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Bridging tradition and innovation: strengthening food system resilience through Indigenous Guardian partnerships and knowledge sharing in the Sierra Nevada and British Columbia

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The vitality of an Indigenous food system is directly tied to how well a community can access and care for the lands and waters they have historically stewarded. In both California's Sierra Nevada region and British Columbia, Indigenous communities face urgent climate-related impacts, including catastrophic wildfires and drought, which threaten traditional food systems and cultural landscapes. This community case study explores the knowledge sharing efforts and decision support tool development of First Nations (British Columbia), and Indigenous communities in the Sierra Nevada region in California, and academic partners to support the expansion of community-led land and water stewardship. Through Indigenous Guardian programs, participatory mapping, two-eyed seeing, and data sovereignty principles such as Ownership, Control, Access, and Possession (OCAP®), these partnerships strengthen Indigenous governance structures while addressing historical land dispossession and disrupted foodways. Restoration of lands and waterways is a prerequisite for achieving food sovereignty, necessitating cultural fire practices, improved access to ancestral lands, and Indigenous-led policy interventions. Elders and Knowledge Bearers play a critical role in transmitting Indigenous Knowledge (IK) through oral traditions and hands-on stewardship, reinforcing the importance of intergenerational learning and community-driven processes. Furthermore, this case study underscores the need to create Indigenous-led spaces for knowledge-sharing, collaboration, and policy engagement that prioritize Indigenous voices, sovereignty, and self-determination. By integrating IK with emerging technologies and policy frameworks, Indigenous communities in California and British Columbia are not only restoring stewardship rights by reclaiming their own data but also shaping resilient, climate-adaptive food systems. This paper advocates for sustained investment in Indigenous governance, intertribal collaboration, and equitable decision-making processes that support the continuation of traditional foodways for future generations.

KEYWORDS

cultural fire, decision support tools, indigenous guardianship, data sovereignty, two-eyed seeing, food sovereignty, land access

1 Introduction

California and British Columbia face escalating challenges in mitigating the threat of destructive wildfires, which year after year devastate millions of acres/hectares. Indigenous communities in these regions share a deep history of applying Indigenous Knowledge (IK) like cultural burning - practices that control insects and disease, promote fire-adaptive native plants, enhance water use efficiency, improve community safety, and restore wildlife habitats (Anderson, 2005; Goode et al., 2022). Rooted in thousands of years of place-based stewardship, IK offers critical insights into sustainable stewardship practices, from soil health, water conservation to wildfire resilience.

Over the past few centuries, western land and water management practices have led to Indigenous land dispossessions and resource exploitation, excluding IK from decision-making (Fernández-Llamazares et al., 2021; Vinyeta, 2022). This disruption has weakened Indigenous food systems, and undermined environmental and cultural sustainability (Norgaard, 2019). Today, in response to the increasing risks posed by climate change, including the uptick of wildfires, Indigenous communities in the Sierra Nevada and First Nations of British Columbia are advancing stewardship efforts in novel ways. This community case study illustrates how integrating IK with other technologies and decision support tool development is advancing community safety, ecosystem restoration, and climate resilience for future generations.

A resilient food system is one that can adapt and rebound from unforeseen stressors to provide appropriate, sufficient, and accessible food to all (Tendall et al., 2015). Food system resilience and disaster preparedness are deeply connected, as both aim to ensure stability and adaptability of food systems in the face of increasing environmental, social, and economic turbulence. The resilience of food systems is critical in the face of climate change, environmental degradation, and increasing wildfire risks, which disproportionately impact Indigenous communities (Thomas et al., 2019). Despite these vulnerabilities, Indigenous Peoples globally continue to grow, respond, and adapt in diverse and resilient ways (Ford et al., 2020). Resilient food systems are possible and sustainable to safeguard food sovereignty - particularly for Indigenous communities. These goals are accomplished by ensuring consistent access to culturally appropriate, nutritious food, and supporting ecosystem health (Fontana et al., 2022) and supporting Indigenous land access (Baldy, 2013). Food sovereignty includes pathways to ensure Indigenous autonomy over traditional agricultural and ecological stewardship practices (Declaration of Nyéléni, 2007). Wisdom held in Indigenous families and communities is critical to responding to climate-related emergencies and the strengthening of regional food sovereignty.

