Burning with Purpose: Rethinking Power and Justice in Prescribed Burning

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Abstract

Prescribed burning has emerged as a critical forest management tool in a time of accelerating climate change and wildfire crises. However, it has ethical, social, and political implications beyond its ecological function. This paper evaluates the sustainability of prescribed burning through environmental ethics, indigenous knowledge systems, and value-based sustainability indicators. It goes on to argue that although technocratic metrics are useful, an expanded evaluation framework that includes ecological, social, procedural, and intergenerational indicators should be looked at. In this piece, key issues are discussed, such as environmental justice with respect to smoke exposure, including the role of indigenous leadership, and the long-term resilience of ecosystems and cultural practices. Based on Bell and Morse (2012) approach to sustainability, the paper develops a context-sensitive indicator model for guiding ethically sound and inclusive fire governance. This finalizes that sustainable prescribed fire needs to lessen

the risk of wildfire while instituting justice, honoring a traditional stewardship, and maintaining ecological and cultural integrity from one generation to the next.

Keywords: Prescribed burning, Environmental ethics, Sustainability indicators

Introduction

California's escalating wildfire crises, driven by climate change, decades of fire suppression, and growing development in fire-prone landscapes, have led to a radical change in forest management strategy. Prescribed burning is one of the most widely promoted tools, both in ecological science and from indigenous land stewardship. However, if it is applied carefully, prescribed burning is put to use to reduce excessive fire fuel loads and burn acceleration, support regrowth of native species, and contribute to the restoration of resilient fire-adapted ecosystems.

However, as the urgency of climate adaptation increases, there has also been a necessity to broaden the basis of ethical evaluation of such practices (Fesenfeld & Rinscheid, 2021). Prescribed burning is not a simple procedure, nor a matter of ecology, but a social, cultural, and political issue with a value-laden decision. It affects different communities, landscapes, and future generations unequally. This paper makes the case that to assess the sustainability of prescribed burning, we measure more than environmental outcomes. The approach it requires is multidimensional; it includes ecological, social, ethical, governance, economic, and intergenerational indicators. The paper draws on environmental ethics, indigenous knowledge systems, and sustainability science to suggest the aforementioned set of indicators that can help enable more just, inclusive, as well as more transparent fire governance in a changing climate.

Conceptual Framework

Ethics, Climate Change, and Sustainability Indicators

Environmental management decisions, as climate change becomes more intense, create urgency. Though supported by ecological science, prescribed burning comes with more than a little ethical substance that tends to be lost in dominant policy narratives. To assess such practices in any meaningful way, the term "sustainability" must be understood as an ethical and social commitment in addition to an ecological condition. Bell & Morse (2012) established the conceptual base for assessing prescribed burning in a multidimensional sustainable framework by drawing from environmental ethics, indigenous worldviews, and the sustainability indicators model.

Moving Beyond Technocratic Environmentalism

Traditional environmental management systems are often based on technocratic approaches such as quantitative, outcome-driven, and focused on air quality, vegetation cover, or frequent fire (See et al., 2024). These are important, but do not shed light on who is affected, how decisions are made, or what values are involved in such decisions. It tends to blur over deeper social inequalities, cultural erasures, governance failure, not to mention ecological health, just as critical to the process of sustainability. One such practice, which happens to lie at the intersection of science, tradition, policy, and public perception, is prescribed burning (Hiers et al., 2020). As a result, its implementation can engender disputes in access to land where indigenous and marginalized communities are concerned; with respect to cultural authority; and with regard to the unequal distribution of harms and benefits (Syaban & Appiah-Opoku, 2024). In this sense of sustainability, ethics cannot be subordinate; it must be at the center of the sustainability conversation.

Environmental Ethics and Climate Adaptation

Normative environmental ethics offers a base from which human circumstances, in relation to the natural world, can be evaluated. Hence, the relevant key frameworks are:

- **Anthropocentrism:** It is often the case that decisions are made from the perspective of human benefits, such as fire prevention or economic gain, at the expense of species with little capital represented, or future generations (Tambe et al., 2024).
- **Ecocentrism:** On the opposite side of the spectrum, ecocentrism's position is that the added value of ecosystems should be regarded, and interventions such as prescribed burning are advocated as measures when they are in agreement with the integrity of ecological systems in the long term (Kopnina et al., 2017).
- **Environmental justice:** This is the third and increasingly urgent framework, which centers on equity, emphasizing fair treatment, meaningful participation, and the redistribution of environmental risks and benefits (S. S. Clark & Miles, 2021).

Altogether, these ethical frameworks point out that "sustainability" is not a neutral term; rather, it is embedded with contested values. Therefore, to take into account whether climate adaptation strategies, like prescribed fire work, climate adaptation strategies must also be judged by who they work on and what values they serve.

