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Review

Barriers to Prescribed Fire in the US Great Plains, Part I: Systematic Review of Socio-Ecological Research

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Abstract: Prescribed fire is increasingly being considered as a viable management tool by public and private land managers. Fully expanding prescribed fire use in a land management context, where it is an ecologically effective but not commonly applied tool, requires a comprehensive understanding of barriers that limit prescribed fire, especially in working rangelands of the North American Great Plains. While there is an emerging body of work on the perceptions of prescribed fire, there has yet to be a compilation of the research. We present a systematic review of the published literature on the perceptions and attitudes of land managers towards prescribed fire in the Great Plains in an effort to provide a social-ecological perspective on the issue. The aim is to share the methods used to assess social perceptions of prescribed fire in the Great Plains and regional distribution of these studies as well as to identify perceived barriers and limitations that restrict the use of prescribed fire by reviewing studies primarily located in the Great Plains ecoregion and focused on perceptions of fire. Surveys were the most commonly used method to assess social perceptions, with most research concentrated in the southern Great Plains. Barriers included a range of social, informational, practical, and regulatory concerns. This compilation of research synthesizes the current knowledge regarding social perceptions of and potential barriers to prescribed fire use so that fire practitioners and communities considering prescribed fire use for rangeland management have the most current information to make sound decisions.

Keywords: prescribed fire; landowner perception; rangelands; socio-ecological

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1. Introduction

As a natural resource management concern, wildland fire has been characterized as a *wicked problem* for which integrated social-ecological research is important for a thorough understanding. In ecosystems management, "wicked problems" are those without clear-cut solutions that require collaborative and adaptive processes that involve a diversity of stakeholders [1]. Rather than quick fixes, wicked problems related to wildland fire are best addressed with long-term improvements to systems [2], ideally from an integrated social-ecological perspective. In the US Great Plains, the exclusion of fire from fire-dependent ecosystems is the root of many wicked socio-ecological problems (e.g., [3], Table 4.2), and reducing this fire deficit with prescribed fire management is a common example of long term system improvement.

To develop a meaningful understanding of environmental dynamics in complex landscapes, researchers must consider 'natural' and 'human' systems as combined social-ecological systems. The delineation between the social and ecological fields is artificial and arbitrary [4]. The social-ecological systems approach replaces the idea that humans are simply external drivers in ecosystems and that natural spaces are only resources for humans [5]. Social-ecological research is an interdisciplinary approach that emphasizes the relationship between ecology and society. Research from the social-ecological perspective is more than the sum of social and ecological research done independently, but rather a third space that highlights the interconnectedness of the two [6].

Although forest ecosystems (and resources therein) have long been understood to be affected by fire, wicked problems of fire in rangeland ecosystems have also emerged. Rangelands are inherently social ecological systems that can be studied and managed as such [7]. Covering nearly 50% of land area worldwide [8], the majority of rangelands are working landscapes—land with economic and cultural values in addition to biodiversity conservation and ecosystem service delivery. Without consideration for both social and ecological components, attempts to change management practices on rangelands may not succeed [9]. Managing rangelands as social-ecological systems requires understanding feedbacks between ecosystem dynamics and how social perspectives modulate those dynamics via management decisions and practices.

Individually, social-ecological studies largely focus on local and place-based studies [6]. However, the scope of social-ecological research is broad, and considers climate change, biodiversity loss, livelihoods, poverty, policy, land use changes, water, and sociological and environmental justice [5]. Pluralism characterizes the social-ecological field [10]. Researchers that engage in social-ecological research often use methodologies, theories, and frameworks from their home field, e.g., economics, policy, psychology, sociology, etc. These methodologies, theories, and frameworks are often used in tandem with the social-ecological systems research framework based on resilience, adaptability, and transformability of a human community to challenges and changes [11]. This framework aims to unify the complex and evolving multidisciplinary knowledge of social ecology.

Fire & The Great Plains

Globally, the frequent, low-intensity fire regimes of many pre-settlement rangelands have been altered by changes in human land use [3]. In the central US, these alterations are typically characterized as either infrequent, high-intensity fires following encroachment of highly flammable *Juniperus* species into grassland in the south [12,13], alternatively, current-day fire exclusion and suppression in the northern Great Plains leaves these grasslands typically unburned [14].

As the impacts of fire exclusion have been realized worldwide, managers have sought to use prescribed fire to restore ecological function and ecosystem service delivery. Prescribed fire is the intentional application of fire to land for management purposes [15]. Prescribed fire provides several important services in rural landscapes and native prairie-dominated pastures, including reducing wildland fuels that could lead to wildfires [16], controlling woody invasion and non-native species [17,18], enriching habitat and forage for both wildlife and livestock [19,20], and enhancing native species diversity and heterogeneity in grassland communities [21].

