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Abstract

Prescribed fire is an important management tool for restoring fire-adapted ecosystems and mitigating the risk of high-severity wildfire in the North American Mediterranean Climate Zone (NAMCZ), much of which was historically characterized by frequent low-to-moderate severity fire. A century of policies that excluded fire, curtailed Indigenous cultural burning, and prioritized harvesting timber have combined with climate warming to drive large-scale, high-severity fires that are wreaking ecological and socioeconomic havoc. Despite the recognized need, the use of prescribed fire at appropriate scale has been slow to occur. We describe some of the principal obstacles to increasing the application of prescribed fire in the NAMCZ and suggest four strategies for policy makers and high-level managers to overcome them: (i) redouble agency commitment and reward assertive leadership; (ii) increase funding for prevention-focused management (as opposed to suppression); (iii) build capacity through cooperation; and (iv) expand monitoring to inform burn strategies and adaptive management.

Keywords: California; cultural fire; fire return interval; fire severity; Indigenous; managed fire; prescribed burn; resource benefit; tribal; wildfire.

In a nutshell:

- Extensive high-severity wildfire in the North American Mediterranean Climate Zone is the result of interactions between climate, fire suppression and historical forest management practices.
- Prescribed fire can mimic natural fire regimes, improving forest health and reducing the likelihood of high-severity fire in ecosystems adapted to low- or mixed-severity fire.
- Prescribed fire is underapplied due to a fire culture that: (i) prioritizes fire suppression over prevention; (ii) limits the prescribed fire work force; and (iii) fails to incentivize and protect those who burn responsibly.

- Increasing prescribed fire requires top-down measures that promote: (i) favorable cultural norms in land management agencies; (ii) increased funding; (iii) cooperation among practitioners; and (iv) quantitative monitoring and data-driven forest management.

Introduction

The North American Mediterranean climate zone (NAMCZ) includes most of California, SW Oregon, westernmost Nevada, and NW Baja California, Mexico (Fig. 1). It is characterized by cool, wet winters and warm, dry summers with an annual drought of three to six-plus months – a climate suited to growing vegetation that subsequently dries out and is available to burn (Safford et al. 2021). Fire in the NAMCZ is a naturally recurring ecological process that has shaped the structure, composition and function of the forested landscape. In this contribution, we focus on forest ecosystems adapted to low-to-moderate severity fire occurring at roughly 5 to 35-year intervals, including oak woodland, yellow pine (*Pinus ponderosa* and *P. jeffreyi*), and mixed conifer forests. However, our perspective extends to other conifer and hardwood forest types where the long-term lack of fire has resulted in high accumulations of forest fuels (Safford and Van de Water 2014, Metlen et al. 2018). The buildup of combustible biomass in these forests is the result of more than a century of fire exclusion and historical management that has left millions of acres of forestland with dense, small diameter trees, excessive surface and ladder fuels, and fire return intervals many times longer than in the past (Dolanc et al. 2014, North et al. 2016). With a changing climate marked by warmer, drier winters and longer fire seasons (Jolly et al. 2015), wildfires in the NAMCZ today burn much larger areas at high severity ($\geq$ 95% tree mortality) than they did historically (Steel et al. 2015, Safford et al. 2022, Williams et al. 2023), adversely impacting people, air quality, carbon stores, ecosystem services, and the integrity of ecological communities (e.g., Dove et al. 2020, Burke et al. 2021).

There is widespread consensus among scientists and resource managers that reducing the negative ecological and socioeconomic impacts of current wildfire trends in NAMCZ forestlands will require a coordinated management response that includes a significant increase in the use of fire as a management tool (North et al. 2015, Kolden 2019, CFMTF 2021). Empirical evidence supports prescribed fire as a cost-effective fuel reduction intervention that can restore ecological function and mitigate high-severity wildfire (Kalies and Kent 2016, Prichard et al. 2020, Francos and Úbeda 2021, Cansler et al. 2022). Furthermore, the low-to-moderate severity burning that characterizes prescribed fire begets more of the same, and is critical for maintaining forest cover over time in fire-prone forest types (Coppoletta et al. 2016, Taylor et al. 2022). However, numerous obstacles need to be overcome before prescribed fire is applied at spatial or temporal scales commensurate with the magnitude of the fuels problem in the NAMCZ (Quinn-Davidson and Varner 2012, Miller et al. 2020). The area burned with prescribed fire in 2019 – a "big year" – was about 37,000 ha (~90,000 ac) in California (CAL FIRE 2021) and 22,000 ha (~55,000 ac) in Oregon (ODF 2020), but these numbers include grasslands and areas outside the NAMCZ. As such, they pale in comparison to the 2 to 5 million ha (5 to 12 million ac) that are estimated to have burned in an average year due to wildfire and Native American cultural fire practices prior to 1850 and the widespread application of Euroamerican forest management practices (Stephens et al. 2007).