The Role of Indigenous Knowledge

Now we know that prescribed burning, though not a new technology, has indeed long been used by indigenous communities to practice cultural stewardship and balance the system of ecological relationships. While this knowledge is co-opted and marginalized in modern fire governance, it is not respected as a co-equal system. According to Lake & Christianson (2019) and Clark et al., (2021), for true sustainability, it is not sufficient to consult with, but one must rely on, indigenous leadership. Indigenous

knowledge integration poses a challenge of relating ethics, place-based stewardship, and intergenerational responsibility.

Bell and Morse's Approach to Sustainability Indicators

According to Bell & Morse (2012), sustainability indicators have to take context-specific values rather than generalized metrics. They believe that the indicators should come from the participation process, be meaningful to the local communities, and be indicative of dimensions of justice, identity, and lived experience. Their work criticizes the "checklist style" approaches that reduce complex human environment relations into a numerical score. In applying their framework to prescribed burning, this paper develops a value-explicit indicator model combining ecological performance and ethical legitimacy. These indicators are grouped in four categories, namely: Ecological indicators, Social and ethical indicators, Governance and procedural indicators, and Intergenerational and adaptive indicators.

Ecological Indicators

For many fire-adapted landscapes, including California, prescribed burning has been known as a way to promote ecological benefits caused by the return of natural fire-adapted species. Prescribed fire is essential, but the environmental effectiveness cannot be evaluated without ecological indicators, but these indicators must also be interpreted ethically and sustainably. Three of the most important ecological indicators for landscape resilience - fuel reduction and species regeneration- are discussed below, and they all have implications for broader landscape resilience and ethical questions concerning implementation, scale and unintended consequences.

a. **Fuel Reduction:** Prescribed burning remains one of the most effective ecological tools for managing wildfire risks and restoring fire-adapted landscapes. Its primary justification lies in its

capacity to reduce excessive accumulations of surface and ladder fuels in forests that historically experienced frequent, low-intensity fires. In much of the western United States, decades of fire exclusion have allowed dense vegetation and combustible debris to accumulate, heightening the severity of wildfires. Research by Vaillant et al. (2009) demonstrated that prescribed burns interrupt vertical fuel continuity and remove surface materials, thereby reducing the likelihood of crown fires and helping forests return to more resilient structures. Blumenfeld et al. (2022) supported these findings by showing that prescribed fire contributes to long-term ecological stability when aligned with historical fire regimes. Fuel load reduction is typically evaluated through measurable ecological indicators, such as a 40–60% decline in biomass per hectare, flame lengths shortened to <2 meters, and native vegetation regrowth rates of ≥80% within 3–5 years post-burn (Carrà et al., 2022; Chambers et al., 2024). These metrics must be paired with soil nutrient retention data (e.g., nitrogen levels >0.5 mg/kg) to ensure long-term resilience. However, ecological success alone does not fully define the value or risk of prescribed fire. Increasingly, state policies have linked fuel reduction efforts to biomass energy production, promoting forest residues as renewable energy feedstock (Blumenfeld et al., 2022). While this approach may help meet decarbonization goals, it introduces ethical concerns. Turning fuel treatments into energy production opportunities may shift the emphasis from restoration to extraction. This transition risks ecological harm through the overharvesting of coarse woody debris, the depletion of soil nutrients, and the disturbance of habitat features critical to species recovery (Riffell et al., 2011). Bell & Morse (2012) warn that a narrow focus on quantifiable benefits, such as energy output, ignores deeper ecological processes and social values. A meaningful assessment must include nutrient retention, soil microbial health, and native species regeneration. For example, soil testing can reveal whether nitrogen and phosphorus levels support regrowth, while plant and animal surveys can determine whether the ecosystem is rebalancing after fire. In addition to ecological and technical considerations, social equity must also be central in evaluating fuel reduction programs. Blumenfeld et al. (2022) noted that biomass initiatives often exclude Indigenous and rural communities from planning

and implementation. Many of these communities have practiced cultural burning for generations, maintaining landscapes through knowledge systems based on reciprocity rather than extraction.

