahoma:

> *"There's two different types of CRP. There's the types of CRP that needs to be managed every three years by either fire, mowing, or grazing. I don't think that helps or contributes to wildfire. The CRP that's put in for 25 years that's total wildlife or whatever that you can't ever touch, I've got a bunch of that around me. Yes. That stuff there, I believe contributes to wildfire…It's just years and years of dead vegetation and they plant Indian Grass that gets eight foot tall, and they don't enforce you to clean the trees out of it because they don't want you on it. It just becomes out of control, in my opinion."* (Interview, Woods County, Oklahoma)

It should be noted though, that only 10% of those interviewed perceived CRP as a direct factor contributing to wildfire risk. Most responses were nuanced and hinged on perceptions on how CRP land was managed. Another interesting finding was that acreage devoted to grazing and grass production was not a statistically significant predictor, given that a large portion of lands burned by wildfires are grasslands (Donovan et al., 2020). This result may be due to the large amount of grassland amongst producers in our interview sample, as well as being the dominant land use in the study region.

Of the 65 producers who answered the question about the likelihood of another megafire occurring within the next 10 years, 63% perceived that it was very likely. One farmer commented:

> "*Well, it could be very likely. In fact, it's kind of amazing that we don't have more than we do, really, with the number of acres in grass, and as dry as it can be, and then with the winds.*" (Interview, Texas County, Oklahoma).

Estimation results for the binary logistic regression model examining producer perceptions about the likelihood of another megafire event (Megafire Model) are reported in Table 3. The McFadden Pseudo R^2 for the regression was 0.22. The factors or predictors shaping perceptions about the likelihood of a large and significant wildfire or megafire event within the next ten years (Megafire Model) was distinct from the perceptions about changes in the frequency of wildfire events in the past. This difference is not unexpected as wildfire frequency may not directly coincide with severity or size of wildfires. There were four statistically significant predictors: being a Kansas Resident, Frequency of Past Fires, Grazing and Grass Acreage, and Experience. The likelihood of perceiving a megafire event is very likely to occur in the next decade was 33% lower for residents of Kanas than Texas, with no significant difference between Oklahoma and Texas (i.e. the marginal effect for an Oklahoma Resident relative to a resident in Texas was not statistically different form zero).

Farmers and ranchers that experienced wildfires more often, had a greater likelihood of perceiving that it is very likely a major wildfire event or megafire, such as the Starbuck Fire, would occur within the next ten years. About 80 percent of the producers interviewed have experienced a wildfire and over 75 percent experience one every 1 to 5 years, on average. The marginal effect for Frequency of Past Fires was 1.08, which may require some clarification for interpretation given its coding. The range of the variable for Frequency of Past Fires was between 0 and 1, with 0 being no occurrences and 1 indicating a wildfire occurs about once every year on average. A value of 0.5 indicates a respondent experienced a wildfire once every 2 years on average, while a value of 0.2 indicates a respondent experienced a wildfire once every 5 years on average. To interpret the marginal effect then, consider an increase in frequency by 0.1, or an increase in frequency by 1 additional wildfire every 10 years. This increase would increase the likelihood of perceiving another megafire within the next 10-year period by approximately 11%. For producers that experience wildfires more frequently, it may be the case that they perceive one of these will likely be a very large wildfire event or megafire.

Farmers and ranchers with more land in grassland, rangeland or used for grazing were less likely to perceive a megafire event being very likely to occur in the next decade. The factor had a marginal effect of -0.00039, indicating for each additional hectare (acre) of grazing and grass land, the likelihood of perceiving a megafire being very likely to occur in the next decade decreases by 0.096% (0.039%). While this may be relatively small in magnitude, an increase of 1000 hectares decreases the likelihood by about 10%. The average amount of grazing and grass land for our sample was 2161 hectares with a standard deviation of 3385 hectares. Interestingly, while not statistically significant, farmers with more head of cattle had a greater likelihood of indicating another megafire event was very likely, which may result due to the close connection that some producers have with their livestock (Rethorst et al., 2018). About 33 percent of producers interviewed had lost livestock to a wildfire. The remaining significant predictor was farm experience. The marginal effect for Experience was 0.0052, indicating that for each additional year of experience, the likelihood of perceiving that a megafire is very likely to occur in the next decade increases by 0.52%.