Prior to the arrival of Euroamericans, wildfire and Indigenous ignitions in NAMCZ forests and woodlands tended to burn at low-to-moderate severity, reducing fuels that can lead to severe burning and contributing to forest resilience and stability in fire-prone landscapes (Mallek et al. 2013, Safford and Stevens 2017). However, as early as 1793 in Mexico and 1850 in the United States, governments began banning cultural fire by Indigenous groups (California Statutes 1850), as well as limiting fire use by other landowners (Biswell 1999). Such restrictions diminished ecosystem health, promoted fuel accumulation and severe wildfires, and hurt Indigenous and agricultural communities (Goode et al.

2018, Norgaard 2019, Vinyeta 2022). Although attitudes are changing, fire-averse mentalities and suppression-oriented land management policies still impede the widespread use of fire as a restoration or fuel reduction tool in the NAMCZ (North et al. 2015, Miller et al. 2020, Clark et al. 2021).

Prescribed fire is rooted in the millennia-old cultural fire practices of Indigenous groups who employed fire across a range of applications – from spiritual purposes to safety, food security, and ecological sustainability (Anderson 2005). We focus here on prescribed fire's use to reduce the negative effects of fire exclusion, mitigate the risk of high-severity wildfire, and restore ecological communities and the processes that support them. We limit our consideration of cultural fire (Panel 1) to the contexts where it overlaps with prescribed fire for these purposes. Similarly, we do not address the use of wildfire for resource benefit (i.e., wildland fire use), other than to acknowledge its importance for the same goals (Van Wagtendonk 2007). Our main goals are to identify the principal obstacles to expanding prescribed fire use, explain why there must be a cultural shift on the part of government agencies towards putting prescribed fire (and other types of fire use) on the same footing as fire suppression, and describe ways to increase the resources, readiness and opportunities to apply prescribed fire and improve its effectiveness. We have written this paper for two principal audiences: (i) non-specialist readers interested in understanding why prescribed fire continues to be underutilized; and (ii) policy makers and agency/organizational leaders who may use the ideas presented here to dismantle obstacles, facilitate collaboration, and marshal the resources needed to increase the effective and ecologically appropriate application of prescribed fire.

Obstacles and Opportunities for Prescribed Fire

Shared stewardship agreements and memoranda of understanding between the US Forest Service and the state governments of California, Nevada and Oregon have set ambitious goals (e.g., 400,000 ha [1 million ac] per year in California by 2025) for forest treatment, including prescribed fire, in the NAMCZ. There are many obstacles in the way of these goals, however, and even if realized, the increase in burn area will not sufficiently address the backlog of unburned forest that continues to accrue as historical fire return intervals are exceeded (Safford and Van de Water 2014, Schweizer et al. 2020).

Prescribed burning faces regulatory and operational hurdles, including permitting and environmental compliance, insurance and liability, and lack of resources and trained personnel (Quinn-Davidson and Varner 2012, Miller et al. 2020, Striplin et al. 2020). As prescribed fire gains more attention, the underlying contexts of these obstacles have become clearer, as have opportunities to overcome them. We highlight four areas where leadership and institutional intent could expand the conditions under which prescribed fire is a preferred management option: (i) fire culture; (ii) funding; (iii) capacity building through cooperation; and (iv) monitoring and adaptive management.