Prior to Euro-American settlement of the Great Plains, fires of natural and human origin were not uncommon. Indigenous peoples who first called the Great Plains home used fire to remove old grass, promote new growth, manage game, and for other cultural uses [22–24]. As the Great Plains were settled by Euro-Americans, the indigenous peoples of the Plains were removed from their traditional lands and forced further west. This removal of indigenous peoples also largely removed the cultural use of fire from the landscape. Concurrent with Euro-American ideas of land ownership and permanent settlement came buildings, fences, and other improvements vulnerable to prairie fires on the open plains [25,26]. To support this permanent settlement, native grasslands were

cultivated and cropped, which in turn reduced grazing and fire on the landscape [27]. Extirpation of native grazers, coupled with a loss of cultural fire resulted in an abundance of grass fuel that led to extreme fire behavior.

Colonialism, capitalism, and a disconnect between humans and natural processes in the space they inhabited contributed to the reduction and removal of fire from the Great Plains. The previously described period of extreme wildfires in the early 1910s that ecologically and economically devastated great portions of the nation also created a lasting depiction of fire as a dangerous and destructive force [22,28]. The development of a strong anti-fire sentiment and perception that fire is inherently dangerous to American people and their way of life resulted in fire suppression policies that excluded fire from the landscape even further [29].

While this anti-fire sentiment led to decades without fire in many fire-dependent ecosystems, fire use did persist in some areas, particularly in the southern Great Plains. In the Flint Hills of Kansas, private landowners and the National Park Service's Tallgrass Prairie National Preserve have been burning for decades to maintain the prairie ecosystem [30,31]. Communities in the Southern Great Plains beyond the Flint Hills have also regularly employed fire in rangeland management. A culture in a community that supports burning can normalize the elective use of prescribed fire, thus removing or alleviating the social pressures one faces when deciding whether to burn or not [32,33].

Community-level acceptance and use of prescribed fire in the southern Great Plains led to the development of Prescribed Burn Associations (PBAs). PBAs are land manager coalitions that support the use of prescribed fire through training, resource pooling, and community support [34]. These landowners widely use, support, and promote prescribed fire. Beyond these associations, there are significant barriers that limit individual landowners in their ability and desire to apply fire to the landscape.

The cultural acceptance of fire as a legitimate management strategy has not fully extended throughout the Great Plains. Prescribed burning as a management practice in the Northern Great Plains is largely limited to wildlife management objectives by federal entities, state organizations, and non-governmental organizations (NGOs) [19,35].

Understanding the perceptions and barriers to fire application in the Great Plains helps researchers and natural resource managers appropriately address fire perceptions in discussions regarding fire use with private land managers. This review collected and reviewed all current work on the perceptions of prescribed fire to identify trends and gaps in the current knowledge. This article is comprised of two sections: "How we know what we know" examines the geographical scope and breadth of methodologies employed in the social science research on prescribed fire in the Great Plains, including the types of studies conducted; location of the participants and respondents; and demographics of stakeholder groups studied. "What we know" examines the specific results, broad implications, and knowledge gaps left by the body of social science literature on prescribed fire in the Great Plains.

This first paper in the two-part article series focuses on the common barriers to fire application in the Great Plains. The second paper will investigate the solutions currently employed to overcome barriers (i.e., 'busting' barriers) where increased fire use is desired as well as barriers that are currently unaddressed. Potentially expandable solutions to address barriers to prescribed fire use will be introduced as well.

2. Materials and Methods

This systematic review was completed December 2021 using three databases: Web of Science, the North Dakota State University Library, and Google Scholar. Each database was searched using the following search phrases: "Prescribed fire" + "Perception," "Prescribed fire" + "Attitudes," "Prescribed fire" + "Human dimensions," "Prescribed fire" + "Barriers," "Prescribed fire" + "Liability," and "Prescribed fire" + "Economics". These terms were selected as they define the scope of the review.

Initial article selection involved reviewing titles and abstracts with references to the aforementioned search topics. After the initial articles were compiled, they were read in their entirety and then either retained or removed from the study based on the following criteria. The 44 articles retained for the review were directly related to prescribed fire, occurred within the United States, and focused on open ecosystems: grasslands, savannas, and other rangelands. Retained articles were then sorted into themes: Private landowner perception studies, Federal State and Local natural resource perception studies, Fire Organizations, Liability and legal regulations, Smoke, Economics, and 'other.'

The articles were classified as quantitative or qualitative by their method of data collection. Quantitative works were those that employed surveys as the primary research tool. Qualitative works were those that used interviews and focus groups as the research tool. The articles were further labeled at the methodology level by research tools. Non-empirical works were included such that the research tool classification also listed literature reviews, record analyses, and economic modeling. An annotated bibliography was developed for the 44 included articles.

3. How We Know What We Know: Methods in Social Science on Prescribed Fire

3.1. Research Method

Two-thirds of the retained studies (28/44) reporting on social perceptions of prescribed fire used quantitative research methods, while the other third used qualitative methods. Whereas quantitative research methods primarily relied on one research tool, a survey, qualitative methods used a greater variety of tools to investigate social perceptions (Figure 1). Of the 44 studies, only 34 directly solicited information from stakeholders. The other 10 articles reported information from relevant literature, legal records, and economic models.