4.3 Wildfire Preparation and Mitigation

As seen in the prior sub-section, a majority of farmers and ranchers interviewed perceived that wildfire frequency had increased over the past 30 years and another megafire would likely occur within the next decade. Given the potential for an increase in frequency and intensity of wildfires, we asked farmers about how they manage their lands to help prevent and mitigate wildfires and the impact from wildfire events. Preparation and mitigation of wildfire on their land varied greatly across the producers interviewed.[2] A few producers expressed a belief that efforts to protect from, prevent, or obtain help with wildfires that occur on their land was futile. One producer simply stated "*Definitely, nothing I can do*." (Interview, Hemphill County, Texas) when asked about what practices they could do on their operation to help prepare for or mitigate wildfires. Other producers indicated:

> "*Well, there's really not just a heck of a lot you can do when you have open range land. We're running our operations so they have plenty of forage and that's the name of the game. And, so you just run that risk. You can put up fire guards and there's oil field roads all over the place, but they don't help much when the wind's blowing 40 miles an hour... when you're trying to increase your forage production on your range land, you just run the risk of having fires. And when it gets on fire, you just got to get out of the way*." (Interview, Lipscomb County, Texas)

> *"That's a good question. What've somebody else answered? What are the others' answer? Because there's not much you can do. I'll say this, on a fire like 2017, or a fire like there was in November, or a fire like they had in Oklahoma on Saturday, there is no prevention. There is none. The only thing you can do is plant a wheat field 200 yards wide and that's it. There's nothing else you can do. If a highway right-of-way that's 60 feet wide won't stop a wildfire, what can I do? There's no prevention for it."* (Interview, Hemphill County, Texas)

Other producers who indicated that they did not engage with wildfire mitigation efforts responded in somewhat similar ways, often describing wildfires as 'unstoppable' given the environmental conditions of the local area.

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[2] Given that many farmers operated farm land across multiple counties and even across state lines within the study region, we did not specifically analyze differences across county or state boundaries within the study region.

This contrasted with the majority of producers that took a more active role in trying to suppress and mitigate wildfires on their lands through removal of red cedar trees (11%) and other woody biomass, use of fire breaks (14%), use of prescribed burns (for wildfire prevention) (17%), active land management practices (e.g. disking, tillage, grading of land) (57%), having fire-fighting equipment on-hand (e.g. sprayers, water tanks, fire trucks) (51%), mowing to reduce fuel loads (29%), and actively grazing to reduce fuel loads (25%) (Table 2).

Of the farmers interviewed, 57% percent indicated that they heavily relied on local and volunteer fire departments to assist with suppressing wildfires. Many of the producers indicated that they had good and effective local fire departments. It can take time for local and regional fire department help to organize and arrive due to long travel distances in the study region. Describing the response from the fire department, for example, a producer explained,

> "*Ninety percent of the time if there was a fire and you call the fire department, we usually have it contained before they get there and then all we get is the $500 bill"* (Interview, Texas County, Oklahoma).

Wildfire on the plains can burn and move across the landscape quickly (Noble, 1991). Twenty-nine percent of producers interviewed indicated that they relied on help from neighbors for being prepared and suppressing wildfires.

Many farmers had insurance for crop and livestock damages, but less have it for loss of grasses and fence, when damages occur due to wildfire. Many producers indicated they rely on government assistance (e.g. disaster relief, helping to cover cash crop, livestock and grass/forage losses, conservation program support, etc.), as well as assistance from neighbors, through emergency grazing options and donated hay in order to feed livestock. Once producer commented:

> *"Well, I had insurance on my home and I had some insurance on my fences. I got donations from various sources, including Farm Bureau and other volunteers, who just collected money and gave it to us. I don't even remember who they were. … Some of it was money. Most of it was in the form of fencing material, hay, salt, salt blocks. I guess that'd be it. Clothes and furniture and things like that. Our church was very helpful.*" (Interview, Ochiltree County, Texas)

While this provides some relief, one farmer indicated it does not cover all the loss, as a governmental program he took part in only covered 70% of the market value for a cow, not the registered value. Another producer indicated at times that the federal government has helped to cover up to 70% of fence costs and some cost of loss grasses and livestock feed during large wildfire events.

5 Discussion

Farmers and ranchers have experienced losses due to wildfire across the Southern Great Plains. Losses can be quite varied, with farmers and ranchers experiencing losses to crops, livestock, fencing, buildings, forage, amongst other sources. As highlighted by Brunson and Tanaka (2011), a potentially significant impact of wildfires in grass- and rangeland areas is loss of forage and feeding opportunities, which can result in significant economic costs for these operations. In addition, as experienced in Australia, another significant economic cost of wildfires for these operations is lost fencing (Wittwer and Washcik, 2021). Of the 72 producers interviewed in our study 79% have had a direct experience with wildfire on their operation, with 74% experiencing damage to and loss of fencing and 49% experiencing loss in forage and feeding opportunities for their livestock. Making sure that flexibility with emergency grazing regulations on public and conservation lands (e.g. CRP) is provided locally to allow for needed grazing opportunities and access to forage may help to reduce risk exposure and economic losses related to forage and livestock impacts from wildfires.