2 Context

2.1 Centering Indigenous guardianship (i.e. proposed innovation)

Indigenous Peoples worldwide have been stewarding landscapes for thousands of years. The Indigenous Guardians movement is a collaborative approach to environmental governance, where Indigenous communities reassert their roles as stewards of their lands (Reed et al., 2020). Known by various names - Guardians, Observers, Rangers, Stewards, or Watchmen, depending on the region - the movement shares a common goal: to enhance Indigenous capacity in natural resources planning, monitoring, stewardship for future generations (Popp et al., 2020; Sheil et al., 2015; Social Ventures Australia, 2016; Trousdale and Andrews, 2016). This work encompasses monitoring land use, revitalizing cultural practices, intergenerational knowledge sharing, and managing land, water, fire, wildlife, and harvesting resources. These practices, rooted in millennia of Indigenous knowledge, have demonstrated that Indigenous-managed lands often maintain equal or higher biodiversity than state-led protected areas (Schuster et al., 2019; Nepstad et al., 2006). A growing body of international research demonstrates that Indigenous-managed areas are at least as effective as state-governed protected landscapes in mitigating land disturbances such as logging and deforestation (Carranza et al., 2014; Nolte et al., 2013; Waller and Reo, 2018). Indigenous-led conservation is widely recognized for reducing species loss, better protecting landscapes (IPBES, Weltbiodiversitätsrat, 2019), and increasing conservation efforts (Artelle et al., 2019; Turner and Spalding, 2013), while simultaneously strengthening community health, culture, language, and most importantly, governance.

The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), adopted in 2007, was a landmark human rights instrument designed to protect the rights of Indigenous Peoples globally (UN General Assembly, 2007). Initially, the United States, Canada, Australia, and Aotearoa-New Zealand voted against the declaration, citing concerns over self-determination, land rights, and free, prior, and informed consent (Lightfoot, 2016). These countries later shifted their positions to support UNDRIP, though their commitments remain largely aspirational and non-legally binding. In contrast, British Columbia became the first jurisdiction in Canada to enshrine UNDRIP into law in 2019, followed by Canada in 2020 (Bellrichard, 2019). Despite varying levels of legal recognition, Indigenous Guardian programs continue to expand globally (in Canada, Australia, Aotearoa-New Zealand and the U.S.), illustrating how Indigenous knowledge systems and governance structures are driving conservation efforts and advancing environmental stewardship in ways that link ecological health with cultural and economic revitalization. As of September 2023, successful Indigenous Guardians initiatives are now in over a quarter of First Nations across Canada. By investing in $70 million in over 170 First Nations, Inuit, and Métis Guardians initiative since 2018, it has helped support the creation of over 700 culturally meaning employment opportunities (Government of Canada, 2025). Since the establishment of the Indigenous Protected Area (IPA) Program in 1997, Australia has designated 85 Indigenous Protected Areas, now comprising 50% of nations national reserve system (Australian Government, 2025). Research shows that for every $1 invested, Australian Ranger programs generate $3 in health, conservation, and economic results (Social Ventures Australia, 2016).

Over the past three decades, Indigenous Guardian programs across the world have emerged as powerful institutions supporting Indigenous-led conservation, fostering self-determination, and enabling decision-making authority over traditional lands (Artelle et al., 2019; Schuster et al., 2019; Zurba et al., 2019). Canada leads the way with approximately 160 programs, beginning with the Haida Gwaii Watchmen in 1973 and formalizing in the 1980s (Dean, 2009; Government of Canada, 2025; Trousdale and Andrews, 2016). In Australia, around 120 Indigenous Ranger groups now steward national parks, Indigenous Protected Areas (IPA), and other critical

territories (Ayre et al., 2021). Aotearoa-New Zealand exemplifies Māori-led guardianship, or *Kaitiakitanga*, which is embedded in federal legislation like the Resource Management Act (Morad and Jay, 2000). This approach has set significant precedents, granting rivers and mountains legal personhood while maintaining provisions for community use (New Zealand Government, 2016; Te Aho, 2016).

Across the U.S.-Canada border, Indigenous guardian initiatives continue to expand, including the Guardianship program of the Blackfoot Confederacy (Thomson, 2024), the Bristol Bay Guardians in Alaska, and the Tlingit & Haida Seacoast Indigenous Guardians Network (SIGN), (2023). In northwestern California, holistic community-based approaches to food sovereignty and access to native foods are improving the health of Karuk, Yurok, Hoopa, and Klamath Tribal households (Baldy, 2013; Sowerwine et al., 2019). The Karuk has recently published findings on the outcomes of their agroecosystem initiative (Karuk Tribe-UC Berkeley Collaborative, 2023). Most recently, the Resighini Tribe of the Yurok People, the Tolowa Dee-ni' Nation, and the Cher-Ae Heights Indian Community of the Trinidad Rancheria declared the first-ever U.S. Indigenous Marine Stewardship Area (IMSA) in California (Kimbrough, 2024).