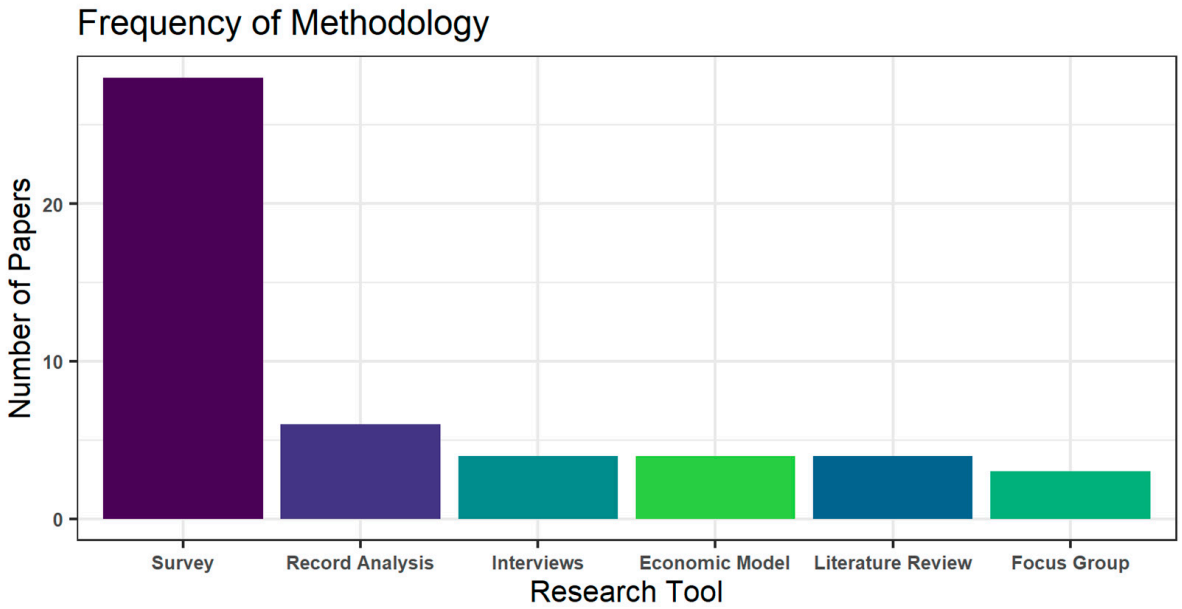

Figure 1. The frequency with which various research tools have been employed in the investigation of social perceptions of prescribed fire in the US Great Plains. There are more than 44 observations recorded in this figure, as some articles employed multiple research tools.

Most of the knowledge available in the peer-reviewed literature on the social perceptions of prescribed fire has come from surveys—28 of the 44 studies reviewed here employed surveys as the primary research instrument. Both email and conventional postal mail were used to distribute surveys, with a considerable preference for conventional postal delivery methods (95%). A limited number of the retained studies employed interviews and focus groups as the primary research tool. Of the 44 primary articles, only 6 used one

or more of these qualitative methods. Often, focus groups and interviews were secondary research tools that accompanied or informed quantitative analysis.

Due to few instances in which the complex and wicked problem of prescribed fire in rangelands has been examined using qualitative or mixed-method approaches, the current knowledge available is limited in richness. While quantitative methods such as surveys can reach a greater number of respondents and can be easier to analyze, when used alone they have the potential to miss relevant issues or questions due to their rigid design and fixed a priori hypotheses [36]. Qualitative methods can provide a greater depth of understanding through their flexible design and results in the form of the respondent's own words [37,38].

In addition to the 10 articles that did not directly solicit information from stakeholders, 4 others included indirect approaches, resulting in 14 of the 44 review studies using literature reviews, record analysis, and economic modeling. Literature reviews focused on prescribed burn associations, legal liability, and the economics of prescribed fire. The reviews of legal liability also incorporated reviews of prior case law and the change in liability over time. The economic literature reviews often included predictive modeling to estimate financial outcomes.

3.2. Respondents and Location

In the studies included in this review, respondents consisted of private landowners, fire organization members, non-governmental organization members, county judges, county commissioners, state, and federal natural resource managers. Empirical studies have primarily focused on private landowners (60%). Federal, state, and private natural resource entities were the next most included (23%). The stakeholders least commonly contacted were judges, county commissioners, and fire professionals (1%). Some respondents may have fit into multiple categories, but studies only provided classifications per the targeted respondent roles.

Most of the current knowledge is regionally based in the southern Great Plains, with more than 47% of study participants being from Texas and 32% from Oklahoma (Figure 2). This focus on the southern Great Plains is likely due to a stronger pro-fire culture, a greater use of fire on the landscape, and lead scientists working from institutions based in those states. While the findings from these works are generalizable to communities in the southern Great Plains, they do not consider the unique context or the specific attitudes and perceptions of communities in other parts of the Plains.

