Towards a Theory of Default Suppression: Decision Making in the Context of Full Suppression and Managed Wildfires on Federal Lands, U.S.A.

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Abstract

The use of wildfire to accomplish natural resource based outcomes has been an allowed practice within US wildfire policy for over 50 years. Despite this, the scale of implementing wildfires with this strategy falls far short of those wildfires managed with a full suppression strategy, which is the dominant US wildfire response paradigm. Research has suggested that increasing the scale of wildfires managed to achieve resource benefits may help reduce the 'fire deficit' and increase the resilience of ecosystems to catastrophic wildfire outcomes. However, decision makers are often reluctant to assume the risk that breaking the suppression paradigm incurs. This dissertation presents three studies that examine the decision making process that US Forest Service agency administrators and their fire management staff consider whe deciding to manage a wildfire to achieve resource benefit or not. The first study conducted a review of the literature pertaining to decision making processes in this context, however it was limited to research conducted before the 2009 federal wildfire policy update. The second study examines the use of the Wildland Fire Decision Support System (WFDSS). It specifically probes how US Forest Service employees leverage WFDSS to help make decisions during wildfire incidents, and also explores their perspectives with the use of WFDSS and wildfire managed to achieve resource objectives. The final study largely builds on the first, expanding the decision factor set and updating it to the post-2009 wildfire policy context. While the first study was a literature review, the second two studies both were conducted by interviewing participants currently employed by the Forest Service. All three studies were thematically analyzed using qualitative data analysis methodologies; principally thematic analysis rooted in the practice of Grounded Theory. The conclusions from all three studies support the notion that wildfire decision making is complex and must consider many divergent, sometimes contradictory, and often uncertain factors. The level of complexity and uncertainty coupled with external pressures, internal cultures, and personal risk appetites appears to support the conclusion that choosing to manage a wildfire to attain resource based objectives is a riskier decision that deciding to suppress it. Risk is derived from uncertainty in the outcome, lack of comfort or resources to manage it, previous bad experiences, or loss of sociopolitical credibility. I provide a set of conclusions that supports using a framework to assist decision makers to choose the correct course of action for any wildfire that is considering of the most important and salient decision factors relevant to their current wildfire scenario.

Acknowledgments

Personal Narrative

Like so many others involved in the wildfire management profession, I am intrigued with the thought that we can find a way to live with wildfire. I may be obsessed with the aspiration that we could, and should, be doing more to leverage the opportunities that free-burning fire on the landscape can provide for restoring and maintaining the natural environment so critical to our given way of life. Ecosystem services are used by everyone in society, urban or country dwellers alike. We all breathe air, we all consume water, and we all require food. There is universal enjoyment in a blue sky and green forested hillside while either hiking within it or driving past it at eighty miles an hour. It is a basic human need to exist within a functioning ecological system, and fire is one of the ancient maintainers of these systems. Ultimately, the entirety of this dissertation process has been an effort to satisfy my personal desire to contribute to restoring and maintaining these ecosystems by leveraging the one component I know best - wildfire. The problem we collectively face is that there is no clear path forward for how to achieve this. From the very beginning, my undertaking of this doctorate program has been an attempt to understand why the wildfire governance, of which I am a part, struggles to restore wildfire to the landscape in an environmentally, socially, and strategically acceptable way. I hope that the research herein helps in some small way.

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This entire experience of attaining a doctorate degree has been an exercise in humanizing characters in a story that otherwise may have remained as flat as the pages upon which their words and messages are carried. The greatest privilege has been to meet many of my heroes; people who built the base upon which this works stands, and who I found, in the end, were just fellow searchers also looking for the right way forward. I'll mention a few here now – there are many others.

First, to Neil Sugihara, for being, still to this day, the most selfless human being I have ever met. He is ubiquitously an inspiration for anyone who had the good fortune to work with him. One of the most treasured moments I have is walking alone with him in a burned unit in Yosemite during a class we taught together; fortunately, it was caught on film. Neil was the

singular catalyst for me to begin this effort and was the first who thought I could do it. He was correct, and I thank him for his faith and encouragement both before and during the course of it.

I must thank my friends Daniel O., Scott G., and Robyn W. for their friendship, patience, concern, levity and above all else – their delivery of brutal honesty and a solid humbling that was and is periodically required and only deliverable by someone who has walked the line.

I've had the good fortune of working for people throughout my career who were more mentor than supervisor. Lisa N. bestowed upon me the virtue of patience; Chris S. persistently prodded me to make needed moves forward (and provided many quotes to live by), and was my first model of a humble man who believes in the culture of fire. Our rides together chasing the phantom smokes are cherished memories. Carlton Joseph took a chance on an unknown kid coming in from outside California and was always open to my crazy ideas – many of which became the roots for which this work flowered. Brian Rhodes followed afterwards and allowed me to pursue the program through my work with the Forest Service. He saw the larger vision and believed that maybe in the end it would help us all. Lance Noxon took me on, and both provided bottomless support but also willingly inherited the vision that this may lead to a state that we all have wished so hard to see realized. Eric Schlumpf also resides here, although not a supervisor, he paved the way by paying for the way because he too believed that there were farther horizons.

Hugh S. warned me that it was the hardest thing he'd ever done, and I would have to do. He was correct. Nicole M. said it was the most writing she had ever done, and I would have to do. She too was correct.

Immeasurable thank you to Vicki C., a (then) Deputy Chief who was gracious enough to spend a few minutes with a random employee and follow that up to one day to send an introductory email to RMRS that changed the entire direction of my program, much to the better. I miss your leadership.

Dr. J. Groninger and Dr. C. Ruffner deserve special mention for being among the earliest true mentors and guiders for the direction of my career. Both showed me aspects of the natural world I deeply appreciate.

Stephen Pyne showed me the way of the word – an immeasurable honor to have some of his time – and provided subtle and apt advice. I thank him for patiently putting up with me nipping at his heels throughout the years. I hope that we still have words to write together someday.

Also, many thanks are due to an anonymous and now retired District Ranger from a Southwestern Forest who graciously and enthusiastically allowed me to visit, spent many hours with himself and his staff, and took me under a wing that was needed. He provided insights that will have far reaching effect.

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Finally, to my ever patient committee. I deeply appreciated several things that Dr. Leda Kobziar provided – first, I thank her for stepping in and filling out my committee when I was in a time of need. I had admired her work for many years, and it was an honor to have her join. She challenged me in was that I deeply appreciate, especially during my prelims, and I am the better for it now. Thank you.

Dr. Matthew Thompson is an incredibly productive and busy researcher, yet he took a great deal of time to not only facilitate a directed studies course, but also to allow me into the fold of their research group to see what that side of the Forest Service looks like. It has been an honor to mingle with the giants and learn from their processes. I've enjoyed our thoughtful conversations and hope they continue into the future. Thank you.

To Dr. Sarah McCaffrey, who patiently and repeatedly pulled me back from the brink of despair and existential crises, and who showed me how to find the fire in the human and the human in the fire. I could not have found a better mentor in the social sciences. I have not yet determined whether she knows this or not, but she cut the path for most who followed in that difficult and underappreciated pathway. The amount of advice, guidance, collaboration, mentorship, and friendship that I received during our long series of talks is a debt that I will carry forever. I could not have done this without her. Thank you.

Finally, to my Major Professor Dr. Alistair Smith who agreed to take me on literally sight unseen (and for a year after), believing only my good story and the proofs along the way. Dr. Smith was everything in an Major Professor that I needed and could have wanted. He was there when I needed, he guided in his gentle way, and he put a stop to any nonsense before it got out of hand. His deep understanding of the ways of academia, mostly foreign to me after so many years away, was an absolute necessity. I appreciated his levity, his wit, his wisdom, and his counsel. For that I thank him.

And to every wildland firefighter who is out there scraping the line and trying to get by. You may not believe it, but in the end, this has all been for you. And thanks to you, too.

Dedication

My parents, who believed that I could do more than drive a truck, even when it didn't really look all that promising. They facilitated a different and much better way to see the world.

I owe a debt to my son Sage for understanding that Dad needs some quiet time more than I would have liked. His support and love persisted through this time, and I regret the time lost that we should have spent together. I did what I could to model the behavior of a man and father. While this process unspooled, I had the great pleasure of watching him grow into a man himself. I am proud of Sage in so many ways and am excited to be there for him again as he starts on his own journey of life.

And finally, my gratitude and admiration for Amanda. She was an enduring source of support, encouragement, intellect, and friendship during this program. Attaining this degree was just yet one more sacrifice that fire demanded of her, and she gave willingly even as she was setting about her own new and wonderful course within her professional life. She always gives more than she takes and likely always will. She started her support by buying me an iPad pro and ended it by ushering me along during my procrastinations. She kept it urgent. She facilitated the Year of the No. Along the way there were walks in the desert, talks by the pool, stories in the evening, and a depth of friendship and collaboration that I suspect few ever achieve. Thank you for exploring the ways to live with me for more than 20 years now. I will listen to her advice and warnings with more attention in the future.

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Statement of Contribution

Chapter 2: Published in the journal Fire as:

Fillmore S.D., McCaffrey S.M. and Smith A.M.S. (2021). A Mixed Methods Literature Review and Framework for Decision Factors That May Influence the Utilization of Managed Wildfire on Federal Lands, USA. Fire 4(3). MDPI AG: 62. DOI: 10.3390/fire4030062.

S.F. conceived the overall approach of the paper. S.F. and S.M refined the methods, performed the analysis, structured and wrote the paper with assistance from A.S.

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S.F. and T.P. conceived the overall approach of the paper. S.F refined the methods and performed the analysis. S.F and T.P. structured and wrote the paper.

Chapter 1: Introduction: The Fundamental Wildfire Choice

This dissertation concerns itself with a moment in time that sparks a process, repeated countless times, that begins simply and rapidly becomes infinitesimally complex. This moment and process intertwines the relentlessness of nature with the imperiousness with which a bureaucratized collection of individuals engages with it. The moment of concern is when a human is made aware of the existence of a wildfire. The process is the entirely anthropogenic framework that follows in deciding what to do about it.

Ubiquitously, the choice of what to do with a wildfire is broken neatly into two conceptual pathways. On the one hand, we can walk away and let the fire burn as it will within the confines of topography, weather, and fuel. On the other hand, we may pick up the wood and metal tools designed for such tasks and begin to scratch lines in the dirt that starve flame from fuel; empty our canteens to rob its heat; or smother it with the nearest garment or sack. Neither pathway is inherently a bad or a good choice and the outcome of either is impossible to know at the moment. However, the governance of an industrialized, professionalized society such as the one that exists in the United States (U.S.), which spatially bounds this dissertation, demands the choice be made. The governance here is flexible enough that it may use one individual alone in a firetower to observe and report on its progress over a matter of weeks. At other times the system may mass several thousands of firefighters to work day and night to swarm the perimeter in a singular effort to stop it from growing. It may do nothing at all: peculiarly, all are allowable responses, which makes choosing a socially, politically, environmentally, and ethically optimal pathway difficult at best.

The research that follows will explore the numerous factors that decision makers must take into account to optimize fire outcomes according to whatever criteria bounds their decision space. The perspective of nearly 100 professional land managers and members of the public are represented, comprising over 100 interview hours and multiple field visits. It also incorporates more than 50 years of wildfire research which has struggled to place just what and where exactly the role of wildfire on American landscapes should be.

Study Background

The origin of this research begins well over a hundred years ago, as the newly organized United States Forest Service (USFS) was given the reins over vast swaths of the American West to manage for 'multiple use,' as dictated by its Organic Act in 1897 (and later affirmed by other

legislation, notably including the National Forest Management Act of 1976). Lands the USFS were given to manage were seen as threatened. They had been burned over, cut over, mined over, grazed over, and then often abandoned after those resources had been extracted. The USFS pillared their overarching management approach to one of protection, whether that threat be a logger, a miner, a domestic animal, or wildfire. Their chief concern at that time were negligent ignitions, although that soon also extended to naturally ignited wildfires and the damage that USFS managers believed was occurring to the timber resource National Forests contained CITES?

Although using fire as a tool to protect forests had numerous proponents, including members of USFS and the timber industry itself (Pyne 1982; van Wagtendonk 2007; Larson, 2016)[1], early field surveys conducted by Forest Service researchers selectively reported that fire was overtly damaging to trees, reduced market value, allowed pathogenic infestations, and was aesthetically displeasing to recreationists (Show and Kotok, 1924). Although the conclusions from these surveys were eventually disproven by external fire ecology research, they allowed the USFS to construct a narrative that forests needed protection from fire. The best way known to achieve that was a system of aggressive detection, response, and suppression modeled off on the European forestry doctrine most senior USFS managers had been educated in (Pyne 1997). The upshot of this system was an influx of funding to support an existential rationale for the new USFS as well as the seed for an institutional culture of forest protection that continues to this day. In 1935, the USFS codified their approach into what was called the "10 a.m. policy," where an attempt was made to suppress every fire no matter the cause or values at risk, which persisted until 1978. Echoes of this policy are seen in the full suppression mandates that nearly every state agency now follows, itself a result of legislation such as the Clarke-McNary Act of 1924 and the Rural Community Fire Protection Act of 1972, which Congress mandated the USFS to administer (Pyne 1982). The Forest Service has long leveraged these mechanisms to get the states to follow the doctrine of the USFS, even when dissenting employees of states thought perhaps another way was better (Schiff 1962).

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[1] The famous *Sunset* magazine debates are the best example from this time when a public back and forth discourse for the use of fire within forestry existed. Numerous scholars have wondered how the course of American forestry and wildfire management may have been different if proponents of fire's use had won the argument. This entire debate is described at length in David Carle's 2002 *Burning Questions*.

Although the consequences of fire exclusion were observable early in the 20th century (Leopold 1924) contemporary voices of dissent were aggressively suppressed in the prominent literature outlets. However, as the average size of fires began to grow, as degraded quality and condition of forested stands began to affect the timber products industry, and as the environmental awakening of the 1960's filtered into the mainstream, the problem of fire exclusion began to be unignorable. Under pressure attendant to the mounting costs of blood, treasure, and ecological functioning, the tide began to finally turn away from strict suppression policies to something that more accommodated the role of landscape fire. The National Park Service led the way in 1968, allowing some fires to burn first in Yosemite and Kings Canyon, followed by Saguaro and Everglades (Kilgore 2007). In 1972, the USFS reluctantly, and only slightly, loosened its' wildfire policy. The scope was limited to one of the most remote landscapes within the purview of the Forest Service: the White Cap Wilderness in Montana and Idaho (Smith 2014). Begun on a strictly experimental basis, the softened policy allowed managers to use wildfire to achieve an ecological benefit within this one large remote wilderness area. Perversely, perhaps defiantly, the 1972 policy also included a provision that directed managers to suppress all other new fires to less than 10 acres in size, which added to the long-standing policy to put them out before 10 a.m. the morning after it starts. Between 1972 and 1978, when this 10 acre & 10 a.m. policy was discarded for good, internal research showed that not only was it failing in practice, but also that it would cost on the order of 90% more than was already being spent to increase success 2 more percentage points (Pyne 1982). In 1978 all previous USFS fire policies were rescinded in favor of 'fire management' over 'fire control.'

Prior to 1978, there was no room in the official dialogue to discuss fire as a net positive event, even on small portions of a fire or in remote areas. Even after the policy shift, the concept of using fire as a landscape management tool on USFS lands started as a hidden thing, shunted to far wilderness areas out of view of the populace. Within the White Caps Wilderness, where the seed of modified Forest Service wildfire response began, the size of the landscape was forgiving and gave a buffer to management uncertainty. Yet, the wilderness may have been the best nursery for fire use. Fire conditions in wilderness areas tend to be more easily managed, the fire seasons are shorter, and topography tends to be favorable to reducing spread. Wilderness areas tend to be higher in elevation, so fires burning there often have nowhere to go but upward in elevation away from civilization. To wit, the earliest use of fire by the National Park Service (NPS) in Yosemite specifically used the elevational band of higher than 8,000 feet

as a boundary. If it started lower than 8,000 ft, it was immediately suppressed. If higher, it was a candidate for being managed (Kilgore 1976).

The lessons learned by visionary researchers like Bob Mutch began to spread out of the White Caps into other National Forest Systems (NFS) lands, picked up by others who held a vision of fire management as something other than fire suppression. These fires remained in the wilderness for a number of years afterwards and soon adopted the moniker 'Wilderness Fires,' although the NPS also introduced the terms 'natural prescribed fire' and 'natural fire program in 1971 and 1972, respectively (Agee 1974; Kilgore 2007). In 1983, a first of its kind "Symposium and Workshop on Wilderness Fire" was held in Missoula, MT, where many leaders in academia, agency research, and management convened to discuss the practical and philosophical use of fire to achieve ecological goals. This resulted in a technical report produced by the USFS (Lotan 1985). In 1986, the term 'prescribed natural fire' (PNF) was broadly agreed upon by federal agencies, later confirmed in 1995 within the first consolidated Federal Wildland Fire Policy (FWFP) and used continuously until 2001 when the FWFP was updated (Bunnell 1995; Dale 2006). The 2001 update changed the preferred term to 'appropriate management response' (AMR) and was meant to indicate that all tactics and strategies employed on a wildfire should be tied to what is most 'appropriate' for the circumstances of values, risk, and fire conditions. AMR was short lived, replaced in a 2005 policy update with 'Wildland Fire Use' (WFU), which for the first time provided direction regarding how and where wildfire strategies could be employed (Fillmore *et al.* 2021). The WFU era dictated that a fire could be managed to achieve resource benefit objectives, or could be managed for suppression, but could not do both at the same time. In other words, it was an all-or-nothing approach, and if any portion of the fire was seen to require full suppression, the strategy for the entire fire irrevocably reverted to suppression. A benefit of managing wildfires as a 'WFU fire' was that the acres burned could be counted towards fuel reduction targets, which was an incentive for managers singular to this policy era. In 2009, the federal wildland fire policy was again updated to the version that is current to the time of this writing and research. This 2009 update eliminated the rigidness of WFU while simultaneously blending provisions of many previous policies into a new overall approach that bifurcates wildfires into either 'planned' fires (more commonly known as prescribed fire) or 'unplanned fires,' meaning those ignited by humans or nature. As long as a fire is naturally caused, it may be managed in whole or part to achieve resources benefits, which ostensibly opens up wide possibilities but has been shown in this

research and others before it to have resulted in confusion and communication gaps when trying to describe intent (Seielstad 2015; Young *et al*. 2020; Iniguez *et al*. 2022).

As their predecessors had, today's wildfire decision makers must balance the same tradeoffs of risk to firefighters and the public versus the risk to the landscape. They must navigate the same tension of having enough financial, technological, and human resources to respond to the fire versus the net value benefit of doing so; all made more complicated when neither the costs nor net benefits can be known ahead of time. Often, fire managers will default to the 'safe' option of suppression, which has become the American wildfire governance norm, despite the well-known paradox that this approach is perpetuating and perhaps extenuating the problem it seeks to avoid. On the surface, the notion of redoubling efforts to suppress unwanted wildfire sounds like a reasonable ask, especially considering fire seasons that often one-up the previous year in terms of acres and homes burned. For years federal fire responders have been running at the red line of initial attack suppression capability. Nationally, for those fires where the attempt is made to fully extinguish it at initial response, agencies have consistently been ~98% successful. Success equates to the fire being extinguished quickly - usually within the first few hours, and at a small size. The other 2% of fires are the ones that escape despite our efforts and grow large. We've never been able to change these numbers, and simply keeping it at 2% is growing more challenging every year (Belval *et al*. 2017). Meanwhile, this 98% success rate slowly adds to the fire deficit, altering ecological trajectories (Adams 2013) and making the natural environment more hazardous to those living within it (Parisien *et al*. 2020).

Yet, a standard point of agreement among wildfire practitioners and academics alike is a notion that more wildfire needs to be allowed to burn on the landscape to pay back the deficit of fire intervals that have been missed (Ager *et al*. 2017). However, exactly how to best accomplish this feat remains an unresolved dispute, and the decision to not suppress a wildfire is not the simple inverse of the decision to suppress one. Some stake their argument by doubling down on the existing structure of applied fire - prescribed burning. Despite decades of trying that approach, prescribed fire has failed to reach the scope required to alter trends, and it is possible that prescribed fire will never affect more than boutique objectives in areas of particular concern, such as high value Sequoia groves and prairies seeking restoration (Kolden 2019).

Others argue that structures and other valued bits of infrastructure should be engineered to the point where they would be unharmed within the path of any actively moving fire (Paveglio *et al.* 2010; Smith *et al.* 2016). Wildfire would become a temporary inconvenience, would change the view outside, but would no more threaten our values in a physical sense than a

strong breeze. This idea has an attraction to it, but the socio-political reality is that in order to achieve this end requires both a high level of public awareness of the risk and the economic means to mitigate it (Lee *et al*. 2022).

Technocratic solutions have long been offered to address the worsening wildfire situation (Pyne 1982). New fires rarely have the chance to gain a foothold before a remotely observable webcam running an algorithm designed to detect rising heat and smoke has detected and autonomously notified authorities with triangulated coordinates before the staffed lookout can put down their paperback book and swing the Osborne around to shoot an azimuth. Should the webcam (or lookout) fail, a satellite in geostationary orbit above the earth otherwise unencumbered with detecting nuclear detonations will automatically recognize a new heat signature and beam down an alert. Following detection, the usual routine of launching aircraft, mechanized and pressurized water delivery, dirt movers, and human transport will follow close behind. As these resources mobilize, predictive models of fire behavior and spread overlaid on downloadable georeferenced maps are sent to their smartphones. The only barrier to a swarm of drones overhead is cost and desire to adopt the technology (Saffre 2022).

Neither the US public nor its fire agencies have collectively chosen which path to embrace. Unfortunately, this leaves a wildfire decision maker alone trying to balance policy nuances, social expectations, technological tools, information overflow, and professional demands. They must ingest these inputs and make that final decision regarding how to engage with every wildfire. The widening of the current policy has made this effort more complicated in practice, as most policy-based decision sideboards have been stripped away. The manner in which a decision maker goes about balancing these competing factors is an area of research largely unexplored in any holistic manner and has even more rarely been approached from the stance of looking at the suppression/ non-suppression decision. This is the context where this dissertation will linger, poking into corners of decision making that has not been explored in any great detail.

Literature examining the wildfire strategy decision context

Existing research has examined different elements and factors that characterize the wildfire decision environment, but no study has specifically tried to frame the entire decision space within the context of barriers and facilitators to choosing differing available management strategies. Even fewer have collected direct data from wildfire practitioners, and even less during actual wildfire incidents while decision makers were living with the uncertainty of their

decisions. Most studies fall into one of three contexts: factor identification and analysis (Cortner *et al*. 1990; Williamson 2007; Kolden and Brown 2010; Steelman and McCaffrey 2011; Thompson 2014; Meyer *et al.* 2015) or risk-based decision making (Wilson *et al.* 2011; Thompson *et al.* 2013; Hand et al. 2015; O'Connor et al 2016).

Several papers that outline decision frameworks were the primary inspiration that carried through this research. The earliest example was in a paper co-published by O.L. Daniels, the main author in two of the 24 papers used in Chapter 2 and an early advocate of wilderness fire (Daniels and Mason 1985). In this paper, they offer a simple yet powerful illustration of a 'decision space' that future models emulated. Interestingly, they differentiate political from social as well as economic factors, which are sometimes combined in other models (Figure 1.1). They also differentiate biological from physical inputs.

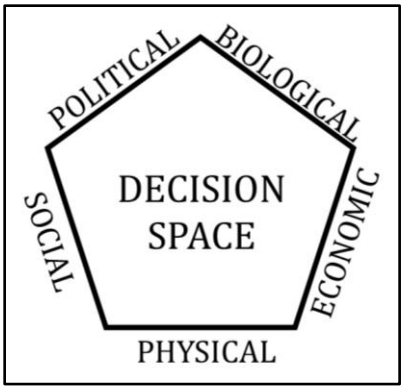

Figure 1.1. Decision model reproduced from Daniels and Mason (1985).

The next attempt at modeling the decision environment arose from Martha Williamson's (2007) thesis work, which examined decision factors within the context of WFU, the policy at the time of her writing. It expanded decision factors to include public health issues, staffing limitations, policy, internal support, and risk management (Figure 1.2). Previously identified factors that pertained to political, budgetary, and social issues were carried forward. For the first time, her work specifically focused on the pathway towards or away from managing a fire to achieve resource benefit. Framed another way, her work provided early insight into what allowed any deviation from the dominant suppression doctrine.

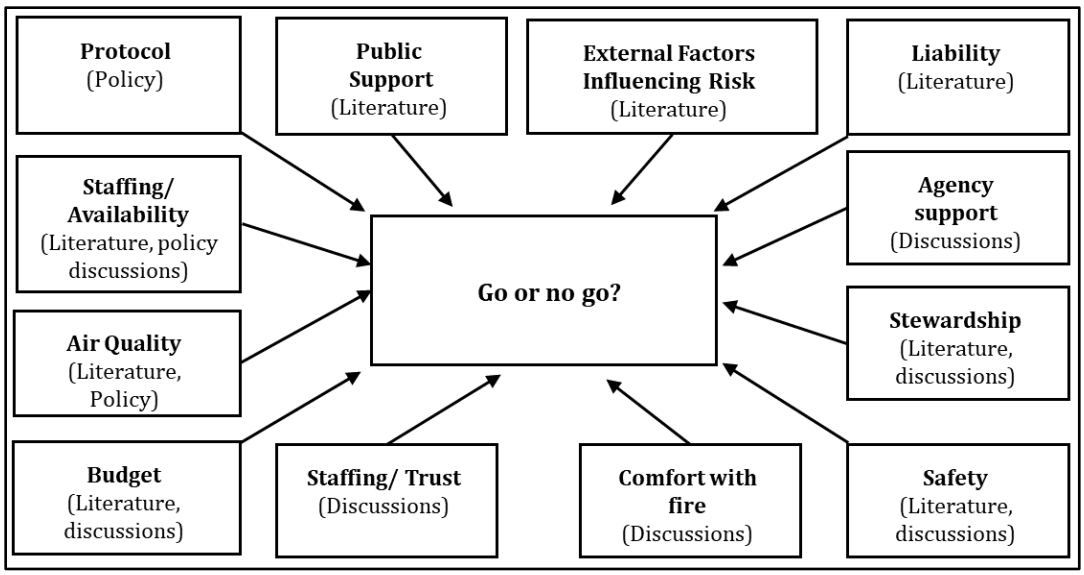

Figure 1.2. Wildfire decision model reproduced from Williamson (2007).