While some of these losses may be covered through insurance or government aid, which some producers interviewed received and felt was adequate, other losses may not be sufficiently covered. For example, loss of a herd may be recuperated partially through insurance claims and government assistance, but the built-up value in genetic stock lost due to the loss of a herd may be much more significant and may likely not be recoverable. In addition, damage and losses to fencing may not be fully covered by government assistance programs and producers may not have insurance for fencing losses as mentioned by interviewed producers. Whittaker et al. (2012), examining vulnerability of resident and agricultural producers in southeastern Australia, found that many agricultural producers were uninsured or underinsured for damage to certain farm assets, including fencing, livestock, and farm structures (e.g. sheds). Producers in their study indicated they could not afford comprehensive insurance, forgot to reinsure, undervalued their assets, and/or faced other economic pressures, such as drought. Underinsurance may be a result of a "ratchet effect" of vulnerability, where significant events prior to the wildfire, such as a severe drought, can leave fewer resources, particularly financial, to deal with or plan for the wildfire event, which may also occur less often (Pelling, 2003; Whittaker et al., 2012). Underinsurance in the U.S. may be exacerbated by higher premiums and exclusion from insurance markets due to wildfire risk. In California, agricultural producers have had a harder time obtaining coverage in areas with higher wildfire risk and have had to turn to the state's Fair Access to Insurance Requirements Plan (the state's insurer of last resort) (Kabeshita et al., 2023). Innovative solutions to help provide additional and affordable insurance to cover wildfire risk are likely or will likely be needed if wildfire frequency and intensity continue to increase. Watson et al. (2021) illustrate how the cost of insurance and the level of premiums can take account of wildfire mitigation and resilience efforts across a forested landscape to make them more affordable and cost effective. Such measures could be explored for similar insurance products that could be made available to agricultural producers in grassland landscapes. More accessibility to insurance may be an important factor in helping to avoid post-hazard economic stresses, as well (Siegel, 2016).

Disaster assistance programs through the U.S. Department of Agriculture may also assist with wildfire damages and losses (USDA-FSA, 2022). The U.S. Department of Agriculture, Farm Service Agency offers several disaster assistance programs that can help farmers recover from wildfire events, including the Livestock Forage Disaster Program, Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish, Noninsured Disaster Assistance Program, Tree Assistance Program, and Wildfires and Hurricanes Indemnity Program (USDA-FSA, 2022). Eight percent of the farmers indicated that they have worked on removing red cedar trees from their land to reduce fuel loads and wildfire risk. A number of these farmers where incentivized through programs offered by the USDA- Natural Resource Conservation Service to help with such removal. While producers interviewed in our study indicated receiving financial assistance from these programs, at times access to needed funds from these programs was significantly delayed or complicated to obtain, which has been found to be the case in other studies (Whittaker et al., 2012). Additional education and streamlining of access to disaster assistance programs through USDA may be needed to help better provide for the needs of agricultural producers in this and other regions to provided needed financial assistance soon after disaster strikes.

A focus of wildfire impacts on agricultural operations is on livestock, forage, and related losses, but impacts on crop production can be significant too (Kabeshita et al., 2023). As mentioned by producers interviewed in this study, crop productivity was impacted by wildfires, damaging winter wheat and reducing soil productivity, which has been evidenced in the literature (Kabeshita et al. (2023). These impacts may be partially covered by crop insurance but should be recognized by policymakers and researchers when thinking about the impacts of wildfire across agricultural landscapes.

Many of the producers interviewed perceived an increase in wildfire frequency over the past 30 years and that it was very likely that another major wildfire event or megafire would occur within the next decade. This is confirmed by empirical evidence from Donovan et al. (2017), who indicate that between 1985 and 2014, the total area burned in the Great Plains by large wildfires increased by 400%, with the western portion of the Great Plains seeing the highest increase in incidence. In addition, this confers with prior literature where interviewed and surveyed agricultural producers in wildfire prone areas are often aware of and concerned about wildfire risk. McNeil et al. (2013) indicate that perception of wildfire risk is a significant predictor of wildfire preparedness and use of mitigation practices. Wolters et al. (2017) found that increased wildfire risk perceptions increased adoption of Firewise behaviors, which includes preparedness and mitigation practice adoption and participation in regional and local fire associations. Many of the producers interviewed in our study indicated they had adopted some mitigation practices to reduce wildfire risk on their operations, but this did vary, with some producers thinking that such efforts may be futile.