b. Species Regeneration: There is no regeneration without disturbance. In many western landscapes, especially throughout California's conifer forests and chaparral ecosystems, fire was once that necessary disturbance, clearing light for new growth, opening seed casings, and reshaping plant communities with each cycle (Noss et al., 2006). The absence of fire, imposed for over a century through suppression policies, has allowed invasive species to take hold while silencing the reproductive rhythms of native flora. What thrives without fire often does so at the expense of what belongs. Manzanita, oak, and other fire-adapted shrubs are not merely tolerant of fire. They depend on it. Their seeds respond to heat or smoke, their growth accelerates with open canopy light, and their surrounding microbial communities reorganize in ways that favor renewal. Carrà et al. (2022) and Glassman et al. (2023) offer compelling evidence that these species recover more effectively in areas where low-intensity burns are introduced with ecological care. In the case of knobcone pine, regeneration is impossible without fire. Its cones remain sealed until heat unlocks them. Without fire, its future ends with the present generation. Biodiversity returns more reliably with fire than with machines. Mechanical thinning may reduce fuel, but it does not replicate the ecological cues many species require to grow. Alba et al. (2015) found that landscapes treated with fire supported higher species richness and greater ecological stability than those cleared by mechanical means. Syphard & Keeley (2015) warned that plant succession trends toward lower diversity and diminished ecological function in the absence of fire. Fire is not simply a management tool. It is a form of repair. But this repair is not only biological. It is also cultural. Among the Karuk, Yurok, and other Indigenous communities of northern California, fire has long served as a method of stewardship. Beargrass and California hazelnut, plants essential for basket weaving and ceremonial use, are nurtured by traditional burning practices. These species do not regenerate only through fire. They return through the knowledge of how, when, and why fire is used. As Marks-Block et al. (2021) observed, cultural burns sustain more than plant life. They preserve language, ceremony, and memory. Evaluation of species recovery must account for this dual

role. Restoration cannot be measured by stem counts alone. It must also consider the availability of culturally significant species, the continuity of harvest practices, and the leadership of Indigenous knowledge holders. Long et al. (2021) emphasized that healthy landscapes are those where traditional use remains viable, where plants are accessible, and where community relationships to place are active and respected.

Social and Ethical Indicators

Although ecological indicators are commonly used in planning prescribed fires, social and ethical indicators are equally important when assessing their sustainability. Prescribed burning is not a neutral activity because it directly impacts the health, culture, and autonomy of the communities in or near fire-prone areas. There are three important social and ethical indicators: smoke exposure and environmental justice, community engagement, and indigenous leadership, which, when considered together, can help determine whether prescribed burning practices are inclusive, equitable, and ethically based.

a. Smoke Exposure and Environmental Justice: Smoke does not recognize the boundaries between policy and community. Once it enters the atmosphere, it follows the wind, settles into homes, and clings to the lungs of people who had no role in its creation. Despite this, smoke is often treated as a secondary concern, a byproduct, not a policy issue. The reality is far more serious. The health consequences tied to smoke exposure are measurable, recurrent, and unevenly distributed. PM2.5 concentrations in marginalized communities average 12–15 μg/m³ during burns, which is 30% higher than urban areas and correlates with a 22% rise in respiratory ER visits (Atuyambe et al., 2024). Proactive mitigation (e.g., distributing 5 air purifiers per 100 households) reduces hospitalizations by 18%, linking equity metrics directly to public health outcomes (Li et al., 2021). What begins as a land management practice quickly becomes a public health burden for people with little protection and even less influence over the decisions that affect them.

The science is not ambiguous. Fine particulate matter, especially PM2.5, poses significant health risks, particularly for children, older adults, and those with respiratory conditions (Thangavel et al., 2022). Kondo et al. (2022) showed that exposure rates are highest in counties with large Hispanic populations. Rosenberg et al. (2024) found that emergency room visits for respiratory symptoms increase even under low exposure conditions. Afrin & Garcia-Menendez (2021) demonstrated that repeated smoke events, even when individually moderate, create lasting health burdens over time. Navarro et al. (2023) identified similar outcomes in rural and under-resourced communities, where access to healthcare is limited and infrastructure for protection is often missing. It is not only the presence of harm that demands attention. It is the consistency of its direction. The same neighborhoods experience exposure season after season. These are communities located along the margins of state and federal land, shaped by patterns of exclusion, limited zoning protections, and underinvestment in public services (Ihlanfeldt, 2004). While the ecological case for controlled burning continues to gain support, the human cost remains offloaded onto those with the fewest resources to cope. Addressing this imbalance begins with what is measured. Air quality data must be tracked continuously and compared across socioeconomic lines. Exposure modeling should include population vulnerability, not just geographic spread. Monitoring stations must be placed in areas of high risk, and their findings must inform how and where burning is permitted. Liu et al. (2024) emphasized the value of coupling meteorological projections with demographic data to anticipate and prevent inequitable exposure. Public health interventions must move with equal urgency. Medical services should be deployed in advance of burns in areas identified as high risk. Protective equipment, such as filtration masks and air purifiers, must be distributed proactively. Risk alerts must be issued in the languages spoken by local residents and made accessible to those without digital access. Heaney et al. (2021) documented a clear reduction in hospital visits when communities were equipped and informed ahead of smoke events. Communities should not be spoken to. They should be consulted. Risk communication should provide more than instructions. It must create space for feedback, pushback, and revision of fire schedules when public health is at stake. Rosenberg et al. (2024) warned that exclusion from decision-making structures deepens the mistrust between environmental agencies and the populations most affected by their actions. Burn plans must