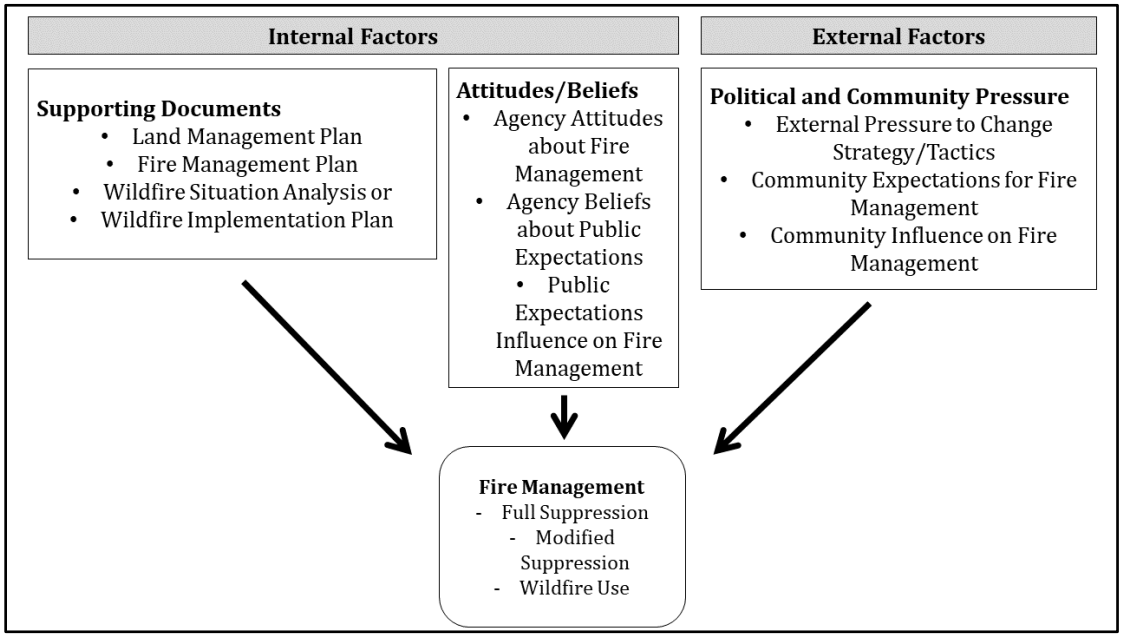

Figure 1.3. Wildfire decision model reproduced from Steelman and McCaffrey (2011).

Toddi Steelman and Sarah McCaffrey examined the decision environment in their 2011 paper that looked specifically at internal and external pressures that fire managers face while making wildfire strategy decisions (Figure 1.3). In the two cases where they conducted field research, they found that internal factors such as policy and planning documents frame the decision space, while employee attitudes frame the interpretation of these documents into action. As before, external inputs like public and political actors display a range of support or

opposition to alternative management strategies, which in turn affects the strategic decisions for a given fire.

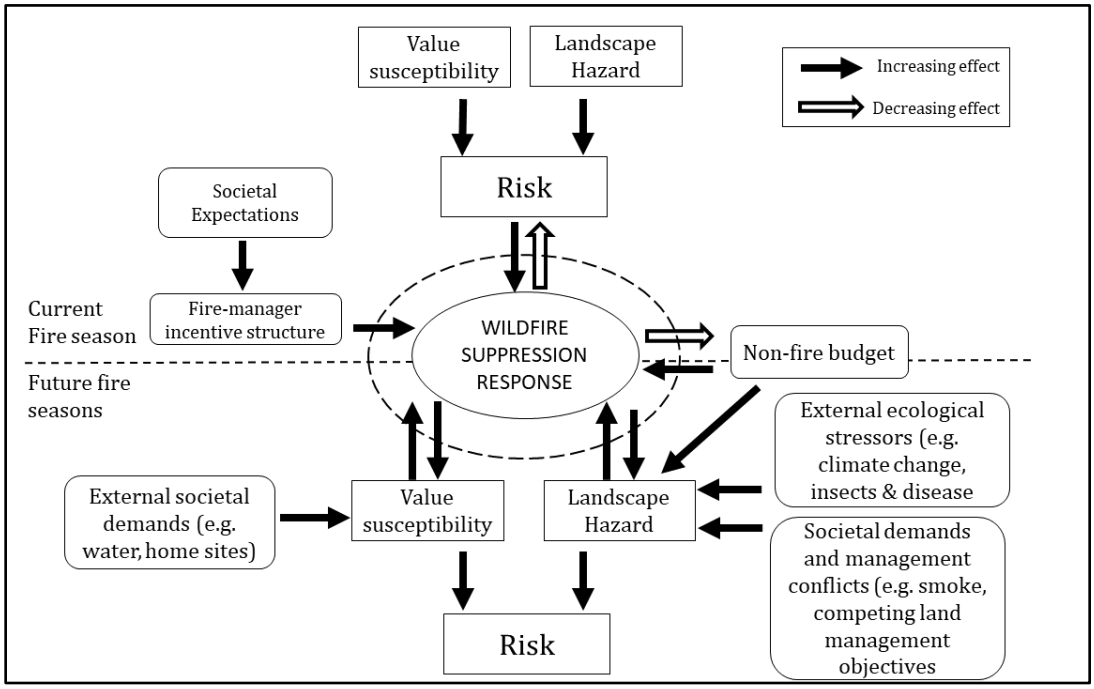

Figure 1.4. Wildfire decision model reproduced from Calkin *et al*. (2015).

Finally, in a paper that reviews the literature, Calkin *et al*. (2015) looks at aspects of risk and hazards that drive response strategies, with an interesting twist that their model incorporates both current fire events and how those reinforce the suppression response strategy into future fire responses (Figure 1.4). Although this decision model is primarily framed in risk, it does incorporate many elements seen in other models, including fire environment factors, internal and external pressures, budgetary concerns, and public health.

Although these papers, and others that also explore the use of wildfire managed to achieve a resource benefit, provide a substantial base of information in which to work off, none specifically looked to encapsulate the entirety of the decision environment. The research in this dissertation began with a focus on the factors that allow a fire to be managed. However, as discussions with interview participants progressed, an advantage to characterizing the entire decision space began to emerge, especially as evidence accumulated in the data that the original hypothesis where only one factor was required to suppress a fire was perhaps false. Fortunately, all three research chapters managed to fill an important missing gap in the literature. Chapter 2 describes the overarching historical trends of managed fire decision

making up to 2009 when the policy changed. Chapter 3 examines the standard federal wildfire decision support tool, and specifically asks how this system is used to assist managed fire decision making, which has not been presented before. Finally, Chapter 4 updates and validates the decision factors reported in Chapter 2 and brings the decision framework model up to the current time, which also has not been reported elsewhere in the literature.

Research Scope and Summary of Chapters

The research undertaken in this dissertation was driven by a desire to understand the decision making process of managers as well as understand how the decision environment affects their decision making process. This ended up incorporating elements of risk management, ecological functioning, decision theory, policies, personality-driven motivators, and even social constructionism. Most previous research identifies the problem in modern wildfire management and spends most of its letters discussing the consequences of the problem without ever looking at the core elements of what is making decision makers at all levels perpetuate a pattern of behavior that continues the problem into the future. This is akin to medical doctors focusing on treating the symptoms and not the root cause, which has unfortunate parallels, as the medical community has grown an industry around this practice the same as the wildfire-industrial complex has. The aim here was to largely ignore the consequences and attempt to get to the root cause - what exactly drove managers to perpetuate fire suppression as the standard response, and even more importantly, what factors allowed them to use fire as a tool despite that being counter to the normative behavior? We found decision elements that arose from their own personal experiences as well as ones that tiered to the institution for which they were working. There were three main contexts for the collection of data presented in this dissertation The first was an extensive literature review that provided a base of information; the second was an interview-based study that allowed for non-temporal and non-spatial exploration of decision making processes, and the third was a case-based study interviewing managers during the fire event.

There is really only one core question that runs through all of this work: if fire managers know that more fire needs to be allowed to burn on the landscape in order to improve the overall condition and services that the landscape provides, why is it not happening more? Many more questions follow from this, but the basis for all other research questions contained herein flow from this seeming paradox.

The first research paper, presented in Chapter 2, was an extensive literature review conducted in order to understand what other researchers who spent time in this vein had uncovered. This Chapter was moved by one simple research question: *within the available scientific literature, what factors have been considered in the managed fire decision-making process, and how do they affect the decision made?* This research found an incredible number of factors at play within the decision making environment which had never been cataloged within one research paper before. Interestingly, the inclusion criteria that we used naturally created a cut-off of papers that ended in 2008, just before the policy change. Although not intentional, this created a perfect 'before' examination of the decision factors that then allowed an 'after' look, researched and discussed in Chapter 4. Finally, in Chapter 2, we encapsulated the decision factors into a 'Managed Fire Decision Framework' which clearly identifies major thematic areas found within the pre-2009 wildfire decision environment. This paper was published in the journal *Fire* in 2021 and has been cited in recent publications when those papers needed to cite factors that contribute to decision making.

Chapter 3, the second research paper, is the first research I conducted collecting original data. It is research that examines the use of the Wildland Fire Decision Support System (WFDSS) among USFS employees. I chose to conduct this research for two reasons. First, because it would allow me to learn how to conduct interviews under academically professional conditions with an established researcher outside of my committee. Second, I was allowed to modify the research intent to include a line of questioning of specific interest to my research. There were three research questions for this project. First: *how is WFDSS used in the fire incident decision making process*? Second: *what is the perceived effectiveness of WFDSS training modes*? Third: *how do fire managers use WFDSS differently when developing decisions for full suppression or when considering fires managed for resource objectives*? Although the use of decision support systems was not my main intent, it provided a different perspective and reinforced the notion that decisions do not entirely reside in the mental framework of the decision maker themselves, and that outside assistance provides value to the process. This project also allowed the first discussions directly with fire managers about their use of wildfire to achieve resource benefits.

Chapter 4, the third research chapter, is the culmination of the research in this dissertation and represents the largest gap in the literature. This project was designed to follow up on the factors found in Chapter 2 and explore some attributes discussed with managers in Chapter 3. Although the true scope of it was large, we returned to another two-pronged research question:

among agency administrators (AAs) and fire managers, what factors are being considered in the wildfire decision-making process, and how do they affect the decisions that are made? This research, conducted during the fire season of 2021, focused on AA's who were overseeing active wildfires, which allowed contemporaneous discussion of decision factors outside of any hindsight lens. Our interviews included the full range of available management strategies, which created a full picture of the contemporary fire decision making environment. This allowed novel themes to emerge, corroborated the presence of others observed in Chapter 2, and ultimately resulted in an updated framework renamed to the 'Wildfire Decision Framework,' which has value for characterizing the principal thematic factors driving the modern wildfire decision making environment. This framework will allow other research to explore decision factors at any of the three levels presented in it, and hopefully allow a more fully realized understanding of the influences that affect decision makers.

As with any research study, certain limitations were present. First among them was my limited ability to speak with wider segments of the fire management community. Although I spoke with nearly 100 individuals in many different parts of the country, this is still a very small portion of the entire wildfire community. Therefore, any inferences contained within these Chapters may be only representative of small cultural pockets and not the wider whole. Only further research that expands the aperture of perspective will validate the degree of closeness to truth that these data present. In all Chapters, I actively encourage this, and in fact the frameworks are structured so that future researchers may check any assumptions that we have made and provide needed refinements. So too, with future policy iterations, will these frameworks need to be updated.

The second limitation pertaining to this research was that of my own biases which is particularly important to be aware of when conducting social science research, as qualitative data by design must be run through the personal filter of interpretation. My biases were especially concerning, as I had been in the field operating for more than 15 years when I started this dissertation. Advice that I received early in the process corroborated that this was something to be aware of; yet was also inescapable no matter how seasoned of a researcher you are, and that just being aware of it, and avoiding its pitfalls, was the largest hurdle to overcome.

Of course, analyzing the data alongside other researchers, especially the experienced ones who contributed to these papers, helps keep this issue in check.

Out of Scope

While researching the following chapters, numerous lines of additional inquiry had to be passed by in the interest of keeping the scope within reasonable limits. Principal among these is that nearly all the research contained here is bounded within the scope of US Forest Service (USFS) decision making. The only deviation from that is some inclusion of non-USFS data in Chapter 2; even that represents only limited perspective from the National Park Service. Because of this, the results and implications of this dissertation should only be applied to the processes used by the USFS. However, other federal land management agencies could be examined with the lens provided here with only minor modification to research questions that incorporated their specific processes and cultures.

Even within the USFS, the data collected hints at regional differences in cultures that translate to their approaches towards wildfire management. This is a line of research that I discuss in the conclusion – in terms of scope, it was outside the scope of this research to elucidate these regional differences, which could itself likely entail an entire dissertations' worth of research.

Finally, it was beyond the scope of this research to validate the degree of truth that decision makers spoke to. For example, if a decision maker reported that tensions existed with a local political entity, it was beyond the scope for us to go and contact that entity to verify their claim. This extends to all decision factors. As the future research section in Chapter 5 elaborates on – future research should spend time determining the actual magnitude of these factors at a more granular level than this research could hope to achieve. These chapters merely point the direction.

Thought Experiment

Removing fire entirely from the landscape is as unachievable as removing its rivers, although in our human hubris, we have certainly made the attempt. As our society continues to intermingle with wildlands and the fires that burn there, we are forced to blend the role of fire within the larger goals of society. At its core, this forms the basis for the most pressing overall problem we currently face with wildfire management in the US. How do we live with wildfire, and maintain our societal status quo?

The middle road describes a nuanced perspective that is rooted in finding ways to "live with wildfire." This approach is the vaguest, but perhaps also the most reasonable, as it contains a

recognition that the opportunity is open to everyone and that the best solutions are still in the future. It provides space for local responses to local issues while providing an overarching vision. Still, this path is also the most uncertain. It does not provide a guarantee that we will ever find a way to coexist with wildfire in a mutually beneficial way. It does not provide strict technocratic direction. It leaves some things to chance. Worst of all, it leaves open the possibility of maintaining the status quo, which no one seems quite satisfied with. Early in writing this dissertation, I mused on the idea of starting a wildfire system over from scratch with, something impossible now, unless perhaps Antarctica thawed completely out and resumed its ancient fire regime. The philosophical notion of *tabula rasa*, or 'blank slate' has been around for several millennia, however I had never seen it applied to wildfire management. As a result, we developed the following essay, which in turn generated a Topical Collection in the journal Fire, although few if any papers actually rose to meet the challenge posed in this paper. The notion of starting over from scratch is as good a place to start this dissertation as anything else.

Taking a Tabula Rasa Approach to Wildfire Governance: A Thought Experiment

The following paper was published in the journal *Fire* on June 5th, 2020 as:

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Abstract

This perspective presents an opportunity, framed within the classic approach of a thought experiment, to discuss how a new wildfire governance framework may be created from the ground up if it were unencumbered by any existing construct, or experiences. It is not specific to any one country or fire regime; rather it is intended merely to stimulate a wider conversation about where we are at collectively, and where we may want to move to in the future with our policies, organization, science, management, technology; or any of the myriad components that comprise the greater discipline of wildland fire science and management. The authors suggest that loosening the shackles of reality may allow for innovative discussion and the generation of transformative ideas to help ecosystems and communities better coexist with fire.

In order to frame this thought experiment, we follow the premise defined by Locke (1690) that is commonly referred to as a *Tabula Rasa* approach (Duschinsky 2012; Eng, 1980), whereby we assume that everyone leaves the country. It doesn't matter which country. The reason for leaving is not political dissent, rampant disease, colonization for a new planet, or any other such drama. No reason at all - we're all just going to take off for a while. While away multiple generations pass and the environment returns to nature. At some distant point in the future, a group of adults having heard of the myths of the old world, decide that they want to go back to recreate life and society there. They are aware that it's a clean slate, as Locke stated, a '*white paper, void of all characters, without any ideas*' (Locke, 1690). The current societal leaders are okay with their wish, with the strict caveat that before they leave, they must make a coordinated plan for how they want to manage the landscape and the fire within it.

They would of course have access to the historical fire history leading up to the point when their ancestors left the country. At their disposal they would have mountains of wildfire-related research papers, lessons learned, textbooks on fire ecology and community response, reams of governmental management plans, surveys, models and designs. Yet, they get to choose their own path for what to do with this information, if they decide to use it at all. They are not beholden to any of it. This is their chance to start over. The advantage they have here is the ability to work with both a clean slate and the hindsight of others' experiences.

This thought experiment ignores any of the required societal planning details except for those directly related to the question we're interested in: just how might this returning generation choose to reengage with wildfire on the landscape if they were able to do so from a position of hindsight, but with no existing governance to restrict them?

Now then; let's enter into their discussion as a participant-observer.

The first question is perhaps the most obvious one, so we will start there. Of what existed before, what should be recreated? The returners start with the acknowledgment that fire will be present either from the fire natural or the fire they bring. From a review of the fire ecology literature, they would know that fire possesses a role in nearly every ecosystem. They would know that fire came naturally at different intervals and intensities and expressed itself as definable regimes. They know that fires lit by humans could have a dramatic effect on these fire regimes, and that the removal of human fires could be equally influential.

They would know that fires ignited within the natural patterns of the regimes could have a complementary effect. Fires lit outside of these rhythms could serve as an interruption. The ecosystems and fire regimes that the newly arrived would enter back into would not be the

same as the ones that the earlier indigenous peoples entered, nor would it be quite the same as the ones that their parents left. The species that exist on the landscape now are different; caused by worldwide transport of humans, animals, and seeds, and climate change. Knowing all this, would they chose to incorporate that approximated what existed before?

The next question is the simple converse. What aspects of wildfire as it was before everyone left would be most important to discard? The first and most obvious idea may be to question the paradigm of whether wildfire can be controlled entirely within the intentions of humans. They will explore this question through the lens of knowing how policies of fire suppression and fire use played out in multiple countries. It is tempting to believe they will intrinsically accept that wildfire will burn where available fuels and conditions allow it, and adjust their plans to enable coexistence accordingly (Schoennagel *et al*. 2017; Smith *et al*. 2016; Smith *et al.* 2018). In that event, they may design communities that mimic how plants and animals have adapted to coexist with fire (Schoennagel *et al*. 2017) and perhaps will not ignore it for economic reasons or assume that someone will simply put the fire out. Nor may they choose to ignore inevitable 'downstream' cascading consequences such as soil transportation within denuded waterways impacting human values placed downstream or mudslides that occur following storms in burned areas (Smith *et al*. 2018). Perhaps they will rethink what their values are, how much importance to place on them, or simply where to place them. They may be more contemplative about sending humans to fight wildfires when the humans sent are the only tangible values at risk. Perhaps some among them would argue to avoid relocating their values as archipelagos within a sea of future fire.

Having sketched out some options for what they may choose to keep or discard, some deeper questions arise. What is the necessary level of investment and engagement with wildfire in this scenario? Lessons from the past show that over time, wildfires drew in more and more investment from local and national resources. The newly arrived may be wary of repeating this mistake. They may wish to seek only to entangle themselves with wildfire at the level that meets their societal goals (undefined at this point, perhaps), and allows nature to meet its own goals unassailed. This would require deliberately retooling the juxtaposition found at the human-nature interface. It could be seen as a separation, a barrier, or a mutually beneficial welding. We may hope that they find some middle ground whereby fire is allowed to work its intentions and humans are unaffected except perhaps by the occasional drift of smoke, or an umber sunset worthy of remark.

Without doubt, someone in the re-peopled country would be tasked with keeping an eye on the flames. What then would be the most appropriate governance? The colonizers would have to ask themselves the question of scale. At what scale do they wish to see wildfires be governed or at all? This may be one of the most challenging questions to answer. They could emulate the majority of countries that have either organized their fire responses under local organizations such as states or territories, or others who have chosen to nationalize the entire fire service. Some countries have an extremely complicated hybrid of local, state, and national responsibilities that operate in a patchwork fashion; even private contractors get in on the game. Deciding the complexity of their governance will reflect their desired level of entanglement with the fire itself. Is it an occasional worry, with an occasional response? Does it equate to the scale of an individual fires impacts, or does it aggregate into a national level concern?

There are several countries that have institutionalized a nationalistic approach to what is otherwise a local problem. At first, most of these countries only engaged with the wildfires it was required to. These were the fires close to settlements, visible to the populace. After experiencing both successes and failures they often chose to manage further into the backcountry and engage with fires that they really didn't need to, beyond principles of dominion. So, do they continue to chase that smoke into the backcountry, or do they let it burn as it may? Do they continue the argument that the backcountry fire becomes the front country if left alone?

We will end the thought experiment at this stage. In your mind, return people to their homes and homelands. Return the existing government to its place of institutional oversight. Place the fire engines back in their engine bays ready for the call-out. Before we go, however – a question to leave you with. If the discussion leads to general agreement that starting over with a clean slate would lead us back to the same place we are now, well then, we can be satisfied in knowing that we are currently have the optimum approach to managing wildland fires. If there is agreement, however, that a clean slate would produce a different direction, we then have to ask ourselves, are we taking those steps now? If not, why not? Perhaps it's too easy to forget that what has been put into place can just as easily be replaced. Institutions take on a life of their own and often it becomes difficult to realize that its collective visions are encultured and indoctrinated.

If a new path is needed, dare we reset the successional pathway of wildfire governance?

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Chapter 2: A Mixed Methods Literature Review and Framework for Decision Factors That May Influence the Utilization of Managed Wildfire on Federal Lands, USA.

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Abstract

There is increasing discussion in the academic and agency literature, as well as popular media, about the need to address the existing deficit of beneficial fire on landscapes. One approach allowable under United States federal wildland fire policy that could help address this condition is by deliberately managing wildfire with a strategy other than full suppression (hereafter referred to as 'managed wildfire'). To improve the understanding of the managed fire decision-making process, we conducted a mixed methods review of the existing literature. This review spanned 1976 to 2013 and used thematic coding to identify key factors that affect the decision to manage a wildfire. A total of 110 descriptive factors categories were identified. These were classified into six key thematic groups, which addressed specific decision considerations. This nexus of factors and decision pathways formed what we describe as the 'Managed Fire Decision Framework', which contextualizes important pressures, barriers, and facilitators related to managed wildfire decision-making. The most prevalent obstacles to managing wildfire were operational concerns and risk aversion. The factor most likely to support managing a fire was the decision maker's desire to see the strategy be implemented. Ultimately, we found that the managed fire decision-making process is extremely complex, and that this complexity may itself be a barrier to its implementation.

Introduction

Numerous scholars have noted that a century of fire suppression has contributed to a deficit of characteristic wildfire in many parts of the western United States [1–4] and that neither fire frequency nor fire-related effects is sufficient to maintain characteristic ecosystem function,

goods, or services [3–8]. This recognition has led to increased interest, from fire managers to policy makers, in how fire can be safely and effectively reintroduced into these landscapes.

There are two main strategies for reintroducing fire. The first strategy, commonly known as prescribed fire, entails carefully and deliberately igniting fire to achieve land management objectives [9]. These burns are often conducted by professional land management agencies, private landowner cooperative groups or individuals, tribal entities, or non-profit landholders. Prescribed fire is referred to as 'planned fire' in US federal wildland fire policy as well as in other countries [10,11]. Prescribed fire as a management tool in North America has a long history, originating among the indigenous peoples who first populated North America [12,13], later used by early European settlers and private landowners [14], and eventually adopted by government land managers as early as the 1930's [15,16]. On US federal lands, prescribed fires are subject to a formal environmental review and are implemented within strict prescriptive parameters designed to meet specified objectives. They are typically conducted outside of the characteristic season for wildfire in the local ecosystem, but within the margins of available burning conditions [4,12,14,15]. Recent research has shown prescribed burns are difficult to implement at the scale necessary to achieve landscape restoration goals [14,17].

The second strategy to reintroduce fire, used primarily on federal lands, occurs when the response strategy to new wildfires does not unilaterally focus on suppressing the fire at the smallest possible size within the shortest time frame. This strategy is currently referred to as managing the wildfire for an objective 'other than full suppression' (OTFS) in federal reporting documents such as the National Interagency Fire Center (NIFC) Incident Management Situation Report (IMSR) but has been known by other names in past policy iterations, including 'Wildland Fire Use fires' [18]. For the sake of simplicity, the OTFS term is usually shortened by wildfire professionals to 'managed fire.' This strategy often entails managing the wildfire in a manner that achieves ecologically beneficial outcomes. Under current US policy, the OTFS strategy may be implemented either on the entire fire, or on segments of the fire [11]. This is a change from pre-2009 wildfire policies that required wildfires to be managed for either suppression or resource benefit, but not both simultaneously [18]. The current policy allows for all unplanned fires to be managed for suppression objectives, or for resource benefit objectives (or both), but is ambiguous regarding when and where the appropriate usage of these strategies should be employed. An OTFS strategy often requires local pre-planning to have been completed, such as amending the Land Management Plan, to allow for its use as a management tool [19–21]. Additionally, external regulatory agencies such as air quality districts address OTFS wildfires as

a planned land management action rather than an emergency response [22]. Without careful dialogue and mutual understanding, land managers may be inadvertently sending mixed messages to collaborating agencies regarding the true strategic intention during wildfires managed for OTFS [22].

Although the strategic outcome of managed fire is largely the same as that of prescribed fire, it lacks the same project-specific prescriptive and administrative requirements that accompany prescribed fire implementation. Moreover, the desired end state objective of managed fire tends to be more open-ended, as these fires frequently burn for longer periods of time and have greater heterogeneity in their fire effects [5,23]. Recent studies have shown that managed fires can provide beneficial ecological effects on the landscape, especially where it has been used over a long period of time [24,25].

The ability to manage wildfires on US federal lands became a possibility in the 1960's [10,16]. In 1968, the National Park Service (NPS) became the first federal agency to officially allow managed natural fires [26]. The US Forest Service (USFS) followed suit to a limited degree in 1972 within designated areas of the Northern Rockies [16,27] and officially transitioned from a policy of 'fire control' to 'fire management' in 1978 via an update to the National Forest Manual, which also enabled the use of managed fire strategies [28,29]. In 1995, the first formal interagency fire management policy was adopted and included support for the use of managed wildfire on federal lands [30]. National wildland fire policy updates occurred in 2001, 2003, 2007, and 2009, all of which have encouraged federal fire decision-makers to find opportunities to use wildfire for positive outcomes [11,18,31,32].

Policy changes and updates have also changed the language used to describe managed fire. Official nomenclatures tied to significant policy changes or updates include 'Prescribed Natural Fire' (PNF), from 1968 to 1994, 'Wildland Fire Use' (WFU), from 1995 to 2007, and the brief use of 'Appropriate Management Response' (AMR), in 2008 [33]. Other terms we encountered in the literature include 'let burn,' 'natural fire,' and 'wilderness fire' [34,35]. After US wildland fire policy was updated in early 2009, the terminology shifted again; all vegetation fires became classified as either 'planned' (i.e., prescribed fire) or 'unplanned' (i.e., wildfire). An unplanned fire can be managed for 'resource protection' objectives or 'resource benefit' objectives, or both if the circumstances allowed [11,36]. In this review, we use the term 'managed fire' as an all-encompassing phrase when a policy context is not otherwise stated and nomenclature (e.g., WFU, PNF) is used when a particular policy period is being referenced.

Although both recent academic and agency literature [37–43] have advocated the need to increase opportunities to leverage the use of managed fire to achieve the desired resource-based outcomes, studies explicitly exploring how and why decisions are made to manage rather than suppress a wildfire are limited. Decision-making that occurs during wildfire events has been shown to be complex, requiring the consideration of myriad factors [44]. Previous research seeking to identify and describe the principal factors affecting wildfire suppression decision-making, their influences, and the pathways these decision processes take have covered a range of subjects including sociopolitical pressure, resource allocation, ecological ramifications, and risk reduction [27,33,45–47]. However, these research efforts have focused more on the attributes of suppression-based decisions. Fire scientists and managers have long identified managed wildfire as an important component within the larger integrated fire management system to mitigate increasing wildfire impacts in the western US [48,49]. Despite this, little work has been completed to provide tools or knowledge to managers that might help them to identify potential pathways for expanding its generally limited application.