Factors that positively predicted an increase in perceptions about wildfire frequency and risk included past wildfire experience, land enrolled in CRP, and farming experience. Increased education and outreach for wildfire mitigation to improve adoption of such practices may continue to focus on farmers with land enrolled in the CRP or have marginal lands not used directly in production (for better fuels management). In addition, evidence shows that adoption of mitigation behaviors and practices is heavily influenced by past exposure to wildfire events (Gan et al., 2015; Wolters et al., 2017). Thus, ensuring that timely and well-funded education and outreach opportunities are systematically provided in areas impacted by a recent wildfire event becomes important for managing and mitigating future wildfire risk.

Another potential way to help improve preparedness, mitigation, and pool resources to help suppress wildfires are fire protection associations (such as Rangeland Fire Protection Associations) that could bring together residents, producers, and organizations to help better manage wildfires, pool resources and reduce wildfire risk. A number of the agricultural producers interviewed participated in prescribed burn associations or were local volunteer firefighters, but not many indicated participation in local fire associations. Such associations may help local residents and producers better adapt to changing wildfire conditions, but these associations have to overcome challenges, such as social fragmentation that may inhibit group formation (Stasiewicz and Paveglio, 2018). McCormick et al. (2016) indicate how these associations can help coordinate local activities, improve wildfire response, and help with mitigation practices, where local resources for wildfire prevention and suppression are limited. Many of the producers interviewed relied on volunteer and local fire departments, local social and farm networks, and local equipment on-farm. In the event of a major wildfire event, producers indicated these resources can be strained due to limited equipment, limited funding for emergency response and preparedness, long distances to travel to help in combatting wildfire, and different levels of preparedness across different size operations. Local fire protection associations may provide one way to help alleviate these situations and reduce wildfire risk. Such associations and networks would need to be adequately funded and well organized in order to help combat wildfires more quickly and efficiently, improving emergency response and reducing damage and loss, which could be supported by local, state and federal agencies.

6. Conclusion

As wildfire frequency and intensity increase across the Great Plains of the United States and other similar landscapes worldwide in part due to climate change, it is important we better understand wildfire impacts across different agricultural landscapes. While this is being explored, documentation is more limited for farmer and rancher experiences in the Southern Great Plains of the U.S. This study helps to provide additional insights by examining the experiences and perceptions about wildfires of farmers and ranchers in southwest Kansas, western Oklahoma and the Panhandle of Texas in the U.S. About 80 percent of the agricultural producers interviewed had experienced a wildfire on their land, with almost the same percentage having done so within the past five years since being interviewed in 2020. Many of these producers had losses due to wildfire to their crops, livestock, forages, grazing lands, fences, buildings on-site, amongst other impacts. The information and findings from this study can be used to educate policymakers, the public and other interested parties about challenges and experiences faced by more rural residents and agricultural producers in order to better provide emergency management planning and funding to combat wildfires, provide needed disaster assistance (e.g. for fencing and lost forage), and guide educational efforts for disaster planning and preparedness.

This research provides an initial look at the scope of agricultural producers' experiences, preparedness and perceptions in a rural area of the Southern Great Plains of the U.S. While the findings may be applicable for similar plains landscapes, cultural, social, political and agricultural practices will likely differ in other areas. Additional research is needed across the Great Plains and the United States on wildfire impacts on different aspects of agricultural landscapes, as well as similar environments around the world.

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References

Agovina, M., M. Cerciello, A. Ferraro and A. Garofalo. 2021. Spatial analysis of wildfire incidence in the USA: the role of climatic spillovers. *Environment, Development and Sustainability* 23: 6084 – 6105.

Alló, M. and M.L. Loureiro. 2020. Assessing preferences for wildfire prevention policies in Spain. *Forest Policy and Economics* 115: 102145. Available at: https://doi.org/10.1016/j.forpol.2020.102145.

Amissah, L., B. Kyereh and V.K. Agyeman. 2011. Wildfires as dominant force driving farming systems in the forest transition zone of Ghana. *Ghana Journal of Forestry* 27(2): 52 – 65.