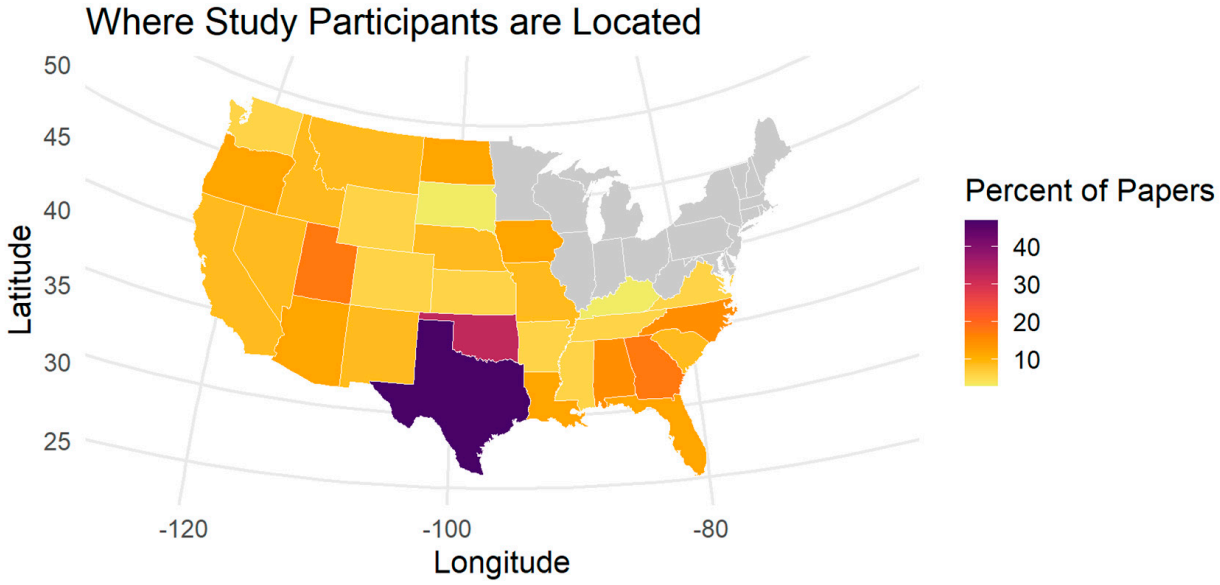

Figure 2. This map shows the location of study participants in 44 articles included in this review. While the Great Plains was the primary focus of this review some of the articles included gathered information from participants in states beyond the Great Plains as well.

4. What We Know

The studies included in this review present the primary barriers to fire application: Social Perception, Conceptual Understanding, Technical Proficiency, Practical Barriers (Labor, Equipment, Changing landscapes, Time, Economics), and Policy and Liability (Figure 3). The results are presented in this order to emphasize the importance of social perception on all other barriers. The acceptance of burning as a practice precipitates the decision to engage with information, resources, and policies that are relevant to the practice.