The purpose of this review is to identify what factors decision-makers consider in the decision to manage a wildfire for an objective other than full suppression. We analyze and synthesize literature that directly addresses decision-making in the context of managed fire to identify the range and relative influence of decision factors. A simple research question guided the review process: Within the available scientific literature, what factors have been considered in the managed fire decision-making process, and how do they affect the decision made? We hope this systematic assessment of known decision-making factors specifically related to the managed fire decision-making process can provide insights into potential future opportunities to manage wildfire as well as illuminate areas where further research on managed wildfire decision-making is needed.

Materials and Methods

A systematic process was used to identify publications that specifically addressed decision-making in the context of managed wildfire. Papers were sought that included data derived directly from federal land managers in the United States who possessed wildfire decision-making authority. Although we acknowledge that such data may exist in Australia and other countries with a rich legacy of both wildland fire management and policy, the focus of this review is solely on the US, given that social, cultural, and geopolitical factors vary widely across national views regarding fires. The methods used were modeled and adapted from those used

in [50–53]. The search process was designed to be detailed and iterative. It included four separate search phases (Figure 2.1). Papers that met the inclusion and evaluation criteria were thematically coded and synthesized.

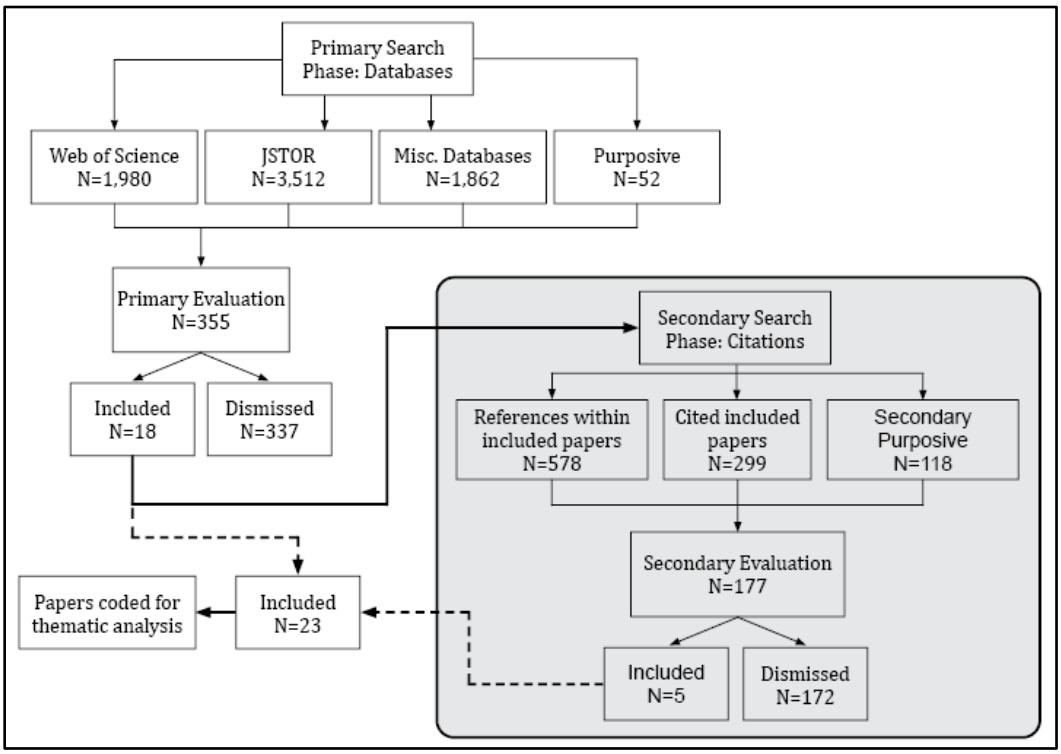

Figure 2.1. Visualization of the literature search and evaluation process. N refers to the number of papers evaluated at each phase. At each phase, abstracts or full paper texts were examined and compared to the inclusion criteria. Only those meeting the inclusion criteria were coded during the thematic analysis process.

The primary literature search was completed using bibliographic databases of academic papers (e.g., Web of Science, JSTOR) as well as a purposive sample of previously discovered titles and researchers. Search terms were designed to locate literature that specifically examined decision factors used by fire managers in the context of managed wildfires. Example queries included phrases such as 'wildland fire use,' 'let-burn,' 'prescribed natural fire,' and 'fire for resource benefit.' We limited our search to papers published after 1968, as US wildland fire policy did not allow for managed fire before this date [54]. The research in our review appeared soon after policy changes were implemented in the 1970's, continued through the late 1990's, and peaked during the WFU policy era of the early to mid-2000's. Although several papers were published after the 2009 policy update, these included data collected from before the changes took effect. Although we had hoped to gain a sense of whether the policy update had affected

the decision process, no papers were found that deliberately sourced their data after the 2009 policy update. The most recent paper included in this review was published in 2013, which we postulate was due to the research time lag or lack of research.

Literature titles and abstracts were first assessed for consistency with the two primary inclusion criteria: 1) peer- or editor-reviewed, and 2) within the context of managed fire decision-making in the US. Papers that met these initial criteria were then examined in greater detail to ensure that papers directly addressed decision factors related to managed wildfire decision-making, with evidence derived from either original research or personal fire manager experience (Table 2.1). Finally, a second search, using a modified sourcing approach, was conducted. This phase assessed every citation contained within the final set of papers from the initial search, as well as every paper that cited one of them. Finally, we repeated this process for titles and researchers uncovered during the second search.

Of the approximately 8,400 publications that were peripherally or directly examined, only 23 met the full inclusion criteria. The 23 papers included in this review are described in Table 2. While it is possible that relevant papers were not identified through this process, after a retrospective examination, we believe that the literature included represents the primary body of literature that directly discusses decision-making factors in the context of managed wildfire in the United States.

Table 2.1. All 110 descriptive themes organized under their respective Key Thematic Categories. The actual descriptive theme occurrence count is shown in parentheses. In total, 23 papers were coded.

Facilitators	Unaligned	Barriers
Fire Environment		
Favorable fire behavior conditions (2) Favorable climatic conditions (1) Favorable fire weather conditions (1) Previous fuel reduction work (1)	Fire danger rating (4) Expected weather (3) Drought index (2) Fuel type and condition (2)	Fire conditions unfavorable (2) Fire danger too high (2)
Fire Outcomes		
Improvement to forest health (4) Allow natural processes in general (3) Expected future fire behavior (3) Reduction in fuel (3) Improved wildlife habitat (3) Reduce exposure to fire staff (2)	Air quality concerns (6) Expected fire behavior (5) Expected fire growth (5)	Uncertainty of outcome (6) Air quality – regulatory (5) Air quality - public impact (4) Lack of information (1)

Table 2.1 Continued

Reduced suppression damage (1) Expected reduction in smoke impact (1)		
Sociopolitical Factors		
Collaborative relationships in place (7) Public supports (5) Communication related to the event (4) Public has been educated (2) Education opportunity for the public (1) Economic gain (1)	Public support (3) Impact to cooperators and neighbors (2) Impact to recreational users (2) Political support (2) Economic impacts (1) Opportunity to educate the public (1)	Political fallout concern (8) Lack of public support (6) Conflict with cooperators (3) Economic impact (3) External input opposes (2)
Institutional Influences		
Cost savings (7) Policy supports natural role of fire (5) Culture of fire use (5) Agency supports (2) Planning completed (2) Technology and data support (2) Peer recognition (1)	Available funding (6) Policy details (3) Differences of opinion (3) Fire cause (1) Agency support (1)	Culture not normalized to WFU (5) Lack of resources – Financial (5) Lack of agency support (4) Post fire rehab - no money (2) Local-Regional prohibitions (2) Not a priority (2) Policy as a barrier (2) Financial cost - post fire (2) Policy misinterpretation (1) Reporting accomplishments (1)
Operational Considerations		
Previous fires make it easier (3) Understanding of local area (2) No smoke impact (1) No infrastructure at risk (1) Better access in non-wilderness (1) Reduced resources need (1)	Resource availability (5) Proximity to boundary (4) Planning support (4) Coordination is in place (3) Expected duration of fire (2) Preparedness level (2) Amount of fire allowable (2) Experience with fire (1) Fatigue of staff (1)	Lack of resources, operational (10) Ownership boundaries (8) Lack of resources, planning (3) Lack of dedicated training (2) Fatigue length of time required (2) Existing fire load too heavy (2) Insufficient ignitions (1)

Table 2.1 Continued

Perceived Risk		
Personal ethic supports (9)	Risk to infrastructure (4)	Bias for suppressing wildfire (6)
Personal satisfaction (1)	Acceptable risk levels (3)	Threat to infrastructure (6)
	Risk to human life (3)	Threat to natural resources (5)
	Risk to natural resources (3)	Threat to public safety (4)
	Personal risk (2)	Stigma of failure (4)
	Risk of escaping boundary (2)	Concern for career advancement (4)
	Risk to firefighters (1)	Generalized risk aversion (3)
	Agency Administrator satisfaction with the plan (1)	Threat to private property (3)
	Confidence in staff (1)	Lack of incentive (2)
		Threat to firefighters (1)
		Lack of fire familiarity (1)
		Liability concerns (1)
		Threat to reputation (1)

Coding and Thematic Analysis

The papers that met our inclusion criteria were loaded into the NVivo 12 Plus qualitative data analysis software [55], read line by line, and coded using an inductive 'grounded theory' strategy [56]. This approach to coding is useful for allowing factors and category themes to develop organically, without a predetermined codebook [50,52]. The code and theme description language was continually adjusted during the coding process until consistent representations of decision-making factors were derived.

Topic Codes

In the initial review of the literature, we observed that decision factors could be alternatively discussed as a barrier, a facilitator, or sometimes even described without a clear indication of the effect on a final decision. To represent these observed differences, we created the overarching topic codes we called Barriers, Facilitators, and Unaligned. Barriers served to persuade the decision away from managing a wildfire; these were often obstacles that needed to be mitigated. Conversely, Facilitators made the decision to manage a wildfire easier to make for fire managers. Unaligned factors existed as a consideration, but with no clear effect on the decision on a particular fire, and are likely context dependent in their influence. In this review,

we will use capitalization when referring to a specific Barrier, Facilitator, or Unaligned factor that was derived from our thematic coding.

Descriptive Categories

Next, we coded to identify descriptive categories. These categories characterized specific decision factors reported within a paper to affect the decision-making process. These factors were coded to specific descriptive categories as well as one of the three topic codes. For example, if a decision maker remarked that times of high fire danger were not the best time to implement managed fire, the language was coded as 'fire conditions unfavorable,' and was also coded under 'Barriers.' This process was repeated wherever a specific decision factor was identified in a paper. Because we were coding for factor presence, descriptive themes were only coded once per paper. The clearest example of each descriptive theme was kept if multiple examples were found. In total, 110 descriptive categories were derived from the coding process.

Key Themes

During the descriptive coding, similarities across categories began to emerge and, as a result, 110 descriptive categories were subsequently grouped into a set of six organizing principles that we describe as 'key themes.' These thematic categories operated as a nexus between topic codes and descriptive categories and provide an analytical framework for understanding decision-making. The key themes are described as the Fire Environment, Wildfire Outcomes, Sociopolitical Factors, Institutional Influences, Operational Considerations, and Risk Perception. This final organization resulted in all 110 descriptive categories being classified under both a topic code and a key theme within the final Framework (Figure 2.2). For example, the descriptive category 'favorable climatic conditions' is classified under the Fire Environment key theme as well as the Facilitator topic code. The final Managed Fire Decision Framework is a visualized arrangement of all the Barrier, Facilitator, and Unaligned descriptive categories organized under six key themes. We discuss the Framework in more detail in the Discussion section.

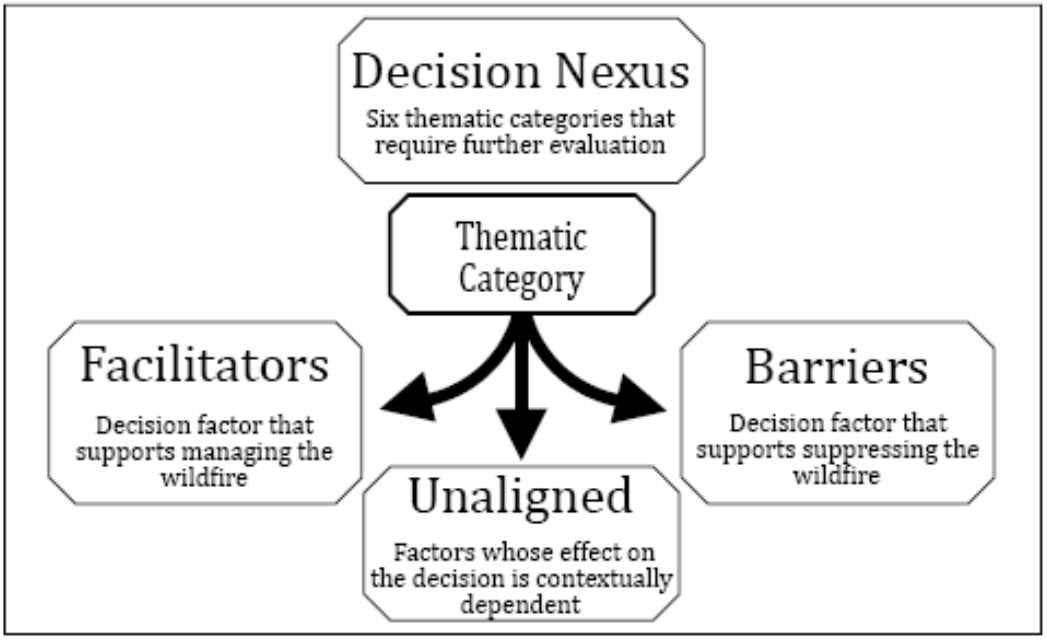

Figure 2.2. Thematic category decision flow within the Managed Fire Decision Framework.

Results

The complexity associated with making managed wildfire decisions is immediately evident in the first descriptive coding iteration, which identified 110 specific categories. Of these, 36 were considered Unaligned, 41 as Barriers, and 33 as Facilitators. Unaligned factors were reported in 9 of the 23 included publications, whereas at least one Facilitator or Barrier was reported in 21 of 23 papers. The most frequently occurring descriptive category was the Barrier 'lack of resources: operational.' Among Facilitators 'personal ethic supports' was the most prevalent, and among Unaligned, 'available funding' and 'air quality concerns' co-led in frequency. Table 2.2 lists all descriptive categories, how often they occurred, and their respective key themes.

Table 2.2. Literature included in the review as well as the research design, the authors' role in data derivation, and the policy context under which the data were collected.

Paper Citation	Research Design	Author's Role	Policy Context
Bonney, B.J. 1998. Use of alternative suppression strategies during 1994 on the Clearwater National Forest.	Case Study	Decision Maker	Prescribed Natural Fire
Bunnell, D.L. 1995. Prescribed natural fire planning considerations: conflicting goals.	Case Study	Researcher	Prescribed Natural Fire
Daniels, O.L. 1976. Fire management takes commitment.	Case Study	Decision Maker	Prescribed Natural Fire
Daniels, O.L. 1991. A Forest Supervisor's perspective on the prescribed natural fire program.	Case Study	Decision Maker	Prescribed Natural Fire
Desmond, J. 1995. Interagency wilderness fire management.	Case Study	Fire Manager	Prescribed Natural Fire
Devet, D.D. 1976. DESCON - Utilizing benign wildfires to achieve land management objectives.	Case Study	Fire Manager	Prescribed Natural Fire
Doane et al. 2006. Barriers to wildland fire use: a preliminary problem analysis.	Qualitative research	Researcher	Wildland Fire Use
Hunter, M. 2007. Wildland fire use in Southwestern forests: an underutilized management option?	Case Study	Researcher	Wildland Fire Use
Kolden, C.A. and T.J. Brown. 2010. Beyond wildfire: perspectives of climate, managed fire, and policy in the USA.	Qualitative research	Researcher	Wildland Fire Use
LaSalle, V.J. 1995. A vision for the future of fire in wilderness.	Case Study	Decision Maker	Prescribed Natural Fire
Miller, C. and P. Landres. 2004. Exploring information needs for wildland fire and fuels management.	Qualitative research	Researcher	Wildland Fire Use
Mutch, R. 2008. Wildland fire use: incentives and disincentives. Case Study.	Case Study	Researcher	Wildland Fire Use
Poncin, D.B. 1995. Prescribed natural fire strategies and tactics.	Case Study	Fire Manager	Prescribed Natural Fire
Steelman, T.A., and S.M. McCaffrey. 2011. What is limiting more flexible fire management - public or agency pressure?	Qualitative research	Researcher	Appropriate Management Response
Steelman, T.A., and S.M. McCaffrey. 2013. Best practices in risk and crisis communication: implications for natural hazards management.	Case Study	Researcher	Appropriate Management Response

Table 2.2 Continued

Tomascak, W. 1991. Improving a prescribed natural fire program: the Northern Region's approach.	Case Study	Researcher	Prescribed Natural Fire
van Wagtendonk, J.W. 1995. Large fires in wilderness areas.	Case Study	Researcher	Prescribed Natural Fire
Wildland Fire Lessons Learned Center (WFLLC). 2005. Initial impressions report: wildland fire use.	Qualitative research	Researcher	Wildland Fire Use
Wildland Fire Lessons Learned Center (WFLLC). 2006. Wildland Fire Use: lessons from the past and present that impact local fire and fuels management programs.	Case Study	Researcher	Wildland Fire Use
Wildland Fire Lessons Learned Center (WFLLC). 2006. Wildland Fire Use: lessons from the past and present that impact local fire and fuels management programs.	Case Study	Researcher	Wildland Fire Use
Williamson, M.A. 2005. Influences on the decision to authorize wildland fire use.	Qualitative research	Researcher	Wildland Fire Use
Wilson, R.S., P.L. Winter, L.A. Maguire, and T. Ascher. 2011. Managing wildfire events: risk-based decision making among a group of federal fire managers.	Qualitative research	Researcher	Wildland Fire Use
Zimmerman, G.T. 1999. Appropriate management responses to wildland fire: options and costs.	Case Study	Researcher	Wildland Fire Use
Zimmerman, T., M. Frary, S. Crook, B. Fay, P. Koppenol, R. Lasko. 2006. Wildland fire use - challenges associated with program management across multiple ownerships and land use situations.	Case Study	Researcher	Wildland Fire Use

Fire Environment

Fire Environment factors related to local physical conditions that influenced the decision-making process. Unaligned factors appeared to operate as background contextual elements; items were mostly considered prior to new wildfire ignitions with no clear indication of how they may ultimately influence the final decision. Several authors reported that, along with fire location, getting a sense of what the fire is likely to do if left to burn was among the first evaluation tasks required of fire managers [33,57]. The current fire danger rating was the most frequently reported Unaligned factor [33,57,58]. Other considerations included the state of the fuel bed [35,57] and expected near-term weather patterns [57,59,60]. These factors were often

associated with discrete metrics or descriptive rating scales such as fuel moistures, fuel loading, or the Energy Release Component. As these factors are measured and recorded over long periods of time, they allow for a direct comparison of past conditions to potential future fire behavior [27,60].

Fire Environment Barriers were identified when conditions were associated with the potential for large fire growth, such as a high fire danger rating, or when excessive fuel loadings were present [20,61,62]. Facilitators were described when either the short-term weather or seasonal climatic conditions were favorable [61,63]. Previous fuel management work in the area also helped facilitate the decision, as did a belief that favorable fire behavior would be present while managing the fire [57,61,64]. Overall, findings across papers suggest a preference for managing wildfires when fuel and weather conditions were moderate, or when end-of-season events were closer at hand. One study found an interesting relationship, where 94% of the managed fires studied occurred during wetter La Niña climatic conditions [63].

Fire Outcome

Fire Outcome factors related to potential positive and negative effects if a fire were to burn. These outcomes could manifest at different time scales and were largely conjectural. Unaligned Fire Outcome descriptive categories considered what the direct and indirect effects of a managed wildfire were expected to be. Air quality was the most often identified consideration [35,60,65], with decision makers evaluating air quality acceptability [58], ambient visibility [59], and potential air quality impacts to adjacent residential valleys [57]. Managers also sought information regarding potential burn patterns and whether the fire would burn within the natural range of variability [35,57–59,65].

Fire Outcome Barriers generally focused on uncertainty regarding two distinct air quality concerns: regulatory and public impacts. Regulatory concerns generally related to the implementation of the federal Clean Air Act, the management of which is delegated to the state level [10,58,66]. Decision-makers were concerned that managed fires may be viewed by air quality regulators as planned events, thereby subject to air quality standards similar to prescribed fire [35,67,68]. When managed fires exceed air quality standards, land management agencies are potentially subject to considerable fines. Air quality standard exceedances were also described as potentially leading to interagency distrust and limitations to future managed fire events [68,69]. The complicated patchwork of air quality oversight across state agencies

was also seen as a Barrier [67,68]. The second air quality Barrier related to the impact of smoke on the public, especially from managed fires close to communities. Several papers reported reluctance to manage fire due to their belief that the public views them as unnecessarily polluting the air [20,62,67]. Concern about negative community feedback also appears in the Sociopolitical Factors and Perceived Risk key themes.

A generalized lack of certainty regarding what the outcomes of a fire would be was another common Fire Outcome Barrier [59,67,70]. Although uncertainty is also related to risk aversion, several papers specifically defined uncertainty as present in the decision process without directly tying it to measures of likelihood or consequences. The uncertainty in outcome was sometimes enough to create a disincentive to managing a fire [68].

Outcome Facilitators tended to focus on the expected beneficial outcomes from managing the fire. The most frequently reported Facilitator was an expected improvement to forest health and ecology [20,57,59,62]. Reduced fuel loads were also a potential benefit, as was hope for an improved wildlife habitat [20,57,62]. Some decision-makers saw benefits in simply letting natural processes occur on the landscape [20,62,71].

Sociopolitical Factors

Sociopolitical factors focused on external influences on managed fire decision-making: the potential impact of managed fire on external stakeholders, recreational users, adjacent landowners, and cooperating agencies, including businesses dependent on public lands such as outfitters and loggers [27,57,59]. The potential interest level of the public and political entities was also considered [20,58,60,65].

The reaction of the public, elected leaders, and cooperators was a dominant Sociopolitical Barrier. As federal lands are managed for the public, political entities can create a real or perceived leverage over decision-makers. As such, the most prevalent Barrier was the potential political fallout if a wildfire were to be managed rather than suppressed [33,60,62,72–74]. Another Barrier occurred when decision-makers felt that the public held a negative view of managed fire, especially if previously managed fires had led to negative outcomes [33,68,73]. Both [20] and [60] found that public opinion exerted considerable negative pressures on managed wildfire decisions.

Conversely, public opinion could also help facilitate managed fire decisions. The most frequently occurring Sociopolitical Facilitator related to strong collaborative relationships

being in place prior to the decision to manage a fire. Relationships with neighboring landowners, wilderness users, and cooperating fire agencies were particularly important [20,23,33,35,65,72,74]. The public's influence also appeared as a Facilitator in instances where the public had shown previous support for managed fires [20,57,70,75]. Relatedly, several papers documented that the decision to manage fire was easier to make when local community members were known to understand fire's role as a natural process within forested lands or had even encouraged its wider application [57,67,75].

Institutional Influences

Institutional Influences reflected considerations internal to the land management agency. These included communication among individuals who work for the agency, bureaucratic concerns such as available funding and existing policy, and internal differences of opinion regarding the use of wildfire [20,27,57–60,65,72].

The most frequent Institutional Barrier reported was when fire cultures were not normalized to managing wildfire. Internal resistance to managed fire at both the organizational and individual level was broadly reported [20,60,71,74]. In his role as the Forest Supervisor overseeing the White Cap Wilderness Fire Study, O.L. Daniels wrote several times about his personal experience navigating the cultural shift from a suppression-biased program to one inclusive of managed fire [70,76]. Research published several decades later, after the 2001 policy update, reported the same Barrier when the implementation of WFU fires was outside the cultural norm of suppression at the local level [68,73]. Land managers with organizational values rooted in suppression as the default response were also described as more hesitant to integrate managed wildfire into their strategies and unsure whether a managed wildfire decision would be supported by their superiors [60,71].

Financial limitations also appeared frequently as an Institutional Barrier, primarily reflecting the pre-1995 policy that required local units to fund PNF's from their local budget allocations [57,58,70,72,76]. The later WFU period also created an inherent disincentive to managed fire due to the policy caveat that emergency stabilization funds were not allowed to be spent on WFU events [20,75]. Changes to policy over time and the resultant policy confusion was itself identified as a Barrier. One report described how many managers perceived managed fire as only allowable within designated wilderness areas, despite the fact no such policy

existed [68]. Within agencies, local and regional prohibitions on the practice were also identified as a Barrier [33,68,73].

Notably, Institutional Facilitators were also heavily influenced by fiscal considerations. The most frequently occurring factor was the potential to realize cost savings by managing the fire. Savings were expected to arise from implementing a strategy that used fewer resources than a traditional suppression response [20,27,33,61,62,77]. Publications from the mid-2000's described a desire to see lowered fire suppression costs, and reflected the fact that, as fire costs began to escalate in that decade, fire managers were being asked to find ways to reduce fire management costs [46,78]. One suggested way to help achieve cost reductions was to increase the scale of WFU incidents [20,62].

A local culture that supported the use of fire was another primary Facilitator, especially on land management units with a tradition of implementing managed fire [20,63,65,75]. An examination of fire practices on the Gila NF found that the acceptance of managed fire was related to a long-term commitment to foster a culture that both supported its implementation and recognized its potential ecological benefits [23]. Other papers found that the commitment and personal ethic of key organizational decision-makers served to move fire programs toward managing wildfires [58,60,70,72,76]. A national policy that explicitly supported the use of fire was also reported as a Facilitator and was even seen as causal in shifting opinions among fire managers [20,33,60,67,72]. Technological advances in pre-planning, air quality monitoring, and decision-support tools were also identified as Facilitators [20,65].

Operational Considerations

Operational Considerations primarily accounted for the amount and kinds of resources available to the decision-maker to implement a managed fire. This included personnel considerations such as the experience with managed fire, cumulative fatigue, the decision-maker's confidence in their staff, and confidence in their planning [58,60,65]. Other factors such as the regional, national, or local preparedness levels were related to availability of firefighting resources [35,57–59,65]. The fire's proximity to a management boundary was considered, especially when discussed in combination with the point in the season when a fire started [20,35,59,60,63].

The most frequently reported Barrier concerned whether insufficient operational resources would be available to staff a managed fire, especially during periods of significant resource

drawdown late in the fire season [58,60–62,65,68,70,73]. Insufficient staff to help plan a managed fire was also a Barrier [58,62,73]. Papers also consistently reported a lack of desire to manage fires that had the potential to cross management boundaries [57,58,62,65,68,72,73]. One paper observed that a small fire close to the boundary was as concerning as a larger fire further away [35]. The long duration often required to manage fires was also a Barrier, particularly when there were other fires already being managed in the area, or when fatigue was seen among local staff [35,62,76].