Anderson, B.E. and J.L. Stubbendieck. 2006. Conducting a prescribed burn on warm-season grass CRP sites. Publicaitons, etc. Nebraska Forest Service. 22. Availabe at: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1021&context=nebforestpubs.

Balch, J.K., B.A. Bradley, J.T. Abatzoglou and A.L. Mahood. 2017. Human-started wildfires expand the fire niche across the United States. *Proceedings of the National Academy of Science* 114(11): 2946 – 2951.

Bates, B.R., B.L. Quick and A.A. Kloss. 2009. Antecedents of intention to help mitigate wildfire: implications for campaigns promoting wildfire mitigation to the general public in the wildland-urban interface. *Safety Science* 47: 374 – 381.

Behrer, A.P. and S. Wang. (2022). Current benefits of wildfire smoke for yields in the U.S. Midwest may dissipate by 2050. Policy Research Working Paper 9953. Development Economics, Development Research Group, World Bank Group. Available at: https://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-9953.

Bergtold, J.S., A. Spanos, and E. Onukwugha. 2010. Bernouilli regression models: revisiting the specification of statistical models with binary dependent variables. *Journal of Choice Modeling* 3(2): 1 – 28.

Bergtold, J.S., E.A. Yeager, and A.M. Featherstone. 2018. Inferences form logistic regression models in the presence of small samples, rare events, nonlinearity, and multicollinearity with observational data. *Journal of Applied Statistics* 45(3): 528 – 546.

Boryan, C., Yang, Z., Mueller, R., Craig M. 2011. Monitoring U.S. agriculture: U.S. Department of Agriculture, National Agricultural Statistics Service, Cropland Data Layer Program. *Geocarto International* 26(5): 341 – 358.

Brenkert-Smith, H., P.A. Champ and N. Flores. 2012. Trying not to get burned: understanding homeowners' wildfire risk-mitigation behaviors. *Environmental Management* 50: 1139 – 1151.

Brinkman, S. 2015. Unstructured and semi-structured interviewing. *In*: The Oxford Handbook of Qualitative Research. P. Leavy (ed.). Oxford UK: Oxford University Press. pp. 277 – 299.

Brunson, M.W. 2008. Gauging the acceptability of fuels management: a matter of trust. Western Rural Development Center. *Rural Connections* 2(3): 2 – 4.

Brunson, M.W. and B.A. Schindler. 2004. Geographic variation in social acceptability of wildland fuels management in the western United States. *Society and Natural Resources* 17: 1-18.

Brunson, M.W. and J. Tanaka. 2011. Economic and social impacts of wildfires and invasive plants in American Deserts: lessons from the Great Basin. *Rangeland Ecology and Management* 64(5): 463 – 470.

Cahill, M. 2022. The range has changed: my viewpoint on living in the Sagebrush Sea in the new normal of invasives and wildfire. *Rangelands* 44(3): 242 – 247.

Calviño-Cancela M., M.L. Chas-Amil, E.D. García-Martínez, and J. Touza. 2017. Interacting effects of topography, vegetation, human activities and wildland-urban interfaces on wildfire ignition risk. *Forest Ecology and Management* 397: 10 – 17.

Cameron, A.C. and P.K. Trivedi. 2005. Microeconometrics: Methods and Applications. New York, NY: Cambridge University Press.

Cochrane, M. 2019. Burning questions about ecosystems. *Nature Geoscience* 12:86-87.

Corrieri, M.L., N.C. Roy, K.N. Rose-Davison and C.J. Roy. 2019. Wildfire associated health risks impacting farmers and ranchers. *Journal of Agromedicine* 24(2): 129 – 132.

Cowled, B.D., A. Hillman, M.P. Ward, H. Clutterbuck, M. Doyle, J. Webb Ware, M. Thomas, K. Plain, R. Barwell, M. Laurence, and C. Pfeiffer. 2022. The black summer bushfires: impacts and risk factors for livestock bushfire injury in south-eastern Australia. *Australian Veterinary Journal* 100(7): 306 – 317.

de Block, D., and B. Vis. 2019. Addressing the challenges related to transforming qualitative to quantitative data in qualitative comparative analysis. *Journal of Mixed Methods Research* 13(4): 503 – 535.

Deák, B., O. Valkó, P. Török, Z.S. Végvári, T. Hartel, Z. Schmotzer, I. Kapocsi, and B. Tóthmérész. 2014. Grassland fires in Hungary: experiences of nature conservationists on the effects of fire on biodiversity. *Applied Ecology and Environmental Research* 12(1): 267 – 283.

