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A Geodatabase of Historical Indigenous Fire Practices in the Pacific Northwest

Running footer: Indigenous burning practices

4 tables, 5 figures

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Abstract

Indigenous communities across the Pacific Northwest of North America (PNW) historically used fire for subsistence and cultural practices. Burning occurred across multiple seasons as fuels and weather permitted, including late winter and early spring in some regions. Regular, mixed-severity burns were applied to enhance resources, support hunting and game management, and maintain ecosystems, with these practices having the ancillary effect of reducing fuel accumulation, improving habitat, and mitigating wildfires. Fire suppression in the 20th century, including the prohibition of Indigenous burning and suppression of lightning-caused fires, resulted in widespread fire exclusion and decreased fire frequency. However, with increasing fuel accumulation, invasive species, and climate warming, fire probability has increased in many systems, contributing to higher fire frequency, severity, and burned area. Interest is growing in restoring Indigenous burning for rebuilding resilience in fire-adapted ecosystems, but implementation remains limited by regulations, land ownership, and in some areas, loss of knowledge. Here, we document Indigenous fire practices in the PNW and synthesize these observations into a geodatabase. Through literature review we collected data on cultural-linguistic group, location, seasonality, frequency, purpose, severity, post-burn vegetation response, environment, burned area, fuel type, and uncertainty. The geodatabase contains 73 observations linked to 80 polygons from California to Alberta, showing that Indigenous burning historically occurred during multiple seasons but mostly in summer and fall, primarily for resource enhancement, hunting and game management, and ecosystem maintenance. Our research provides insight into historical anthropogenic fire, supporting the integration of traditional fire knowledge into wildland fire management.

Key Points

- The use of frequent, mixed-severity fire was widespread across the Pacific Northwest and mostly occurred in late summer and early fall.
- Fire was primarily used for food crops, medicinal, and basketry resource enhancement, hunting and game management, and ecosystem maintenance.
- This geodatabase links historical fire practices to Indigenous territories to inform future fire stewardship.

Keywords: Cultural burning, Fire stewardship, Traditional ecological knowledge, Wildfire resilience, GIS

Introduction

As a natural ecological process, fire is deeply intertwined with vegetation growth and climate variability, shaping ecosystem structure and function (Loehman et al., 2020). In many fire-adapted ecosystems, regular low-intensity fire helps reduce surface fuel accumulation, thereby decreasing the likelihood and severity of future wildfires (Fernandes & Botelho, 2003; Keeley & Pausas, 2022; Schwilk et al., 2009). In western North America, the frequency and severity of wildfires has increased significantly in recent decades, driven largely by climate change, including rising temperatures, earlier snowmelt, increasing fuel loading and aridity, and longer fire seasons (Abatzoglou & Williams, 2016; Turco et al., 2023; Westerling, 2016; Westerling et al., 2006). Rising temperatures consequent drought are significantly extending the duration and intensity of the fire season, contributing to a two- to threefold increase in area burned across many western forests (Dennison et al., 2014; Reilly et al., 2021; Turco et al., 2023; Walsh et al., 2018; Wimberly & Liu, 2014). For example, in Pacific Northwest forests, the area burned increased by nearly 5000% between the 1970s and early 2010s, largely due to a very low baseline in the earlier decade (Westerling, 2016). Compared to historical patterns, recent wildfires are larger, more intense, and more frequent, hindering forest resilience and driving shifts in plant species (Mansoor et al., 2022). In tandem, past and present fire suppression policies, including those related to lightning-ignited fires and traditional burning by Indigenous Peoples beginning in the mid-19th century, have modified long-established fire regimes, resulting in fuel accumulation and compositional change, ultimately increasing the risk of larger, more severe wildfires (Boerigter et al., 2024; Pyne, 2017).

In the Pacific Northwest, where old-growth forests comprise an important part of many ecosystems, the increasing frequency and severity of wildfires raises important questions about how these landscapes respond to human activities and climate change over time (Hessburg et al., 2021; Prichard et al. 2021). While recent decades have provided an abundance of data on short- and medium-term effects of fire, it remains difficult to assess long-term ecological impacts (Whitlock et al., 2010). To understand how fire shaped Pacific Northwest ecosystems and how these might respond to future changes in climate and fire, it is valuable to consider centennial to millennial timescales (Reilly et al., 2021). This is especially important for old-growth forests that can take 150–400 years to reach maturity depending on forest type (Coughlan et al., 2024; Strittholt et al., 2006). Gaining a long-term understanding of fire's role in these landscapes, and anticipating the long-term consequences of ongoing climate change (Eisenberg et al., 2024), may be aided by analysis of the paleoecological record (e.g., Patterson, 2006; Whitlock et al., 2010). By examining paleoenvironmental archives including charcoal deposited in lake sediments and fire-scarred trees, we can begin to piece together how human use of fire, in parallel with climate variability and change, influenced forests, woodlands, grasslands, and shrublands throughout the