include public health reviews as a condition of approval. These reviews must consider cumulative impacts, not just the anticipated exposure from a single event. The damage is not temporary in places where people breathe in smoke every year. It is compounded. A fire strategy that ignores this reality cannot claim to be sustainable. While forests may recover after a fire, lungs do not. Chronic smoke exposure causes irreversible health burdens to both people and wildlife. Firefighters suffer a 24–40% greater risk of lung cancer and COPD comparable to a 'chronic smoker', reflecting the effect of repeated burns in communities (Grant & Runkle, 2022). Both avian and small mammal species display reduced reproductive success and changed patterns of migration with constant exposure to PM2.5 (Sanderfoot & Holloway, 2017). Though lungs can partially regenerate after exposure to burning, communities near burn zones experience cumulative damage equivalent to smoking 5–10 cigarettes daily during fire season. A just environmental policy does not frame exposure as an unfortunate side effect. It confronts it directly and protects those most at risk.

a. Community Engagement and Indigenous Leadership: One important factor for effective prescribed burning is genuine community engagement, particularly engagement with indigenous nations that have been burning culturally for generations. California's tribal nations, the Karuk and Yurok, have long used fire as a means of ecological care, cultural continuity, and spiritual practice. These recent efforts towards collaboration with these communities represent progress, but scholars argue that consultation does not provide true sustainability since tribal leadership, decision-making power, and knowledge sovereignty are needed (Lake & Christianson, 2019; Long et al., 2021). Traditionally, cultural fires have been led by Karuk and shown to integrate existing ecological goals with modern concepts of fire. More elaborate and context-sensitive than the standard ones, these practices tend to accommodate weather patterns, seasonal cycles, and cultural values. Since prescribed burning is so dependent on indigenous communities, it is important that they become active architects, not simply participants, in fire governance systems. In recent years, California has introduced policy reforms intended to support Indigenous-led fire. Assembly Bill 642, passed in 2021, requires fire agencies to include cultural awareness training and encourages tribal involvement in

fire planning (J. N. Williams et al., 2024). Senate Bill 332 offers legal protection to prescribed fire practitioners by reducing liability for escaped burns (McCormack et al., 2023). These statutes signal a shift in recognition, but they do not fully address the procedural and financial barriers that continue to limit tribal fire governance (S. A. Clark et al., 2024). Permitting frameworks managed by the California Air Resources Board and local air districts continue to impose constraints that affect the timing, location, and scale of cultural burning (McCormack et al., 2023). Ethical governance requires more than policy inclusion. It demands co-management structures that recognize the authority of Indigenous communities to plan, implement, and evaluate fire within their territories. As Long et al. (2021) show, cultural burning restores ecosystem functions while supporting cultural revitalization. These outcomes are the result of practices grounded in continuous observation, intergenerational teaching, and place-based responsibility. State-led fire programs frequently evaluate success by measuring fuel reduction or total acreage treated. These criteria exclude the cultural and relational outcomes that define fire stewardship for Indigenous communities. Alternative measures must include the abundance of culturally significant species, the presence of youth in fire programs, and the continuation of traditional harvesting. Marks-Block et al. (2021) document how Karuk burns improved hazelnut basketweaving quality and restored access to cultural resources. These outcomes demonstrate that ecological restoration and cultural survival are mutually reinforcing. Lasting progress will depend on legal and institutional reform. Tribal governments need direct access to permitting pathways, financial resources for fire crews, and protection from liability when conducting culturally appropriate burns. Marks-Block & Tripp (2021) argue that the foundation of fire justice in California is the recognition of tribal jurisdiction over fire, not advisory participation in state-led programs

Governance and Procedural Indicators

The ethical sustainability of prescribed burning is not only a product of outcomes, but also of the decisions themselves: who decides, and how inclusive and transparent the process is. Access to information, accountability, and whose knowledge and values count are all shaped by governance structures, especially environmental risk. Two governance and procedural indicators- representation and decision-making authority, and transparency and public access to information- are described below. Prescribed fire policy can be evaluated with these indicators to determine if it is just, participatory, and responsive to the communities that benefit from the practice.