Indigenous-led governance, including Guardian programs, not only supports communities but also enhances conservation efforts globally (Artelle et al., 2019). While Canada's Indigenous Guardians programs provide key models for success, similar initiatives the U.S. face significant barriers, including the absence of dedicated government funding and clear regulatory frameworks. To overcome these challenges, cross-boundary and cross-cultural collaboration is essential. This involves community-driven knowledge sharing to integrate Indigenous Knowledge (IK) with innovative technological tools, ensuring best practices that honor tradition while embracing innovation. Strengthening these partnerships will be critical for increasing community resilience and improving disaster response, particularly in the face of escalating climate threats such as wildfires, floods, and droughts.

2.2 Integrating Indigenous Guardian programs with western science

With this knowledge in hand, the authors represent and are guided by Nisenan, Maidu, Miwok, Fisher River Cree, and Washoe communities working together to address our collective challenges. The authors also represent former staff and former Indigenous coordination with First Nations Emergency Services Society (FNESS), Indigenous Futures Society (formerly The Sierra Fund, recently transformed into an Indigenous-led and -governed California-based nonprofit), and the University of California, Davis (Figure 1). Together, we have organized in-person workshops, monthly training sessions, resource sharing spaces to develop community-led decision support tools. Through these efforts, we are forging collaborative approaches that bridge disciplines, agencies, backgrounds, and knowledge systems – dismantling traditional silos between western and Indigenous perspectives, while addressing challenges that arise.

Cross-cultural learning and sustained community collaboration are essential to addressing the growing challenges posed by climate-driven disasters across our communities and borders. Effective resilience strategies require partnerships that bridge Indigenous knowledge systems, western science, and governmental frameworks to create holistic, adaptable solutions. Indigenous communities bring time-tested practices and knowledge that align with natural processes, fostering long-term ecocultural balance (McGregor, 2004; Sheil et al., 2015). Both Indigenous science and Western science are grounded in observation and data gathering. Western science typically focuses on pre-determined objectives (Berkes and Berkes, 2009) while Indigenous science is rooted in thousands of years of place-based knowledge held in community intergenerationally (Johnson and Arlidge, 2024). Western methods can support Indigenous science by mindfully integrating contemporary technologies (Lam et al., 2019; Reed et al., 2020; Artelle et al., 2021; Bohensky and Maru, 2011; Conzon, 2023) and disaster response systems. For example, the US National Science Foundation (NSF) funded its first Indigenous knowledge research hub called the Center for Braiding Indigenous Knowledges and Science (CBIKS) in 2023. The Center includes 57 Indigenous partners across four continents, with a focus on ethically weaving Indigenous and western science research, education, and practice to address environmental challenges (Tollefson 2023). By fostering partnerships among Indigenous Nations, government agencies, cultural practitioners, scientists, and local communities, we can collectively strengthen preparedness, share expertise, and address vulnerabilities while supporting cultural continuity.

Upholding Indigenous data sovereignty and fostering intentional knowledge-sharing spaces are essential to meaningfully working across cultures and knowledge systems. This work is not linear; it is an

FIGURE 1
(A) Community members engage in mapping exercises alongside FNESS staff to develop decision-support tools during a three-day workshop at Shingle Springs Rancheria, California, in May 2024. **(B)** Community members and FNESS staff collaborate during a three-day workshop in Kamloops, British Columbia, in October 2024, refining decision-support tools to better address specific community needs.

ongoing, iterative process that requires patience, empathy, and deep engagement. Trust is built over time through sustained dialogue, shared experiences, and a commitment to reciprocity. Relationships and understanding emerge gradually, forming a foundation of effective leadership and collaboration. Equitable decision-making frameworks must center Indigenous voices and leadership, ensuring that outcomes are both culturally grounded and ecologically effective. When partnerships are rooted in mutual respect and shared purpose, they strengthen community capacity, deepen trust, and empower communities to lead in disaster response, conservation, restoration, and climate adaptation. By prioritizing process, we aim to cultivate trust, reciprocity, and a depth of understanding needed to forge lasting, transformative change that honors both tradition and innovation.

2.3 The complementary strength of two-eyed seeing

"Two-eyed seeing," a concept introduced by Mi'kmaw Elder Albert Marshall in 2004, offers a framework for uniting knowledge systems. It is described as "learning to see from one eye with the strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to use both these eyes together, for the benefit of all" (Bartlett et al., 2012). This approach emphasizes the value of integrating Indigenous Knowledge with Western science, recognizing their complementary strengths in addressing complex environmental and societal challenges. Indigenous guardianship programs exemplify this approach by operating under Indigenous leadership while employing two-eyed seeing to steward lands. By bridging these knowledge systems, these programs foster equitable, reflective, and just collaborations that honor Indigenous ways of knowing alongside Western methodologies. This shift in leadership is crucial for advancing meaningful, place-based solutions that support ecological and cultural resilience in an increasingly interconnected and challenged world. Our collaborative presents a case study that approaches this challenge with a two-eyed perspective, integrating the layered experiences and expertise of Indigenous and non-Indigenous members from the Sierra Nevada region of California in the U.S. and British Columbia, Canada. This perspective informs an innovative approach to food sovereignty that grounds land access and IK to support community and ecosystem health. Indigenous food sovereignty cannot be achieved until land access and Indigenous leadership are centered.