Holocene in the Pacific Northwest (Gavin et al., 2007; Marlon et al., 2012; Parks et al., 2025; Patterson, 2006; Walsh et al., 2015; Walsh et al., 2018; Whitlock et al., 2003; Whitlock et al., 2010). Knight et al. (2022) provide a regional example from the Klamath Mountains, demonstrating how Indigenous burning and climate variability in a natural fire regime together maintained long-term stability of forest structure over the last millennium. This historical context is essential not only for understanding past ecosystem dynamics, but also for anticipating how these landscapes may respond under ongoing and future climate change.

Millennia before modern fire management practices were introduced, Indigenous Peoples across the Pacific Northwest (PNW) employed frequent, low- to mixed-severity fire, often more frequent than lightning ignitions, as a deliberate tool to manage landscapes for both material and food resources (Hamman et al., 2011). The PNW has been inhabited by Indigenous Peoples since at least the late Pleistocene (>16,000 years ago), with archaeological evidence from the Cooper's Ferry site in Idaho indicating repeated occupations between 16,560 and 15,280 calibrated years before the present (Davis et al., 2019). Additionally, preliminary findings from the Rimrock Draw Rockshelter in eastern Oregon suggest possible occupation as early as ~18,250 years ago (BLM, 2023). There is abundant archaeological evidence of continuous use of and impact on vegetation mosaics throughout the Holocene (Coughlan et al., 2024; Letham, 2024; Walsh et al., 2015; Walsh et al., 2018). Prior to Euro-American colonization, many landscapes were adapted to regular application of anthropogenic fire, with each fire reducing the intensity and extent of subsequent fires by consuming available fuel and creating barriers in a form of self-regulation (Boerigter et al., 2024; Parks et al., 2014, 2015). Indigenous fire stewardship also modified fire regime components such as frequency, seasonality, locality, extent, and intensity relative to lightning-driven fire regimes, while sustaining ecological and cultural values, including food, materials, biodiversity, and ceremonial practices (Lake, 2021; Long et al., 2021). Euro-American colonization of the PNW in the 19th century led first to large scale land use changes that affected wildfire from the regional extinction of native megafauna, e.g., grizzly bears, wolves, and on the eastern margins, bison, widespread beaver trapping that altered riparian ecosystems, the expansion of ranching and agriculture, and the development of logging and mining industries (Bell, 2024; Boerigter et al., 2024; Fairfax and Westbrook, 2024; Hamman et al., 2011; Reilly et al., 2021). Indigenous burning practices were initially adopted by some Settlers, including Métis fur traders who may have combined Indigenous fire use traditions, e.g., for hunting with some European practices. Later European Settlers introduced new applications for fire such as slash-and-burn agriculture, firing for pasture, ease of travel, and reduction of brush (Pyne, 2017). However, suppression of both natural and anthropogenic fire began in the mid-19th century, when territorial and state governments passed ordinances restricting burning (Pyne, 1982; Hamman et al., 2011) and was further intensified in the 20th century under state, provincial, and federal initatives, including the U.S. Forest Reserves (1906), British Columbia Ministry of Forests (1912), Civilian Conservation Corps and Canadian unemployment relief camps (1933), and smokejumpers (1940) (Copes-Gerbitz et al., 2022; USDA Forest Service, 1995). This fire suppresion caused further changes to vegetation (Hamman et al., 2011).