Fire culture

In emphasizing wildfire suppression over prevention (i.e., fuel treatments, including prescribed fire), fire management agencies in the United States have created a culture that does not adequately promote prescribed fire as a management tool (North et al. 2015). Schultz et al. (2019) found that productive prescribed burn programs depended excessively on specific individuals who were motivated and willing to accept risk, rather than on clear mandates throughout the chain of command, combined with incentives and backing within their respective agencies. In fact, the incentive is often *not* to burn, as career risks and implementation challenges outweigh perceived benefits. The result is that broad-brush, politically-driven mandates and moratoriums imposed by leaders impede prescribed fire programs. For example, in the summers of 2021 and 2022, in response to fire events in California and New Mexico, the Chief of the US Forest Service restricted use of managed wildfire and prescribed fire across all Forest Service lands nationwide (see, e.g.: https://www.gov.ca.gov/wp-content/uploads/2021/08/8.2.21-

USDA-letter.pdf). Such actions reflect political pressures but ignore the diverse climatic, ecological, and cultural contexts across the US, as well as regional variation in degrees of risk, preparedness and treatment urgency. While it may have made sense to put a moratorium on burning in drought-affected western states, it seemed counterproductive to curtail burning in other parts of the US where ample precipitation provided ideal burn conditions. These sorts of decisions reflect a culture of risk aversion within the federal fire management system and perpetuate the status quo to the detriment of ecosystems and communities in fire-prone landscapes.

Non-agency practitioners likewise face cultural and institutional challenges in prescribed fire. They need state and federal partners to support the training, certification, and permit programs that allow them to expand their impact. But agencies have been slow to embrace a broader role for local implementation of prescribed fire by groups such as non-governmental organizations (NGOs) and prescribed burn associations (PBAs). For example, in 2018, the California legislature mandated a state-certified burn boss program (https://osfm.fire.ca.gov/divisions/state-fire-training/) to expand the number of people qualified to lead prescribed burns and to provide them with liability protection, but the program has been slow to launch and only certified its first graduates in 2022. Delays were administrative in nature, but also due to extensive deliberation and discomfort within CAL FIRE about the merits and design of the program (Quinn-Davidson 2022).

Similarly, more than a year after California set aside $20 million to establish a Prescribed Fire Claims Fund to reduce the burden of potential liability, the program had yet to be operationalized. The benefits of the legislation will only be realized when the efforts are implemented, but progress remains slow. Separately, some cultural burn practitioners have been hampered because they lack legal jurisdiction over their homelands or because agencies do not recognize their practices or experience as legitimate (Clark et al. 2021), demanding that they demonstrate federal qualifications to conduct cultural burns if their ancestral territory is under federal jurisdiction. These examples have real impacts, stalling projects and limiting the ability of prescribed fire practitioners to conduct priority burns.

Removing these barriers requires support for prescribed fire implementation all the way up the chain of command within agencies, as well as support for agency leaders from legislative and executive levels of local, state and federal government. Burn bosses need to know their superiors will back them if, despite following best management practices, a fire escapes the pre-defined burn perimeter. Rather than shutting down entire burn programs when rare escapes occur, leaders should stress the increasingly vulnerable and hazardous condition of the landscape in the absence of treatment, and that the liability and responsibility for that condition may lie more with public agencies and policies than with individuals who implement the work. Likewise, regulatory protocols need to be revised so that fire exclusion is no longer considered a baseline condition, but rather a management action that requires justification (in a hopeful development, new National Forest Plans in California are zoning large landscapes where managed fire is the default management option).

As the urgency of these issues becomes more apparent (e.g., Collins et al. 2019, Hanan et al. 2021), there is a need for bolder leadership in support of prescribed fire, even when it is politically uncomfortable. There is also a need for innovative thinking by upper management and elected officials about how to incentivize and enable practitioners—not just within agencies, but also outside of government. Innovative approaches will necessarily involve co-ownership of prescribed fire: sharing risk through clearly articulated employee protections; amending liability laws; further investments in state or federally backed claims funds; sharing resources and funding for implementation; and sharing success. We need to reward the programs and individuals leading the way, and foster a shared vision of a diversified prescribed fire workforce.