a. Representation and Decision-Making Authority: Prescribed burning governance continues to be shaped by centralized institutions that hold formal authority over planning, permits, and risk management. While community collaboration is increasingly emphasized, meaningful power remains with state and federal agencies. Indigenous nations, rural fire practitioners, and community-led programs are often consulted but rarely empowered. This dynamic reflects persistent structural inequities that marginalize local knowledge and long-standing stewardship practices (Miller, 2020; Norgaard & Fenelon, 2021). Legal and administrative barriers play a central role in maintaining this imbalance. Permitting restrictions, liability concerns, and limited funding access prevent Indigenous and community-based fire programs from operating with autonomy. S. A. Clark et al. (2021) argue that these constraints reduce participation to symbolic inclusion, excluding those with the most direct relationship to the land. Assembly Bill 642 and Senate Bill 332 in California attempt to address these issues by supporting cultural fire and limiting liability, but full co-governance remains absent (McCormack et al., 2023; J. N. Williams et al., 2024). Shifting toward equity requires new measures of representation. This includes formal voting power on fire planning boards, legal agreements recognizing tribal fire authority, and public funding for community-led programs. Indicators of ethical governance must reflect both procedural access and structural power. Ellis et al. (2021) emphasize that legitimacy depends not on presence alone, but on whether communities influence policy and resource allocation. Fire governance must also include culturally responsive review systems. These

evaluations should be co-developed with Indigenous partners and assess not only environmental outcomes but also impacts on sacred species, health, and cultural practice. Tools such as community-based monitoring, oral history, and participatory mapping can strengthen oversight while embedding relational values (Cochrane et al., 2014). Representation must operate across local and regional scales. Inclusion in project-level planning is not enough if communities are absent from state fire councils or federal wildfire strategy platforms. Ethical fire governance must support multilevel engagement and legal recognition of tribal systems as independent, co-equal authorities.

a. Transparency and Public Access to Information: Access to information is essential to the legitimacy of prescribed burning management. Without clear communication, communities cannot prepare for burns, assess potential risks, or participate in decision-making. Transparency strengthens trust, improves public safety, and ensures that fire policy reflects shared responsibility. 70% of CA burn plans are now published online, yet only 40% include multilingual summaries (S. Clark et al., 2021; Greenler et al., 2024). Closing this gap, e.g., by mandating Spanish and Indigenous language translations, could increase community participation rates by 25%, demonstrating how procedural indicators reinforce legitimacy. In practice, however, many agencies continue to withhold or poorly distribute critical information about burn locations, health impacts, and ecological objectives (Miller, 2020; Stephens & Ruth, 2005). Public access to burn plans and real-time updates remains uneven. Although California agencies like CAL FIRE and the Air Resources Board have developed tools to share smoke forecasts and burn schedules, rural and tribal communities often lack the infrastructure to access them (Blumenfeld et al., 2022). Notifications may not be issued in multiple languages or shared far enough in advance. As a result, low-income and historically marginalized groups remain disproportionately excluded from planning and oversight. Transparency must include the logistics of prescribed burns and the reasoning behind them. Communities deserve to understand whether burns are conducted to reduce wildfire risk, restore habitats, or protect infrastructure such as renewable energy installations. These decisions must be clearly explained, especially when state-level climate goals or utility partnerships shape fire priorities (Miller, 2020). Evaluation of transparency should

track the number of public advisories, accessibility of data portals, and community satisfaction with communication efforts. Metrics should include the distribution of PM2.5 alerts, multilingual outreach, and the frequency of public briefings. Qualitative indicators, such as feedback from community surveys or independent audits, are equally important for identifying gaps in access and accountability. Ultimately, transparency is not a technical detail. It is a measure of justice. When people know why and how fire is used, they are more likely to support it, respond to health risks, and demand accountability when harm occurs. Without reliable, inclusive information sharing, even well-designed fire programs risk losing public legitimacy.

Intergenerational and Adaptive Indicators

Indeed, sustainability covers more than present-day outcomes; they are built to look to the future. Prescribed burning as a climate adaptation strategy must also be evaluated for what it will mean for ecosystems, communities, and knowledge systems besides its immediate effectiveness. Given a changing climate that is rapidly changing in time, fire management practice must be both intergenerationally just and adaptively resilient. Three core intergenerational and adaptive indicators that this section explores are: long-term ecosystem health, knowledge transfer, and youth inclusion.