The disruption and cessation of Indigenous burning practices by the middle of the 20th century resulted in structural changes in ecosystems due to the encroachment of shrubs and trees and subsequent increases in forest density (Cocke et al., 2005; Hamman et al., 2011; Pyne, 2017). With the exclusion of frequent, small fires, ecosystems lost processes that stimulated native vegetation growth and reproduction, reduced invasive species and weed seeds, and consumed fine fuels such as thatch and moss. Without these fires, populations of both native animal and plant species have declined (Hosten et al., 2006, Hamman et al., 2011). For example, fire exclusion in the 1900s has allowed native Douglas-fir (*Pseudotsuga menziesii*) to encroach into coastal prairies and oak woodlands, while invasive exotic species such as Scotch broom (*Cytisus scoparius*) and cheatgrass (*Bromus tectorum*) have also spread and altered fire regimes across the PNW (Tveten & Fonda, 1999; Whitlock et al., 2003). Today, with the growing severity of wildfires and the limitations of suppression-based strategies becoming increasingly evident, there is increasing interest in traditional ecological knowledge (TEK) and its potential role in mitigating wildfire risks (Charnley et al., 2007; Coughlan et al., 2023; Stucki et al., 2021). Traditional fire knowledge (TFK) is a more specific concept, defined by Huffman (2013) as the knowledge, beliefs, and practices related to fire that are passed down through generations and developed for specific purposes and landscapes. Incorporating TFK into current fire management strategies is an opportunity to create sustainable approaches to wildfire, supported by arguments for place-based fire management rooted in local ecological and cultural knowledge and applied case studies such as the Confederated Colville Tribes' collaboration on fuels treatments (Ray et al., 2012; Wynecoop et al., 2019). It is important to note, however, that shifting fire regimes under climate change may necessitate adaptation of traditional fire practices (Lake et al., 2017). To understand how to apply traditional fire knowledge in the future, we must first understand how fire was used in the past (Boyd, 2021).

The goal of this study is to build upon previous regional overviews that recognize Indigenous fire as part of broader cultural-ecological systems (e.g., Pullen, 1996) by cataloging historical anthropogenic fire use by Indigenous Peoples in the Pacific Northwest and surrounding regions, addressing critical gaps in the historical record and their relevance to modern fire management. While it is well-documented that Indigenous Peoples actively used fire to shape ecosystems for millennia, the literature lacks a comprehensive synthesis that spatially maps these practices within a common descriptive framework. To address this need, we created a geodatabase of historical Indigenous burning practices to assess variability in space, time, and purpose of burning. We ask: where, how, when, and why did Indigenous Peoples practice burning in the PNW? We hypothesize that Indigenous burning was historically widespread, adapted to seasonal weather patterns and local vegetation, and successfully used to achieve a range of beneficial outcomes. Our study aims to offer valuable insights for policymakers, researchers, land managers, and Indigenous communities to better understand historical fire regimes and evaluate the potential of traditional ecological knowledge (TEK) to inform modern fire mitigation and ecological restoration efforts (Coughlan et al., 2023; Long et al., 2021). Revitalizing Indigenous fire stewardship also supports community-grounded priorities such as cultural revitalization and food sovereignty, sustaining knowledge systems, ceremonial and subsistence practices, economies, and livelihoods (Lake, 2021). Furthermore, the resulting geodatabase will serve as a resource for numerical simulation modeling to improve understanding of human-environment interactions in both the past and future.

Methods

Study area

Our study area comprises the Pacific Northwest and adjacent regions, including the U.S. states of Washington, Oregon, California, Idaho, and Nevada, as well as portions of British Columbia and Alberta in Canada. The exact boundary used in this study originates from Level 5 watersheds in the Pacific Northwest and California regions (Lehner & Grill, 2013), with a 100 km buffer along the eastern slope of the Canadian Rocky Mountains, and a 200 km buffer east of Idaho to include the Greater Yellowstone Ecoregion of northestern Wyoming (Figure 1). This transboundary region spans a range of ecological zones from coastal temperate rainforests to interior dry coniferous forests and grasslands and Great Basin semi-deserts. We expanded beyond a strict definition of the PNW to include adjacent regions both to capture additional high-quality data sources immediately outside this boundary and to reflect the seasonal movements of Indigenous groups (e.g., Nez Perce and Cayuse) whose territories and activities extended into the Great Plains, where seasonal buffalo hunts were a prominent practice (Branson, 1995). We also incorporated ecologically analogous fire-prone systems in neighboring regions, such as oak-prarie mosaics in California, where Indigenous burning has long been documented as a keystone ecological and cultural process (Hankins, 2015; Stewart, 2009).

The study area includes 36 biogeoclimatic ecosystem zones from the BEC v13 dataset (2025). In the Biogeoclimatic Ecosystem Classification (BEC) system, zones are the highest ecological unit and characterize areas where environmental conditions and dominant plant communities remain relatively consistent (MacKenzie & Mahony, 2021). These ecosystems provide insight into the types of landscapes Indigenous Peoples were burning. Zones included in the study area are shown in Figure 1.