FNESS, an Indigenous-led non-profit organization in British Columbia, began in 1986 with Fire Services and has significantly expanded its scope of services since then. Since 1994, FNESS has supported over 200 Native communities in mitigation, fire services, decision support, preparedness response, and training (First Nations' Emergency Services Society of British Columbia (FNESS), 2024). By developing decision-support tools in collaboration with communities and strategically layering publicly accessible data to address their specific needs, FNESS has worked with communities to implement comprehensive climate adaptation strategies. With effective data governance in place, Tribal communities can more effectively allocate funds and implement climate adaptation strategies that bolster community and environmental health, leading to food sovereignty.

Inspired by FNESS's successful approach, we are introducing strategic tools and technologies tailored to the needs to Sierra Nevada Tribes. With support from a UC Davis Aggie Climate Action for Equity Grant, the primary author is collaborating with current and former FNESS staff as well as Indigenous partners in the region to strengthen community-based resilience efforts. Sierra Nevada is home to more than 40 Native communities—some federally recognized, others state-recognized, and many still advocating for recognition—while some Tribal-identified individuals remain more dispersed. Indigenous Futures Society, an Indigenous-led organization, is dedicated to advancing cultural, ecological, and economic justice. Through partnerships with Indigenous communities and individuals, they support the development of tools and skill-building programs that enhance emergency preparedness, conservation, restoration, and climate adaptation efforts across the Sierra Nevada bioregion.

IK in the Sierra Nevada is inherently place-based and responsive to the many microclimates and microecologies within the region. Each community also has its own unique history and cultural traditions. It should not then be a surprise that when we approached several Indigenous communities with the suite of Decision Support Tools, we first needed to listen, to better understand each community and its challenges, current solutions, and needs. Group discussions could then move forward to identify how to adapt the lessons and know-how of FNESS for each group. Conversations took place through virtual meetings, phone calls, and importantly, in-person training-learning-adapting workshops, in Kamloops (See Figure 1) and on Sierra region Tribal-owned lands. A common thread was deep understanding of the extractive nature of previous western-led initiatives and a desire for knowledge-gathering that was Indigenous-led and that would stay within each community. Too many of previous western-based studies led to assumptions and presumptions about Indigenous communities and individuals, the relationship between and within groups, and their relationships to land and water. This led to developing a collaborative process of decision tool development centered on upholding data sovereignty (Figure 2).

3 Discussion: collaboration and adaptation of new strategies in the Sierra Nevada

It was critical to our collaborative approach that we center place-based knowledge of Tribal-owned lands and larger ancestral homelands. All agreed that better documentation of IK was needed. This in turn landed upon discussions of mapping, understanding that creating new maps centering Indigenous perspectives is a form of resistance against previous western-based representations of Native communities (Hunt and Stevenson, 2017). Nuances of multi-layered histories and understandings of landscape, ecologies, and peoples are centered. Place is not static; rather it holds countless layers of stories, meaning, memory, and relationality. Landscapes carry ancestral histories of stewardship, colonial disruptions, stories of survival, and current efforts of renewal. By honoring these interwoven histories, mapping is more than a technical exercise – it becomes a living assertion of Indigenous sovereignty, ecological memory, and cultural continuity. Indigenous-based mapping honors the rights of existence laid out in the UNDRIP, inclusive of the rights of lands, waterways, and human communities. Using GIS-based mapping technologies then can become an integral part of the process of transferring knowledge intergenerationally. Mapping also becomes a form of