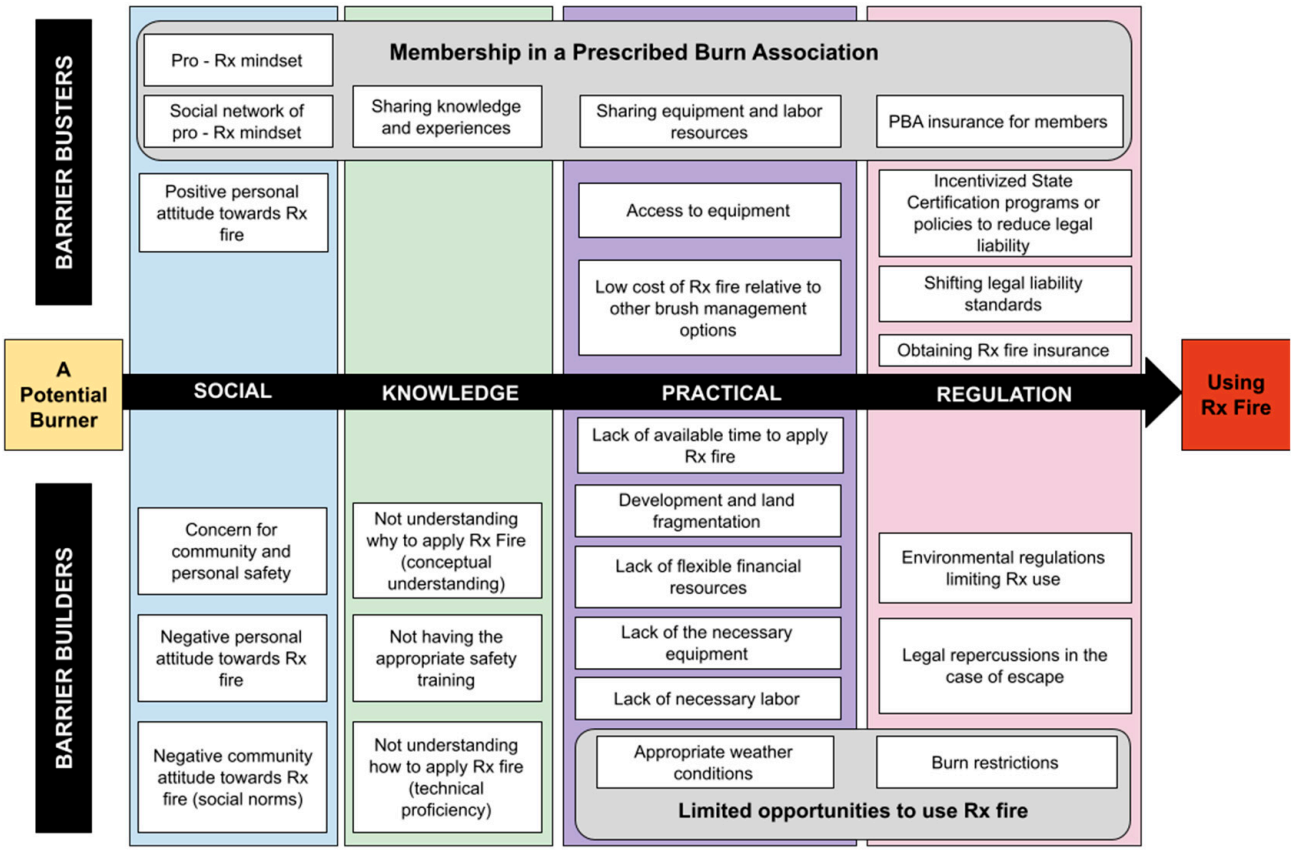

Figure 3. Conceptual model of the barrier builders and barrier busters currently reported by the studies included in this review that affect whether a potential prescribed fire practitioner in the US Great Plains might actually use prescribed fire. Barrier builders are circumstances that limit or prohibit the use of prescribed fire. Barrier busters are tools or resources that support or encourage the use of prescribed fire. Barrier builders and busters were organized into four categories as interpreted by the research team. The gray boxes represent barrier busters or builders that span more than one category with specific examples listed therein. Citations for these statements can be found in Appendix A.

4.1. Social Perceptions

Here we review attitudes towards fire (or outright support for or against fire) and effects of social norms towards fire (or the perception of what neighbors or community members accept or not). Perceptions regarding safety, which are emotionally based, are included here. The safety portion of this section features risk perceptions and concerns regarding smoke caused by prescribed burning. Risk perceptions pertaining to legal liability in the case of an escape are covered in a following section.

4.1.1. Attitudes

Respondents across the studies included in this review did not agree that prescribed fire is a beneficial and legitimate land management practice. Five percent (2/44) of studies

reported that more than 50% of their survey respondents believed that fire is ecologically beneficial [39,40], 2% (1/44) reported survey respondents holding a more neutral stance on the benefits of prescribed fire [41], and 2% (2/44) reported that more than 50% of their respondents did not believe that fire was beneficial [42]. PBA members were found to have stronger support for prescribed fire than nonmembers [39,40,43]. This result is not surprising, as a group interested in and invested in a management practice would be expected to support its use.

In addition to the general acceptance of burning, the relative preference of fire compared to other management practices varied across studies. Eleven percent (5/44) of studies reported that landowners favored burning over other brush control methods [40,44–46], even if only by a narrow margin [39]. Some landowners preferred mechanical methods [41,47] or grazing [48] over the use of fire.

4.1.2. Social Norms

Regardless of a practitioners' personal acceptance of fire, some felt their ability to burn was limited by the perceptions of prescribed fire held by members of their community. These are the social norms which are the formal and informal rules of attitudes or behaviors that are acceptable in a group [32]. Within ranching communities, social norms are important to the decision-making process of community members [49].

State agencies, private entities, and private landowners reported community members not liking or not using fire as a barrier to their own fire use [50–53]. Respondents from federal agencies expressed some limitations on fire use due to public opinion, but generally rated it as a smaller limitation than other groups [52,53]. This is not to say that federal agencies do not practice neighborliness or disregard public opinion, but rather that in included studies they did not report social norms to be as limiting as other groups did regarding the use of fire. Perhaps this is because local or state regulations on prescribed fire often do not apply to federal burners on federal land.

4.1.3. Risks

The perceived risk associated with prescribed fire by potential burners is a barrier to prescribed fire use. Landowners have cited their decision not to burn out of concern for neighbors, concern for the community, and concern for the burner's own personal safety and property [41,42,47,50,51,54]. The preponderance of responses to interviews conducted by Harr et al. [51] were centered around the emotional response and language used to describe the fears related to fire risk.

Perceived risks related to prescribed fire can be related to insufficient technical proficiency of fire use and application. In a structural equation model, risk was marginally associated with the use of fire; instead it was found that a lack of resources needed to apply fire safely and control the risk led to a limited use of fire [40]. This concern regarding risk could be circumvented by providing further training and resources to increase the competency that potential burners feel.

While some landowners elect not to burn due to concerns regarding their personal safety, those safety concerns might be rooted in an inaccurate perception of prescribed fire. When compared with other agricultural practices, prescribed fire resulted in significantly fewer fatalities than other operation actions such as crop and animal production [55]. Prescribed fire risk is often conflated with the danger of wildfire management, which leads to an inflated perception of the risk involved in prescribed burning. In a 50-year span from 1963 to 2013 on forests and grasslands, only 6 deaths were related to prescribed burns as opposed to 201 related to wildfires [55].