Within our study region, the Native Land database (Native Land Digital, 2015) identifies the traditional territories of 320 Indigenous Peoples in the form of GIS polygons. While the Native Land polygons do not represent legal or official boundaries of Indigenous nations, it provides a framework for Indigenous territories that is informed by Indigenous knowledge holders and the contributions of Indigenous communities. When these territories are overlaid with Level I ecoregions (Commission for Environmental Cooperation, 1997), 10 territories intersect with The Great Plains, 184 intersect with the Marine West Coast Forest, 76 intersect with Mediterranean

California, 64 intersect with the North American Deserts, 13 intersect with the Northern Forests, and 158 intersect with the Northwestern Forested Mountains. Across this ecological range, there is also a great diversity of tribal cultures, represented by distinct culture areas like the Northwest Coast, Columbia Plateau, Great Basin, Plains, and California (Kroeber, 1939). Although our spatial framework is based on ecological ecosystems rather than anthropological cultural areas, we acknowledge areas of overlap between these systems.

Literature review

We conducted a comprehensive literature review to compile observations of Indigenous burning practices in the study region. Using a systematic approach, we recorded the documented attributes of Indigenous fire practices, including Indigenous group, period of record, seasonality, frequency, severity, purpose, post-burn vegetation response, environment, burned area, fuel type, and uncertainty of the observations. Our review utilized both primary and secondary literature identified through Google Scholar and Web of Science database searches, along with selected gray literature and library resources. Primary sources included ethnographic accounts containing oral histories, interviews with Indigenous knowledge holders, and firsthand Settler observer records. Secondary sources included syntheses, ecological reviews, and historical analyses. We recognize that these sources are shaped by biases and that it is important that communities ground-truth the data to ensure accurate representation of fire practices. One example is the inherent male bias in many ethnographies, which led to the underrepresentation of women's activities related to Indigenous fire use in the late 19th and early to mid-20th centuries (Zeig, 2024). Selection criteria prioritized sources that explicitly discussed Indigenous fire management practices of specific Indigenous Peoples in the Pacific Northwest, increasing the relevance and reliability of the information. Key words in our database searches included "Indigenous burning practices", "Pacific Northwest", "cultural burning", "traditional ecological knowledge" and more. It is important to note that these search terms reflect primarily academic framings and are not always reflective of how these practices are discussed within Indigenous communities, and thus represent a limitation on the scope of source material yielded. The primary search terms are listed in Table 1. While the number of relevant hits reported is approximate, particularly in the case of Google Scholar where relevance could not always be determined without a full-text review, Table 1 reflects the general scope of results. We conducted additional searches using the names of specific Indigenous Peoples in data gaps and when initial search results lacked detail or certainty, though these group-specific searches are not individually represented in Table 1. In cases where a source referenced a broader cultural-linguistic group that includes multiple Indigenous Peoples, attributes were assigned to all corresponding Indigenous territories in the Native Land polygons to maintain consistence between the literature and spatial representation, recognizing that these polygons serve as a generalized spatial framework rather than definitive territorial boundaries. We then identified attributes and extracted using an uncertainty classification to assess the reliability of the information (Table S1). We carefully reviewed each source to determine whether our selected attributes were explicitly stated or inferred from the broader context of the paper. This uncertainty classification system helped ensure accuracy in the analysis.

Lexical analysis

To support the thematic coding of Indigenous fire practices, we conducted a lexical analysis using RStudio. A combined text file containing all of our literature sources was read into R and processed using the tidytext package. The text was tokenized into individual words, and common stop words and domain-irrelevant terms were removed to clean the dataset. We then generated a frequency table to identify the most commonly used words across all sources. To examine how fire was typically described in the literature, descriptive terms were manually assigned to each attribute: fire frequency, fire severity, purpose of burning, post-burn response, seasonality of burning, types of fuel, environment, burn area, and period of record. Each attribute was associated with a curated list of relevant keywords based on prior reading and coding schemes. We filtered and grouped words matching each list by attribute to produce a faceted bar chart visualizing the most common descriptors within each category. Using a lexical analysis allowed for a structured, quantitative view of how specific aspects of Indigenous fire use are characterized in literature. However, it should be noted that this analysis captures only word presence, not contextual nuance, and should be interpreted as a preliminary lexical overview demonstrating broad trends in support of qualitative interpretation. Analysis of the literature and manual coding into categories allows for this qualitative interpretation that accounts for contextual nuance, and is subsequently a better reflection of the literature itself.