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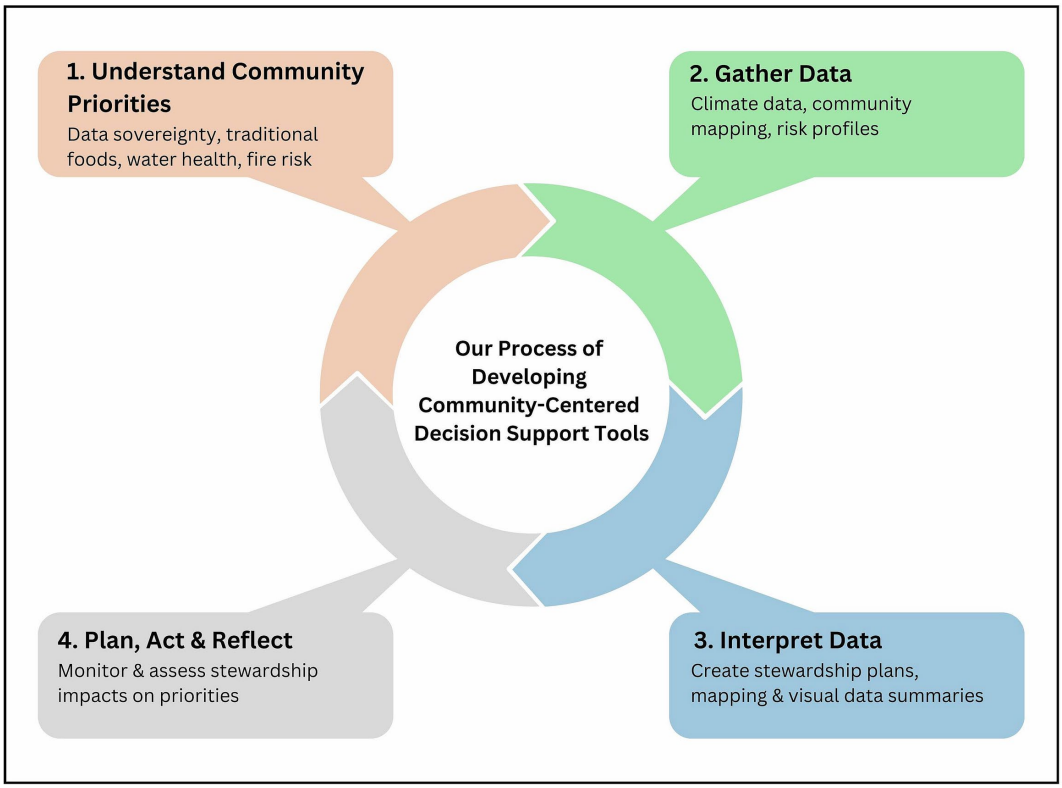

FIGURE 2
Our process of developing community-centered decision support tools with First Nations Emergency Services (FNESS) and diverse communities in the Sierra Nevada.

documenting, acknowledging, and creating new maps for future generations to build upon, using current technologies to tell old stories and old histories in new ways.

For some communities, the immediate priority is addressing the lack of emergency services and infrastructure available to Tribal members before and after climate-related disasters. Many California-based Tribes and Indigenous communities have limited access to their ancestral lands due to the impacts of colonization, and community members are often dispersed across rural landscapes, making communication and connection challenging. Mapping roads, pathways, outside-community fire and emergency services assists Tribal governments in better understanding where people are located, how they are housed, and what outside-community infrastructure is available (if at all). Importantly, these Decision Support Systems are accessible by phone and tablet applications. Its ease of use (after limited training) makes it accessible to more community members. Several workshops and field testing (in California and British Columbia) show the promise of this program, and its immediate adoption by community elders and younger (20–30 years) Tribal members, with concomitant knowledge sharing.

3.1 Sierra Nevada native communities: building tools for food sovereignty case study

By adapting strategies developed by the First Nations' Emergency Services Society (FNESS) to local contexts, our collaborative has worked with individual Native communities to integrate two-eyed seeing (Indigenous Knowledge with Western safety protocols). This approach has addressed broader community-driven questions about climate mitigation, adaptation, resistance, and resilience. Recognizing that rural Tribes are among the populations most vulnerable to climate change impacts—particularly destructive wildfires in the Sierra Nevada region and British Columbia (Box 1)—each community has developed tailored, place-based solutions.

Staff from Colfax Todds Valley Consolidated Tribe and their FLICKER crew are utilizing Indigenous Decision Support Systems to map areas where cultural burning has been conducted, plan for future burns, and pilot a system to document Tribal values tied to archaeological and sacred sites, as well as areas critical for native plant propagation. By layering different types of data over time, communities can develop meaningful metrics for monitoring and success based on their own priorities. Similarly, community members from Greenville Rancheria are documenting the impacts of cultural burning on various species and habitats, creating GIS-based story that highlights its ecological and cultural significance. This effort showcases the benefits of cultural burning, including enhanced native plant understories and the regeneration of basketry materials, foods, and medicines. Additionally, leaders are developing a cultural burn plan to help other Indigenous communities navigate the often-complex regulatory processes required for controlled burns, streamlining jurisdiction-specific documentation. This initiative underscores the critical role of data sovereignty, ensuring that

BOX 1 Along the Western Coast of North America: a shared history of cultural fire

> *"Fire has been a natural process for eons. The tribes understood the role of natural fire and used fire as a management tool by intentional burning practices to promote a healthy ecosystem. This is Fire Governance in a responsible manner, caring for the lands."* – Darrel Cruz (Washoe)

As a long-standing impact of colonization, California's and British Columbia's Indigenous communities are now disproportionately impacted by the escalating threat of wildfires due to persistent inequities, the prevalent location of homes in rural and remote areas, and exclusion from policy-making processes. Alarmingly, in the U.S., Native Americans are six times more likely than other demographic groups to reside in areas highly susceptible to wildfires (Davies et al., 2018). The historical suppression of Indigenous cultural burning not only intensified the ecological challenges leading to elevated wildfire risk (Long et al., 2017). It also deepened the societal disparities faced by Indigenous communities, emphasizing the need for collaborative, sustainable, and mindful solutions.