Funding

Annual wildfire suppression costs in the US often surpass $2 billion and dwarf expenditures on prevention measures that include prescribed fire and other fuel treatments (Moreira et al. 2020, NIFC 2021). While data indicate that spending on prevention is more cost-effective than on suppression (North et al. 2012, Heines et al. 2018, UNEP 2022), many government entities find it easier to free up funds or be reimbursed for emergency spending on active fires than to justify budgeting for prevention ahead of time. Lack of dedicated funding and inflexibility as to when money can be spent on prescribed fire negatively affect fire staffing, availability, and the kind of projects they can undertake.

Commonly, prescribed fire is a secondary duty for agency fire professionals and contractors – only possible when wildfire season has calmed. Wildfire season in the NAMCZ increasingly extends into winter months (Jolly et al. 2015), creating seasonal staffing voids for prescribed fire . Moreover, many state and federal agency fire professionals are in temporary (<9 month) positions – requiring time off during potentially ideal prescribed burning conditions. Many prescribed burning positions in agencies have also been reduced or eliminated and pay scales and benefits are often inadequate to attract and retain qualified, experienced employees. Additionally, they generally lack opportunities to earn overtime wages and/or hazard pay – contributing to the flight of qualified people to suppression jobs where such bonuses are commonplace. These staffing shortages also impact private land burners, since permits may be denied on the basis that there would be insufficient resources to respond to an emergency if needed. Taken together, these factors demonstrate why funding for year-round, dedicated prescribed fire staffing is critical for increasing prescribed fire capacity.

With additional resources dedicated to prescribed fire, agencies could afford to bring prescribed burn operations into their incident management framework to conduct large, complex prescribed burns. Many large (≥1000 ac) prescribed fire projects take days or weeks to conduct, and weeks of patrolling afterwards. The use of such frameworks, already in place for wildfire management, would improve the integration of the many elements that go into these large-scale burns and create more equal footing between prescribed fire and wildfire suppression operations. Once year-round staffing and capacity is in place, agencies must normalize overtime/hazard pay for prescribed fire.

Increasing capacity through cooperation

Many opportunities for cooperation in prescribed fire go unrealized because potential partners/agencies are not in regular communication, operate on incompatible budgets/timetables, use different protocols or do not have the necessary agreements in place to facilitate cooperation. Examples include disconnects between federal and state agencies, distinct state agencies, and neighboring private and not-for-profit landowners (pers. obs. all authors). Rather than examine idiosyncratic reasons why past opportunities were missed, we focus instead at examples of cooperation in the NAMCZ that show promise for increasing prescribed fire capacity on public and private lands (Fig. 2, Panel 2). These efforts include educational opportunities for community members, hands-on training for fire practitioners and professionals, and formal cooperative agreements among agencies and their partners. For example, the University of California Cooperative Extension and Oregon State University Extension Service provide workshops on fire ecology and prescribed burning. The national Fire Learning Network and Fire Adapted Communities Learning Network also provide opportunities for capacity building and connecting people with different backgrounds and skill sets (https://www.conservationgateway.org/conservationpractices/firelandscapes/firelearningnetwork/pages/fire-learning-network.aspx, https://fireadaptednetwork.org/). In the southern Sierra Nevada, the North Fork Mono Tribal Chairman has partnered with UC Davis and the Southwest Climate Adaptation Science Center to offer cultural burning workshops that attract participants from tribes, state and federal agencies, NGOs, and academia – all connected by an interest in the traditional relationships between humans, fire and ecosystems.

Throughout the US, prescribed fire Training Exchanges (TREXs) and PBAs provide hands-on training to address the needs of government agencies, local landowners, tribes, and community members. TREXs are good examples of cooperative burning and training, bringing diverse practitioners together to build skills and increase the capacity of their respective programs (Toledo et al. 2014, Bailey and Quinn-Davidson 2018). The reach of these programs is limited, however. Although TREX events have been active and expanding in the NAMCZ since 2013, they are still unable to accommodate demand (LQD, ARG, CA pers. obs.). PBAs are a more recent phenomenon with significant momentum but also small in number and scope. The first PBA in the West formed in 2018 in the North Coast of California. There are now 20 groups in California (www.calpba.org), with more developing in southern Oregon and other parts of the region. Both TREXs and PBAs require investment and support to meet demand. State governments can promote these efforts with funding, training and equipment, and by streamlining and supporting state-certified burn boss programs, ensuring that suppression resources are available during prescribed fire season, providing liability protections and insurance options, and demonstrating commitment to empowering prescribed fire practitioners outside of agencies.