Thematic coding schemes

We organized the data extracted from our literature review in Microsoft Excel with attributes in columns and different Indigenous Peoples in rows. Fire frequency, severity, and burn area were categorized as Low, Medium, or High depending on language used in the sources to describe the burning practices. We coded the purpose of burning into 6 different categories, including ecosystem maintenance, invasive species control and pest reduction, spiritual and community practices, hunting and game management, fire management and land clearing, and resource enhancement. These categories were chosen based on the occurrence of various reasons found throughout this specific literature review, and they align with more detailed typologies documented in the literature, such as Williams (2003), who summarized eleven major purposes of Indigenous fire use. The coding scheme, including overall categories and what purposes are listed under each category, is shown in Table S2.

Post-burn response was coded into similar categories, including ecosystem maintenance, hunting and game management, fire management and land clearing, resource enhancement, soil replenishment, and increased water flow (Table S3). We chose these categories based on post-burn response occurrence. Fuel type and environment attributes were coded into 10 categories depending on occurrence (Table S4 & S5). Each of the categories were assigned a corresponding number in the final geodatabase. Due to ambiguity, we left period and culture information attributes as broad descriptions and divided seasonality into 14 categories to maintain precision due to the similarity of the data.

Attribute table

Once the fire attributes were categorized and coded numerically, we organized the data into a final attribute table, with each row representing an Indigenous Peoples. We then assigned the identification ("id") values from the Native Land Digital (2015) data to each corresponding Indigenous territory in our attribute table, allowing the table to be spatially joined to the Native Land Digital (2015) polygons.

Geodatabase

We loaded the attribute table into QGIS version 3.38.1-Grenoble, an open-source Geographic Information System (GIS) software (QGIS.org, 2025), and linked each row to polygons of Indigenous territories from Native Land Digital (2015). To accomplish this, we clipped the Indigenous Territories Native Land Digital (2015) file to the study and removed all Indigenous territories that we did not find linked to burning practices in the literature review. The data was exported as a comma-separated values (CSV) file, imported into QGIS as a table without geometry, and joined to the Native Land Digital (2015) polygons.

After joining fire attributes to Indigenous territories, we converted each Native Land polygon to a centroid point. This prevented implying that burning occurred uniformly across entire territories and avoided flattening ecologically distinct fire practices into one spatial unit. Each centroid was then intersected with Biogeoclimatic Ecosystem Classification (BEC) zones from the Forest Carbon and Climate Services Branch of the BC Ministry of Forests (2025), which represent major ecological units defined by climate and dominant vegetation (MacKenzie & Mahony, 2021). The described fuel types and environmental context for each burning observation were compared with vegetation descriptions in the intersected ecosystem (Meidinger & MacKenzie 2024). If the burning description did not align with the mapped ecosystem, the centroid location was either moved to a more ecologically suitable neighbouring ecosystem while remaining within the territory boundary, or, when available, directly to a named place referenced in the source. We acknowledge that historical land management and subsequent fire exclusion may have altered vegetation communities over time, meaning that present-day ecosystem classifications (based primarily on climate and soils) may not fully reflect historical vegetation conditions at the time of burning. Uncertainty in ecosystem assignment was evaluated by considering how well documented fuel types aligned with ecosystem vegetation descriptions, while also incorporating potential ambiguity related to proximity to ecosystem boundaries and the number of ecosystems intersecting each Indigenous territory. This classification resulted in three uncertainty levels (High, Medium, Low), which were used to assess confidence in ecosystem assignments in the study area.

After placement of centroid points was finalized, fire attributes were summarized at the ecosystem scale. First, point attributes were assigned to ecosystems using a modal approach, where the most common value among all centroid points within an ecosystem was selected. However, because many ecosystems contained more than one type of observed fire practice, we created combination categories to preserve within-ecosystem variability for fire frequency, severity, and observation uncertainty attributes. By joining attributes by location, we counted how many centroid points of each category (e.g., low-, medium-, or high-frequency burning) occurred in each ecosystem. New fields were created to assign labels such as low-medium, medium-high, or low-high when multiple categories were present, and single labels (e.g., low) when only one category was present. This approach maintained ecosystem-scale summaries while avoiding flattening differences in fire frequency, severity, and uncertainty across landscapes in the study area.