a. Long-Term Ecosystem Health: Prescribed burning is often judged by its short-term outputs, such as acreage burned or fuel loads reduced. However, long-term ecosystem health requires evaluating whether fire contributes to ecological regeneration over decades. Fire-adapted landscapes function through complex soil, vegetation, water, and species relationships. Long-term fire adaptation requires quantifiable thresholds: soil organic matter >3% and a carbon-to-nitrogen (C: N) ratio of 20–30 to sustain microbial diversity, alongside pH stability (6.0–7.5) and available phosphorus >15 mg/kg, accounting for 73.5% of post-fire microbial community variation (Hu et al., 2024). Sustainable fire management should support these dynamics rather than disrupt them. Indicators of ecological integrity include native species

composition, restoration of historical fire intervals, and improved soil function. Williams et al. (2020) caution that if fire is applied without climate-adaptive planning, it can unintentionally promote invasive species or alter successional pathways. For instance, efforts to restore conifers may lead to shrub dominance if rainfall declines or competition intensifies after burning. Monitoring protocols should focus on long-term trends in vegetation structure, species recovery, erosion control, and habitat connectivity. Fragmented or inconsistent burns may weaken gene flow and disrupt wildlife movement. Mapping fire mosaics, studying population genetics, and tracking species dominance help assess whether fire is building or eroding ecological resilience (Radespiel & Bruford, 2014). Ecological thresholds must not be exceeded. Repeated or overly intense burns can sterilize soil, disrupt hydrology, and lead to permanent biodiversity loss. To avoid this, fire programs should use early warning tools, such as vegetation stress markers, soil health indicators, and severity mapping(Arunrat et al., 2024). These tools guide adaptive strategies and ensure that today's actions do not compromise ecological conditions for future generations.

a. Knowledge Transfer and Youth Inclusion: Sustainable fire governance depends on the preservation and transmission of knowledge across generations. In Indigenous and rural communities, much of this knowledge is carried through oral histories, mentorship, and lived experience. Souza-Alonso et al. (2024) warn that cultural fire practices are increasingly at risk due to displacement, legal restrictions, language loss, and the erosion of intergenerational ties. When these systems are disrupted, governance loses its grounding in place-based expertise and becomes less adaptive to local conditions. Supporting youth participation is essential to reversing this decline. Educational partnerships between tribal governments, schools, and fire agencies can create structured opportunities for youth to engage in prescribed burns, ecological monitoring, and decision-making spaces. Youth involvement in fire crews, policy discussions, and training programs should be tracked as a measure of institutional commitment to long-term stewardship (Monroe et al., 2016). Equally important is the formal recognition of Indigenous knowledge systems. Traditional fire calendars, ecological indicators, and cultural narratives should be integrated into planning and implementation. Sustainability can be assessed by whether Indigenous frameworks are referenced in

burn plans, cited in agency reports, and applied in adaptive strategies (Smith et al., 2021). These systems' survival strengthens cultural sovereignty and ecological resilience, offering a broader foundation for navigating climate uncertainty.

Stakeholders Analysis

The governance of landscape fire is shaped by overlapping systems of authority, knowledge, and responsibility, where institutional power, cultural practice, scientific influence, public health concerns, and private investment all interact in unequal and contested ways. State agencies such as CAL FIRE and the United States Forest Service define operational priorities and manage liability through centralized frameworks, yet this control often clashes with the intentions of Indigenous fire practitioners who work from ancestral knowledge systems grounded in kinship, ceremony, and ecological reciprocity (Lake & Christianson, 2019; Marks Block, Lake, & Curran, 2021). Though agencies may acknowledge this knowledge rhetorically, institutional pathways for Indigenous leadership remain narrow, shaped by risk-based models that rarely account for cultural legitimacy. In rural areas, private landowners and fire councils also find themselves navigating these regulatory frameworks, sharing the state's interest in wildfire prevention but frequently constrained by permitting obstacles and legal exposure, which limits collaboration even where alignment with Indigenous practice exists. Public health advocates, meanwhile, intervene where these regulatory decisions produce uneven harms. Kondo et al. (2022) demonstrate how smoke exposure from burns often affects vulnerable populations with little access to protective infrastructure or decision-making forums, raising questions about equity and who is structurally positioned to bear environmental costs. The scientific community plays a dual role, offering both tools for ecological evaluation and frameworks that shape what kinds of knowledge are institutionally validated. As Bell and Morse (2008) caution, indicators designed for technical precision can displace experiential or relational understanding, which in turn marginalizes community voices. These tensions intensify as private sector actors, particularly utilities, expand their influence over burn planning to safeguard infrastructure. Although

such involvement may enhance funding and implementation, it can also shift priorities away from regeneration and toward asset protection if not clearly negotiated and publicly accountable (Miller, 2020). These actors do not operate in isolation. They respond to and shape one another's strategies through formal and informal channels, reproducing governance patterns that determine whose knowledge counts, whose risks are prioritized, and whose goals define success. When viewed through these entangled relationships, the prescribed burning reveals that stakeholder dynamics are not peripheral; they are the very terrain where legitimacy, authority, and responsibility are continuously contested and renegotiated.