Operational Facilitators were reported with less frequency and consistency than Operational Barriers. The most frequently identified Facilitator was the presence of previous fire burn areas that made it easier to implement the current managed fire [35,62,67]. Situations where agency staff had a long work experience were also a facilitator, as was the belief that fewer resources would be required to manage a wildfire than to suppress it [61,68].

Perceived Risk

Perceived Risk was expressed as the level of personal and professional risk decision-makers were willing to accept. The risk factors considered by decision-makers included firefighter and public safety, the risk of the fire escaping management boundaries, the risk to the infrastructure, and the risk to natural resources, as well as the potential career risk [20,35,57,60,65].

Risk Aversion as a Barrier was the most frequently reported concern in this entire review. This Barrier contained thirteen descriptive categories, which was the most within any of the six themes. Concerns driving risk aversion were often personal in nature, and included factors related to career advancement as well as a generalized sense that there was less risk in deciding to suppress fires. This risk-based bias for suppression was reflected in numerous papers [57,60,65,68,71,74]. Concern was found by managers about placing their careers at risk if a PNF left the intended management boundary [35,59,70]. Papers also reported that managers can be concerned about being stigmatized for deciding to manage a fire that later had to be declared a wildfire. Concern was also expressed about being held personally or legally liable in the event of adverse outcomes [58,60,76].

The possibility that values at risk might be threatened was another frequently reported Barrier, especially regarding possible threats to the built environment [27,59,61,62,67,77]. When noted, threats to human life addressed both an acute concern for public safety as well as

the risk to firefighter lives [33,57,62,67]. Also identified in several papers was the risk to natural resources that managed fire might pose, including the potential impacts on endangered fish species or the potential to inadvertently spread invasive plants [20,59,60,62,67].

The most frequent Facilitator was where the decision maker possessed a personal ethic to manage wildfires [60]. A greater risk tolerance was observed when decision-makers personally valued the possible benefits of managing a fire [33,58,67,70,72,73,76]. The potential to reduce risk exposure was also identified, particularly when firefighters possessed an understanding of locally important terrain features and burn patterns [33,61].

Discussion

This review was conducted to identify the range of factors in the published literature that are considered in the managed fire decision-making process. We found an extremely broad array of factors that may be considered when deciding whether to manage a wildfire for an objective other than full suppression. While some factors were consistently identified in the literature as operating as a Barrier or Facilitator, others were simply described as something a decision-maker considered without directly indicating how it affected the decision, which we describe as Unaligned. Overall, 110 decision factors were found, which fell into six key thematic groups: Fire Environment, Wildfire Outcomes, Sociopolitical Factors, Institutional Influences, Operational Considerations, and Risk Perception.

Across the papers included in this review, barriers to managed wildfire were more consistently reported than facilitators. The fact that barriers were reported with more prevalence may indicate that decision-makers rarely begin the wildfire decision-making process from a stance of neutrality. It also may be, in part, an artifact from the research focus of most of the papers which tended to focus on identifying barriers. However, the greater overall number of barriers suggests that the decision to manage a wildfire is one that must be justified toward, instead of justified against, and that a truly neutral approach toward new ignitions is rare.

The findings from this review indicate that decision-makers have tended to view managed fire as an inherently risky endeavor. Such concerns are not unfounded, as managed fires have ‘escaped’ their intended boundaries and, on occasion, resulted in negative outcomes. Although these escaped fires may also result in negative ecological effects, the main concern was consistently sociopolitical in nature, such as decreased community trust, impaired air quality, and lost economic opportunity [79]. Interestingly, although papers often intimated a general

fear that consequences may occur for the decision-maker, the only specific consequences described in the papers were limited to having to endure oppositional feedback and negative press. A sentiment was also seen whereby decision-makers indicated an expectation of perfect decision-making despite an imperfect decision environment. Under these circumstances, it is no surprise that decision-makers tend toward being conservative in accepting managed fire under their jurisdiction, as suppressing the fire allows them to accept less sociopolitical risk only at the expense of unknown rewards. We found no paper that described the criteria that must be met to allow a decision maker's personal or professional fortitude to withstand negative attention in exchange for the reward of realizing positive landscape outcomes.

However, the findings did indicate that the cultural context within which decision-makers were operating can influence how risk was interpreted and acted on. As a component of wider socioecological systems, culture has been shown to influence the process of natural resource-based management decisions, including the circumstances under which risks (such as managing a wildfire) are accepted or rejected [80,81]. The literature in this review frequently reported that a key predicate for managing fire was the presence of a culture within the local fire management organization that supported its use. How this culture had been originally created was unclear but seemed to be something that built upon itself with time and experience. Statements bridging culture and policy were also common, with some papers suggesting that a policy that supports managed fire should, in and of itself, be sufficient to overcome cultural norms favoring suppression [20]. [82] similarly suggests that within federal wildland fire organizations, culture is formed by policies as well as norms. However, we saw no evidence across different policy periods of an institutional-level cultural shift away from suppression as the primary fire response strategy. Our findings indicate that the reluctance to manage fire has persisted across time and through numerous policy iterations, including the introduction of well-defined policies and procedures that otherwise supported broadening the scale of managed fire. However, our review did find evidence for cultural shifts toward managed fire at the scale of the individual and the local land management unit.

More recently, while examining how the 2009 policy update may have affected managed fire outcomes, [83] found evidence that the update provided opportunity for a greater number of managed fires to occur. However, they did not find a significant increase in the number of acres burned. In the context of this review, their results appear to suggest there may be a greater level of cultural acceptance for managed fire by decision-makers, but with a retained reluctance to allow managed fires to grow large. If this is true, the 2009 policy change may seem

to allow decision-makers the ability to meet agency policy-based expectations while not also exposing themselves to the sociopolitical pressures associated with large fires.

Finally, this analysis has several limitations. First, only 23 papers ultimately met our inclusion criteria. As such, although we have suggested some potential dynamics that may be more critical than others based on the review, these should be interpreted with appropriate caution. This also limited the ability to assess the degree to which relevant factors may have changed over time. Perhaps the most important limitation is that while we classified decision factors into individual units to describe them, discussions within the papers often described a complicated network of factor interactions that were both individually and cumulatively considered. For example, if a fire environment factor such as low fuel moisture is present, fire managers may expect new fires to display extreme fire behavior. This expectation may move the response decision toward suppression. However, there may be plentiful firefighting resources available to point-protect values at risk, allowing more flexibility in the fire management approach. Or, even if there were few firefighting resources available, concern may be lower if the fire was distant from a management boundary or if it occurred late in the season. The potential network of interactions found in this review is multifarious. As such, implementing conditional or prescriptive decision-making processes for managed fire would likely be exceedingly difficult. Given the highly qualitative nature of wildfire decision-making, and the extensive latitude given to local managers to select courses of action, it should perhaps be no surprise that, within this review, the simple personal ethic of a decision-maker to want to implement managed fire was often seen as the most important facilitating factor in the decision

Managed Fire Decision Framework

The conceptual Managed Fire Decision Framework MFDF (Figure 2.3) began as a tool to help us organize the complexity associated with the managed fire decision-making, we observed during the coding process. However, the framework may have a wider potential applicability to future research efforts. For instance, future research could use the different decision factors identified in the framework to assess how different factors interact to shape decisions of whether to manage fire. The framework could also potentially be used to guide actual managed fire planning and implementation efforts at multiple levels by providing a consistent means to conceptualize and anchor conversations regarding managed fire, especially as efforts to increase the extent and scale of managed fires are explored.

The MFDF could also serve as a starting reference point for those working to address barriers and facilitators. It could be used to assess where barriers could be decreased or facilitators supported, essentially to enable a more systemic identification of potential leverage points at various levels of governance to facilitate an increase in managed fire implementation. It could also be used in the development of coursework around managed fire, which several papers in this review found to be absent from the training catalogue. The decision-making tools currently in use, such as the Wildland Fire Decision Support System [83] and Potential Wildfire Operations Delineations [84], and future decision support tools could also incorporate attributes of the framework [85].

It is important to note that the framework is not intended to provide a checklist that must be met, as not all the decision factors we identified here (or others that future research may identify) will be present in all situations. Also, as the number of Unaligned factors identified indicates, how a factor may affect the decision can depend heavily on the specific wildfire context under which it is considered. However, the literature to date suggests that all six key thematic categories at the core of the framework will be present in any wildfire decision-making process. Examining the relative influence of decision factors within those six key categories in the framework could create a useful structure to systematically identify not only critical barriers and facilitators, but also the gray areas of uncertainty that may need to be taken into greater account.

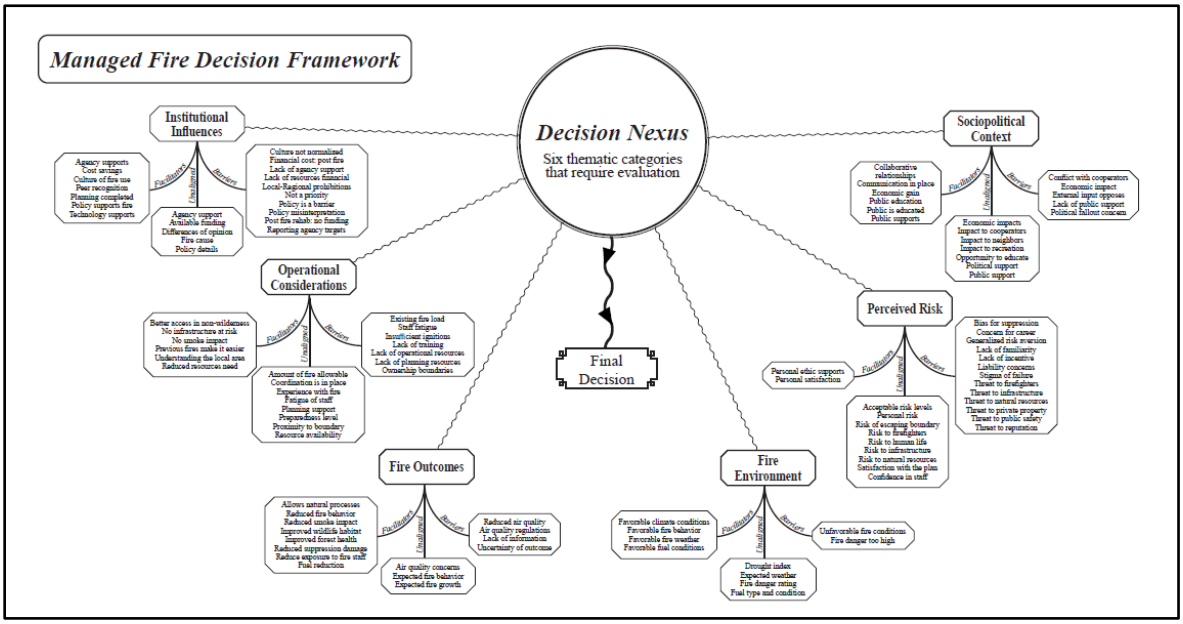

Figure 2.3. Managed Fire Decision Framework. Six key theme areas with their associated descriptive factors are connected to the central decision nexus. The final decision is made after incorporating elements of the key themes within the decision nexus.

Conclusions

There has been a consistent call to reintroduce beneficial fire in landscapes, as well as recognize the potentially important role managed fire could play in achieving this. Despite this, our literature review found surprisingly few scientific papers examining the managed fire decision-making process from the 50 year period it has been allowable under various federal wildfire policies. The key finding of this review is simply that there is a very large number of potential decision factors managers may be faced with when considering whether they wish to manage a wildfire for an objective other than full suppression. Although little can be said at this point as to how these factors interact, the number and complexity of factors alone creates an uncertain decision environment that favors personal and institutional risk aversion. This also suggests a need for more work to understand the interactions between factors and potential means of decreasing barriers and increasing the number and influence of facilitators.

Looking across these factors we see some potential reasons why, despite growing institutional support in the form of codified policy to support the goal of incorporating managed fire, the actual use of the managed fire strategy continues to be limited. Findings across papers suggest that wildfire decision-makers are under considerable internal and external pressure to make decisions that lead to favorable outcomes. The institutional default course to extinguish wildfire—thus removing both concern and uncertainty—is an attractive course of action. It is an acceptable and known practice and makes an otherwise complex decision much simpler. Although our review identifies a range of factors, including some that are more likely to act as a Barrier or Facilitator, in six key theme groups, it can only provide a general sense of how the various factors interact throughout the decision process. These factors may or may not be present on a given fire. They may operate singularly or in an interconnected manner. It is our hope that this review and the Managed Fire Decision Framework might provide a useful structure to guide future research efforts. For instance, future research could investigate whether there is a specific order to the factors that are considered, whether certain factors or thematic groups are more critical in decisions to manage fire, and, hopefully, identify potential leverage points that could be targeted to shift the balance of decisions away from default suppression.

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Chapter 3: Use of the Wildland Fire Decision Support System (WFDSS) for full suppression and managed fires within the Southwestern Region of the U.S. Forest Service

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Abstract

Background:
United States federal wildland fire policy requires the use of formal decision support systems (DSS) when it appears that fire incidents will last for an extended period of time. However, the ways that wildfire managers use DSSs to arrive at decisions regarding fire management remains relatively understudied, including how users engage with or utilize such programs to make strategic decisions.
Aims:
Researchers sought to understand how users engage with the Wildland Fire Decision Support System (WFDSS), what they view as its utilities or challenges, and their perspectives about WFDSS training.
Methods:
This study presents the results of thematic analysis derived from 46 semi-structured interviews with employees in the Southwestern Region of the U.S. Forest Service who possess a WFDSS user account.
Key results:
WFDSS users indicated that the program is viewed as an efficient way to share information about a wildfire and to document decision rationale surrounding management decisions. They identified emerging gaps in technical proficiency with the program and the need for specialized training that creates a cadre of high-level users who can help guide teams using the program.
Conclusions:
We conclude the paper by offering suggestions about continued use of the WFDSS including modifications to the distribution of information, revision of user roles, and expanded support for skills training.

Implications: Our results suggest that small changes to the WFDSS program and training curriculum may improve the experience of end users and better match how they are using the program.

Introduction

Existing literature recognizes that decision making during wildland fire events is inherently complex and uncertain due to the influence of various environmental, social, and political considerations (Jensen 2006; Thompson 2013). The change to a warmer, drier climate, accumulation of fuels in forested ecosystems, and expansion of human settlement into combustible wildlands further complicates the wildfire decision environment by promoting larger and more intense fires (Stevens *et al.* 2017; Cattau *et al.* 2020). Choices about when to suppress, steer, or even use wildland fire to achieve resource objectives poses a multitude of potential response alternatives that are evaluated in relatively short time frames, and which often must gain multiple levels of leadership approval as conditions change (Calkin *et al*. 2013; Castellnou 2019). Paradoxically, technological advances such as widespread internet connectivity, advances in fire behavior modeling, real-time resource tracking or video feeds, and social media influences can inundate fire managers with information to inform decisions. The result is a critical need to evaluate how end users of technological advances in decision support utilize or struggle to incorporate new information into fire management practices (Rapp *et al.* 2020; Neale *et al.* 2021).

Complex decision-making during natural hazard incidents often relies on the use of Decision Support Systems (DSSs). DSSs combine information derived from multiple sources into a common decision-making environment. They are designed to improve decision efficiency, provide a process for weighing trade-offs across the objectives present in a complex environment, and to avoid delayed responses during unfolding emergency conditions, all of which can help reduce negative impact to humans and the environment experiencing fires or other hazards (Tufecki 1995; Thompson *et al.* 2006). The research presented here explores the process by which U.S. Forest Service (USFS) fire managers from the Southwestern Region use the Wildland Fire Decision Support System (WFDSS) to navigate the balance between information intake and decision outputs during wildfire incidents.

Despite the widespread use of WFDSS to guide decisions on complex wildfire incidents, there is little research investigating how managers engage with the program or how professionals use it to aid their decision making process. Existing research examining the use of

WFDSS by fire managers is limited, and primarily tends to focus on end-user evaluations surrounding specific components of the program. This includes evaluations of information produced by predictive fire behavior models, comprehensiveness of risk assessment information, and case studies of tool use during specific fire conditions, (Calkin *et al.* 2011; Noonan-Wright 2015; Thompson 2015; Rapp *et al.* 2020). Others explain the development of the program or discuss generalized impressions that users have towards the program without formal data collection (Noonan-Wright *et al.* 2011; Zimmerman 2011b).

DSSs are most useful when they help guide the aggregation of disparate expert judgements or information, reduce uncertainty of decision inputs, and help confirm professional experience or intuition (Sprauge 1980; Power 2007). However, these findings do not always match the stated purpose of WFDSS to provide optimal decisions that are directly implementable by Incident Commanders (ICs) (WFM-RD&A 2016). Other authors question whether managers are using the program to its full potential in providing detailed trade-offs that lead to resource maximization (Noonan-Wright *et al.* 2014). Similarly, what little research has been conducted on wildfire DSSs suggest that their perceived utility is contingent on a number of factors specific to the individual, training, or information available in the given context where a fire is taking place (Noble and Paveglio 2020; Rapp *et al.* 2020; Colavito 2021a; Colavito 2021b).

The research presented in this paper addresses research gaps surrounding WFDSS utility for wildfire management using data collected from a range of USFS employees who possess experience with the WFDSS program. We conducted 46 semi-structured interviews with WFDSS users in the Southwestern Region of the USFS. The research seeks to expand existing knowledge about the ways that wildfire managers utilize DSS, how the WFDSS program is currently being utilized for decision making, how users interact in the production of decisions using WFDSS, their experiences with program training, and their suggestions of possible improvements for future iterations of wildfire DSSs. Results from this research could eventually be compared to existing work from other regions of the U.S. to determine if there are differences in WFDSS use or application across circumstances. Results can also be used to make specific recommendations about the expansion of the WFDSS program, training programs, or evaluation metrics designed to understand how the program interfaces with directorates to improve wildland fire response.

Literature Review

Decision Support Systems (DSS) arose in the early 1980's from concepts related to Electronic Data Processing (EDP) and Management Information Systems (MIS) (Sprauge 1980). EDPs focus on the way information is packaged to optimize its use and understanding by decision makers managing larger organizations or hierarchically organized institutions (Mann and Williams 1960). MIS built upon EDP-produced data by focusing on the ways that information could be collected or utilized by mid-level decision makers to increase the efficiency of organization, often by structuring the flow of information or aggregation of data in ways that allow for common understandings among larger, complex organizations (Dickson 1981; Hirschheim and Klein 2012). DSSs aggregate information from EDP and MIS to provide context to the decision-making environment. They often dictate a series of decision considerations or steps for evaluating disparate information using structured rules, weightings, or options in ways that reflect common decision objectives. DSSs emphasize flexibility, rapid use, and the ability to respond to differing decision making preferences (Sprauge and Carlson 1982).

DSSs are utilized in a wide variety of fields such as clinical medicine and agriculture, as well as in disaster management such as earthquakes, toxic spills, and wildfires (Wallace and De Balogh 1985; Sim and Berlin 2003; Keenan and Jankoswi 2019). Early DSS developers suggested that DSSs should be designed to reflect a few key propositions: (1) they should be simple so as to be easily understood; (2) robust to the point that they provide relevant and useful answers; (3) controllable so that inputs match outputs in a consistent form; (4) adaptable so that iterative changes can be made as conditions change; (5) complete to the point that the principal factors influencing the decision are included; and (6) easily interfaced with so that the decision evaluation process is not unnecessarily difficult to move through (Little 1970; Power 2007). DSS can be used help plan response activities during the entire arc of an emergency, including activities for preparedness, training, mitigation, detection, response, and recovery (Van De Walle and Turoff 2008). DSS also possess a common typology, including the availability of integrated data, ability to compare alternatives, the inclusion of models, and a user interface that allows the display of information (Wallace and De Balogh 1985; McIntosh *et al.* 2011).

DSS have been utilized by federal wildland fire managers for several decades (Zimmerman 2011a). Early wildfire DSSs used pre-defined, structured decision pathways that fire managers evaluated at various stages of the fire in order to match fire behavior (e.g., flame length or

intensity) to desired fire effect outcomes (e.g., vegetation mortality, scorch height). Some authors described this type of flow-chart DSS as rigidly prescriptive in nature, in part to provide metrics that were justifiable under scrutiny (Devet 1976). The 1978 USFS fire policy revision recognized the need for standardized and more flexible fire decision support tools (Pyne 1982). This led to the development of the Escaped Fire Situation Analysis (EFSA), a form of DSS designed to assist fire managers in determining appropriate wildfire suppression strategy alternatives (Seaver *et al*. 1983). The 1995 National Wildland Fire Policy included direction to update DSSs used during wildfires, leading to the Wildland Fire Situation Analysis (WFSA), which replaced EFSA (Philpot *et al.* 1995; MacGregor and Gonzalez-Caban 1999). WFSA was less prescriptive and incorporated greater flexibility in choosing a course of action as long as it supported a suppression strategy (Donovan and Noordijjk 2005). Soon after WFSA was developed, the Wildland Fire Implementation Plan (WFIP) and Long Term Implementation Plan (LTIP) were added to the DSS suite in order to provide specific support for long duration fires managed to achieve a resource objective (van Wagtendonk 2007; Zimmerman 2011b). The decision making processes in WFIP and LTIP were determined to require their own DSS tools because WFU fires were not intended to be suppressed and thus required different considerations than fires managed predominantly for suppression (NWCG 2005).

The most recent update to DSS used in federal wildfire management came in 2005 when the National Fire and Aviation Executive Board chartered a replacement for all existing wildfire DSSs (WFM-RD&A 2010). This charter directed that the new wildfire DSSs be platformed on the internet which allows the incorporation of external data sources, incorporates fire behavior modeling, and uses a geospatial interface. The result was WFDSS, which was fully implemented by September of 2009 and is the DSS currently used by all federal agencies with wildfire response responsibilities (Noonan-Wright *et al.* 2011).

Completing the WFDSS process results in a WFDSS "decision." Federal wildland fire policy requires a WFDSS decision when a fire exceeds initial attack, initial response, or if the fire management strategy includes both protection objectives (i.e., defending structures, infrastructure, or cultural values) and objectives designed to achieve a resource objective (USDI and USDA 2022). The WFDSS decision document is designed to provide the leaders intent of the "approver,' who is the assigned Agency Administrator (AA) for the fire. The WFDSS decision process allows AAs to consider available information or multiple risk factors, determine the scaled complexity of the incident, integrate spatial data and fire behavior modeling, and document a final decision rationale tailored to achieve objectives derived from local land

management plans (Noonan-Wright *et al*. 2011). A completed WFDSS decision document typically includes maps, figures, tables and supporting descriptive text that: (1) define the geographic area covered by the decision; (2) assesses values at risk given the likely progression of the fire; (3) recommends the Incident Command level that should respond to the fire; (4) provides strategic management objectives for the fire; (5) outlines a primary course of action for achieving fire management objectives; (6) outlines the rationale for the course of action chosen; (7) provides an estimated final cost of fire management actions; and (8) provides a list of individuals who are capable of approving the decision (Noble and Paveglio 2020). Integrated tools and modules within the program are designed to help facilitate the outputs described above. For additional descriptions of the WFDSS decision process, please see Zimmerman (2012), Taber *et al.* (2013), or Thompson (2015). AA decisions based upon the WFDSS decision are intended to reflect long-term fire management strategies, while the IC implements strategies or works with the AA to revise tactics.

Early wildfire DSSs were not formalized throughout agencies and were often localized in their applicability. They also lacked the robustness of computational resources, applied modeling, or a spatial interface that provided operational data relative to potential management actions. For instance, the EFSA was rooted in expected utility theory, where the most appropriate course of action among alternatives is the one that results in a calculated maximum utility for the entity or person making decisions (Tversky and Kahneman 1981; Dimitrakopoulos 1987). The preferred alternative was the one with the lowest calculated Cost plus Net Value Change (C+NVC) over an expected area burned basis (Seaver *et al.* 1983). A maximum utility approach was and continues to be prioritized in many wildfire DSSs or simulation tools because the option perceived as the most risk-reducing is expected to translate into decreased negative wildfire outcomes (higher utility) (Mavsar *et al.* 2013). Studies looking more closely at maximum utility methods have cast doubt on its merit, finding instead a greater prevalence of wildfire decisions where decision makers overcompensate for low occurrence, high risk outcomes (and vice-versa), or have their decisions influenced by qualitative factors such as personal affect (Wilson *et al.* 2011; Wibbenmeyer *et al.* 2013). Other authors conclude that highly subjective and varied alternative outcomes in DSSs are driven by the personal judgements of those completing the process (Seaver *et al.* 1983; Dimitrakopoulos 1987).

We found few studies that examine users' general impressions and experience with operating the WFDSS program, which is the aim of this research study. Those research efforts that do focus on WFDSS indicate that the program can be useful to fire managers through the

aggregation of disparate information by providing projections of potential outcomes and through the fostering dialogue among diverse specialists or resource managers involved in fire management decisions. For instance, both Colavito (2021) and Noble and Paveglio (2020) found that managers appreciated the way that the WFDSS program helps structure the decision process through discrete steps and through the incorporation of various tools such as fire models, spatial data layers, or cost analysis. Completing a WFDSS decision can also increase communication or information sharing among fire professionals and technical specialists, which their study participants indicated had the potential to improve decisions about how best to manage a fire.

While existing work on DSSs or WFDSS indicate potential utility, those same studies also note a somewhat complicated relationship between the intent of DSSs and their ultimate use by end users. For instance, results of existing WFDSS and DSS studies suggest that personal attributes of the user (e.g., experience, intuition, trust in model outputs) situational factors (e.g. time constraints, political pressure), or training opportunities for complex programs all influence the ways decisionmakers incorporate the objective, risk-informed outcomes that a DSS is intended to create (see for example Alavi and Joachimsthaler 1992; Thompson and Calkin 2011; Dulcic *et al.* 2012; Neale *et al.* 2021). The result can be variability in the adoption of WFDSS outputs or use of WFDSS to justify decisions made based on professional experience. For instance, Rapp *et al.* (2020) found decision makers often used fire behavior models to corroborate their intuition of what a fire would do instead of examining the results empirically to compare alternatives. Meanwhile, Noble and Paveglio (2020) found that WFDSS users appreciate the ability to document their decision rationale and concurrently justify those decisions in the program to alleviate potential liability.

Noble and Paveglio's (2020) examination of WFDSS users in Oregon and Washington focuses specifically on the factors that might lead to variable utility of the program, which matches the intent of this study. Their results suggest that many fire managers found the WFDSS process complex and time consuming to complete. This was especially true if users were inexperienced or did not use the program frequently. Respondents in Noble and Paveglio's (2020) study reported an overt reliance on staff who were known to be technically proficient in the program, but also recognized that they were in short supply and high demand. Also, those same technical experts were frequently engaged with fire operations and unavailable to assist in drafting the decision document when it needed to be done, leaving a shortage of qualified

staff to assist. Training on the use of the WFDSS program was perceived to be of mixed quality, and often depended on the technical skill and teaching quality of the instructor.