Inter-organizational agreements are another way to enable resource sharing, cross-boundary work, and shared liability. Agencies within the US Departments of Agriculture (USDA) and Interior (DOI) have access to Service First, a partnership authority that allows them to work together and share resources. For example, in northern California, a Service First agreement between Six Rivers National Forest (USDA) and Redwood National Park (DOI) facilitates shared fire resources and staffing, resulting in increased prescribed fire implementation. In the Mexican portion of the NAMCZ, the National Forestry Commission (CONAFOR) and the National Protected Areas Commissions (CONANP) have leveraged interagency collaboration as well as community involvement to conduct prescribed burns in national parks in Baja California (Panel 2; Figs. 1, 2). Although this collaboration is encouraging, prescribed burning has yet to be properly integrated into the wildfire management strategies of these institutions and formalization of a cooperative agreement remains a challenge.

Collaborations that support Indigenous cultural burning are also key to a comprehensive prescribed fire strategy because the two burning practices, while overlapping in their objectives, are not synonymous. Such partnerships must address the unique dimensions of cultural burning, which is inseparable from its cultural context and the social dynamics that uphold its use by current and future generations. For example, practitioners value the involvement of elders and youth to facilitate intergenerational knowledge transfer; they require guarantees of long-term access and management to allow lifelong, place-based cultural stewardship; and they may require funding for travel, stipends, and/or honoraria for practitioners and teachers. Partners can support these needs through outreach to land managers, help fundraising, and collective problem-solving (Adlam et al. 2022). Additionally, government agencies must consider tribal sovereignty when asserting that cultural burning practitioners must obtain the same permits and follow the same smoke management process as non-Native burners (Clark et al. 2021). Collaborations between tribes, NGOs, and policy experts can help resolve these issues by educating land managers and decision-makers about federal Indian law, or by introducing legislation that supports cultural burning (Marks-Block and Tripp 2021). For example, California's Assembly Bill 642 (2021) established a definition of "cultural burning" and "cultural burning practitioner," and called for a cultural burning liaison to serve on the State Board of Fire Services to support cultural burning through partnerships that respect tribal sovereignty.

Monitoring and adaptive management

Previously discussed funding and personnel limitations as well as an unfamiliarity with monitoring techniques result in many prescribed fire practitioners not having the time or capacity to include a monitoring component. Yet, quantitative monitoring of burns provides feedback on variables like fuel consumption, tree mortality and forest structure that are key to improving forest stand health and assessing project success. The California Prescribed Fire Monitoring Program (CPFMP) is an example of a collaborative data monitoring effort serving some of the most significant prescribed fire implementers in the State, including CAL FIRE, the US Forest Service, California State Parks, irrigation districts, conservation organizations, public utilities, timber companies and private landowners (Safford et al. In press). The CPFMP and a handful of other monitoring efforts (e.g., Yosemite and Sequoia-Kings Canyon National Parks) collect data on variables that help land managers, researchers, and agencies evaluate the effectiveness of prescribed fire for achieving goals such as fuels reduction, pest management, and ecological restoration. Used alongside information on the natural range of variation in specific vegetation types (e.g., Meyer and North 2019, Bohlman et al. 2021), monitoring data can help managers decide how often to treat and what combination of techniques to use (Safford et al. 2012), saving money and improving outcomes. Prescribed fire monitoring programs are limited in capacity, however, and monitoring protocols have yet to be adapted to the full range of ecosystems. Thus, as prescribed fire implementation expands to meet forest management needs, monitoring programs and methodologies will need to grow and adapt.

One area where monitoring efforts need development is in cultural fire, where practitioners could benefit from quantitative feedback on the use of fire for pest management, traditional food plants, and other culturally important species (Marks-Block et al. 2019, Halpern et al. 2022). Monitoring of cultural burns could center on outcomes such as production of healthy basketry material, foods, medicinal plants, watershed benefits, and the extent of multigenerational learning and sharing generated in the process of harvesting and preparing materials. The objectives of cultural burning are ecological, cultural, and social (Goode et al 2022), and monitoring protocols need to be adapted to capture the diversity of cultural fire outcomes.