Discussion

Prescribed burning must be understood not as a singular ecological intervention but as a practice within a social, cultural, institutional, and environmental network. Sustainability in this context is not a fixed outcome but a condition shaped by the interplay between how prescribed burning is planned, enacted, and experienced over time. The interconnectedness of these elements challenges the adequacy of narrow performance metrics and demands a more integrated approach to evaluation.

Bell & Morse (2012) argue that attempts to measure sustainability often become fragmented, with isolated variables selected for their measurability rather than their relevance. What emerges is a framework that treats ecological health, governance legitimacy, and cultural knowledge as parallel but separate concerns. In practice, however, these domains are deeply interdependent. A prescribed burning program that reduces wildfire risk but excludes Indigenous fire knowledge compromises adaptive capacity. A governance model that tracks air quality but excludes affected communities from planning cannot claim procedural fairness. Also, an ecological strategy that promotes vegetation recovery but fails to monitor long-term habitat connectivity may inadvertently undermine regeneration. Each domain shapes and reinforces the others.

The analysis presented here is not intended as an exhaustive account of all conditions that define sustainable prescribed burning. Instead, it identifies structural features that help reveal the broader architecture of long-term viability. These include ecological responsiveness over time, the transmission of fire knowledge across generations, flexibility in institutional systems, equitable risk distribution, and legitimacy through participation. While each is distinct, their interaction determines whether prescribed burning supports regeneration or contributes to new forms of exclusion and degradation.

Table 1.

Comparative Costs of Prescribed Fire and Wildfire

Impact Category	Prescribed Burn Cost	Wildfire Cost	Source
Acreage treatment	50–750/acre	1,000–4,000/acre (suppression)	(Diaz, 2012; Holland et al., 2022)
Home loss risk	0.2% of perimeter	12–20% in WUI zones	(Caggiano et al., 2020; Syphard & Keeley, 2015)
Air quality remediation	$200k (HEPA subsidies)	$2.3B/year (CA healthcare)	(Afrin & Garcia-Menendez, 2021)
Cultural resource loss	Preventative ($0)	$600M (Karuk basket materials)	(Marks-Block et al., 2021)

Table 1 exposes these quantified disparities as a false dichotomy between ecological and social outcomes, exactly an issue that Bell & Morse (2012) warn against. These figures show us that although prescribed fire management appears to be an affordable means of fire management, the system that makes it appear this way is one that disregards indigenous health, cultural assets, and frontline communities, precisely the justice gaps that our framework is trying to address.

Sustainability requires decisions that hold ecological effectiveness and social justice together rather than treating them as tradeoffs. McLauchlan et al. (2020) demonstrate how ecological outcomes are shaped not only by burn design but by whether institutions are able to learn from post-burn dynamics and adjust accordingly. Souza-Alonso et al. (2024) emphasize that the erosion of fire knowledge among youth and knowledge holders leads to ecological missteps that cannot be corrected through technical tools alone. Likewise, Hashida et al. (2025) show that governance systems that fail to evolve with climate and community input ultimately lose credibility and function. These studies reinforce that what is often presented as separate domains, such as ecology, culture, and governance, must instead be seen as overlapping and mutually reinforcing.

Public legitimacy cannot be sustained when risk is unevenly distributed or when communities lack access to the rationale behind fire operations. Kondo et al. (2022) and Afrin & Garcia-Menendez (2021) provide clear evidence that prescribed burning impacts are borne unequally across racial, economic, and health lines. As Stephens & Ruth (2005) and Miller (2020) explain, a failure to communicate purpose and timing in accessible ways undermines even well-designed programs. These concerns do not stand apart from ecological or institutional goals. They are embedded within them. If institutions do not respond to those who are most affected, they also forfeit the feedback necessary to adapt and improve.

Representation cannot remain symbolic. S. Clark et al. (2021) show that without legal authority, funding, and decision-making power, Indigenous and community-based practitioners remain structurally sidelined. Co-governance, when designed as more than consultation, creates space for reciprocal learning