The research presented here was designed to expand understandings about the ways the WFDSS program is being used by employees of the USFS. We chose to focus data collection within the Southwest Region of the USFS to capture regional-specific attitudes or preferences. Fire season characteristics are generally homogenous within the Southwest Region, such as an early dry onset followed by a wet monsoon, which makes it a consistent sample frame across National Forests. This region is also known to have an established history of managing wildfires for resource objectives, making it an ideal location to investigate how WFDSS is being variably used across full suppression and fires managed to achieve a resource objective. The following research questions guided our research WFDSS within the Southwestern Region of the USFS:

- How is WFDSS used in the fire incident decision making process?
- What is the perceived effectiveness of WFDSS training modes?
- How do fire managers use WFDSS differently when developing decisions for full suppression or when considering fires managed for resource objectives?

Methods and Analysis

The sample frame for this study included employees of the USFS who possessed an active WFDSS user account and who were employed within the USFS Southwest Region, also known as Region 3. This region comprises National Forests and Grasslands in Arizona, New Mexico, and portions of Texas and Oklahoma. We chose to focus on the USFS because it is the federal agency with the most active users of the WFDSS program. We sampled within Region 3 because National Forests there experience frequent large fires and because fire managers there are known to regularly manage wildfires to achieve a resource objective (Young *et al.* 2019; Iniguez *et al.* 2022). Selecting users from the Region 3 also allowed the authors to assess perspectives surrounding WFDSS in additional USFS Regions, as Noble and Paveglio (2020) studied the Pacific Northwest Region.

Contact information for all potential study participants was downloaded from WFDSS directly with permission from the Wildland Fire Management Research Development & Application (RD&A) program that oversees and manages the WFDSS program on behalf of all the agencies. Initial sample frame development resulted in 368 potential users for the study. Researchers (i.e., the authors) employed a stratified random sampling approach, similar to Noble and Paveglio (2020) to further ensure representative perspectives across our sample

frame (Babbie 2004). More specifically, we organized potential participants according to one of the five user roles in WFDSS to ensure representation across all user role classes. WFDSS roles in ascending order of accessibility privilege are: Viewer, Dispatcher, Author, Fire Behavior Specialist, and Geographic Area Editor (see Noonan-Wright *et al.* 2011 for a descriptions of these user classes). We assigned potential participants to the category that reflected their highest authorized role if more than one role was listed. Each of the five users class lists was copied into Microsoft Excel and then assigned a randomly derived number identifier. The researchers randomly selected participants from each strata (i.e., user role) for potential interviews to maximize representation across user roles. Table 3.1 provides a breakdown of the participants listed by user class expressed a percentage of the whole.

Table 3.1. Distribution of WFDSS users classified by User Role. Distributions are reported by the total number of users within the Southwestern Region (R3) and the distribution of study participants. Regional numbers are current as of 12/23/2019.

Distribution of WFDSS users in Region 3				Distribution of WFDSS users within study participants		
	No. of Users				No. of Interviews	
Dispatchers	17	4.62%		Dispatchers	5	10.87%
Viewers	137	37.23%		Viewers	17	36.96%
Authors	188	51.09%		Authors	18	39.13%
FBAN	24	6.52%		FBAN	6	13.04%
GACC	2	0.54%		GACC	0	0.00%
Total	368			Total	46	

The USFS Southwestern Regional Office distributed an introductory email notifying staff about our study prior to initial contact. Our first contact method was to send a personalized email that included the individual's random number ID and instructions about how to sign up for an interview time in a private cloud-based scheduling tool. Other interviews were arranged verbally or through email communication. If no response was gained from the initial email, we attempted contact up to two additional times at varying time intervals and via multiple, non-repeating modes of communication (e.g., a phone call, followed by USFS direct-messaging software). After three non-responses, we moved to the next potential participants on the list. We continued the process of recruitment and interviewing until theoretical saturation across

user classes of the sample frame was achieved. Theoretical saturation occurs when researchers agree that no new major themes or ideas are becoming apparent from subsequent interviews (Bryman 2015).

The SARS Covid-19 pandemic affected both the contact process and our interviewing methodology. Our initial research plan was to conduct most interviews in person. However, pandemic related travel restrictions and stay-at-home orders forced interviews to be completed via telephone or video teleconference. Interviews began on February 24th, 2020 and continued through March 17th, 2020. At that point, we were forced to suspend data collection for a period of time during the height of the pandemic due to work-from-home orders at federal agencies as well as social uncertainty. Interviews resumed on May 5th, and we completed data collection on July 30th, 2020. In total, we attempted to contact 131 individuals at least once. Of the 131 potential respondents, 21 were excluded after we discovered they did not meet the inclusion criteria (e.g., they had retired or moved out of the Region). Approximately 46 responded to our contact attempts, of which all 46 agreed to be interviewed.

Researchers (i.e., the authors) created a semi-structured interview protocol to guide data collection. Semi-structured interview protocols allow for consistent questions to be asked of all respondents, but they also allow researchers to propose follow-up or probing questions that allow for the emergence of novel ideas (Patton 2002; Bryman 2015). Interviews lasted between 27 and 88 minutes and averaged 52 minutes in length. Interview participants spanned all 11 National Forests and Grasslands in Region 3 as well as the Regional Office. We interviewed users from all available roles except for Geographic Area Editors, of which only 2 exist in the Region (one contact attempt was non-responsive). Participants occupied a broad range of positions within the USFS including AAs, fire management staff, dispatchers and dispatch supervisors, module-level firefighters, biologists, rangeland staff, planners, recreation staff, and support service staff. All telephone interviews were recorded using the NoNotes application. Interviews on Microsoft Teams (VTC) were securely recorded within the program. All interviews were transcribed verbatim for later analysis.

Data were analyzed using the QSR Nvivo 12 qualitative coding software (QSR International 2022). We utilized an iterative, inductive and multi-stage coding process guided by principles of thematic analysis and analytic induction (Boyatzis 1998; Ryan and Bernard 2000). Thematic analysis focuses on identifying commonalities in the experiences articulated by research subjects, while analytic induction provides a systematic process for deriving causal explanations of that shared experience through comparison across individual respondents.

Coding took place in three increasingly restrictive phases, with each phase representing a separate "read" of the data and discussion about consistency among the researchers to ensure reliability. A first phase of "topic coding" assigned a primary topic to each distinct segment of respondent dialogue in the interview transcript (Richards 2014). Researchers independently coded interviews at regular interviews, reviewed topic codes, and discussed any inconsistencies until there was shared agreement about the coding strategy (Strauss and Corbin 1990). The second round of coding employed "descriptive coding," which looks within topic codes to inductively identify patterns in the perspectives or experiences articulated by respondents (Richards 2014). Researchers periodically reviewed their independently generated descriptive codes that were emerging across data and discussed any inconsistencies to ensure reliability (Gibbs 2007). The final stage of "analytic coding" allowed us to identify consistently occurring themes within the experience of WFDSS users. It also helped identify consistent relationships among the descriptive codes articulated by respondents, including any similarities or differences among respondents (Saldaña 2016). Finally, researchers jointly selected representative quotes associated with analytic or descriptive codes to aid in presentation of results in subsequent sections.

Results

The WFDSS decision making process

Interviewees described a relatively consistent decision making process associated with the WFDSS program. Decisions were frequently produced and finalized in a small group setting, which interviewees often compared to "Interdisciplinary Teams (IDT)" that are used to develop National Environmental Policy Act (NEPA) analysis documents (see Cerveny *et al.* 2011 for an example). Small groups completing a WFDSS decision typically included the delegated AA, fire management staff, natural resources specialists, and the fire IC.

Interviewees indicated that WFDSS decision groups typically came together within a day of the fire starting, though there was some variance based on fire behavior and any associated need for risk management. For example, if a fire was displaying low fire behavior activity and was tentatively going to be managed to achieve a resource objective, the decision making group often chose to delay the WFDSS development meeting to allow for more pre-planning. Interviewees indicated that teams would be better prepared for such longer-term fire events by crafting a deliberate and thorough WFDSS decision. Conversely, fires that were being actively

suppressed, especially those with high fire behavior and the potential for rapid spread, led to more immediacy in the completion of WFDSS decisions even if it required working late into the night. This was especially true if an Incident Management Team (IMT) was needed. One interviewee described the difference this way:

The timing on these things is very short, almost impromptu, because the fire is continuing to spread, and we need to know whether we're going to suppress or allow it to grow, and it usually happens pretty quick.

Participants indicated that that the most desirable outcome of a WFDSS decision was consensus about the next steps for managing the fire. They also acknowledged that the first decision created in the program may not be the best possible outcome, stressing that WFDSS allowed for iterative refinement over time as conditions changed. Likewise, participants described a general sense of aversion to putting extremely detailed information into an initial WFDSS decision. Some even suggested that the appropriate strategy was to 'publish first and refine second' instead of trying to get it perfect the first time. One AA described their perspective this way:

It doesn't take us very long here on the unit to publish a decision. I think if we're over two hours, then we're not doing something right. Even midnight or whatever, but we definitely strive not to do that...I mean, you can always adjust it.

Internal conversations that occur during the WFDSS decision process were seen to have unique value. Staff who worked within a natural resource specialty (e.g., biologists, archeologists) reported that these conversations allowed them to feel like their feedback regarding the fire was going to be included in the ultimate decision. Natural resources staff and other casual users indicated that they predominantly log onto WFDSS to attain basic information related to wildfires, including where the fire is located, the current fire perimeter, intended location of control lines, and fire modeling projections so they could inform the fire managers about values that may be at risk. Both user groups found particular value in the provision of timely and accurate information to ensure that concerns were both known and addressed. Some users suggested that conversations occurred among natural resource and fire staff regardless of the WFDSS requirement. However, they articulated that a structured approach helped to facilitate these interactions more regularly. One natural resources specialist saw their experience with collaborating on WFDSS decisions this way:

Does that mean that every specialist leaves happy? No, but that's not the point. The idea is to get all the information from all of us, so that the decisions can be made. And obviously when

it comes down, timing is going to be the first thing. So, from what I've seen, it looks like it balances it pretty well. It takes in account risk from all sides.

There was no clear 'right way' offered in which to conduct the WFDSS decision making process. Instead, participants described how personal preference and comfort with known decision making pathways informed the various approaches teams or individuals took to complete decision documents. Moreover, users saw this flexibility in approach as a strength of the program, allowing the way decisions were made to be adapted to the current fire conditions and timeframes. For instance, although the vast majority of participants described working in a small group setting towards a decision document, some AAs preferred to complete the WFDSS decision on their own, with only limited input from their staff. In other cases, teams might conduct a series of meetings with staff from different specialties (e.g., wildlife biologists, recreation specialists) to incorporate their expertise and inputs. Some interviewees suggested the latter approach helped mitigate WFDSS users from being overwhelmed, and ensured that all staff areas had equal representation in the decision.

Regardless of the process used to carry out WFDSS, participants acknowledged a tendency to rely heavily on an increasingly concentrated and shrinking pool of 'WFDSS drivers.' Drivers take on the actual task of inputting data and interacting with the WFDSS program. These drivers were viewed as a critical resource and the small group of trusted WFDSS drivers were often mentioned by name among interview participants. The shrinking pool of WFDSS drivers was alarming to our interviewees, as the demand for their skill set was seen to be increasing due to changing fire conditions and the complexity of running the program. One participant described the situation as such:

I don't feel like we have enough depth, and that's another fault. We maybe have two people that are super good at WFDSS here. I think for the complexity of this Forest and the size of the Forest, it's not enough, and we could use more depth, more training for sure. No question.

Participants described the spatial interface as the most information rich and easily accessible attribute of WFDSS. The intended use of the interface is to delineate strategic spatial features such as management action points, planning areas, known perimeters, or contingency lines. Respondents indicated that spatial outputs or capacities in WFDSS related to fire behavior modeling were a helpful way for managers to validate decisions and courses of action. They stressed the value of preloaded spatial data in WFDSS that was strategically relevant and accurate for helping the decision making process. For instance, respondents indicated that the most valuable data layers were nationally managed products such as fire history perimeters,

property boundaries, and infrastructure of national significance. However, data layers that are site specific such as archeological or sensitive biological sites were often seen as less available or outdated, often because local data managers were unable to keep up with maintaining the accuracy or recency of spatial data. This had the potential to cause confusion among users, as one of our interviewees related:

One of the conversations I haven't really heard happen is that it seems like a lot of stuff gets preloaded in there. And when I've asked the question of who does it, it's always like, oh, the [Regional Office] did, or the Washington Office or whatever, but we end up with some of the weirdest layers and some of the oldest, most outdated stuff in there. And again, that could be a miscommunication on my Forest side of not knowing what to do with some of that.

Participants also described challenges integrating more complex data sets or supplemental information in the WFDSS program, including Potential Wildfire Operational Delineations (PODs) (Thompson *et al.* 2016; 2022). They described loading PODs into WFDSS as an arduous task they would like to be automated or maintained at a higher organizational level.

Validating WFDSS decisions

Participants reported that while WFDSS assisted their wildfire decision making process, the function of the program was not to make the decisions for them. Users broadly agreed that decisions such as the course of action, response strategies, and incident complexity levels should be retained by human decision makers. In this capacity, WFDSS was described variously as a 'laundry list,' as a reminder for items needing assessed, or as a guide for bringing the decision process to fruition. For instance, one user described the program as such:

It helps, as I said before, it's not a decision maker, it's a decision support tool and so having a decision support tool that is...consistently used by land managers helps us to be more consistent in our decisions that we actually make...there has to be room for professional judgment and experience in actually making the decision. But I like the fact that we have this sort of a standardized approach to ask the right question.

Interviewees described WFDSS as an important mechanism to document the actions and decisions made as wildfire incidents evolved. It could allow decision processes to be traced and understood in the event of adverse outcomes such as the loss of life or property. The results of this documentation could include an ability to learn about alternative decisions that might have been made during the event or to alleviate liability of the decisionmaker. Others indicated that

decision documentation could be used as a frame of reference to assist with administrative tasks such as cost-apportionment. Hence, users reported WFDSS as providing both a way to contemporaneously document the rationale leading to the final decision and provide a strategic course of action for others to read. One interviewee described the importance of documenting decisions in WFDSS this way:

And the ask that they had, it was that we document our decisions and the rationale for the risks that we were taking, so I basically just took that seriously. And I feel like since it is a life-and-death thing, and since it's involved with hundreds of thousands or millions of dollars, that I owe the taxpayer or anyone that wants to look at it as an explanation for what I'm doing. And so, I guess it's just kind of a sense of duty in part.

Although outputs such as the suggested organizational complexity level are rigidly expressed in WFDSS, study participants had varying opinions on how close these recommendations should, or needed, to be followed. Likewise, they indicated that fire managers may base decisions on preconceived notions of fire risk ratings or personal experience rather than using outputs of the decision process that is built into the WFDSS program. For instance, users described deviation from WFDSS outputs for the relative risk rating of the fire (which determines what risks are present and how complex they are) and organizational assessment (denotes the type of incident management organization required), especially when the program recommendation was on the borderline of complexities. Decision makers wished to retain the ability to either take the route of caution and order a higher level IMT or manage the fire at the local unit level if they believed that they could handle it. Experienced fire managers were the most transparent regarding their comfort in 'gaming' WFDSS to match their experience, which they regarded as more nuanced and responsive than the WFDSS outputs. Similarly, most AAs desired to retain this scope of authority. They described being comfortable constructing a rationale to support decisions they made, and desired to retain their authority to deviate from WFDSS when they felt it was necessary. One AA described their view this way:

I see people really stressed out needing to defend why they want to do something different than what WFDSS is telling them. I'm just not in that place. I'm a selector of information and we make our own decisions.

However, caution was also expressed when decision makers choose to deviate too much from suggestions made in WFDSS for fear that any negative outcomes arising from the fire could be traced back to their overriding the recommendations the program provided. As such, respondents who were commonly tasked with helping to assess risk articulated that more time

should be spent exploring risks that were specific to the current fire. They also expressed a desire to have a more deliberate focus on user-inputted narration that explains how risk ratings were derived, especially if clear deviations from WFDSS outputs were incorporated into the final decision.

WFDSS training and help

Interview participants indicated that the annual "WFDSS refresher" conducted by individual Forests provided an important and often initial training in the use of WFDSS. The refresher provided instruction on the general use and intent of the program, but was not necessarily formalized training. Both users and providers of these refreshers agreed that the WFDSS refreshers were not sufficient for developing the skills necessary to become an independent WFDSS driver. Likewise, few participants were aware that detailed training materials existed online or knew for certain that a WFDSS Help Desk existed, however there did appear to be a general awareness that there was an online WFDSS training site available. As one WFDSS author described with regard to refreshers:

I think we're more like introducing them to it, we're not expecting a whole lot. I think just exposing them to the process, to understand that fire is a lot bigger than just the operational side. There's a lot that goes into it, so it's good for them to know so they can help convey that information to whoever's doing it.

One way the refresher training could be helpful was in understanding how diverse professional expertise was integrated into the decision making flow of the program. For example, resource specialists such as archeologists, recreation staff, and biologists described how the bulk of their input was required early in the decision process to properly inform the values-at-risk analysis. Specialists reported that the WFDSS refresher and other entry-level training about WFDSS helped clarify the type and quantity of information most relevant to the WFDSS decision process. This allows an efficient incorporation of information without over-analysis under time limited conditions.

The preferred mechanism to learn about WFDSS was live, in-person training, as this would allow participants to fully concentrate on the training session. Participants expressed reservations about video teleconferencing or virtual trainings, as such environments might include the distractions of their regular work like attending to email, conversations with co-workers or the need to accomplish other tasks. Virtual classes also were viewed as a difficult setting in which to interact with classmates or ask clarifying questions of trainers. Select

participants did provide examples where virtual training had been effective. Those trainings featured well-structured scenarios, a mix of instructor-led and self-directed learning, and the ability to attain direct help from instructors. Regardless of the training mode, participants saw value in the ability to utilize WFDSS using a variety of hypothetical scenarios during training sessions. They described how the ability to ask questions or experiment with the program during these hypothetical fires could help develop their proficiency with the information and decisions the program would provide during real world fire incidents.

We observed that perspectives on training somewhat diverged based upon the individual user role in WFDSS. Those with dispatcher or viewer roles tended to be only lightly engaged with the WFDSS process and may not be directly involved with the program besides supplying initial information. These users did not see the need to possess any technical ability in using WFDSS beyond the basics such as logging in and navigating between pages. They felt it was more important to know how the components and technical information was integrated into the eventual decision. WFDSS 'drivers' reported a greater desire to be technically competent in the workflows of the program. Although this group is not usually a part of the decision making process, they often serve as a skilled guide to help others navigate through the process. Users who sought to become proficient using WFDSS, usually those with an author role, described two primary ways to learn the program. The first way was through one-on-one training with a skilled user, often during actual fire incidents. Others described undertaking a self-motivated path of independent learning reinforced by occasional opportunities to use WFDSS during actual fires.

WFDSS drivers valued rapid access to help when needed. They expressed a desire for specialized, task-focused online help, for instance, a short explanatory video on importing photo files into decision documents. The official WFDSS Help Desk and online training tutorials were frequently mentioned as important sources of help. Participants tended to call someone when they needed help immediately and used the help desk or online resources when time pressures were less present. In that regard, the video and written tutorials were mentioned as a means to support the self-directed training users described above.

WFDSS and wildfires managed to achieve resource objectives

Participants described finding greater value in the WFDSS process when fires were expected to burn for extended periods of time, and particularly during managed fires where the

strategy was to achieve a resource objective in addition to protection objectives. The planning tools within WFDSS allowed users to plan for potential control lines, values at risk in both short- and long-term timeframes, and potential fire effects over time. One participant described the importance this way:

Line officers are interested in whether to…try to get a good idea of potential effects. So, if we're looking at hotter fire for the next two months, they're considering what's that going to do to the timber stand out there. Reduce stand density more than what we would hope for, or is it going to be so cool and calm that really, we're going to just create smoke and not really change the stand to move toward the desired condition, so that it may or may not be worth taking something on?

Interviewees reported less value in suppression-oriented WFDSS decisions as those tend to follow simple strategies, and little cross-disciplinary planning is typically required. One author discussed their role as an IC on managed fires:

Well, that's what's nice about using WFDSS when we're doing management fires, we can actually jump in when the acreage is small. So, we usually start the next day, or day three or four [after the fire ignites], after we've made our plans and stuff and kind of drawn in our blocks, and determined where we're going to have to fire at…so let's say within three operational shifts, that's when we start using it. I've never dealt with it for suppression.

The interdisciplinary decision development process that users commonly employed to complete a WFDSS decision did not appear to differ between suppression and managed fires. However, participants did report that the time frames under which WFDSS decisions were created for each condition could vary greatly. Fires managed with a suppression strategy came with pressure to complete a WFDSS decision as quickly as possible. This reflected users' perception that if a large number of values were at risk, a fire should be suppressed, and a rapid response was needed. Conversely, values at risk may not be the principal influence on fire management decisions. Participants indicated that in these instances decision making groups could take more time to work through the decision process and build a comprehensive plan that addressed as many concerns or values as possible. The longer-term planning approach, facilitated by WFDSS during managed fires, also allowed for external discussions with affected parties. For instance, livestock producers supportive of managing fires for resource objectives did not wish to see their fences be damaged during fires. Another common example was the need to talk with nearby communities who may be concerned about potential impacts from smoke or the fire itself. Participants indicated that the result of taking more time in the up-front

planning process, including early and continuing conversations with affected parties, allowed for a comprehensive understanding of the values at risk and better protection strategies for valued resources such as fences, cabins, or vulnerable archeological resources.

Discussion

The purpose of this research was to explore how a regional subset of US Forest Service employees are utilizing the Wildland Fire Decision Support System (WFDSS). We were interested in better understanding users' experiences with the program, including its perceived effectiveness, and the provision of training or help in the use of the program. We also explored participants experiences' using WFDSS during fires that were being managed with a strategy other than full suppression, which has not been well explored elsewhere in the literature. We found that WFDSS users often utilize the program to document or inform the decision making process rather than to guide ultimate decisions, which is consistent with some other recent studies on the topic (Noble and Paveglio 2020; Rapp *et al.* 2020). Users do see utility in the program for integrating various perspectives or in documenting rationale, but they also maintain that the program and its uses should be flexible given the situation encountered during each fire (e.g., available personnel, resources, fire conditions), which can influence how much the program actually informs fire management decisions. This reflects a continued interest in valuing the professional experience of managers while using WFDSS to make decisions. We also found that only a small number of users actually possess the skill to operate the WFDSS program, and that these users help to incorporate other users' contributions made possible by the program. Moreover, the concentration of skilled WFDSS 'drivers' appears to be consolidating into a small subset of users capable of running the program and who bear most of the responsibility for running the program. We also found that in the Southwestern Region of the US Forest Service, participants saw utility for WFDSS during fires managed for objectives other than full suppression.

Participants in this study made it clear that DSSs such as WFDSS serve important roles in wildfire management despite the work, time, and effort required to complete a decision. WFDSS was seen as useful because it can help guide or provide input to the decision process or improve communication and documentation of the decision rationale as the incident evolves. The result, according to our participants, is more efficiency among fire professionals attempting to reduce potential damage to values at risk. Although the WFDSS program was seen as assisting making decision making, it was not viewed as a tool that could or should dictate decisions without some

application of critical thinking a broader decision making group. Those findings reflect foundational DSS literature, including Sprague (1980), who recommends that DSS be used for decision support when the problem is unstructured, which is often the case during wildfires (Castellnou *et al.* 2019).

Participants rarely suggested that the outcome of a WFDSS analytic process should be the 'final answer.' Instead, they often felt that WFDSS was a guide to be corroborated by their own experience. Use of WFDSS as a decision input is consistent with findings from Noble and Paveglio (2020) and Colavito (2021b), both of whom found that strategic decisions about a fire were often made prior to undertaking the WFDSS process, thereby making the exercise more akin to a decision documentation process. Similarly, Rapp *et al.* (2020) found decision makers often used fire behavior models to corroborate their intuition of what a fire would do instead of examining the results empirically to compare alternatives. Neither of these outcomes are the original intent of WFDSS, which was designed to guide decision makers through a step-wise process of evaluating alternatives, risk, and potential courses of action.

Although our participants did not want decision authority to come solely from the WFDSS program, there was very little discussion related to how much emphasis or responsibility should come from professionals using WFDSS. Likewise, there was less clarity about how outputs from the program should influence a range of manager decisions. Instead, participants indicated that decisions based in part on WFDSS outputs were still dependent largely on professional judgement, with variation among decision makers in terms of how they valued the information from WFDSS or how they utilized IDTs to arrive at a rationale for the ultimate course of action. Similar dynamics were observed in Noble and Paveglio (2020) and are noted in other DSS literature (e.g., Alavi and Joachimsthaler 1992; Neale *et al*. 2021). Future research should explore this "gray area" of professional judgement in wildfire decision making by exploring users' trust in or use of specific quantitative outputs from WFDSS. That exploration could also incorporate explicit comparison across USFS regions to uncover whether and how managers in different areas of the country conceive of decision support from the program. Special emphasis could be placed on how and whether various outputs from the WFDSS program help inform judgements made by professionals, their role in reducing uncertainty related to the fire environment, and whether they uphold or contradict their professional experience as the complexity of the incident unfolds. Results from these more specific efforts might help extend theory surrounding DSS integration as a part of cognitive processes for

managing risk and provide specific recommendations about which components of the WFDSS program need revised outputs or additional substantiation.

Our results suggest that managers often utilize the existing practice of using small interdisciplinary teams (i.e., specialists and technical experts) for land management planning efforts when approaching the use of WFDSS. This approach also was apparent in WFDSS studies of other USFS Regions (see Noonan-Wright and Opperman 2015; Noble and Paveglio 2020). Although using the IDT process is mandated by policy within the context of NEPA (Stern and Predmore 2012), there is no policy-based direction on how to complete a WFDSS decision. Therefore, emulating the use of an IDT during WFDSS may serve as a form of organizational heuristic, especially as WFDSS decisions are often completed in a time compressed context. We would suggest that the preference for using small IDT teams to complete a WFDSS can serve as an important acknowledgement and strategic opportunity in the continued use of the program. Likewise, use of IDT teams to complete WFDSS might open up opportunities to discuss tradeoffs in tactics, resources affected, or managed fire use. Working through scenarios for fire impact, response, and their application in particular contexts may also increase the amount of trust and comfort among specialists and decision makers tasked with applying WFDSS to improve operational efficiency. Trust and experience in collective decision making are both noted as important influences on effective DSS use in uncertain environments (Fröhlich *et al.* 2022) and also appear to have helped facilitate the use of managed fire for resource objectives to the extent seen in Region 3, despite being a course of action that can carries considerable risk (Canton-Thompson *et al.* 2008; Calkin *et al.* 2011).

We observed three functional roles articulated by WFDSS users in this study: 1) data managers who were also advanced authors or fire behavior specialists; 2) “authors” who possessed technical competency with the WFDSS program; and 3) peripheral viewers who only sought information. This arrangement seems to have arisen organically as managers learned efficient ways to arrive at a final decisions and processed adapted to realities. From a decision hierarchy standpoint, decision makers seemed to value having access to a pool of experts from which to receive counsel and avoid liability, and another (smaller) pool of experts to simply run the program in a way that reflected their decision making process. Also, organizational process changes influenced how user classes interacted with WFDSS. For example, the recent introduction of the Integrated Reporting of Wildland Fire Information (IRWIN) program altered dispatching workflows in a way that eliminated the need for dispatchers to directly populate WFDSS.