4.1.4. Smoke

An additional safety concern that can impact the decision to burn or support burning is the smoke produced by prescribed fire. Smoke concerns, a negative element of prescribed fire, are a safety issue for the surrounding community of a burner [41]. There is substantially

greater tolerance for smoke from a lightning strike or wildland fire over smoke from prescribed fire [56,57].

Particulate matter in smoke produced by fire, or any origin, can impact human health. Unlike wildfire, prescribed fire does not occur at the same intensity and can be conducted when weather conditions are favorable [58,59]. Additionally, as prescribed fires are planned events community members and neighbors can be notified prior to the burn so that they can avoid unnecessary exposure to smoke [3]. That being said, narrow preferred timeframes for burning can result in a lot of prescribed fire occurring at one time which can contribute to negative health and safety impacts [60].

4.2. Conceptual Understanding

Of the studies in this review, the concepts of knowledge and education are presented but none explicitly differentiates between conceptual understanding and technical proficiency. In this review, conceptual understanding refers to the rationale and information that guides a landowner as to why one should put fire on the ground. Technical proficiency refers to the training, knowledge, and experience that informs a landowner how one puts fire on the ground.

While understanding the benefits of applying fire to the landscape does not limit the use of prescribed fire, it has not been shown to promote its use either. In some cases, prior research suggested that landowners found a lack of conceptual understanding as only a minor limiting factor to application of fire [51]. In 7% of studies, respondents found conceptual understanding to be more than a minor restraint, which limited their use of fire [39,42,47].

Conceptual understanding has very rarely been reported to impact attitudes towards fire use but is often recommended by authors outside those included in this review as a way to increase fire use. Of studies included in this review, only Loomis et al. [61] claimed that increased conceptual understanding would lead to increased public acceptance of prescribed fire use. Conversely, Brunson et al. [48] emphasized that their findings did not support the notion that increasing citizen knowledge would increase acceptance of the practice (see also [45,46]). Additionally, structured equation modeling shows that limited conceptual understanding has a weak to moderate impact on attitudes towards fire by producers [62].

Understanding decision-making processes of prescribed fire practitioners provides insight into the value and impact of conceptual understanding on burners. An investigation of the decision-making process found that people more often made decisions using affective heuristic and dual processes instead of a purely analytical process [63]. The affective heuristic is the binary positive or negative emotional tag that an individual associates with a concept [63]. In cases where analytical decision processes were used the likelihood of using fire increased. This does suggest that traditional educational efforts are important to the likelihood of application, but educational efforts could increase in their impact if the programming broaches the emotional elements of prescribed fire as well.

4.3. Technical Proficiency

Unlike conceptual understanding, the desire for and the impact of technical proficiency on the use of prescribed fire significantly increases fire use. A lack of technical proficiency (training, knowledge, and experience) was cited by producers as being a major obstacle to getting fire on the ground [34,44,51,54]. Specifically, increased safety training was desired for the increased use of prescribed fire for some practitioners [39,40,64]. Even in fire organizations (PBAs) where private landowners share knowledge and experience and engage in safety training, increased technical proficiency was still considered a top need [65].

Increased technical proficiency gives potential burners a sense of confidence and competency in the use of prescribed fire. Additionally, as fire competency increases through training and experience, both the burner and the community surrounding the burner feel

more comfortable and confident in the burner's ability to conduct a fire. Toledo et al. [62] found that as experience with prescribed fire increases, the perceived benefits of prescribed fire tend to outweigh the risks and attitudes towards the use of fire improve–attitudes towards fire are influenced by feelings of competency that are related to social approval.

4.4. Practical Barriers

Practical barriers represent obstacles that potential burners may encounter after they have decided to accept prescribed fire as a beneficial practice and feel they are ready to apply fire to the landscape. A lack of labor or equipment and the changing landscape of the Great Plains are things that physically limit the ability of a producer to put fire to the ground. Time and economics are less tangible, but they also practically limit the ability to burn after the decision to do so has been made.

4.4.1. Labor

Burners are often legally required to have a certain number of people present and active on the burn line, although the number and qualifications of the group varies from State to State. In North Dakota, for example, no trainings or qualifications are needed, but the crew size is specified: "At least four [people] must be present when the prairie is burned" (North Dakota Century Code § 18-07-06).

Study respondents were limited in their fire applications due to insufficient help. A total of 20% of studies reported that a lack of labor was a moderate to significant barrier to the application of fire by both private and public land managers [34,40,42,44,47,51–53,66]. Respondents and researchers concluded that better access to labor would increase fire applied to the landscape [40]. Specifically, some respondents suggested that assistance from fire departments would increase their use of prescribed fire [39].

Adequate resources, specifically labor, do not directly impact acceptance of fire but rather the ability to burn after one has accepted the practice. A lack of labor was found to have a weak to moderate indirect effect on attitudes towards prescribed fire [62]. As such, increasing labor for potential burners would not be a primary intervention to promote increased fire use but, it is a critical need of those already interested in fire use.