Donovan V.M., Wonkka C.L. and Twidwell D. 2017. Surging wildfire activity in a grassland biome. *Geophysical Research Letters* 44: 5986 – 5993.

Donovan V.M., Wonkka C.L., Wedin D.A. and Twidwell D. 2020. Land-use type as a driver of large wildfire occurrence in the U.S. Great Plains. *Remote Sensing* 12: 1869 – 1886.

Edwards B.L., Webb N.P., Brown D.P., Elias E., Peck D.E., Peirson F.B., Williams C.J. and Herrick J.E. 2019. Climate change impacts on wind and water erosion on rangelands. *Journal of Soil and Water Conservation* 74(4): 405 – 418.

Essen, M., S. McCaffrey, J. Abrams and T. Paveglio. 2023. Improving wildfire management outcomes: shifting the paradigm of wildfire from simple to complex risk. *Journal of Environmental Planning and Management* 66(5): 909 – 927.

Gan, J., A. Jarrett, and C.J. Gaither. 2015. Landowner response to wildfire risk: adaptation, mitigation or doing nothing. *Journal of Environmental Management* 159: 186 – 191.

Gordijn, P.J. and T.G. O'Connor. 2021. Multidecadal effects of fire in a grassland biodiversity hotspot: does pyrodiversity enhance plant diversity? *Ecological Applications* 31(6): e02391. Available at: https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1002/eap.2391.

Greene, W.H. 2012. Econometric Analysis. 7th ed. Upper Saddle River, NJ: Prentice Hall.

Gude, P., R. Rasker and J. van den Noort. 2008. Potential for future development of fire-prone lands. *Journal of Forestry* 106(4): 198 – 205.

Harmoney, K.R. 2020. Saline experimental range dormant season wildfire: short-term effect on forage production and plant composition. *Kansas Agricultural Experiment Station Research Reports* 6(3): https://doi.org/10.4148/2378-5977.7901.

He, T., B.B. Lamont and J.G. Pausas. 2019. Fire as a key driver of Earth's biodiversity. *Biological Reviews* 94(6): 1983 – 2010.

Jajtic, K., V. Galijan, I. Zafran and M. Cvitanović. 2019. Analysing wildfire occurrence through a mixed-method approach: a case study from the Croatian Mediterranean. *Erdkunde* 73(4): 3232 – 341.

Kabeshita, L., L.L. Sloat, E.V. Fischer, S. Kampf, S. Magzamen, C. Schultz, M.J. Wilkins, E. Kinnebraw, and N.D. Mueller. 2023. Pathways framework identifies wildfire impacts on agriculture. *Nature Food* 4: 664 – 672.

Kallio, H., A.M Pietilä, M. Johnson, and M. Kangasniemi. 2016. Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing* 72(12): 2954 – 2965.

Kirchherr, J. and Charles, K. 2018. Enhancing the sample diversity of snowball samples: recommendations from a research project on anti-dam movements in Southeast Asia. *PlosOne* 13(8): e0201710. https://doi.org/10.1371/journal.pone.0201710.

Kobayashi, M., K. Rollins and M.H. Taylor. 2010. Ranching, invasive annual grasses, and the external costs of wildfire in the Great Basin: a stochastic dynamic programming approach. Selected paper presented at the Agricultural and Applied Economics Association's 2010 Joint

Annual Meeting, Denver, CO, July 25 – 27, 2010. Available at: https://ageconsearch.umn.edu/record/61869/.

Kouassi, J.L., N. Wandan and C. Mbow. 2022. Exploring wildfire occurrence: local farmers' perceptions and adaptation strategies in central Cote d'Ivoire, West Africa. *Journal of Sustainable Forestry* 41(2): 173 – 192.

Kpienbaareh, D. and I. Luginaah. 2019. After the flames then what? Exploring the linkages between wildfires and household food security in the northern savannah of Ghana. *International Journal of Sustainable Development and World Ecology* 26(7): 612 – 624.

Kreuter, U.P., M.L. Treadwell, C.L. Wonkka, D. Toledo, D.L. Stroman, and D. Twidwell. 2021. Fighting wildfire with prescribed fire in the Southern Great Plains, USA: liability, regulatory and social factors. IGC Proceedings. Theme 1-1: Rangeland/Grassland Ecology. Available at: https://uknowledge.uky.edu/igc/24/1/28/.