In 1850, the U.S. Congress banned cultural burning in the Act for the Government and Protection of Indians (Johnston-Dodds, 2002) while Canada's Bush Fire Act of 1874, made Indigenous cultural burning punishable by fines or imprisonment (Rodriguez, 2021). Many Indigenous communities in British Columbia and California consider their cultures fire-dependent, with cultural practitioners for millennia using mixed-intensity controlled fire to actively steward landscapes, species, waterways, and habitats (Christianson et al., 2022). These practices maintain cultural keystone species used for textiles and medicines, reduce fuel loads, create wildlife habitats, and promote biodiversity among many others (Stewart, 2002; Goode et al., 2022). Cultural keystone species (CKS) "shape in a major way the cultural identity of a people, as reflected in the fundamental roles these species have in diet, materials, and/or spiritual practices" (Garibaldi and Turner, 2004). The suppression of cultural burning has disrupted these carefully balanced ecosystems, leaving landscapes more vulnerable to extreme fire events.

In the last decade, both British Columbia and California have been undergoing a transformation of fire governance from one of control and suppression to one of shared stewardship. Since 2021, pivotal policy changes in California, namely SB 332, AB 642 and more recently SB 310, signify a recognition of Indigenous science, Tribal relationships, and sovereignty (SB 310, Dodd, 2024; SB 322, Dodd, 2021). California now formally defines cultural burning and cultural fire practitioners, with adjusted liability standards, laying the foundation for increased cultural fire implementation on state lands. Starting in 2017, the province of British Columbia has taken a more collaborative approach with fire stewardship with B.C. Wildfire Service, First Nations (in alignment with UNDRIP), local communities, Ministry of Forests, and the forest industry all working together to build community resilience (Copes-Gerbitz et al., 2022). These changes are instrumental in mitigating wildfire risks and fostering Tribal engagement.

A consistent gap in the collaborative efforts is understanding and implementing the diverse values that Indigenous communities hold when it comes to stewardship. Current prioritization of landscapes for treatment and funding heavily relies on quantitative mapping methods, assessing ecological metrics, but lacking considerations for social, economic, or climate justice priorities. Additionally, while there are many geospatial tools used by state, federal and private entities to determine prescribed burning opportunities, very few of them consider community-guided Indigenous values, land use history, or intentionally identify stewardship opportunities (like cultural burning) for Tribal communities. These stewardship tools developed in collaboration with FNESS serve as a catalyst for initiating multi-agency partnerships and centering Indigenous priorities and leadership in the strategic application of cultural burning in various jurisdictions. Ultimately these tools strengthen Tribal capacities by leveraging data to secure essential funding for climate mitigation, reduce wildfire risk, and contribute to the healing and restoration of native plant communities integral to customs and traditions. The tools' versatility expands its use beyond wildfire risk mitigation, encompassing risks like drought and flood for Tribal communities.

communities generate and manage their own actionable data. By strategically sharing these data, Indigenous Nations can strengthen collaborations with agencies while maintaining authority over their land stewardship practices.

Both Indigenous communities navigate integrating IK with Western technologies and strategies while prioritizing the return of land stewardship to communities. They aim to do this in a way that preserves Tribal sovereignty while navigating requirements from government agencies. These efforts show promise to expand access to lands, increase funding through grants and contracts with agencies, and create more acres stewarded through Indigenous-led programs, as seen through Indigenous Guardianship programs. As a collaborative, we are still in the phase of tool development and improvement and outputs will emerge after multi-year implementation. Building on FNESS' success in British Columbia, we hope to see healthier macro- and microecologies emerge in the Sierra Nevada, fostering increased Indigenous access to ancestral lands, the revitalization of Native foods and other cultural processes.

In addition, other partnerships with regional Tribes are exploring Decision Support System technologies and strategies to establish Indigenous Guardian programs focused on protecting waterways, particularly the critical headwaters of the Sierra Nevada that sustain both the region and the Central Valley to the west. Mapping these waterways has proven essential for understanding current plant and animal communities, riverine contaminants, historical changes to water flows, and—most critically from an Indigenous perspective—the interconnected relationships between these elements, Tribal sovereignty, and the well-being of communities.