4.4.2. Equipment

Various types of equipment are needed for the preparation of burn units and to conduct a safe burn. Tools are needed to create fire breaks (tractors, plows, mowers), to conduct the burn (torches, hand tools, water units, vehicles), and to ensure the burn crew's safety (fire-resistant personal protective equipment, hand-held radios). Some resources are readily available on a typical farm or ranch, whereas others are more specific and costly, so the average land manager may not have them on hand. Additionally, some equipment is required by formal prescribed fire programs, such as fire-resistant fabrics, which is not required—but is encouraged—for private landowners.

Whether or not a potential practitioner has access to equipment substantially affects their ability to burn. Several studies (14%) in this review reported that a major obstacle to both individual burns and an active fire program was a lack of proper equipment [34,42,44,47,54,67]. Researchers have documented that access to equipment could increase use of prescribed fire [39,40].

4.4.3. Changing Landscape

There has been a notable change in the landscape of the Great Plains with the continual spread of non-ranch development, land holding fragmentation, and an increase in absentee landowners. These fragmented and subdivided landholdings create more fire breaks in the landscape and as such limits the size of prescribed fires [68]. Residential areas and development have limited burning for federal, state, and private land managers [52,53]. This change has created a physical barrier to fire application.

4.4.4. Time

Time, like money, is an investment on behalf of land managers that first requires acceptance of prescribed fire as a beneficial and worthwhile practice. Time, or a lack thereof, has been found to be a constraint to applying prescribed fire [42,51]. The time it takes to apply fire to the land is not the only time investment required–producers listed the increased complexity and workload of planning the burn as an additional investment of time [51].

As solutions to barriers are developed, the time investment a potential burner may be required to commit continues to grow. States that provide certified burn manager training programs before one can burn and receive reduced liability are asking for an investment of time from practitioners. As are PBAs when they require members to assist with a burn on the land of other members before they would get to use the PBAs resources to burn their own lands. These solutions, while helpful, heavily rely on the willingness of potential burners to invest their already limited time.

Variability of weather, changes in seasonality due to climate change, and regionally applied burn bans can make the planning and application of fire a challenge for potential burners by narrowing the time frame in which they can burn. The time frame in which a burn is conducted is dependent on the land management goals of the burner. Burners at the Federal, State, and private levels all consider these narrow time frames a significant barrier to fire application [52,53]. A disconnect between preferred burning season and seasons with ideal weather days serves to further limit fire use [67,69].

4.4.5. Economics

In the case of woody plant control methods, prescribed fire is the cheapest long-term reduction option. Respondents in both the northern and southern Great Plains agreed that the cost of fire is cheaper than mechanical and chemical treatments for controlling brush [39,44,67]. This perception that prescribed fire is significantly cheaper than other treatments was confirmed by economic modeling [70].

Despite the cost-effectiveness of burning, cost emerged in this review as a barrier to prescribed fire use. The cost of fire did not serve as motivation for all potential burners to use fire, but rather as a barrier. In the survey by Bendel et al. [42], 50% of ranchers felt that financial resources were a constraint to applying fire. Respondents in Harr et al. [51] felt that fire did not directly benefit their ranching operations, but that it benefited wildlife and thus was incongruent with their management goals and bottom line. Operations with tight budgets may forgo investing in new management practices such as prescribed fire.

Agency land managers are required to work within fixed budgets and as such cost can be a barrier to fire application. Federal and state land managers reported cost to be a moderate to significant barrier to the application of fire [52,53,66]. Quinn-Davidson and Varner [53] found that planning costs and a lack of adequate funding were moderate impediments to the use of prescribed fire by federal land managers, but both were a much higher concern for state land managers. This suggests that larger federal budgets may result in fewer financial barriers to applying fire.

4.5. Policy & Regulation

If a land manager has decided that burning is an acceptable practice, understands why to burn, how to burn, and has the required resources to conduct the burn, they may yet find themselves blocked by legal barriers outside of their control such as burn bans or environmental protection restrictions. A potential burner also may be completely prepared but may fear the legal repercussions of an escape during the burn and thus choose not to burn. These policy and regulation barriers will be explored in the following paragraphs.

4.5.1. Regulations and Burn Bans

While prescribed fire can adequately mimic natural fire effects when conducted under appropriate conditions, the protection by state and federal legislation of resources and

species limits the use of prescribed fire. These protections vary across states and species. Regulation (e.g., air quality) and environmental laws were relatively large impediments to burning by federal, state, and private entities [47,53,66]. Not all articles reported environmental regulations as a barrier to fire use, which is likely due to the variation in these regulations among the various states.

The narrow seasonal time frames for conducting a prescribed fire can be further limited by county and statewide restrictions on open burning. These restrictions, often called burn bans, are statewide or county-wide restrictions on open burning enacted by county commissioners, governors, or forestry division leaders in cases of weather and safety concerns [71]. An investigation of burn ban decision-making found that county commissioners in the Southern Great Plains often enacted burn bans due to objective safety criteria and after seeking information from fire and emergency personnel; however, some commissioners reported applying bans at their own discretion as well [72].

Burn bans can limit the days a potential burner has available to apply fire to the landscape. As noted earlier, the narrow time frames are a barrier to fire application [52,53]. Survey respondents also reported that burn bans negatively impacted their willingness to apply fire to their lands [73].