Our results suggest that WFDSS utility extends to fires that are managed for objectives other than full suppression. That is, participants in this study indicated that naturally occurring fires in the region were often managed with a strategy other than full suppression, and that WFDSS outputs helped support those choices through forecasting the conditions where the use of wildland fire could achieve a resource objective. This positive link between WFDSS use and managed fire has not been reported in earlier research on WFDSS, though it was consistently expressed in this research across multiple Forests and employees, ranging from Forest Supervisors to Engine Captains to natural resources staff. Thus, our results suggest that there may be opportunities to explore additional tools, training, or considerations related to the WFDSS decision making process that support beneficial use of managed fire. Notably, WFDSS does not contain any tools specifically designed to assist decisions for managed fires, rather, tools within it are leveraged the same as in full suppression fires. Integrating emerging guidance such as the Managed Fire Decision Framework discussed in Fillmore *et al.* (2021) (or other similar tools) into fire risk analyses during managed fires may help to inform a more comprehensive understanding of the factors that decision makers used while constructing the WFDSS Decision. For example, the six key decision factor themes identified in Fillmore *et al.* (2021) (fire environment, fire outcomes, operational considerations, sociopolitical factors, institutional factors, and perceived risk) could be incorporated as factors influencing the relative risk rating and organizational assessment function of WFDSS. The result would be a mechanism for identifying influences on decisions made under all wildfire strategies.

Program Conclusions and Recommendations

Managers in the Southwestern Region do not appear to be using the WFDSS program as the explicit decision guidance that was originally intended at the onset of the system. Instead, our results suggest that WFDSS is largely being used as an information source for peripheral users or an archivable location for decision documentation. It also appears that the WFDSS user base is self-selecting into either specialists or generalists, with the former consolidating expert-level skills, and the latter primarily contributing information during the WFDSS decision making process. Although this emerging paradigm does not seem to present any operational barriers, the number of individuals who are technically skilled in operating WFDSS is universally seen as few and declining. In response, the US Forest Service might consider deliberately expanding and promoting a widespread user base who possesses high technical competency with the WFDSS program to maintain an adequate pool of competent WFDSS 'drivers.' Our research found that

there was an untapped reservoir of capable staff willing to increase their involvement with WFDSS, but they will need those duties to be explicitly acknowledge in their position descriptions or to be freed from other responsibilities to serve as 'drivers' on an increasing number of fires in the region.

The WFDSS pool of expertise could be expanded by offering mentoring-based training spanning units and capitalizing on highly experienced WFDSS users in units with frequent fires. One potential route for enabling mentor-based training could be to annually solicit volunteers who want to improve their skill levels and contribute. WFDSS driver 'trainees' could have additional training added to their position description for the year and be paired up with a mentor who could assist their development remotely, or through on-the-job training during fire incidents in home units of the mentor. Mentor-based training would most likely be facilitated or coordinated at the Regional level of the USFS because Regional staff would have a better understanding of their available pool of trainees and strategically use it to augment capacity in units with more forecasted fire. From an administrative standpoint, this type of mentoring-based development program is similar to the existing taskbook-based qualifications system already used extensively by firefighting staff and Agency Administrators (USDI and USDA 2022).

Strategic responses to the process flow and emergent user classes we cataloged in this research might also improve overall utility of the WFDSS program. For instance, future iterations of WFDSS might follow a similar binning of roles we found in this research, whereby "data managers" integrate, catalog or curate WFDSS data; "authors" can function as a 'driver' of the program during fire events and by drawing in quality data from "data managers;" and "viewers" who can observe or query data from the program without requiring the technical skills to run the entire program. Alternatively, the agency could develop a public-facing website that displays WFDSS derived data, thus eliminating the need for a viewer role or passwords. We suggest removing the 'Dispatcher' role altogether.

Finally, we recommend tailoring WFDSS training to more explicitly reflect the level of engagement users have with the program. For instance, although most training is completed at the local or Regional level, a more tailored refresher training for decision authors (i.e., 'drivers') could be more akin to the RT-300FS 'Burn Boss' refresher training, or other wildfire based refreshers such as the RT-130. Such author-focused training could incorporate case-study examples of WFDSS use from real fires, mechanisms to efficiently facilitate arriving at a decision across the range of AA decision making style preferences we uncovered in this research (e.g.,

small group, collating information, etc.), and hands-on experience that is accompanied by feedback from experienced users. Conversely, WFDSS training tailored toward those who contribute information to decision makers or WFDSS drivers may be better served with a curriculum designed to illustrate what the kinds of information that may be requested of them, how to best provide that information to maximize WFDSS utility, or the level of detail that is necessary given potential time constraints. Thus, we would suggest that training surrounding WFDSS be disaggregated and become more specialized to reflect the self-organizing and team-based use of the program in order to further improve its integration into the decision making environment surrounding wildfire management. Varied curriculum would allow respective users groups to better concentrate and excel at what is expected of them during a wildfire incident.

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Chapter 4: Decision Factors and Framework for Full Suppression and Polystrategic Wildland Fires after the 2009 US Federal Policy Update

Abstract

Background:
The decision making process undertaken during wildfire responses is complex and prone to uncertainty. In the case of US federal land managers, outcomes for the resource must also be considered alongside that of human-based values.
Aims:
The aim of this research is to validate the presence of decision factors relevant to the wildland fire decision making context that were previously known and those that have emerged since the 2009 US federal wildland fire policy was updated.
Methods:
Interviewed wildfire decision makers across the US while wildfires were actively burning to elucidate time-of-fire decision factors. Transcripts were coded in qualitative data analysis software and thematically analyzed.
Key results:
Most previously known decision factors as well as numerous emergent factors were identified. To contextualize decision factors within the decision making process, we offer a Wildfire Decision Framework that has value for policy makers seeking to improve decision making, managers improving their process, and wildfire social science researchers.
Conclusions:
Wildfire strategies that managers choose to employ are fluid and difficult to characterize. Attempting to bin strategies into strict categories does not reflect contemporary wildfire management. Researchers and managers should consider messaging that reflects a 'polystrategic' approach when managing a wildfire with strategies other than full suppression.
Implications:
Managers may gain a better understanding of their decision environment and use the Wildfire Decision Framework as a tool to validate their deliberations. Researchers may use these data to help explain the various pressures and influences modern land and wildfire managers experience. Policy makers and agencies may take institutional steps to align the actions of their staff with desired wildfire outcomes.

Introduction

In recent years wildfire management has become a more prominent concern around the world, and thus there is a need to better understand how to improve wildfire management outcomes. Significant scientific attention has been invested in understanding wildfire behavior and ecology, but less is known about the various decision making processes of wildfire management. In the United States, one area of particular interest is how and why different management strategies are chosen to manage a wildfire. This research gap is significant given that the decision making process of key actors must account for an often overwhelming range of elements (Cortner *et al.* 1990; Thompson 2014; Fillmore *et al*. 2021). The elements that complicate informed decisions include a high level of uncertainty related to incomplete information (Borchers 2005), the need to make time compressed decisions (O'Connor *et al.* 2016), rapidly evolving physical and sociopolitical risks (Parsons *et al.* 2003; Thompson 2014), presence of internal and external political pressures (Steelman 2016; Steelman and McCaffrey 2011), uncertainty about whether needed wildfire management resources will be available (Katuwal *et al.* 2017), and difficulty in communicating both timely and accurate information (Steelman *et al*. 2015).

An important decision within any wildfire incident is to develop a primary management objective. Along with the above described complications, this decision must consider existing federal wildfire policy which has shifted over time. In the United States, the early 20th century practice of controlling all fires by 10 AM the day after ignition (10 AM policy) has shifted to a policy that made more room for not immediately suppressing every wildfire. The 1995 federal wildland fire policy was updated in 2009 and fundamentally altered how land managers set strategies during wildfire events. The 2009 update established that every wildfire ignition will generate a response and associated actions are to be 'based on ecological, social, and legal consequences of fire' (USDA and USDI 2009). The appropriate wildfire response is determined by 'the circumstances under which a fire occurs and the likely consequences on firefighter and public safety and welfare, natural and cultural resources, and values to be protected' (Philpot *et al.* 1995). The 2009 policy update differentiates wildfire into two categories: planned and unplanned. Planned fires are intentionally ignited by managers to achieve an objective related to resource or value protection and are more commonly known as prescribed fires (Kolden 2019; Hiers *et al*. 2020). Unplanned fires are those ignited by natural means or through the accidental or malicious action of humans. The 2009 update requires that the initial response

strategy is to suppress and extinguish all unplanned human-caused fires as efficiently and safely as possible (USDA and USDI 2009; Stephens *et al.* 2016). This strategy is known as 'full suppression.' Both categories of wildfire may be managed to achieve one or more objectives at the same time and are adjustable throughout the course of a wildfire to meet changing circumstances (USDA and USDI 2009). Prior to 2009, policy allowed wildfires to be managed for either suppression or resource benefit, but not both simultaneously (NWCG 2001).

Naturally ignited wildfires may also be managed to achieve natural resource benefit objectives if allowable within local Land Management Plans (Miller *et al.* 2012). In general, this means implementing a response strategy that does not aim to fully suppress the wildfire as soon as possible. This strategy is reported in the Incident Management Situation Report (NIFC 2023) as 'managed with a strategy other than full suppression (OTFS).' Examples of resource benefit objectives include restoring wildfire regimes (North *et al.* 2012), reduced fuel loading (Hunter *et al*. 2011; North *et al*. 2021), improved wildlife habitat (Reid and Fuhlendorf 2011), and improved watershed functioning (Stevens *et al*. 2020).

Although the current US policy allows naturally ignited fires to be managed for resource benefit objectives, it is ambiguous regarding when and where the appropriate use of this strategy should be employed which allows fire managers wide latitude in its application (Seielstad 2015). Although this wider decision space was intended to create more opportunity for multiple objectives to be utilized on a wildfire, particularly in areas outside designated wilderness areas, there is some evidence the opposite effect has occurred. This suggests that managers are operating in a risk averse manner regarding the use of wildfire to achieve resource benefits and highlights the need to better understand its associated decision making process (Seielstad 2015; Young *et al*. 2020; Iniguez *et al*. 2022).

Research Background

Understanding the factors managers consider when making decisions is important because tensions may arise if policies are not aligned with the motivations or institutional norms of decision makers. A more complete understanding of decision factors will allow for future policies and strategic decision making tools to incorporate the realities of the decision environment and potentially lead to optimized outcomes. Research into how managers make decisions on wildfires has used a range of methodological approaches and research foci. Studies that have examined the Wildland Fire Decision Support System (WFDSS), a tool developed

expressly to guide decisions on federal lands, have shown that rather than being part of the actual decision process it is most often used to document a decision process that has already occurred, although tools embedded within WFDSS were shown to be useful to validate a priori assumptions or examine alternative scenarios (Noble and Paveglio 2020; Rapp *et al.* 2020; Fillmore and Paveglio 2023). Other studies of the decision process have employed 'choice set' surveys that present decision makers with multiple alternatives to choose from to determine risk preferences. In one 'choice experiment,' Calkin *et al.* (2012) found that social and institutional pressures can lead to increased suppression expenses. A follow up study using the same choice set found that managers' strategy selection was inconsistent with minimizing expected losses and that they might over-allocate resources in low-risk scenarios (Wibbenmeyer *et al.* 2013). Studies focused on whether various heuristics and biases influence wildfire management decisions suggest biases such as discounting, status quo, and risk aversion may contribute to suboptimal wildfire outcomes (Maguire and Albright 2005; Wilson *et al.* 2011; Thompson 2014). Heuristics such as Recognition Primed Decision Making (RPD) are seen as especially prevalent in the wildfire context due to the need to make rapid decisions with limited information (Zimmerman 2011). Case studies have also been useful to explore decision making. For example, Steelman and McCaffrey (2011) found that even when there were divergent viewpoints, early communication between agencies and the public provided a common understanding to emerge over time. Econometric studies have repeatedly found that incentives exist to implement strategies that are risk-averse, although those same strategies tend to be financially unoptimized (Hand *et al.* 2015; Katuwal *et al*. 2017).

A recent review (Fillmore *et al*. 2021) of published research that examined decision making factors related to wildfires managed with a strategy intended to achieve resource objectives found 110 individual factors that influence the decision to either suppress a fire or manage it with a OTFS strategy. These factors were categorized as barrier, a facilitator, or unaligned to either and assigned to one of six overarching key thematic areas (KTAs): *Fire Environment, Fire Outcomes, Institutional Influences, Operational Considerations, Sociopolitical Considerations, and Perceived Risk*. Together KTAs and decision factors were organized into a decision framework to help conceptualize the association between related but discrete prominent thematic considerations. The framework provides a useful leverage point for understanding current decision processes. However, the literature reviewed predated the 2009 policy update which raises the question of the degree that the current decision environment has or has not changed.

The purpose of this research is several-fold. First, we wanted to verify the presence of wildfire decision making factors identified in the Fillmore *et al.* (2021) within the current policy context as that review was relevant only to the pre-2009 policy context. Second, as in the 2021 paper, we wanted to investigate differences associated with the decision to fully suppress a fire or manage it with OTFS, and where on the spectrum of available strategies their decision and decision considerations existed. Our interviews were guided by a simple research question: *Among Agency Administrators and fire managers, what factors are being considered in the wildfire decision-making process, and how do they affect the decisions that are made?*

Methods and Analysis

To answer the research question, we focused on key decision makers responsible for directly managing a wildfire known to be actively burning. A series of semi-structured interviews with these decision makers and fire managers was conducted throughout the 2021 US fire season. A hybrid inductive-deductive analysis methodology was used to validate the presence or absence of decision factors found in the 2021 paper and identify any new decision factors that have emerged within the post-2009 policy context.

Numerous actors contribute information and influence the decision making process on wildfires burning on US federal lands including agency staff, Incident Commanders (IC), cooperating agencies, publics, and politicians. However, only federal Agency Administrators (AAs) possess delegated authority within the Executive Branch to oversee programs derived from Executive Branch and Congressional direction (Lawton 1954). AAs are responsible for overseeing all aspects of wildfire preparation and response. During wildfire events, AAs are responsible for providing the intent about the strategy under which a fire is to be managed and ensuring strategies are aligned with law and policy and possess the delegated authority to sign legal decision documents for the fire (Noonan-Wright *et al.* 2011). Therefore, our primary interview sample was the AA on each identified fire that met our selection criteria, although in select cases, individuals who were operationally involved in the fire or who contributed to its planning were interviewed (Figure 4.1). We spoke with AAs and fire managers during fires that were being managed under a variety of strategies and were particularly interested in discussing why one strategy (or set of strategies) was implemented versus other available options. Additional social context for fires was provided by interviewing with a small subset of the

public directly affected by fires. However, their interview data was only incorporated into the results to the degree that it provided additional social context.

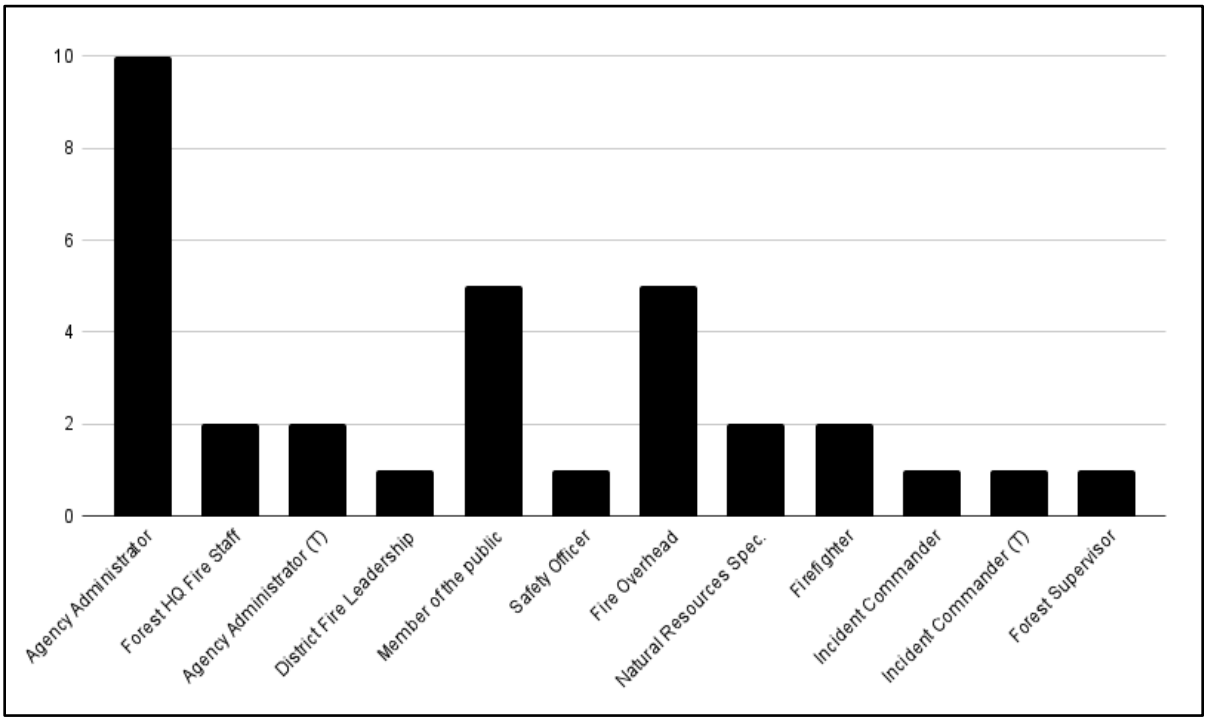

Figure 4.1. Distribution of interview participants shown by incident position (HQ =headquarters; T = Trainee).

Potential fires (referred to as 'cases' from here forward) were initially identified based on inclusion criteria where the fire was 1) less than 50% contained and 2) reflected characteristics indicating that it could have been managed with a strategy other than full suppression (regardless of whether it was or not). These characteristics were guided by the professional experience of the lead author and identified in Fillmore *et al*. (2021) such as proximity to wilderness, elevation, known culture of fire use, and seasonality. Interviews were conducted while the fire was still burning, when participants did not yet know what the outcome of their decisions were, to minimize potential hindsight bias and to increase focus on the factors and biases present within the actual decision making process. Researchers sought to avoid conversations that incorporated aspects of inevitability and foreseeability as these would potentially lead interview data to aspects of decision validation not relevant to the real-time decision considerations we were interested in exploring (Roese and Vohs 2012).

Primary study participants were initially contacted directly through phone calls or enterprise messaging software. Following contact, a short evaluation interview was conducted

to verify the inclusion criteria, after which a full interview was arranged, or further contact was terminated. Most interviews were conducted via phone or video teleconference, with 18 interviews conducted on site which allowed researchers to both contextualize the fire environment and explore lines of questioning based upon personal observations of the fire conditions. The sample frame focused on US Forest Service (USFS) AAs with delegated oversight of the wildfire to which the interview pertained. The reason for focusing on USFS participants was twofold. The first related to methodological accessibility in that the lead researchers were employed by the USFS which brought an inherent level of credibility when approaching participants for an interview. This in turn increased trust and allowed conversations to flow with high levels of mutual understanding. Second, we restricted our sampling frame to the USFS to allow cross-case thematic comparisons without having to account for cultural differences influenced by institutional histories. In-person interviewing was initially facilitated by remote contact, but once on site, followed a purposive-snowballing recruitment strategy (Seidman 2013). All interviews were conducted under the provision of anonymity in accordance with human subject research and was overseen by the University of Idaho Institutional Review Board. Interview data includes participants from the Rocky Mountain, Southwest, Intermountain, Pacific Southwest, and Southern USFS Regions. Field interviews were conducted in the Southwestern and Pacific Southwest Regions. Recruitment and interviews began in April 2021 and continued until theoretical saturation was achieved in September of 2021. Theoretical saturation occurs when researchers agree no new major themes or ideas are becoming apparent from subsequent interviews (Bryman 2015).

A semi-structured interview protocol was used to ensure consistent questions were asked of all respondents, while also allowing for follow-up or probing questions to explore the emergence of new ideas (Patton 2002; Bryman 2015). Interviews lasted between 24 and 108 minutes and averaged 58 minutes in length. All telephone interviews were recorded using the NoNotes application. Interviews conducted via the video teleconference software Microsoft Teams were securely recorded within the program. In-person interviews were recorded by a Phillips digital recording device. Interviews were transcribed verbatim using the Rev.com transcription service. A total of 44 interviews with 33 people across 15 fire cases were conducted, accounting for slightly more than 47 hours of discussion. On several fires that burned for long periods of time, we interviewed the same participant multiple times. To avoid over-representing data provided by these participants, all coding associated with a participant and an individual fire case were consolidated into a single file. For example, if a participant

expressed concern that a community may be impacted in the first interview, that factor was likely to be repeated in subsequent interviews and inflate its overall presence relative to other codes. Combining interview files prevented the numeric file count from being artificially inflated while retaining the overall reference count in the qualitative analysis software. This reduced 44 interviews into 36 files.

Data were analyzed using the QSR Nvivo Windows (Release 1) qualitative coding software (QSR International 1999). We utilized an iterative, hybrid inductive-deductive, and multi-stage coding process guided by principles of thematic analysis, analytic induction, and deductive discovery (Boyatzis 1998; Ryan and Bernard 2000). Coding took place in three main phases, with each phase representing a separate analysis of the data and discussion about consistency among the researchers to ensure reliability. The first phase of coding was conducted deductively by assigning each distinct segment of respondent dialogue in the interview transcript data to one or more of 6 topic codes (Richards 2014). We used a pre-defined codebook adapted from the topic codes described as 6 'Key Theme Areas' (KTAs) in Fillmore *et al.* (2021). We assigned each of the initial 6 topic codes into 3 categories: Barriers, Facilitators, or Unaligned, for a total of 18 topic codes. Barriers served to persuade the decision away from managing a wildfire; these were often obstacles that needed to be mitigated. Facilitators made the decision easier for fire managers who wished to manage a fire for OTFS. Unaligned factors exist as a consideration but have no clear effect on the decision on a particular fire and are likely context dependent in their influence.

The second round of coding used both deductive and inductive reasoning to assign descriptive codes to interview data. This process looked within the data to identify patterns in the perspectives or experiences articulated by respondents (Gibbs 2007; Richards 2014). Descriptive codes equate to factors considered by AAs or fire managers when deciding which fire management strategy to employ for the fire being discussed. Deductive coding was used when we observed a factor that had been seen in the preexisting codebook. Inductive coding was used when new decision factors were observed and added to the codebook.

Interrater reliability was conducted during the topic coding stages (Boyatzis 1998; McHugh 2012). A subset of transcripts were independently coded and then compared. Observed disagreements within topic coding strategies were discussed among the raters. Refinements to the coding rules continued until the Cohen's Kappa values for each KTA topic code met or exceeded 0.6 (Nichols *et al.* 2010; Gisev *et al.* 2013). The final Kappa values for the 6 topic codes are shown in Table 4.1.

Table 4.1. Cohen's Kappa values for the topic coding phase.

Topic Code	Kappa Value	Agreement %
1	0.79	94
2	0.75	96
3	0.72	91
4	0.89	96
5	0.64	90
6	0.63	88

The final stage of "analytic coding" allowed us to refine inconsistent or outlier decision factor codes into thematic areas with greater represented consistency. It also helped identify consistent relationships among the descriptive codes articulated by respondents, including any similarities or differences among respondents (Saldaña 2016).

Results

The primary research goal was to validate the presence or absence of factors related to the decision to manage a wildfire for full suppression or OTFS. Our research sought to bring known decision factors up to date, validate their continuing presence, and determine if new decision factors have arisen in the post-2009 decision environment. We then provide an updated decision framework and list of decision factors validated or discovered in the contemporary policy context. We believe that this revised framework will allow managers and researchers greater insight into the complexity associated with the wildfire decision environment and contribute to solutions that achieve positive wildfire outcomes for firefighters, the public, and the landscape.

We found that many of the pre-2009 decision factors were still being considered by fire managers. Of the original 110 decision factors, 30 barriers, 30 facilitators and 22 Unaligned factors were still present. Proportionally, Barriers saw the least alignment to pre-2009 factors, with only 30 of the original 41 present. While 68 new decision factors emerged, 28 previous codes were not found again. In total, 150 decision factors were found to be operating in the current wildfire decision making context (Tables 4.2, 4.3, 4.4). This is 40 more than found in the pre-2009 context (Fillmore *et al.* 2021) which suggests that wildfire decision complexity is increasing over time. Unaligned factors increased the most (28 new), which suggests that the decision environment is also increasing in ambiguity. Of the original 110 factors, 28 were not

found during our interviews. Because identifying missing factors was not within the scope of this research, no formal analysis was conducted on them. A basic review of the missing factors found thematic clusters related to financial concerns specific to the pre-2009 policy context, some indication that air quality concerns were shifting away from regulations and towards impacting the public (as seen in our data), and broadening interest in the ecological role of fire instead of specific discipline-based foci.

Overall, the six KTAs operated in the same manner within the contemporary policy context as in Fillmore *et al.* (2021). As before, fire environment factors related to local physical conditions that influenced the decision-making process and fire outcome factors were related to the potential positive and negative effects of a fire. These outcomes manifested at different temporal and spatial scales. Operational considerations were driven by the amount and kinds of firefighting resources available to the decision maker. Sociopolitical factors focused on a range of considerations associated with various external stakeholders such as recreational users, adjacent landowners, cooperating agencies, and businesses dependent on public lands. Institutional influences are those considerations and pressures that exist internally in the decision maker's agency. Perceived risk was expressed as the level of personal and professional risk decision-makers were willing to accept.

Fire Environment

When looking at the KTA of the fire environment, favorable expected fire behavior, weather forecasts, and fuelbed conditions acted as a facilitator when they were expected to contribute to favorable fire conditions (Table 4.2). Favorable fire behavior was frequently described as slow to moderate rates of spread and low flame lengths and fireline intensities. Favorable weather conditions were weak winds, high humidity, and moderate temperatures. AAs were more likely to consider managing fires for OTFS when the fuel conditions were not too far departed from their historic range of conditions or had been reduced through prior fuels reduction work. Unaligned factors appeared to operate as background contextual elements, consisting of factors that were considered prior to new wildfire ignitions, although they had no inherent indication of how they may ultimately influence the final decision. Here, the presence or magnitude of ongoing drought was considered, as were general weather and fuel condition trends. A new theme heard from several AAs was the preferred environment under which to manage a fire for OTFS. One AA described the "perfect fire" as one that:

> ...occurs probably in the middle of a wilderness area to where it's got a lot of land around it. It's not going to move. It's not going to threaten a whole lot of value. It's not going to threaten communities. It's not going to threaten a community's infrastructure or water systems or power grid. And it would be one that would start late in September. Later in the year when we've got cooler temperatures at night, where relative humidities are improving and shorter days. Or one that starts maybe a little bit earlier in the season, but it's surrounded by snow pack.

Barriers in the fire environment were mainly made up of newly identified, and often interrelated, factors related to the fuelbed, climate change and drought. Fuel beds were frequently discussed as overly dense or with too much accumulation to manage for OTFS; and climate change was perceived as contributing to drought thereby creating fuels too dry to be managed with an OTFS strategy. One AA interviewed explained how the fire environment on their district led to using a fire suppression strategy on their fire:

> But I feel like things have changed so much over the last hundred years with the climate, with the state of the drought that we're in currently in this part of the state, that sometimes [people] feel that they can just pick up where they left off without really taking into account all of the change that has occurred, and the suppression actions that have happened over the last hundred years.