Lindley, T. T., D. A. Speheger, M. A. Day, G. P. Murdoch, B. R. Smith, N. J. Nauslar, D. C. Daily, 2019. Megafires on the Southern Great Plains. *Journal of Operational Meteorology* 7 (12), 164-179, doi: https://doi.org/10.15191/nwajom.2019.0712

Longhust, R. 2016. Semi-Structured Interviews and Focus Groups. In: Key Methods in Geography. Eds. Clifford, N., Cope, M., Gillespie, T., and French, S. pp143-156

Meldrum, J.R., H. Brenkert-Smith, P. Champ, J. Gomez, L. Falk and C. Barth. 2019. Interactions between resident risk perceptions and wildfire risk mititgation: evidence from simultaneous equations modeling. *Fire* 2 (46): doi:10.3390/fire2030046.

McCarty, J.L., S. Korontzi, C.O. Justice and T. Loboda. 2009. The spatial and temporal distribution of crop residue burning in the contiguous United States. *Science of the Total Environment* 407(21): 5701 – 5712.

McCormick, K. and T. Weurzer. 2016. Ranching with fire and Rangeland Fire Protection Associations: livelihoods, resiliency, and adaptive capacity of rural Idaho. *The Western Planner*: 9 – 13. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2821101.

McGee, T.K. and S. Russell. 2003. "It's just a natural way of life …" an investigation of wildfire preparedness in rural Australia. *Environmental Hazards* 5: 1 – 12.

McKenzie D., Gedalof Z., Peterson D.L., Mote P. 2004. Climate change, wildfire, and conservation. *Conservation Biology*18(4): 890-902.

McNeill, I.M., P.D. Dunlop, J.B. Heath, T.C. Skinner and D.L. Morrison. 2013. Expecting the unexpected: predicting physiological and psychological wildfire preparedness from perceived risk, responsibility, and obstacles. *Risk Analysis* 33(10): 1829 – 1843.

Monitoring Trends in Burn Severity. 2022. Available at: https://www.mtbs.gov/.

Nagy, R.C., E. Fusco, B. Bradley, J.T. Abatzoglou and J. Balch. 2018. Human-related ignitions increase the number of large wildfires across U.S. ecoregions. *Fire* 1(1): https://doi.org/10.3390/fire1010004.

Noble, J.C. 1991. Behavior of a very fast grassland wildfire on the riverine plain of southeastern Australia. *International Journal of Wildland Fire* 1(3): 189 – 196.

Paveglio, T.B., T. Prato, C. Edgeley and D. Nalle. 2016. Evaluating the characteristics of social vulnerability to wildfire: demographics, perceptions, and parcel characteristics. *Environmental Management* 58: 534 – 548.

Paveglio, T.B., A.M. Stasiewicz and C.M. Edgeley. 2021. Understanding support for regulatory approaches to wildfire management and performance of property mitigations on private lands. *Land Use Policy* 100: 104893. https://doi.org/10.1016/j.landusepol.2020.104893.

Pelling, M., 2003. The Vulnerability of Cities: Natural Disasters and Social Resilience. Earthscan Publications, London.

Powell, J., B. Martin, V.J. Drietz and B.W. Allred. 2018. Grazing preferences and vegetation feedbacks of the fire-grazing interaction in the Northern Great Plains. *Rangeland Ecology and Management* 71(1): 45 – 52.

Ramsey, S.M., J.S. Bergtold, E. Canales and J.R. Williams. 2019. Effects of farmers' yield-risk perceptions on conservation practice adoption in Kansas. *Journal of Agricultural and Resource Economics* 44(2): 380 – 403.

Rethorst, D.N., R.K. Spare and J.L. Kellenberger. 2018. Wildfire response in range cattle. *Veterinary Clinics of North America: Food Animal Practice* 34(2): 281-288.

Saengawut, V.C., M.W. Brunson and P.D. Howe. 2015. Localized risk perception of wildland fire hazard. Proceedings of the 13th International Willand Fire Safety Summit and 4th Human Dimensions of Wildland Fire Conference, Boise, ID, April 20 -24, 2015. Available at: https://www.researchgate.net/profile/Voravee-Chakreeyarat-Saengavut/publication/301586373_Localized_risk_perception_of_wildland_fire_hazard/links/571b1ae208ae408367bc92bd/Localized-risk-perception-of-wildland-fire-hazard.pdf.

Siegel, F.R. 2016. Insurance as a mitigator of post-hazard economic stress: coverage and exclusions. *In*: Mitigation of Dangers from Natural and Anthropogenic Hazards. Switzerland: Springer.

Smith, H., K.M. de Beurs and T.M. Neeson. 2022. Evaluation of low-resolution remotely sensed datasets for burned area assessment within the wildland-urban interface. *Remote Sensing Applications: Society and Environment* 26: 100752. https://doi.org/10.1016/j.rsase.2022.100752.