In some jurisdictions, exemptions to burn bans can be made by county commissioners for burners with certain levels of training. States with certified burn manager programs may allow certified burners to burn during open burning restrictions [71]. States with stronger pro-fire cultures and programs see greater legal advocacy for burners.

4.5.2. Legal Liability

In a review of legal barriers to prescribed fire application, Wonkka et al. [71] identified three defined liability standards that could be applied by a court in the case of escape. The most lenient of the liability standards was gross negligence, which holds the burner liable if they wantonly or recklessly applied fire without the slightest semblance of care. The next was simple negligence, which requires burners to practice reasonable care. The harshest standard was strict liability, which holds the burner liable for all damage regardless of any precautions they took while burning. In the case where the liability was undefined, states usually followed simple negligence rules or prior case law.

In 2015, only 4 states applied gross negligence, 20 applied simple negligence, 5 applied strict liability, and 21 states had undefined liability standards [71]. In the Great Plains, only Texas and Oklahoma had simple negligence liability standards, whereas the rest of the Plains states (Kansas, Nebraska, North Dakota, and South Dakota) all were found to have undefined liability standards [71].

The articles included in our review stressed that prescribed fire use has been significantly limited by fear of liability in the case of an escape. Fear of liability was found to be a commonly cited reason across studies as to why many private landowners did not burn [39,41,44,47,50,51,66,74]. In Florida, federal, state, and private land managers all consider the risks associated with liability in the case of an escaped burn to be a very significant barrier to applying fire [52]. This differed from the survey in California where federal and state land managers considered legal liability a less significant barrier than private entities did [53].

While respondents cited liability as the greatest barrier to burning, Weir et al. suggest that what people truly fear is their perception of liability, "Inaccurate perception of the danger and severity of liability is a greater barrier to prescribed fire than that of the actual danger and liability [74]." Weir et al. go on to argue that the actual risks of prescribed fire versus the perceived risks are driving this sentiment. The authors suggest reducing the liability burners might face in an escape would help to change this perception.

5. Conclusions

Future research in this arena should include qualitative work to gain more nuanced perspectives of individuals' perceptions. Inclusion of lesser-studied community members,

especially those of rapidly growing minority groups, could provide a more holistic understanding of changing social norms that influence prescribed fire use. There is also a need for increased work outside of the southern Great Plains to confirm that the current findings apply beyond the previously studied communities.

In addition to methodological expansion, investigations into wildfire and prescribed fire risk conflation and perceptions of liability could provide insight to the true nature of these barriers. As could be seen with paper percentages in Section 4.1.1. titled Attitudes, there is a lack of studies addressing attitudes and perceptions. An increase in studies with direct questions regarding attitudes will provide more comparable data and better insight to community perceptions.

All barriers to the adoption and application of prescribed fire relate back to the perception of fire that a potential practitioner holds. As the future of the Great Plains faces the impacts of climate change, fragmentation, and woody invasion and research demonstrates the benefits of prescribed fire, managers desiring to increase prescribed fire use may need to go beyond the analytical understanding of prescribed fire and consider the emotional and social aspects as well.

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Appendix A

Table A1. Figure 3 presented in tabular format, with APA citations for each text box in the figure.

Category	Barrier Status	Statement	Citation
Social	Barrier Buster	Pro—Rx mindset	[39,40,43]
		Social networks of pro—Rx mindset	[62]
		Positive personal attitude towards Rx fire	[39–41]
	Barrier Builder	Concern for community and personal safety	[41,42,47,50,51,54]
		Negative personal attitude towards Rx fire	[42,63]
		Negative community attitude towards Rx fire (social norms)	[50–53]
Knowledge	Barrier Buster	Sharing knowledge and experiences	[34,62,65]
	Barrier Builder	Not understanding why to apply Rx Fire (conceptual understanding)	[39,42,47]
		Not having the appropriate safety training	[39,40,64]
		Not understanding how to apply Rx fire (technical proficiency)	[34,44,51,54]

Table A1. *Cont.*

Category	Barrier Status	Statement	Citation
Practical	Barrier Buster	Sharing equipment and labor resources	[34,62,65]
		Access to equipment	[39,40]
		Low cost of Rx fire relative to other brush management options	[39,44,67,70]
	Barrier Builder	Lack of available time to apply Rx fire	[42,51]
		Development and land fragmentation	[52,53]
		Lack of flexible financial resources	[42,52,53,66]
		Lack of the necessary equipment	[34,42,44,47,54,67]
		Lack of necessary labor	[34,42,44,47,51–53]
		Appropriate weather conditions	[52,53,67]
Regulation	Barrier Buster	PBA insurance for members	[74]
		Incentivized State Certification programs or policies to reduce legal liability	[65,75,76]
		Shifting legal liability standards	[39,74,77]
		Obtaining Rx fire insurance	[76,78]
	Barrier Builder	Environmental regulations limiting Rx use	[47,53,66]
		Legal repercussions in the case of escape	[39,41,44,47,50,51,66,74]
		Burn restrictions	[39,52,53]

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