Table 4.2. Fire Environment and Fire Outcome KTA decision factors. Factors are listed in descending order of frequency within each facilitator, unaligned, and barrier KTA box. Factors shown in bold are identified in this analysis but not in Fillmore et al. 2021.

Facilitators	Unaligned	Barriers
Fire Environment		
Favorable fire behavior conditions	Expected weather	Fire conditions unfavorable
Fuel conditions favorable	Fuel type and condition	***Fuel conditions not favorable***
Favorable fire weather conditions	***Is it the 'perfect' environment***	***Presence of drought prevents***
Previous fuel reduction work	Drought index	***New fire environment - Climate Change***
Fire Outcomes		
Reduction in fuel	***Expected fire effects***	Air quality - public impact
Good outcomes despite drought	Air quality concerns	Uncertainty of outcome
Improvement to forest health and ecology	***Impacts to grazing allotments***	***Previous bad experiences***
Fire will spread unassisted	***Meeting fuels acre targets***	***Worry for killing trees***
Allow natural processes	***Considering watershed effects***	***Result of past practices***
Expected reduction in smoke impact	Expected fire behavior	***Smoke impacts to wildlife***
Snags are reduced		***Don't manage if it wouldn't grow on its own***

Fire Outcomes

Except for observable first order fire effects (e.g. obvious mortality, scorch height), outcomes are somewhat conjectural when discussed while the fire is still burning. The most often mentioned factor that facilitated the decision to use an OTFS strategies was when managers expected to see reduction in fuel levels on the landscape. Although every fire will inherently reduce fuel, manager comments reflected a Goldilocks principle; enough fuel burned away to have benefits, but not so much where forests would be harmed. The benefits managers hoped to realize include improved forest health and resilience, reduced standing snags, and reduced air quality impact from future wildfires. Managers often described a general desire to allow fire to play its natural role. In several cases, managers described being surprised to see beneficial outcomes despite ongoing drought conditions. In one example, an AA described the effects they observed:

> There's a couple of places where it's sat around and cooked a little hotter than you necessarily would want, but in general, both our fire and aviation staff, as well as the agency administrator folks, we see benefits...it's almost 4,000 acres. If you could just put that thing out right now and just walk away from it, that would be a great prescribed fire, and we'd all be happy. Yeah. I think we do see it doing good stuff right now.

The most prevalent unaligned factor was a generalized concern about fire effects uncertainty. Managers also gave general consideration for potential air quality and grazing impacts. Among barriers, air quality impacts were the most frequently discussed. There were five new fire outcome barriers, however, no individual outcome barrier demonstrated a strong signal: while several managers had previous bad experience using OTFS strategies, most barriers focused on the potential to cause environmental harm (tree mortality, degraded air quality, or reduced wildlife habitat).

Operational Considerations

Results related to fire operations suggest two primary factors facilitated the decision to use an OTFS strategy. First, managers expressed a clear preference to keep managed fires at the local Type 3 (or lower) incident complexity level. When the complexity of a fire increased, requiring a Type 1 or 2 Incident Management Team (IMT), managers saw less potential for using OTFS strategies. This corresponds closely to the second facilitating factor; participants reported greater success managing fires under OTFS strategies when they knew that their fire staff possessed a deep understanding of the local area. The first factor was newly observed; the second had been reported previously. Other facilitators discussed by participants included having sufficient resources, the presence of recent fires proximal to the current fire, and extensive Forest Service land base surrounding the fire. Regarding the use of IMTs, one participant remarked that:

> You don't bring in a Type 1 team because you want to manage a fire, you bring them in because you want to put it out. And maybe at most, you might be

> able to get them to do some planned ignitions to reduce fire severity and stuff like that along the way, if they have time.

Several unaligned factors emerged among operational considerations. The most frequently discussed regarded the use of 'big box' strategies. 'Big box' is a colloquial description of a containment strategy that utilizes a large planning area and tends to employ tactical firing operations and other indirect fire control tactics. Participants also considered whether they were likely to have the necessary resources to achieve their management objectives and fire duration, based in part on personal expectations of fire season continued duration. Many participants also considered the available planning support, and potential tactics available to complete or contain fires under differing management strategy scenarios.

The overwhelming operational barrier to managing a wildfire for OTFS was the expectation of reduced available firefighting resources (e.g., fire engines, handcrews). This was also the most prevalent barrier found in the pre-2009 policy literature. As before, the concern centered around either having insufficient resources to begin managing the fire or that resources would be reassigned to higher priorities (such as communities at risk by other fires) after they had committed to managing their fire for OTFS. Other significant barriers discussed included personnel fatigue of firefighting staff, close proximity to other land ownership boundaries, and seasonality.

Table 4.3. Operational Consideration and Sociopolitical KTA decision factors. Factors are listed in descending order of frequency within each facilitator, unaligned, and barrier KTA box. Factors shown in bold are identified in this analysis but not in Fillmore et al. 2021.

Facilitators	Unaligned	Barriers
Operational Considerations		
Bringing in a Type 3 IMT	***Using 'big box' strategy***	Lack of resources
Understanding of local area	Resource availability	Insufficient ignitions
Previous fires make it easier	***Tactics for achieving effects***	Fatigue length of time required
Having enough resources	Planning support	Ownership boundaries
Working in a large land base	***Working with IMTs***	***Too early in the season***
	Expected duration of fire event	
	Experience with fire	
	Proximity to boundary	
	Fatigue of staff	
	Influence of Wilderness	
	Coordination is in place	
	Preparedness level	
	Amount of fire allowable	

Table 4.3 Continued

Sociopolitical Factors		
Collaborative relationships in place	***Media and public interactions***	***The public is afraid of fire***
Public supports	***Relationship building***	Lack of public support
Easier to manage when conversations are had early	Opportunity to educate the public	Political fallout concern
Mitigating impacts to cooperators	***Classifying fire 'types'***	***The public expects to see suppression***
The public advocates for using fire	***Being responsive to public input***	Conflict with cooperators
Communication related to the event	***Pressure from tribal groups***	Economic impact
Public has been educated	***Managing 'optics'***	***Can't talk about benefits in a suppression fire***
Education opportunity for the public	Impact to recreational users	***Negative public health impacts***
	Public support	***Criminal activity makes firefighting unsafe***
	Political support	***Public has not been prepared***
	Impact to cooperators and neighbors	
	Nomenclature may be confusing	

Sociopolitical Considerations

Respondents reported that the sociopolitical factor which most facilitated the decision to use an OTFS strategy was previously established relationships with the local stakeholders potentially affected, including adjacent landowners, livestock producers, elected officials, and other community leaders. Many AAs discussed the importance of deliberately forging relationships over time, long before a fire started. These relationships were often developed during previous fires or as part of various preparatory actions such as collaborative fuels treatments or fire safe councils. Sometimes relationships existed simply because the interview participant had grown up in the local area. Cattle producers who leased allotments on USFS lands were reported to be among the strongest advocates for managing fires, as they saw a benefit when dense forests and shrublands were opened up for grass production following a fire. This support sometimes extended to their own adjacent private lands as well, where

burning was welcomed as part of management strategies. Any sense the local public supported this strategy also gave managers more confidence to employ it.

Unaligned sociopolitical factors also focused on the status of local relationships, however, in this context there was greater uncertainty with some AAs less sure how the public perceived the use of OTFS strategies. The media and its influence also were discussed and considered but did not influence the decision. Many participants viewed the media primarily as a tool for educating the public about alternative wildfire response strategies, especially when the fire was being managed for OTFS. Some participants expressed frustration around how to describe the spectrum of available strategies to the public, particularly when trying to explain the seemingly dichotomous intent of trying to both protect human focused values and allowing fire to play its ecological role:

> In a managed fire where you're saying, 'you know what, we're going to go ahead and let it do its thing. And we're going to watch it, and we're going to manage effects, and whatever. This is the right thing to do, ecologically.' That's a different conversation with the public. Because now you're making a choice. You're not actively trying to save something, except you're trying to restore [natural resources].

The most frequently expressed sociopolitical barrier also pertained to beliefs about the public's perceptions of acceptable management practices. In half of the cases, participants believed that the public was afraid of wildfire and that managing fires with a strategy OTFS played into their fear. These AAs felt that employing a full suppression strategy helped prevent or alleviate those fears and was often enough of a reason to justify using a full suppression strategy. Believing that the local public did not support OTFS strategies was a barrier. So too was believing that local political figures were opposed to it. Several AAs felt that it was not palatable to publicly discuss any positive outcomes of fires (e.g., ecologically) if it was being managed with a full suppression strategy.

Institutional Influences

The factor that most facilitated the decision to manage a fire with an OTFS strategy was when the managing organization possessed a culture actively supporting the strategy; even to

the point of exhibiting pride in being known for it. The scale at which a facilitating culture was most discussed was at the level of a District or Forest, however we also found evidence for its presence at the USFS Region scale. The Region scale worked both directions; some participants believed their Region possessed a managed fire culture (Rocky Mountain and Southwest Regions) while others suggested their Region did not (Pacific Southwest and Southeast Regions). A second facilitating factor was pre-planning in anticipation to use OTFS fires, this included planning within the Forest's LMP, but also within pre-fire spatial planning tools such as Potential Wildfire Operations Delineations (PODS)(Thompson *et al.* 2016b; Thompson *et al*. 2022) Having these types of anticipatory tools showed that the Forest had already gone through deliberations to prepare for the event. The third factor was when the Agency showed clear support for OTFS fires. The scale for this mimics that of culture; agency support was seen at all levels of the organization, but the most profound for participants was when it came from the Washington Office level.

Table 4.4. Institutional Influence and Perceived Risk KTA decision factors. Factors are listed in descending order of frequency within each facilitator, unaligned, and barrier KTA box. Factors shown in bold are identified in this analysis but not in Fillmore et al. 2021.

Facilitators	Unaligned	Barriers
Institutional Influences		
Culture of fire use	***Cultural shifts in the workforce***	***Suppression as baseline***
Planning completed	***AA taskbooks***	Policy as a barrier
Agency supports	***Strategy nomenclature***	***Chief's letter as a barrier***
Technology and data supports	Fire cause	Culture not normalized to fire use
Shift to defending to put it out	Agency support	***Impact of hiring practices***
Peer recognition	***Need to coordinate with 'ologists'***	Lack of agency support
More outcome focused planning	***Balancing policy***	Reporting accomplishments
NEPA has been completed	***Cost related***	Local-Regional prohibitions
Policy supports natural role of fire	***IMT related***	Post-fire rehab – no money
	Policy details	
Perceived Risk		
Would have been unsafe to staff	***Decision making processes***	Threat to private property
Presence of snags leads to indirect	***Desire to see critical thinking***	Bias for suppressing wildfire
Personal ethic supporting OTFS	***Managing risk first***	Generalized risk aversion
Risk sharing	Risk to infrastructure	Threat to natural resources
Willing to take on the risk	***The 5 'rights'***	Liability concerns

Table 4.4 Continued

Resource benefit and safety both	Confidence in staff	Threat to infrastructure
Low values at risk allow it	***Risk equation has changed***	***Risk of losing public support***
Would have been unsafe to go direct	Risk to natural resources	Concern about career advancement
Personal satisfaction	Acceptable risk levels	Threat to public safety
	Risk to firefighters on the fire	Stigma of failure
	Risk of escaping boundary	Threat to firefighters
	Agency Administrator satisfaction with the plan	***Can't manage due to national need***
	Risk to human life	Lack of fire familiarity to be comfortable
		Lack of incentive
		Threat to reputation

Interestingly, the majority of unaligned institutional factors were new including the three most frequently mentioned factors. The first, described in almost half the interviews, was a sense of cultural changes within the USFS workforce. Many older AA's believed the new generation had much greater interest in incorporating consideration of ecological function into their work, including wildfire management. They also observed greater diversity in the workforce than when they began. One observed the change they saw in these terms:

> But I think that's one of the things that is maybe changing in some ways is that we do have some young people coming into the agency that are from nontraditional backgrounds, and they sometimes can be more engaged in those discussions because they aren't burdened with a whole lot of preconceived notions about what firefighting is or what natural resource management is.

Other participants believed cultural shifts stemmed from changes in policies and practices, especially those that emphasized safety to a greater extent than previously. Older AA's saw the change to using less aggressive tactics as a matter of risk mitigation, improved land management outcomes, and reducing strain on the workforce. Frustration with the ambiguity inherent to the post-2009 wildfire policy update was a commonly mentioned topic. Many managers now found it difficult to describe their intent adequately and consistently to both staff and the public. Within just our dataset of 15 fires we found 6 different ways managers chose to describe the strategy they were employing (Table 4.5).

Table 4.5. Description of strategies employed across the 15 cases, as described by participants.

Strategy described by participant as:	Interpreted strategy	# of cases strategy was described
Full suppression	Extinguishing the fire as soon as possible at the smallest size using direct tactics	6
Managed for multiple objective	Managed to allow fire to burn to achieve desired fire effects regardless of the time required	4
Using modified suppression	Extinguish the fire using tactics that may allow the fire to grow larger before stopping	2
Managed with confine and contain w/ point protection	Extinguish the fire at pre-selected indirect control features while protecting values inside the expected perimeter	1
Managed with confine and contain	Extinguish the fire at pre-selected indirect control features	1
Full suppression with point protection	Extinguishing the fire as soon as possible at the smallest size while emphasizing protecting values inside the expected perimeter, usually with a mix of indirect and direct tactics	1

Comments about institutional barriers were somewhat evenly distributed across 8 factors, including 2 newly seen in this research. Some managers reported that the ambiguity in being able to adequately describe their strategy served to prevent managers from considering managing the wildfire for OTFS objectives: the simplicity of full suppression strategies made it easier to message to the public and staff. Some indicated they thought that full suppression was the default acceptable strategy and deviating from it required extra planning and communication. One AA described their perspective as:

> If we've made a decision that this is not a good place to manage, and we're going to do 100% suppression, that's considered the baseline acceptable position. If you really think about it, it's when you go beyond that baseline of 100% suppression and have different factors that play off what nuances a decision, that's when people want to have the communication.

Of note amidst this ambiguity is the challenge with trying to distinguish strategies from outside appearances alone, a dynamic noted by discussions during some interviews regarding the decision makers intent for their fire, and how they chose to characterize their intent to the public which were not always directly congruent. Two fire cases from one National Forest provides an example (see inset box 1).

INSET BOX 1

The first fire was caused by lightning, and the decision was made to implement an OTFS strategy to achieve resource objectives. A base camp was set up, a Type 3 IMT was ordered, and a plan was made to implement tactical firing operations on planned control lines using a "big-box" strategy. At its peak, nearly 150 firefighters were assigned to the fire. Approximately 10 days after the fire started, crews had completed firing out the planned area of around 12,000 acres; more than 1,000 acres a day of growth on average, and the fire began transitioning down in complexity and the number of resources allocated.

Later in the year, on the same district, lightning ignited another wildfire (and was visited by researchers). The fire was burning within a 9-year old fire footprint containing numerous snags. The fire exhibited minimal fire behavior, primarily smoldering in heavy dead and down fuel, and showed little daily growth due to a lack of available fuel to burn. Because of a nearby community, the decision was made to use a "full suppression" strategy. However, due to the extreme snag hazard, firefighters were unable to safely engage directly with the fire and instead prepared indirect control lines along nearby trails and roads. No aircraft were utilized for suppression on the incident. Growth on the fire was monitored remotely while crews prepared control lines and improved community defense features. Over the course of a month, the fire slowly grew to 500 acres in size. After another month, the fire was listed as 10% contained with no additional growth in size. Eventually the fire received considerable rainfall and was declared out.

In the end each fire the official strategy did not necessarily match how others may have perceived the fire to be managed. From outside appearances, the first fire appeared to be managed in the aggressively characteristic manner of a full suppression fire, whereas the second fire was never directly touched by fire resources and was more indicative of a managed fire but was in fact managed for full suppression with a nearby community as the principal value at risk.

End of Inset Box 1

Perceived Risk

Within the risk context, both of the two facilitating decision factors identified in the pre-2009 literature carried over (*personal satisfaction* and *a professional ethic to manage fires*). Notably, an additional nine facilitating factors were identified in our interviews. The two most frequently discussed were related to safety: (1) whether managers felt it would have been unsafe for firefighters to employ direct suppression strategies, and (2) when the presence of standing snags was considered too risky to use direct suppression tactics. Using OTFS strategies was also facilitated when AA's perceived risk was being shared across multiple levels of the agency. Other conditions that facilitated OTFS included when few values were at risk, or it was feasible to both reduce risk to firefighters while achieving ecological benefits.

Three related unaligned decision factors emerged from our interviews and focused on risk mitigation processes. First, most decision makers interviewed discussed their personal decision making processes which tended to be flexible and open to input from internal and external sources. Most AAs were able to articulate the pros and cons of a given strategy and overwhelmingly used risk-based considerations. For example, one AA described their desired scenario when fire staff first evaluated a fire:

> Okay, when you get out to a tree strike, this is the process we're going to follow. We're going to assess what we see. Is it one tree? Is it just a spot? Is dropping that tree going to be the best option? Or is leaving it burn and then when it falls apart, then we'll deal with it because it's also a nasty tree that somebody may die trying to cut down.

The second unaligned decision factor reflected managers consistently telling us that the first objective of any fire should be to minimize the risk to firefighters and the public, which aligns to national policy (USDI and USDA 2022). Third, to achieve this objective, managers aspired for firefighters to engage critical thinking while responding to and engaging on the fireline.

As in the previous research, managers reported numerous risk-based barriers, however few discrete barriers appeared with consistency. The most expressed risk-based barrier was when private land was thought to be endangered, which corresponds to the similar operational concern with boundary adjacency. Several AAs expressed their belief that suppression was the

best course of action for wildfires regardless of potential ecological benefit, although all regarded safety as the first priority in any fire response.

Discussion

Wildfire decision makers work in a complex, uncertain, and time compressed environment where they must identify and implement response strategies while considering natural environment, local communities, local economies, user groups, political influences, firefighting staff, as well as their personal interests. Despite the important impacts of different management choices, little research has been conducted to understand how decisions are made. Our research provides specific insight into the decision process in the post -2009 policy context, specifically the point of decision at which an AA has to decide to follow the well-trod path of suppressing the fire, or accept the risk of an OTFS strategy in exchange for potential ecological benefits.

Wildfire decision framework

Given the high degree of flexibility the 2009 guidance provides AAs and managers, the factors presented in the results appear to have universal value for wildfire decision making, regardless of the strategy employed. Given this, we suggest that the "*Managed Fire Decision Framewor*k" originally presented in Fillmore *et al*. (2021) might simply be called the '*Wildfire Decision Framework*' (WDF) as our findings indicate it has value for all contemporary wildfire decision making scenarios. We present a simplified version of the framework in Figure 4.2. The WDF framework demonstrates that each of the 6 KTAs and the factors nested beneath them influence the central decision nexus. Decisions are evaluated based on the relative influence assigned by the decision maker based on their risk perception and personal and professional motivations. After the evaluation is complete, a final decision emerges and is represented in a box below the nexus.

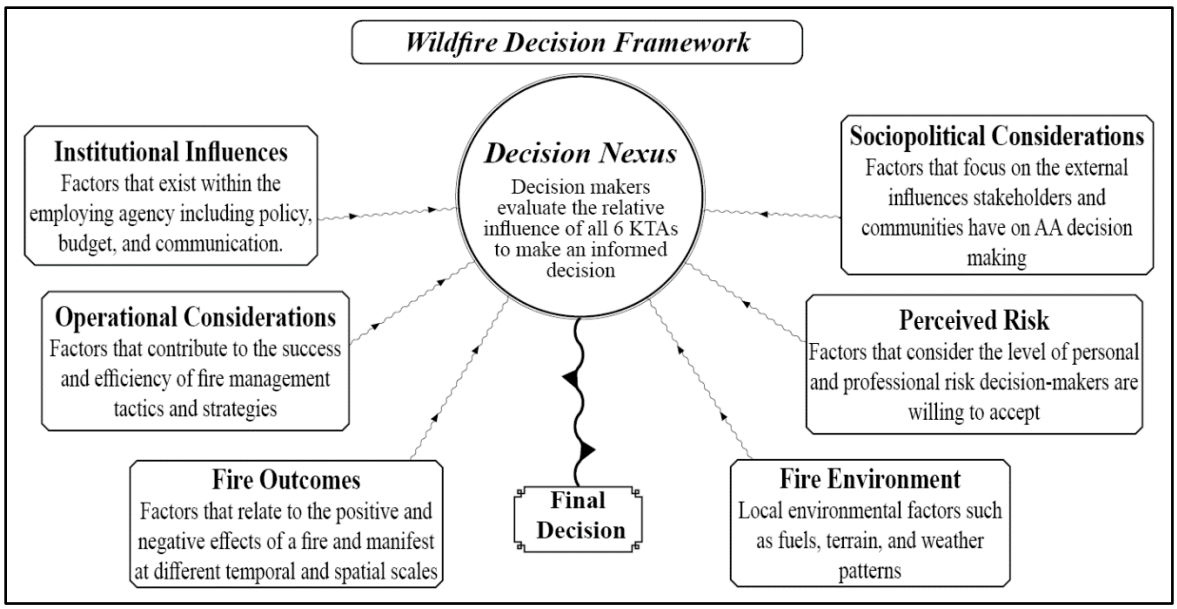

Figure 4.2. Simplified representation of Wildfire Decision Framework. Each of the six KTAs shown here contain barrier, unaligned, and facilitative decision factors. A total of 150 decision factors are nested under the KTAs.

Messaging the overall wildfire strategy

The 2009 policy update was intended to give decision makers greater latitude by considering different strategies within the same fire rather than a single strategy across the entire fire (USDA and USDI 2003). The 2009 update has been successful to that end, as it is now common to see large fires managed with a "polystrategic" approach across portions of the perimeter. Our research corroborates the findings of others suggesting that wildfire strategies now more accurately reflect a spectrum of opportunity that are adjusted throughout the term of the fire depending on the conditions and characteristics of the fire itself (Thompson *et al*. 2019; Riley *et al.* 2018).

We also found evidence that widening strategic possibilities appears to have inadvertently complicated the cogency of the message when communicating with internal and external stakeholders. AAs and managers do not feel the public would understand the wildfire decision making processes. This is evidenced by the disproportionate number of sociopolitical barriers, particularly those regarding public expectations and fear, which decision makers did not want to contribute to through their decision making. Although there were many more facilitating factors discussed, the barriers that exist appear to override them in decision significance. The notion that the public will not understand, is afraid, or is fundamentally opposed to it appears

to be a persistent cultural belief perpetuated among the AAs and fire managers themselves, perhaps reinforced by discrete experiences and intermittent withdrawals of the strategy such as was seen in 2021 when the USFS declared that no fires would be 'managed for resource benefit' (Moore 2021).

Importantly, among the 15 fires we examined, no matter what the strategy, a defined end state with control points was always defined. No strategy was implemented that included allowing the fire to burn without human intervention. Definitive control and contingency lines were established even on fires that acknowledged an OTFS strategy. One of the clearest signals for an OTFS fire was the use of a 'big box' strategy and the use of tactical firing operations designed to surround the planned perimeter with fire. The rate of tactical firing was often determined by the interior spread rate of the fire, while other times the 'box' was fired off as rapidly as conditions and resulting fire effects would allow. Managers liked this methodology for several reasons. First, having predefined control lines allowed them to describe an expected end state for the public and staff. Second, it allowed them to target specific areas of the landscape for management, particularly if those areas had been previously cleared under environmental planning documents and were intended to be prescribed burned.

There was a very clear preference for managing fires for OTFS at the Type 3 complexity level overseen by local fire staff, staff from neighboring Forests, or within the Region. All the OTFS-described fires we investigated were managed this way. Given that wildfire is often driven by local factors, such as terrain driven winds, unusual weather patterns, or fuels-driven burning conditions, managers placed more value on fire management staff with local experience, believing them more capable to manage the fire in a way that produced acceptable (ecological and social) outcomes. There was great reluctance in stepping the complexity up to a Type 2 or 1, as managers believed this would require ordering and turning over operational control to an IMT made up of people from outside the local area. Doing so increases the pressure to implement direct control strategies and tactics, which they may not wish for. However, Type 3 fires are somewhat limited in how large they can become, or how many people can be assigned before the complexity level has to be increased. Together these dynamics create an inherent ceiling to how large most fires managed for OTFS can become with the related effect of reducing the scale of potential benefit that these fires can provide on the landscape.

Risk and institutional culture

AAs overcame the aversion to managing fires for resource benefit or discussing realized benefits on fires managed for suppression in several ways. The personal and professional ethic held by the AA to utilize wildfire for ecological benefit was among the strongest motivators and carried over from the pre-2009 framework. Motivational drivers were expressed variously as deep seated personal philosophies stemming from a naturalistic upbringing while others saw overcoming barriers as a professional duty bolstered by years of experience, especially if they had participated in wildfire events where damage had been done to communities and they believed restored fire regimes could be a preventative action.

The presence of a local organizational culture that embraced using wildfire in a polystrategic way was a key facilitator in making the decision to both implement a non-suppression strategy and to feel they could openly explain that decision to the public. In many ways, this could be considered as required, as many other attributes are founded on it. For example, in locations with a strong polystrategic fire culture, we often found a history of supportive planning efforts, especially when Forest Land Management Plans actively supported the use of fire as a restoration tool. Other types of plans included programmatic prescribed fire environmental analysis, which greatly increases the chance wildfires may be counted towards fuels reduction accomplishment targets, or pre-fire spatial planning like PODs. Sometimes planning was as simple as District staff having discussions throughout the season regarding where and when they thought they could manage natural ignitions.

Although local organizational culture had the power to override wider, regional or national scale influences, managers developed greater confidence when they perceived that the risk was being shared across multiple levels of the organization. Specifically, this often meant a District AA were more confident when they knew their next level supervisor at either the Forest Headquarters or the Regional Office supported their local decision. Several locations mentioned their use of formal risk sharing processes. Typically, these were a structured conversation early in the wildfire with staff at both the local and regional offices. These conversations ensured that local managers understood they would receive adequate operational and sociopolitical support if the wildfire resulted in adverse outcomes. The only Region we saw this formalized into a policy was the Southwestern Region, however Forests in other Regions followed similar processes.

At the Agency level, the annual letter of intent the Chief of the Forest Service issues for the upcoming fire season had a surprisingly strong effect on local decision making. Throughout the 2021 fire season, three such letters were issued. The first, in April, lent specific support for using managed fire to achieve National Cohesive Strategy goals (WFLC 2014; Christiansen 2021a). After a challenging start to the fire season, on July 14th, the Chief issued a second letter urging staff to refocus their efforts towards supporting fire management. This second letter affirmed that managers may "use fire where allowable" (Christiansen 2021b). However, after a continued busy fire season, a newly appointed Chief issued a letter on August 2nd, restricting the use of fire, directing that "managing fires for resource benefit is a strategy we will not use" (Moore 2021), citing rationale that safety should be the first priority and that resources are limited. We saw an immediate effect in our research, as managers were no longer willing to entertain polystrategic wildfires, even in regions where conditions had moderated. Following these letters, managers also felt more restricted in their ability to publicly discuss any potential benefits if they perceived a positive net effect.