Results

Indigenous Peoples linked to fire use

Our targeted literature review resulted in data collected from 63 sources (the bibliography of sources is provided in the Supplementary Materials). Most sources named a number of different Indigenous Peoples and had broader information from a large spatial extent, with a few describing only a single Indigenous People from a specific locality. Some historical ethnographic sources provided more precise geographic detail (e.g., Boyd, 1999; Stewart, 2002), whereas more recent Indigenous authors have been more specific about fire types and fire effects, often influenced by contemporary wildland fire science and management terminology (e.g., M.K. Anderson; F.K. Lake; A.C. Christianson; D. Hankins; M. Wyncoop; J.W. Long). From these sources, historical fire use was described for 73 Indigenous Peoples in the study area (Figure S1). Groups such as the Karuk, Yurok, Klamath, Chumash, Kalapuya, Dënéndeh, Northern Paiute, and Nlaka'pamux were among the best documented in the literature, supported by detailed ethnographies and oral histories. An example of low uncertainty comes from an ethnographic account of fire use by the Dene and Cree of Fort Nelson First Nation:

> In Northeastern British Columbia, the Dene and Cree of Fort Nelson First Nation used fire for multiple reasons, including the following: grass burning and clearing, vegetation regrowth, esthetics, spiritual/ceremonial, hunting, protection from animals and insects, warmth and cooking, communication, and light. Spring burns were more common than fall burns due to the importance of snow being used as firebreaks, and an activity the whole family would engage in together. Burns are still employed to improve bison habitat in their territory. (Christianson et al. 2022: 263)

This example provides clear documentation of purpose, seasonality, participation, and cultural context. Additional attributes we collected are provided elsewhere in the same source, which draws on the extensive ethnographic work of Lewis and Ferguson on Dene and Woodland Cree fire knowledge in northern Alberta (Christianson et al. 2022). For example, frequency and severity are outlined in the statement: "meadow burning was best done in the spring (with snow still in the forest edge) through low intensity burns on a frequent rotation (i.e., every few years)."

(Christianson et al. 2022: 263). This is an example of low uncertainty, as all attribute information is either explicitly stated or supported in the source and is linked directly to Dene Peoples, whose traditional territory is Dënéndeh.

In contrast, many Indigenous Peoples were more sparsely documented, with the Indigenous cultural-linguistic group only mentioned by name and most attribute information derived from broader details in the source (Table S1). This was particularly the case in coastal British Columbia (e.g. Heiltsuk, Ditidaht, Nuu-chah-nulth, and Nisga'a) and in Northern California and Oregon (e.g. Lassik, Yana, Wiyot, and Cahto). While Plateau peoples are generally well-documented in ethnographic sources, Spokane and Kalispel were represented by higher uncertainty. An example of a high uncertainty literature source comes from a Settler diary account cited in Lepofsky et al. (2003) regarding fire near the Upper Skagit:

> On this side of the stream [Skagit River] we found the whole forest burned by late fires, ignited by persons lately encamped here. Smoke was still arising in all directions from numerous footlogs and trees ect. [sic]. Fires are very frequent during the sumer [sic] season in these Mountain forests and are often ignited purposely by some of the Indian [sic] hunting in these Mountain regions, to clear the woods from underbrush & make travel easier. Once ignited, they generally burn the whole summer, and only the drenching rains of the fall are able to check their further spread. (Custer 1866:20, as cited in Lepofsky et al. 2003)

Lepofsky et al. (2003) note that "this reference is consistent with what we know about the use of prescribed fire among the Stó:lô, the Nlaka'pamux, and the Upper Skagit in general," and is subsequently an example of a high uncertainty source where an Indigenous People were mentioned but not directly tied to the attribute information. In addition, we retain the terminology used in the original source while acknowledging that cultural burning and prescribed fire are not synonymous and may reflect different purposes and objectives. Some sources with high uncertainty did not list every attribute; in these cases, inference from the overall context of the paper was used (e.g., inferring seasonality based on the purpose of burning, such as for berry harvest). Overall, the literature included both primary ethnographic literature and secondary syntheses, containing interviews, oral histories, Settler diaries, historical syntheses, and ecological reviews, with relatively little reliance on archaeological or paleoecological data.