Upholding food sovereignty goes hand in hand with maintaining healthy ecosystems—the foundation of any truly sustainable food system (Box 2). Many Indigenous communities state that reinvigorating community stewardship of streams, waterways, meadows, forests, and wetlands—integral to Indigenous food systems—can also play a critical role in mitigating climate change impacts such as floods and wildfires. By removing invasive species, replanting riparian areas, and implementing cultural burning practices, we can restore these vital ecosystems (Goode et al., 2022). Experimental studies in central and northern regions of California document that water stewardship and management – such as dam removal and riparian restoration – improves water quality and fish habitat (Saulters, 2014). Studies in the mid-Klamath region report that the use of fire increases the abundance of food and culturally significant plant species while reducing fuel loads that contribute to wildfire severity (Norgaard, 2014). Reviews of ecocultural restoration centering two-eyed seeing methodologies advance both ecological integrity and Indigenous cultural traditions because they are connected inherently among communities (Hankins, 2013; Saulters, 2014; Long et al., 2020; Martinez et al., 2023). Continuous observation and research that employ two-eyed seeing will deepen our understanding and enhance active management of these landscapes. Together, these efforts not only restore ecological balance but also ensure a resilient future rooted in ancestral practices and sustainable stewardship.

BOX 2 Expanding land access is a key step to sustaining indigenous food sovereignty

> *"Their knowledge wasn't written in textbooks—but it was detailed, tested, passed through generations with discipline and care.*
> *It is empirical, adaptive, and observational. It is science.*
> *You will not find it in peer-reviewed journals.*
> *But ask a Maidu elder when to burn the willow.*
> *Ask how to sweeten an elderberry bush.*
> *Ask why the monarch needs the milkweed.*
> *They'll tell you.*
> *Because they were told.*
> *Because the land told them."* – Trinity Manning (Taylorsville Maidu)

As we gathered together at our workshops in the Sierra Nevada and British Columbia, the enduring impacts of colonialism surfaced repeatedly in our discussions. Conversations highlighted both shared and unique colonial histories in the U.S. and Canada, particularly regarding land access. Land access is a critical need for communities to carry on traditions that maintain both ecosystem and community health (Figure 3). In the U.S., Indigenous Peoples have lost 98.9% of their ancestral homelands due to colonization, and 42.1% of Tribes lack a federally or state-recognized Tribal land base today (Farrell et al., 2021). In British Columbia, Canada, 95% of the province remains unceded First Nations territory, with no treaty agreements in place (Welcome BC, 2025).

A significant challenge for both First Nations, California Tribes and Indigenous communities is securing access to their ancestral lands, as Native Nations typically have small land bases despite vast cultural territories. In California, most land is either federally or privately owned, with only 3% designated as state land (California State Geoportal, 2023). In British Columbia, approximately 94% of land is classified as provincial (comparable to state land), while private ownership accounts for 4.9%, federal land for 1%, and First Nations Treaty and Title lands for just 0.2% [Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRO), 2011]. In both regions, less than 1% of land is officially designated as belonging to Indigenous communities. Given these realities, expanding land access is not just about reclaiming physical spaces—it is about restoring stewardship, protecting sacred sites, and ensuring the survival of cultures and ecologies of these landscapes.

As the original stewards of the land and waters, Indigenous Peoples worldwide continue to face significant barriers to accessing, managing, and restoring their ancestral lands. These barriers are deeply rooted in colonial policies that disrupted traditional land tenure systems, displaced communities, and imposed restrictions (and criminalization) on customary practices such as cultural burning and sustainable harvesting. Despite these challenges, Indigenous communities continue to demonstrate remarkable resilience and innovation in reclaiming their places as land stewards.

Our work in adapting decision support technology is not just about data—it is a policy intervention. Deepening Indigenous partnerships across the Sierra Nevada and British Columbia means that we are leveraging critical resources and data practices to support Indigenous stewardship. These accessible geospatial decision-support tools enable communities to track, map, model, and monitor landscapes. With accurate, up-to-date data, Tribes can secure a meaningful seat at the table to advocate for and implement strategic stewardship efforts, regardless of jurisdictional complexities.

The loss of ancestral lands due to allotments, broken treaties, and privatization has severely restricted stewardship. By integrating decision-support tools with Land Back initiatives, Indigenous communities can identify cross-collaborative, jurisdictional opportunities for restoration and stewardship. These tools can help navigate complex land classifications, overlapping authorities, and regulatory frameworks, empowering communities to reclaim agency over their traditional territories. By mapping ancestral lands, tracking ecological changes, and demonstrating the effectiveness of Indigenous-led stewardship, these technologies not only strengthen Tribal sovereignty but also provide concrete evidence for policy shifts that support Indigenous land and resource governance.

4 Reflection: the future of community collaborations and strengthening sovereignty

> *"History and landscape health is more about place than time."* - Brian Wallace (Washoe/Nisenan).