Conclusions

The expanded use of prescribed fire will be key to addressing high-severity wildfire trends and the legacy of fire exclusion in the NAMCZ. Its effectiveness will depend on greater institutional support and leadership, increases in human and financial resources, expanded collaboration, creative solutions to liability and regulatory hurdles, recognition and support of the contributions of cultural burn practices, and broader implementation of data-driven adaptive management. Some of the high-level changes needed are taking place, such as forest action plans, shared stewardship agreements (Panel 2), and liability protections. While other challenges remain, the growing recognition of prescribed fire's importance and the examples cited here of how people are overcoming some of these obstacles make us optimistic about the prospects for its increased use and effectiveness.

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Figures

Figure 1. The North American Mediterranean Climate Zone (NAMCZ).

Figure 2. Cooperation at prescribed and cultural fire events. A) Veteran firefighters and novices work together on a prescribed burn at the Klamath TREX near Orleans, California (Photo: JNW). B) A cooperative extension burn boss briefs Prescribed Burn Association members ahead of a burn (Photo: LQD). C) The Mexican National Forestry and Protected Areas Commissions collaborate with community brigades on a prescribed burn in Parque Nacional Constitución, Baja California (Photo: HRH). D) A cultural burn conducted to promote basketry plants in the central Sierra Nevada of California (Photo: CA).

Panels

Panel 1. Cultural burning

Cultural burning consists of Indigenous-led application of fire for diverse objectives, including: enhancing the growth, health, and abundance of food, basketry and other culturally important plants; reducing pests; improving wildlife habitat; maintaining water quality and quantity; opening landscapes for travel and communication; and reducing the risk of high severity fire as part of a broader focus on forest resilience (Lake and Christianson 2020, Long et al. 2021, Goode et al. 2022). It is widespread across western tribal homelands and embedded in place-based narratives that describe the relationships between humans and other beings (e.g., Aldern & Goode 2014). Successive waves of Spanish, Mexican, and American colonialism forced drastic reductions in cultural burning, significantly impacting community and ecosystem health. Cultural burning today is essential for cultural perpetuation, maintaining resources and landscapes, and the language, songs, and practices associated with them. Decades of tribal advocacy demonstrating the human and ecological co-benefits of cultural burning have increased opportunities by the North Fork Mono, Yurok, Karuk, Mountain Maidu, and Wintun in California; and by the Confederated Tribes of Grand Ronde and Siletz Indians in Oregon.

Panel 2. Efforts to increase prescribed fire use.

1. The California Wildfire and Forest Resilience Action Plan (https://fmtf.fire.ca.gov/; CFMTF 2021) outlines strategies to increase prescribed and cultural fire, and cooperative partnerships while emphasizing healthy forests and sustainable communities. It sets treatment goals for CAL FIRE and the US Forest Service and for creating an interagency Prescribed Fire Training Center. It also promotes burning on tribal lands and improvements in monitoring and decision-support tools.

2. Nevada was the first western state to pass a law limiting the liability of prescribed burn managers to escaped fires due to gross negligence, protecting them against lawsuits that ignore precautions taken. Colorado, Washington, and California have since passed similar laws.

3. The US Forest Service has Shared Stewardship Agreements to reduce wildfire risk and improve forest management with 27 states (https://www.fs.usda.gov/working-with-us/shared-stewardship). The agreements emphasize partnerships with state and local governments, tribal groups, private landowners and NGOs to encourage cross-boundary collaboration, joint priority setting and risk-sharing.

4. In Mexico, the National Commission for Protected Natural Areas maintains fire regimes in protected areas, yet managed fire is the purview of the National Forestry Commission. In 2017, the United Nations Development Program helped create the Fire Management Program to promote collaborative planning among these agencies, leading to the first jointly-led prescribed burn in Constitución de 1857 National Park at the southern tip of the NAMCZ (CONAFOR/SEMARNAT 2020).