Lexical analysis

The lexical analysis is shown in Figure 2, representing the most frequently used words to describe attributes of Indigenous burning. The most common terms used to describe burn frequency were “annual”, “frequent”, and “seasonal”, while severity was most often described as “low”, “controlled”, and “moderate”. Common words describing purposes included “management”, “restoration”, and “habitat”, with post-burn responses emphasizing “growth”, “diversity”, and “return”. Burning was commonly associated with “spring”, “summer”, and “fall” seasons, burning “oak”, “grass”, and “shrubs” in “oak”, “prairie”, “conifer”, and “grassland” environments. Burn areas were mostly described as “limited”, “patchy”, or “widespread”, and words describing period were commonly “historic”, “modern”, “prehistoric”, and “immemorial”. This analysis highlights general trends in how Indigenous fire practices are described by word counts and does not include contextual nuance. It supports the broader thematic coding conducted in this study.

Geodatabase

Our geodatabase is summarized in 16 maps that include fire frequency, fire severity, seasonality, burn area, purpose of burning (primary, secondary, and tertiary), post-burn response (primary and secondary), fuel-type (primary, secondary, and tertiary), and environment (primary, secondary, and tertiary), and uncertainty of observations. Fire frequency and severity are represented in Figure 3. Fire frequency was most commonly high (approximately less than or equal to every 4 years) and fire severity was most commonly low (low-severity surface fires) in terms of number of observations (Table 2). The primary purpose of burning is shown in Figure 4A. 65 Indigenous Peoples were linked to two purposes and 45 were linked to three purposes and were separated into individual maps. As all 73 Indigenous Peoples in the our study domain were linked to at least one purpose, the primary purpose is displayed in this paper (Fig. 4). Across all listed purposes (primary, secondary, and tertiary), the most common reasons cited for burning include resource enhancement, hunting and game management, and ecosystem maintenance (Tables 4 & 9).

Primary post-burn response is shown in Figure 4B. 45 Indigenous Peoples were linked to two post-burn responses and were separated into individual maps. Across all listed post-burn responses (primary and secondary), the most common responses cited post-burn include resource enhancement, ecosystem maintenance, and hunting and game management (Tables 5 & 9).

Burning most commonly occurred during spring, summer, and fall seasons, with most observations specifically being late summer to early fall (n = 21), followed by spring and fall (n = 17), and fall alone (n = 16). Burn area ranges from small, localized burns approximately less than 100 hectares (n = 50), medium burns, ranging from around 100 to 1000 hectares around specific sites (n = 22) and large burns, approximately greater than 1000 hectares (n = 8). The period of record was commonly described as 'since time immemorial', with some sources specifying timeframes ranging from at least 3,000 to 9,000 years ago. The largest spatial data gaps are in the Sub-Boreal Pine–Spruce, Fescue Grassland, Interior Mountain–Alpine, and Spruce–Willow–Birch ecosystems. A map of the estimated uncertainty in the source data is shown in Figure 5, in which we classified uncertainty from low (n = 21), through medium (n = 26), to high (n = 33).

To support knowledge sharing, we created an interactive ArcGIS StoryMap that displays the geodatabase of Indigenous fire practices across the study area. The StoryMap integrates an embedded collaborative survey (ArcGIS Survey123) that invites Indigenous knowledge holders, researchers, and community members to contribute new insights, corrections, or additional data on Indignous fire use. Survey submissions are anonymously added to a public map and will be reviewed prior to integration in the geodatabase (public URL will be provided before publication).