However, managers used indirect strategies after these letters had been issued, and justified the choice based on risk and safety considerations. One theme we saw repeatedly was managers relating decisions to actions that reduced risk for firefighters and the public, which was a factor also observed in the pre-2009 research, although to a lesser extent than post-2009. This is consistent with multiple safety and risk related initiatives the USFS has implemented in the last several decades, including the 'safety journey,' the '5 rights,' and enterprise risk management (Thompson *et al*. 2016a; Flores and Haire 2021; Flores and Haire 2022). The most commonly expressed facilitator we found was when managers thought implementing direct control actions (fighting the fire directly on the perimeter) was unsafe. Culturally, this is a reversal of the long-held view that direct fireline tactics are the safest option. More recently, indirect tactics (placing control lines away from the perimeter) have grown increasingly more common, both as a matter of reducing fatigue on firefighters, increased focus on protecting specific values (e.g. structures), and because extreme fire conditions have not allowed it (Plucinski 2019).

Many managers we spoke to often justified these large scale firing operations as necessary to restore fire at landscape scales. However, neither media coverage nor USFS policy overtly acknowledges the use of indirect suppression strategies, particularly tactical firing operations, as a potentially net positive scenario for landscape resilience outcomes. By employing risk management reduction as the primary reason for their strategic choices, the current policy

allows managers to legitimately achieve landscape scale objectives while publicly advocating a full suppression strategy. While perhaps a useful outcome from a management perspective, this raises concerns about whether such distinctions are understood by the public. Also, this communication pattern may create a mixed message when individuals are told the fire is employing a full suppression strategy when they do not see traditional suppression tactics being implemented.

Application of fire under changing conditions

Discussions around the fire environment and outcomes were focused on fuels and fire behavior in a more deliberate and sophisticated way than seen in the pre-2009 results (Fillmore *et al.* 2021). Managers related great concern about potential fire effects, especially when the strategy was managing to achieve resource objectives. Discussions frequently turned to their desire to achieve specific and measurable outcomes, often likening desired outcomes to those seen in prescribed fire plans. This desire was often linked to their individual risk appetite, in that if a manager was willing to take the risk of using an OTFS strategy, or even publicly state the benefits of a wildfire that had been suppressed, managers felt such risk should be justified by a certain level of ecological gains. Even in cases where ecological benefits will be gained, managers appear to be unwilling to use OTFS if they perceive social-political risks or negative public feedback. However, the extent to which this influences their decision making is unclear.

The influence of ongoing drought also concerned many managers who feared that their fire could result in a higher degree of burn severity than ecologically appropriate. Interestingly, several AAs decided to manage a wildfire for OTFS despite the ongoing presence of drought and climate change. We attribute this to some managers and unit cultures having greater comfort with using riskier strategies when they may result in positive ecological outcomes. However, interviewee comments also suggest that some managers are sensing that the drought may never actually end (due to climate change), in which there is little reason to wait for that 'perfect year,' as those years are no longer going to arrive with enough regularity to be able to manage for it. In several cases, primary observable fire results were surprisingly favorable, leading them to question the actual difficulty in managing fires when in a drought state. In a sense, these managers may represent an 'early adopter' approach to managing fires under changing climatic conditions.

The importance of relationships

Concerns related to the sociopolitical environment were relatively consistent pre and post-2009, with some important exceptions. As before, managers maintained a high level of concern about smoke affecting downwind communities, with managers often anticipating local community reactions related to smoke from prior experiences. Such anticipation also affected pre-fire messaging and the level of openness managers could relate regarding potential ecological benefits. The sentiment of numerous AAs was that the best time to discuss ecological benefits was outside of fire season, and not while the fire was actively burning, as they perceived the inherent tension associated with a fire as obstructive to education. Also, by engaging with the community after the fire an AAs could appear to be standing on the side of fire suppression and risk avoidance if fire outcomes included damage to property or resources. However, if the fire did provide tangible ecological benefits, those benefits could be discussed after the fire when fear and tension related to the fire were absent.

As seen in other research, AAs were well attuned to the connection between their decision latitude and the status of relationships with land users, local politicians, and the public at large (McCaffrey and Olsen 2012; Davis *et al*. 2022; Huber-Stearns *et al.* 2022). Besides the policy framework, the presence or absence of pre-existing relationships between managers and the community appeared to be among the most important decision factors related to managing a fire for OTFS. Most AAs we interviewed seemed to either understand this intrinsically or had learned it through experiences during and after previous fires. While some AAs welcomed interacting with the public and seemed to embrace it, others saw it as a burden and sought to avoid it regardless of fire outcomes. In the latter case, they seemed to prefer suppression strategies.

The most positive relationship experiences interviewees described was when they were working directly with advocacy groups who had interest in specific areas (e.g., a mountain range, community, or watershed). These groups had the advantage of being tightly tied into the local community and local politics. In the most functional scenarios, they performed the bulk of the community outreach instead of the USFS. Overall, we were told that this led to fewer sociopolitical issues related to wildfire events, assured consistent messaging, and reduced conflict with local community members who were vocally opposed to OTFS fire management strategies. Other than regulatory requirements, having constructive relationships with those

who will be most directly affected by any wildfire was regarded as one of the most important facilitators for managing with OTFS.

Conclusions

The research in this article provides a broad understanding of the complex considerations that go into wildland fire response decisions and in doing so lays the groundwork for improved and better informed wildland fire management. It validates the presence of wildfire decision factors that were first identified within the pre-2009 literature and updates our understanding of wildfire decision factors to the current moment. It also provides a framework for wildfire decision making that has near universal applicability and could provide a useful reference for managers who wish to ensure that key factors have been considered before determining a final course of action. Over longer time scales, the framework could help managers and decision makers identify weaknesses and potential leverage points in planning and implementation efforts, particularly for facilitating fires managed with OTFS. For instance, this research could assist the USFS to more systematically assess the factors that influence field-level decision making and thereby be better positioned to make institutional changes that can foster a culture of actively managing wildfire more closely aligned with stated management goals (USFS 2022).

A greater understanding of factors considered in the decision environment is important because researchers, managers, and policy makers need to have a more robust comprehension of the decision environment under which federal land managers are operating. It is one thing to suggest courses of action, or ways in which managers should be approaching their decisions, and it's another to know whether that is even applicable or available under the modern decision environment with its multiple and often contradictory pressures.

A barrier to using strategies OTFS is hesitancy that AAs have in ordering IMTs for larger scale incidents. This might be overcome by reinstating IMTs that were specifically designed to support wildfires managed for resource benefit, as was common before the 2009 policy update. Although the qualifications that used to exist on these teams are no longer applicable (e.g., Fire Use Manager), IMTs could be configured with additional skill sets that focused on fire behavior modeling, monitoring, strategic use of fire, and public relations. The transition to Complex Incident Management Team typing in 2024 presents an opportunity to incorporate dedicated IMTs for the OTFS tasking (IWDG 2021). Doing so would address the hesitancy that AAs have in ordering IMTs for larger scale incidents. Another suggestion is to create initial and continuing

wildfire training curricula that better incorporates all available strategies and emphasizes the nexus between fire management actions and land management outcomes.

We frequently heard participants use the phrase “all fires are managed” which is intended to suggest that all wildfires in the US on federal lands trigger a response strategy. However, as we saw deliberately described end states to all fires in our data set, it may be more appropriate to instead suggest that ‘all fires are suppressed’ with the only distinction being under what timeframes and with what resource intensity that is accomplished. Another oft-used phrase among firefighters is that ‘all fires go out eventually.’ In many ways, the federal response acknowledges this fact, but wishes to intervene in the natural span of a fire to gain outcomes that are socially palatable. Reframing the intent of wildfire strategies in terms of timeframes and the number of resources leveraged to accomplish that end state may be a more constructive way forward when engaging in messaging with the public.

Though we determined the presence of many factors that influence these decisions, we also found the lines between management strategies are becoming blurred to the extent that differentiating among them has largely become an academic exercise rather than something that translates well into the realities of real-time fire decision making. The data presented here is a starting point for future research that may more fully describe both the KTAs as well as individual decision factors. We would expect that as policies are updated and fire cultures evolve in response, some of these factors will continue to persist, while others will not.

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Chapter 5: Conclusion and Future Work

The research presented here has provided insight into the complex decision making environment that federal wildfire decision makers currently face. While the research was focused on US Forest Service (USFS) land managers, the lessons and decision frameworks that emerged likely have relevance for state, local, and even international fire managers. Together, these three research chapters span a time frame extending from the late 1960's until present. This span offers perspective into how societal, environmental, and policy-based decision factors have changed across time. Most importantly, it allows a fuller understanding of the current decision framework that fire managers rely upon to make optimal decisions during a fire incident.

Federal US wildfire management exists in a decision space that is influenced by factors internal and external to responsible agencies. Within federal land management agencies, factors intrinsic to the decision makers themselves such as personal beliefs and experiences also play a role. Wildfire responses by non-federal agencies are often regulated with singular, inflexible policies that focus on minimizing the size of every wildfire ignition (Fleming *et al*. 2015). This decreases the decision space for responders and in many ways simplifies the response strategy. However, as federal land management policy recognizes, this singular focus on suppression comes at the cost of ecological functioning, an element unignorable for a large public land base being managed for multiple use such as National Forests. The most fundamental tension within the contemporary wildfire context on US federal lands is the need to both suppress wildfire and allow wildfire to perform its natural function on the landscape. Wildfire ignitions are a distributed event managed by distributed decision making entities who are charged with satisfying the needs of multiple disparate interests. As such, there are few quantitative markers to help ascertain what the 'correct decision' leading to an 'optimal outcome' would be. By necessity, this moves the decision process largely out of the quantitative realm and into the qualitative.

Research overview

The research was accomplished in four major steps. First, a series of academic directed studies was completed to become conversant in the topical areas relevant to my proposed future research. These topic areas included risk management, social science, fire ecology,

writing skills, wildfire governance, and policy. Second, existing literature pertaining to wildfire decision making was thoroughly reviewed to gain an understanding of what factors were known to influence decision makers. This review looked at all aspects of wildfire decision making; however, it held a particular focus on the times when a decision maker was managing a wildfire for an objective other than full suppression (OTFS). This review spanned almost four decades of policy iterations and brought insight into how these policies and decision factors have evolved over time. From this review a preliminary decision making framework was developed. Third, we interviewed wildfire managers to ascertain how they used the formal (and mandated) wildfire decision making support system to assist their decision making process. This qualitative research provided important insights into wildfire decision support among USFS managers. In the final step we returned to interviewing USFS employees to broadly explore their decision making processes on wildfires, particularly with an emphasis on fires managed for OTFS. In doing so, we validated the presence or absence of known wildfire decision factors, identified emergent factors, and proposed an updated decision framework that encompasses the breadth of decision making influences within the modern wildfire environment.

The methods used in chapter 2 provided a firm base for understanding what factors researchers have found regarding the decision to suppress, or not suppress, a wildfire. While no one paper captured the entire range of variability that exists, in sum they allowed important insights to the diversity of considerations wildfire managers were taking into account. Just understanding the scale of what must be considered was one of the key findings in chapter 2. Ultimately, we identified 110 discrete decision factors. These factors were divisible into three overarching topic bins titled barriers, facilitators, or unaligned. While other research has divided factors into only barriers or facilitators, our unique approach incorporated an understanding that there is a middle space where the decision maker has identified an element to consider but hesitates while they search for more information to validate the directionality of the decision element. This is an important understanding because it replaces strict bidirectionality with unidirectionality. It also more accurately reflects the reality of decision uncertainty in the wildfire context. After categorizing factors as either barriers, facilitators, or unaligned, we were able to thematically characterize each factor into one of six 'key theme areas' (KTAs) that describe major areas of consideration. The overall conclusion was that uncertainty within the KTAs seemed to incentivize managers to be risk averse and suppress a wildfire instead of managing it for some other objective. While this outcome was not

unexpected, the novelty of the study was the granular level of detail the literature review and analysis provided. The final step in chapter 2 analyzed discussions within a conceptualization we developed and named the "Managed Fire Decision Framework' (MFDF). The MFDF visualized the six KTAs around a central decision space, illustrating that the factors embedded within KTAs influence decisions in a tangible but non-prescriptive manner. It also demonstrates the sheer vastness and disparate nature of decision influences on managers. Importantly, it also allowed us to construct the two research pathways in chapters 3 and 4 to further explore these initial findings.

The research in chapter 3 fulfilled two objectives. The first followed up on research conducted by Noble and Paveglio (2020) that had explored the use of the Wildland Fire Decision Support System (WFDSS) in USFS Region 6. We expanded the scope of the research to USFS Region 3, where we believed that support for wildfires managed for OTFS exists. This chapter was the first to collect interview data directly from wildfire managers. Methods incorporated those used in the Noble and Paveglio study, as well as an expanded set of questions specifically designed to investigate how WFDSS is used in the context of OTFS wildfires. Although this study was focused on the use of WFDSS, the decision factors found in chapter 2 were explored both passively and actively. Passive exploration occurred through listening and noting when factors were present. Active exploration happened when the line of questioning turned to the use of WFDSS during fires managed for OTFS. This research found evidence supporting what is known about the use of heuristics and biases in stressful situations (Wilson *et al.* 2011). The research found that most decision makers use a similar information gathering process during wildfires as they do when performing more routine work such as formulating environmental analyses for land management decisions. It also showed that decision makers typically have a predetermined plan in mind for every wildfire. In the context of WFDSS, this meant that its primary use was documenting the decision they had already made. In the wider context, it corroborated that decision makers are actively aware of and are evaluating the factors that influence their decisions, including elements of all six KTAs found in chapter 2. From a functional standpoint, the use of WFDSS during fires managed for OTFS was not significantly different than that during full suppression fires. However, managers did find that WFDSS was more valuable as a planning tool during OTFS fires because it allowed for a more detailed examination of values at risk, provided direction for long term planning, and allowed them to frame their conversations with cooperators who would be affected. This was an interesting finding because it showed that managers intrinsically valued OTFS fires more

than full suppression fires even though that strategy is leveraged on a small minority of wildfires.

The findings in chapters 2 and 3 provided important information to frame the research in chapter 4. This study also collected interview data from Agency Administrators (AAs) and fire managers, but we expanded the scope to reach as wide a cross section of the country as possible. The research specifically sought to validate the presence or absence of decision factors found in chapter 2, identify emergent factors, and characterize the contemporary wildfire decision space with an emphasis on determining which factors were barriers or facilitators to managing a wildfire for OTFS. Chapter 2 was bounded within the pre-2009 policy context before important changes were made to how wildfires may be managed. chapter 4 updates the state of knowledge to the contemporary, post-2009 context. In this analysis we again used qualitative methodologies to determine the presence and relative magnitude of factors within interview data. We used a codebook derived from chapter 2. This allowed rapid deductive topic coding followed by iterations of inductive coding that looked for emergent thematic findings. The themes that emerged from this study showed the overarching concerns we found in chapter 2 have carried over to current day, especially those regarding risk aversion, defaulting to suppression in response to uncertainty, the influence of local cultures, and the importance of relationships especially when managing for OTFS. New themes included a perception of public fear towards wildfire, difficulty in properly messaging an intended strategy, risk management as a rationale for indirect strategies, and uncertainty associated with managing wildfire under shifting climatic conditions. Most of these thematic findings are a new contribution to the literature, however others provide corroborating evidence. For example, managers have long been known to prefer risk aversion in times of uncertainty (Blattenberger *et al*. 1984; Cortner *et al*. 1990; Hand *et al.* 2015), and the importance of relationships has been shown (McCaffrey and Olsen 2012; Steelman and McCaffrey 2013; Sharp *et al*. 2013). Perhaps the most important contribution this chapter provides, besides cataloging the wide breadth of decision factors, was a reworking of the MFDF into a broader characterization we named the 'Wildfire Decision Framework' (WDF). The WDF reworking acknowledges another key finding of the research, which is that in the post 2009 policy context, managers have essentially molded all strategic options into one approach that seamlessly blends all available strategies and tactics to such a degree that bifurcating wildfires into categories of 'managed' or 'full suppression' is no longer applicable. Trying to do so fails to reflect the reality of what is happening on wildfires. As such, the WDF incorporates all factors that contribute to wildfire strategy decision making without

worrying about the specific nomenclature. This reflects the fact that strategies adjust continually throughout the life of the fire - particularly large, long duration incidents.

Research Implications

The research findings in this dissertation are important as they fill three largely unaddressed spaces within the literature. First, it provides insight into the thoughts and patterns of USFS managers who sought to make use of landscape scale wildfire as a management tool during the four decade period between 1968 and 2008. This provides an historical context for the difficult period where professionals and the public alike attempted to learn what it meant to live outside the paradigm of complete wildfire suppression. The second space offered a more complete understanding of how corporate DSS tools are being used within the USFS. This is important as every large or long duration wildfire in the nation undertakes the WFDSS process, yet very few studies that specifically evaluate the use and application of such an important tool for wildfire decision making support have been performed. The final space was filled by updating the known wildfire decision factors to the post-2009 policy context, providing a thematic understanding of consistent issues AAs consider when making choices among various wildfire strategies. Importantly, it provides a decision framework that wildfire managers and researchers alike are able to leverage.

The USFS has stated in numerous public documents that it recognizes the need to create resilient landscapes (WFLC 2014; USFS 2022). Despite the many barriers to it, increasing the use of wildfire to achieve this resiliency has been recognized as part of the solution for many decades. Research into the numerous discrete influencing factors these research chapters now provide may be leveraged by managers to construct strategies that support this goal. It can do this by identifying barriers to the use of wildfire so that strategies can be constructed that address and overcome them. Importantly, it can also be used to identify those factors that facilitate the use of wildfire so that others may learn and adapt the patterns of behavior that build them. The Wildfire Decision Framework itself could be used as a mental checklist for AAs, fire managers, policymakers, or even cooperators to reference while making decisions on wildfires, to ensure that all important elements have been thoroughly considered. For example, if a fire naturally ignited and an AA was considering managing it for OTFS, an operationalized form of the framework could be used to examine the status of each of the KTAs. In a structured way, a form of the framework could examine the fire environment to see what fire behavior

could be expected, cross reference this to the types of fire outcomes that are likely and if they are desirable or undesirable. Based upon the fire environment and fire outcome potential, what operational considerations are there? Is it a high Preparedness Level, are crews already exhausted, or is it early season? If these are in place, what is the level of sociopolitical interest for the fire? Is there a locally vocal politician who will move sentiment against the plan, or is there a local collaborative in place that is actively seeking fires to be managed in such a way? Will there be economic impacts? Barring these, are there institutional concerns such as land management plans, policy restrictions, or a culture on the unit that expects to manage every natural ignition? Finally, what is the personal and professional comfort with the risks highlighted in all other KTAs? Is the decision maker comfortable with taking on an OTFS fire. If so, how large are they comfortable with it getting, and how much negative media are they willing to withstand? While most of these factors are considered, there is no resource currently available to decision makers to systematically examine these elements particular to managing a wildfire for an objective other than suppression.

This process of using the factors as a checklist does not have to be limited to wildfire incidents. In fact, the considerations would easily be integrated into environmental analysis planning, WFDSS planning, and could even help frame routine pre-fire engagements with the public and elected officials. One of the most pronounced themes from this research was that communities were much more accepting of managed wildfires when they had been engaged both before and during the fire.

Finally, this research has value for future social science research. We found that the codebook we constructed from chapter 2 and used to conduct coding in chapter 4 worked exceptionally well as a starting point for later inductive coding. Although not included in this dissertation, we were able to complete topic coding for 2 other potential future research studies, which demonstrates the multi-faceted power of the six KTAs as a starting point for wildfire based social science analysis. The KTAs themselves, or even analytic codes embedded within them, could serve as a base of knowledge for others who wished to explore more deeply into specific factorial areas of study.

Future Research

Unfortunately, there were several lines of research that I wished to explore that time did not allow to be followed up on. Still other ideas for research were generated from conversation

with various researchers and fire managers as a result of the chapters here. I offer a few potential lines of inquiry here.

First, every KTA deserves a discrete follow up study to refine which factors are influencing the decision to manage a wildfire for OTFS or not. One limitation of this dissertation was that it, by necessity, could only afford to spend a little time covering a lot of decision factors. While this was important pioneering work, it would benefit from iterative follow up studies that examine the decision factors at a more granular level. For example, researchers could focus on one or two KTAs at a time to explore each in a deep, exploratory manner. This would create an additive body of knowledge regarding the decision environment which would help to address barriers and amplify facilitators. There is also a nexus with the KTAs and spatial fire planning, operational risk analysis, and even land management planning efforts. The influences of these KTAs should be investigated within the contexts of these different efforts to see how they interact and influence decision making, influence risk management, and contribute to collaboration. For example, the addition of social science lensing through KTAs within modern planning tools like Potential Wildfire Operations Delineations would be value added.

Further work that adds to the base of knowledge about the use and application of WFDSS is needed, especially as the next generation of WFDSS is forthcoming and opportunities for refinement will exist in its early forms. Although the research in chapter 3 about WFDSS was thorough, it was limited to a specific geography. This came with specific cultural tendencies and fire environment influences that may not be applicable in other areas of the country. To date, only the Southwest and Pacific Northwest regions are represented in the WFDSS literature where holistic use patterns were examined. There is also a need to examine the suite of structured and unstructured Decision Support Tools within the wildland fire service. As more information becomes available due to technological advances, more emphasis should be made on feeding that information into DSS tools capable of distilling it into a format practical for use by decision makers.

The last line of research to discuss is the one that this dissertation wanted to address from the beginning but didn't quite manage to achieve. All three research chapters explored a fundamental question regarding the paradox that the wildland fire profession finds itself operating within. The profession has acknowledged the paradox yet has so far failed to extract itself from it. It knows that wildfire needs to be returned to its natural role within the broader landscape. It knows that the full suppression doctrine is beginning to fail. It knows that the full suppression doctrine is making the landscape condition worse with every fire that it

extinguishes. It knows that it is impossible to be one hundred percent successful suppressing every new wildfire with current resources and technology. Yet, the doctrine of full suppression continues more or less as it has since the beginning of organized wildland fire response. The unresolved issue is simply why, knowing this all to be true, does it persist? This is a decision paradox that stacks on top of the well-known 'wildfire paradox' described by Arno and Brown (1991), whereby the actions of the wildland fire service are actually making the actions themselves harder to accomplish. We have seen that no matter how many scientific articles show the necessity of introducing fire back into the landscape, no matter how many agency initiatives are forwarded, or policies drafted that carve out a place for managing wildfires, these intentions will continue to be overridden by the inertia of default suppression until the cycle is somehow broken. For as long as the default wildfire response is to suppress, landscapes will continue to be ecologically threatened, fire regimes will go unrestored, and humans will continue to exist in their uneasy and occasionally threatening relationship with wildfire. Most importantly, the stated goal of "living with wildfire" will remain unmet.

The research path I propose would be to test the narrative, or hypothesis, that explores why the wildfire service continues this doctrine despite knowing that the consequences of doing so are deleterious. I refer to this line of inquiry and possible answer as the Default Suppression Hypothesis (DSH). Although not fully developed yet, principles rooted in the findings in this dissertation help frame the DSH. That work has the potential to move towards an umbrella Theory of Default Suppression (TODS), where the variables that explain the persistence of the decision paradox are fully articulated; the first step to solving any problem. During the research that collected data for chapter 4, I also collected data specific to the DSH and was able to topic code it within qualitative analysis software. Some preliminary observations include:

- That risk evaluation is the overriding function at play in the decision making process.
- That wildfire risk decisions are structured to be risk-averse in the current wildfire governance structure.
- That internal and external factors exert influence on federal decision makers regarding what strategy to choose for a wildfire.
- That numerous disparate factors operate as barriers, facilitators, or in an unaligned conditional way to managing a wildfire for an objective OTFS.
- That the factors most able to overcome the doctrine of suppression are rooted in local cultures and personal beliefs rather than institutional guidance.

- That the factors that drive a full suppression strategy seem to carry more decision weight than factors that move a wildfire to be managed for OTFS.

Research that ties together these principles within a mixed methods approach that includes literature, case studies, further interview data, and examples from media may yield a greater understanding of the pressures and influences that enables this self-defeating paradigm to continue. In doing so, we would be able to put a name to the problem. Just as the lack of a name hinders AAs from describing their intended strategies for a fire, the lack of common nomenclature for this problem prevents a dialogue from forming around it. Solutions to the self-defeating problem of default suppression may be uncovered only after the problem is fully recognized, common descriptive language is agreed to, and a broadly shared narrative is held that something different will need to be done in the future to correct the course.

Closing Comments

Chapter 1 closed with a Tabula Rasa thought experiment. Although no other authors chose to respond directly to the questions contained within it, in many ways, I came to realize that nearly all wildfire research is attempting to add their small part to the equation of what a potential future with wildfire will be. The actual future is unknowable, but the trends exist and they point to a somewhat bleak picture of a future where wildfires incur greater destruction, occur at higher frequencies and severities, and give cause to the voices of those who wish to continue the prevailing doctrine of complete wildfire suppression. The steps to prevent that future are even less clear. Throughout the course of researching and writing this dissertation, I kept in mind the tabula rasa questions we posed in that first essay as a sort of guiding light. I won't say that I found all the answers that I was looking for, but certain insights did emerge. I'll share these by responding to my own questions from the thought experiment.

The first question posed by the essay asks "*of what existed before, what should be recreated*?" To this, there are several. Foremost to keep is the knowledge that fire is part of the landscape from which we sprang, and the human species is intimately linked to wildfire in ways that its complete suppression would undermine. This knowledge exists in hidden ways, and full suppression is hidden even in our societal movement away from gas stoves and internal combustion engines. We are moving away from fire as a tool with every technological advance; yet, there is no surrogate for what landscape scale free burning fire provides. We must keep the

humility to know that there will likely never be a surrogate for landscape scale wildfire and that the consequence of removing it is to completely turn our backs on the natural systems that we rely on for our continued survival. We must also keep the fascination with wildfire alive through research, discussions, philosophy, and art. We must also keep the ability to control fire, to the limited extent that we always have, and keep it separate from the things that we value. This is not an inherently unwise philosophy, as fire is by its nature a deconstructive agent. It has no role within our homes outside of a well-maintained fireplace. However, it has a role within a well-maintained landscape where it can be appreciated in its natural form.

The second question in the essay asks "*what of the current paradigm should be discarded*?" I won't say the fear of fire, because fire is something to be feared under certain conditions. However, institutional and societal overreaction to that fear must be dismissed from the paradigm. We must not believe that our little control over fire should extend to all presentations of fire, particularly wildfire within its natural state. We should discard the notion of all-or-none when the truth lies in the middle. Collaboratively decided, some wildfires should exist while others should not. We must develop a conceptualization for what could be if we were willing to do the work and make the changes in how we arrange ourselves within a flammable landscape.

Most of all, we need to abandon the notion that we are merely subject to wildfire, and instead fully accept our integral role in both problem and solution. Our decision makers need to feel empowered to make the decisions their professional experience and knowledge has given to them. Our communities need to be engaged in the effort; they are the principal value on the landscape and as such must also rise to the challenge. While our policies are largely consistent with these approaches, our incentive structures are not. Only by constructing a narrative and system of governance that inherently supports these notions will we as a society, a nation, and a profession, find a way forward together into an uncertain future.

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