Reciprocity is at the heart of this collaborative. Our Canadian and Californian colleagues share knowledge and support as we navigate shifting policy landscapes. Collaborating with the First Nations Emergency Services Society (FNESS), an Indigenous-led nonprofit, offers a unique advantage for Indigenous communities seeking to integrate accessible, decision support tools to enhance and monitor the impacts of diverse stewardship practices. Unlike conventional geospatial companies, FNESS operates with a deep understanding of diverse Indigenous values, eliminating the need to first translate an Indigenous worldview to external partners. This shared foundation fosters a more culturally relevant approach to land and resource management. At the same time, the diversity of cultures within Indigenous communities means that while there is a unifying perspective on stewardship, localized knowledge, governance, and priorities still vary greatly.

Data sovereignty remains a central issue in these collaborations—specifically, community-held and community-generated knowledges (See Figure 2). Such knowledge is diverse, powerful, and protected, ensuring that data is generated, controlled, and utilized in ways that align, represent, and uphold community needs and values. Generally, First Nations organizations follow principles of data management, focusing on Ownership, Control, Access, and Possession (OCAP®) (First Nations Information Governance Centre, 2025). This ensures that supporting safe and healthy Indigenous communities includes an understanding that data collected on behalf of communities belongs to those communities. It is important to recognize each community's right to data sovereignty and offers tools and data support to uphold that right. Tools developed through these partnerships must prioritize accessibility, transparency, and respect for Indigenous governance, reinforcing a model where communities maintain authority over their own data to effectively engage in broader policy and land management conversations.

As we reflect on our work, a fundamental truth emerges—Indigenous food sovereignty is inseparable from land, water, and cultural stewardship. The communities we collaborate with, like many other Indigenous communities worldwide, are already facing climate-related crises, making stabilization and community safety their

FIGURE 3
At first glance, this photo may show only the aftermath of a wildfire, with fire-scarred black oak, cedar, white fir, and ponderosa pine standing against the landscape of the Mosquito Fire burn area. For Colfax Todds Valley Tribal members in the Sierra Nevada, this land also reflects thousands of years of deep relationship. It is home to native plant gathering areas - where pine nuts, acorns, manzanita berries, grasses, elderberry, and gooseberry thrive – as well as hunting grounds for deer and quail and cherished ceremonial spaces. Rich with traditional foods and medicines, this landscape embodies a reciprocal connection: as it nurtures the community, the community, in turn, stewards and sustains it.

immediate priorities. Yet, they continue to navigate the ongoing impacts of colonization—genocide, land dispossession, and the suppression of Indigenous Knowledge—while actively reclaiming their histories, rights, and data. The development of these data tools fosters processes, strengthens connections, and creates knowledge-sharing spaces that help envision the future of community-led Indigenous Guardianship programs.

Food knowledge is deeply place-based, shaped by people, culture, regional microclimates, and ecologies, and passed down through generations. A key component is working together towards ecocultural goals that reflect the diversity of communities present on these landscapes. To support food sovereignty, we must first restore the lands and waterways that sustain it. This requires centering Indigenous leadership, honoring the inherent rights of land and water to thrive, and ensuring that cultural practices—such as cultural burning and native plant restoration—are recognized into broader stewardship efforts.

At the heart of this work are Elders and Knowledge Bearers, who hold deep understandings of native plants, cultural fire, and traditional foodways. Indigenous science is not simply documented—it is lived, transmitted through participatory communication, and strengthened through community gatherings. Mapping and technology can support these efforts to build decision support tools, but true knowledge transfer happens through tending the land, gathering with one another, and reinforcing family and community ties (Figure 3).

Our collaboration continues to explore partnerships between several Indigenous communities in California, two Indigenous-led NGOs, and a university partner to lead efforts in building resilient and sustainable food systems through practices deeply rooted in land stewardship including waterway restoration, cultural burning, and emergency response. Emphasizing equitable decision-making processes and data sovereignty, we address how Indigenous governance structures and collaborative approaches can be incorporated into broader food system governance frameworks.

Moving forward, our collaborations strive to foster spaces—where Elders, youth, agency partners and all those in between can come together to share, learn, and thrive. Supporting Indigenous food sovereignty requires more than just technical tools; it demands true access to ancestral lands, the recognition of self-determination, and unwavering commitment to community-led processes. Weaving together Indigenous Knowledges, strategic partnerships, and emerging technologies, we are actively strengthening the pathways toward food sovereignty, ensuring that traditional foodways endure for generations to come.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article. Otherwise, identifiable images or data were blurred.

Author contributions

NF: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. BM: Conceptualization, Methodology, Project administration, Resources, Software, Supervision, Writing – review & editing. BW: Conceptualization, Methodology, Project administration, Resources, Supervision, Visualization, Writing – review & editing. RA: Conceptualization, Project administration, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Correction note

A correction has been made to this article. Details can be found at: 10.3389/fsufs.2025.1646145.

Publisher's note

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