Smith, B., and K. Thompson. 2015. Risk perception, preparedness and response of livestock producers to bushfires: a South Australia case study. *The Australlian Journal of Emergency Management* 30(2): 38 – 42.

Stambaugh, M.C., R.P. Guyette, E.D. Stroh, M.A. Struckhoff and J.B. Whittier. 2018. Future southcentral US wildfire probability due to climate change. *Climatic Change* 147: 617 – 631.

Starr, M.A. 2014. Qualitative and mixed-methods research in economics: surprising growth, promising future. *Journal of Economic Surveys* 28(2): 238 – 264.

Stasiewicz, A.M. and T.B. Paveglio. 2018. Wildfire management across rangeland ownership: factors influencing rangeland fire protection association establishment and functioning. *Rangeland Ecology and Management* 71(6): 727-736.

Stavi, I. 2019. Wildfires in grasslands and shrublands: a review of impacts on vegetation, soil, hydrology, and geomorphology. *Water* 11: 1042. https://doi.org/10.3390/w11051042.

Steelman, T. 2016. U.S. wildfire governance as social-ecological problem. *Ecology and Society* 21(4): http://dx.doi.org/10.5751/ES-08681-210403

Steiner J.L., Briske D.D., Brown D.P. and Rottler C.M. 2018. Vulnerability of Southern Plains agriculture to climate change. *Climatic Change* 146: 201 – 218.

Tedim, F., Leone, V. 2020. The dilemma of wildfire definition: what it reveals and what it implies. *Frontiers in Forests and Global Change* 3: https://doi.org/10.3389/ffgc.2020.553116.

Twidwell, D., W. E. Rogers, S. D. Fuhlendorf, C.L. Wonkka, D.M. Engle, J.R. Weir, U.P. Kreuter, and C.A. Taylor Jr. 2013. The rising Great Plains fire campaign: citizens' response to wood plant encroachment. *Frontiers in Ecology and the Environment* 11: e64 – e71, doi:10.1890/130015.

U.S. Department of Agriculture, Economic Research Service (USDA-ERS). 2019. Characteristics of principal farm operator households, by experience of operators, 2016. Farm Household Income and Characteristics. Available at: https://www.ers.usda.gov/data-products/farm-household-income-and-characteristics/.

United States Department of Agriculture, Farm Service Agency (USDA-FSA). 2020. Conservation Reserve Program Statistics, CRP Contract Summary and Statistics, Monthly Summary, October 2020. Available at: https://www.fsa.usda.gov/Assets/USDA-FSAPublic/usdafiles/Conservation/PDF/crp-summary-oct-2020.pdf.

United States Department of Agriculture, Farm Service Agency (USDA-FSA). 2022. Disaster Assistance Programs. Available at: https://www.fsa.usda.gov/programs-and-services/disaster-assistance-program/index.

U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2020. Census of Agriculture. 2017 Census Volume 1, Chapter 2: County Level. Available at:

https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/.

United States Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2017a. Census of Agriculture. Available at: https://www.nass.usda.gov/AgCensus/index.php.

Watson, N, S. Young, D. Carroll, D. Williams, J. Pollard, M. Christopher, F. Carus, D. Jones, S. Heard, B. Franklin, E. Smith, D. Porter. Wildfire resilience insurance: quantifying the risk reduction of ecological forestry with insurance. The Nature Conservancy. Available at: https://www.nature.org/content/dam/tnc/nature/en/documents/FINALwildfireresilienceinsurance6.27.21.pdf.

Whittaker, J., J. Handmer, D. Mercer. 2012. Vulnerability to bushfires in rural Australia: a case study from East Gippsland, Victoria. *Journal of Rural Studies* 28: 161 – 173.

Wittwer, G. and R. Waschwik. 2021. Estimating the economic impacts of the 2017-2019 drought and 2019-2020 bushfires on regional NSW and the rest of Australia. *The Australian Journal of Agricultural and Resource Economics* 65: 918 – 936.

Wolters, E.A., B.S. Steel, D. Weston, and M. Brunson. 2017. Determinants of residential firewise behaviors in Central Oregon. *The Social Science Journal* 54: 168 – 178.

Zavala, L.M., R. de Cells, and A. Jordán. 2014. How wildfires affect soil properties. *Geographical Research Letters* 40(2): 311- 332. Available at: https://publicaciones.unirioja.es/ojs/index.php/cig/article/view/2522.