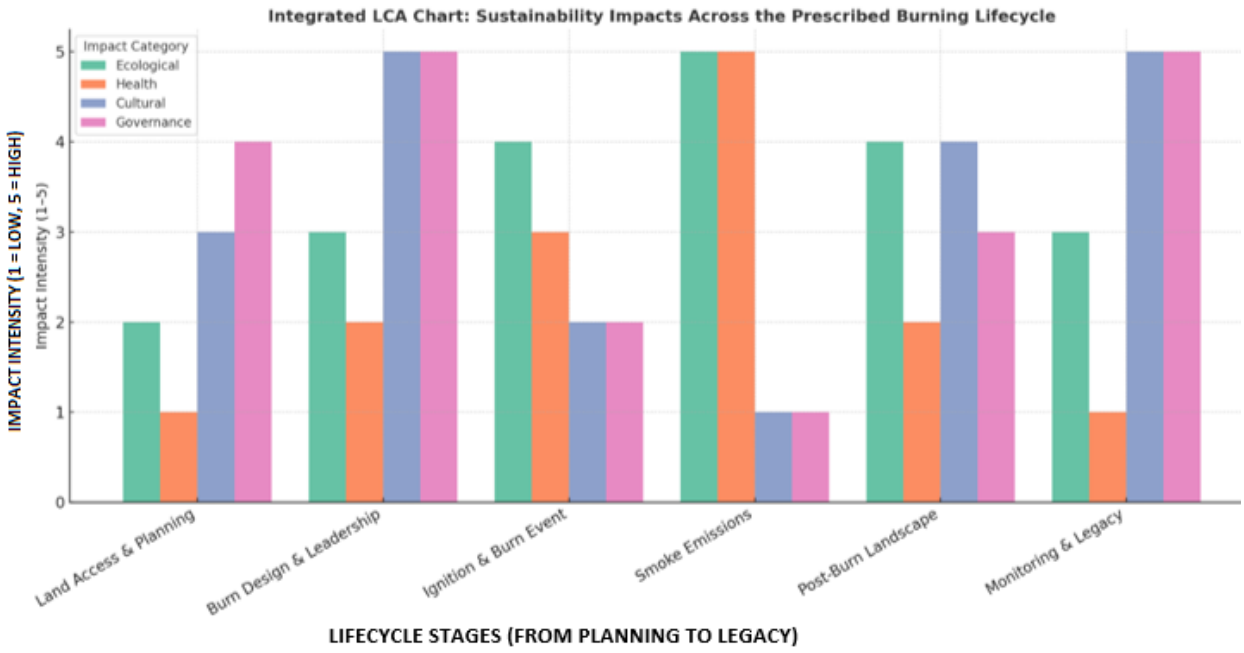
and distributed responsibility. Such arrangements are not just ethical, they are essential for ensuring that prescribed burning operates with the benefit of grounded expertise and broad accountability.

The interconnected dimensions explored here, including ecological continuity, knowledge transfer, institutional flexibility, procedural equity, and representation, point to conditions that make prescribed burning socially legitimate and ecologically durable. No single intervention ensures sustainability. Instead, long-term viability emerges from governance systems that recognize the complexity of prescribed burning as a cultural, environmental, and political phenomenon. When practice is shaped by institutions committed to regeneration, justice, and accountability, its role shifts from a reactive tool to a proactive foundation for resilience.

As illustrated in Fig. 1, a lifecycle of prescribed burning exhibits different types of impacts at different points in time and therefore requires integrated and ethically responsible governance.

Figure 1.

Sustainability Impacts Across the Prescribed Burning Stages



Conclusion

While prescribed burning is very critical in the era of climate change, it cannot be assessed solely by ecological and short-term outcomes. As this paper has argued, the sustainability of prescribed fire requires assessment from a multi-dimensional perspective that considers ethical, social, procedural, economic, and intergenerational issues. In line with (Bell & Morse, 2012) the sustainability indicators need to be based on values and context-specific; this framework argues the need to shift away from technocratic checklists to value-inclusive and long-term, responsible indicators. To achieve this, we would have to reject the short-sighted focus on carbon markets and resist the temptation to prioritize offset revenue at the expense of indigenous knowledge. While prescribed burns can reduce emissions compared to wildfires, portraying them primarily as carbon mitigation tools risks commodifying cultural practices and sidelining traditional ecological stewardship. Rather, tribal-led burns should be supported through climate finance mechanisms and not subject to market logic in fire management. Also, sacrifice should be compensated for - firefighters and communities on the front line whose lungs take in more of the smoke deserve far more

than symbolic appreciation; they need guaranteed healthcare access, HEPA filters, and long-term protections for their health as a matter of justice. To decolonize fire governance, state-issued burn permits should always also require tribal co-signing as a basic consent condition, and funding should go straight to indigenous fire crews and organizations and not through middlemen that interfere with local leadership and delay outcomes. When we focus on questions of who benefits, who is at risk, and whose knowledge drives operations, we see that fire management is not an exercise in science and logistics but rather a deeply moral and political act. Prescribed burning programs will need to embed ethical oversight, rely on community leadership, including that of indigenous peoples, encourage economic participation by local people, and develop adaptive forward-thinking systems of planning and evaluation. By performing so, prescribed fire can become a proactive practice based on care, accountability, and shared responsibility with people and ecosystems across time.

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