Discussion

This study reinforces the ubiquitous role Indigenous burning practices played in maintaining the fire-adapted ecosystems of the Pacific Northwest (Figure S1). Our results show that anthropogenic fire was not only widespread in the region but also highly purposeful. Our geodatabase highlights that Indigenous Peoples made use of frequent, low severity fire (Figure 3), with most territories showing high fire frequency (less than or equal to 4 years between burns) and low fire severity (surface fire). Additionally, these fires were mostly cited as being small-scale, localized patches of burns approximately less than 100 hectares. The results of the database support the idea that Indigenous Peoples deliberately ignited landscape scale wildfires for a variety of purposes, which ultimately shaped vegetation structure and reduced surface fuel accumulation (Loehman et al., 2020; Fernandes & Botelho, 2003; Keeley & Pausas, 2022). In Figure 4A and Table 3, it is clear these purposes were primarily resource enhancement, ecosystem maintenance, and hunting and game management. Knowing that Indigenous Peoples have occupied and stewarded the lands across the PNW for millennia, burning for the reasons described above reflect an ecological understanding passed down through generations. These purposes are mirrored in the most common post-burn responses, which included improved productivity and accessibility of key resources, as well as continued ecosystem health (Figure 4B). Our results strengthen the idea that fire is not always a destructive force, but can be used as a regenerative tool that has direct application for climate adaptation in fire-prone ecosystems. Indigenous Peoples employed this regenerative tool by primarily burning grass, shrubs, and understory vegetation, which correlate with the most common environments, including prairies, shrub-steppe, and oak woodlands (Table 4A & 4B). These environments, once common across the region, have become increasingly rare due to the removal and cessation of Indigenous Peoples and their burning practices, along with land use change, natural fire suppression, and encroachment by species including native Douglas-fir and invasive exotic including Scotch broom and cheatgrass (Tveten & Fonda, 1999; Hosten et al., 2006). The emphasis on summer and fall burning, particularly in late summer to early fall, aligns with traditional harvesting cycles and ecological cues, such as seed dispersal and plant dormancy, reflecting a well-adapted, seasonal management strategy (Stucki et al., 2021). All of these findings align with growing evidence that in many PNW ecosystems, frequent, low-severity fire contributes to increased biodiversity, reduced fuel loads, and more resilient landscapes (Boerigter et al., 2024; Fernandes & Botelho, 2003; Keeley & Pausas, 2022; Lake, 2021; Long et al., 2021; Parks et al., 2014, 2015; Schwilk et al., 2009). Traditional fire stewardship emphasizes fire as a tool for sustaining, not destroying, ecological systems (Hessburg et al., 2021) that contrasts with widespread fire exclusion and related land-use practices that have led to fundamental changes in the structure, composition, and fire regimes of western North American forests (Hagmann et al., 2021).

While the results of our study are instructive, limitations in the dataset must be acknowledged. Approximately a third of our 73 observations were classified as low uncertainty, with the rest fairly evenly split between medium and high uncertainty (Figure 5). This reflects gaps in the literature, reliance on secondary interpretations, and the challenge of quantifying oral histories and knowledge. Similarly, spatial gaps, such as those in the Sub-Boreal Pine–Spruce, Fescue Grassland, Interior Mountain–Alpine, and Spruce–Willow–Birch ecosystems, likely result not from an absence of burning practices, but from a lack of documentation or research. Additional ethnographic syntheses, such as Stewart (2002), may provide further regional detail and could be incorporated in future updates of the geodatabase. These gaps highlight the importance of prioritizing community-led research and meaningful collaboration with Indigenous nations in future studies (Lake, 2021; Steen-Adams et al., 2023). To help address these limitations, the interactive StoryMap created for this study (URL to be provided in final proof) provides an ongoing platform for crowdsourced contributions from Indigenous knowledge holders, researchers, and community members. Through this tool, new contributions can be reviewed and incorporated into the geodatabase, helping to refine and expand the dataset. In addition, while Native Land Digital (2015) offers a valuable spatial framework, it also introduces limitations. Territorial polygons are static representations of much more fluid and dynamic land-use patterns, and do not account for seasonal movement, shared territories, or intertribal relationships , where inter-marriage, hereditary rights, and permissions among related tribes, villages, and clans historically influenced who could burn and steward resources. Similarly, assigning point-based fire observations to entire ecosystems using modal and combination categories introduces spatial generalization, meaning that fine-scale, culturally specific fire practices may be smoothed into broader regional summaries. Fire severity is also highly uncertain in the ethnographic sources. While no observations in our dataset were classified as high severity, there may be cases where the ecological impact of Indigenous burning could be interpreted as high severity, particularly as it pertains to localized tree mortality. For example, patch burning of relatively small spatial extent (e.g., 10–30 m^2) could result in overstory mortality but may not be described or recorded in ways that align with modern severity classifications. We also acknowledge that much of the geospatial information contained in the Native Land database has been produced without consultation with, or the explicit permission of, the sovereign Indigenous nation or nations associated with that information, as noted by Native Land itself ((https://native-land.ca/about/why-it-matters).

While this study reflects only what could be documented through available literature, it is possible that the extent of Indigenous fire stewardship was even greater than what is represented here. The absence of fire-related data for some territories does not necessarily indicate an absence of fire use. Given the ecological suitability of many landscapes across the PNW and the long-term presence of Indigenous Peoples in these areas, it is resonable to consider that fire may have been used more broadly, even in places where specific records are lacking. In this way, this geodatabase may represent a conservative estimate of past fire activity and a lower bound of fire use. This possibility is further supported by paleoecological records, such as charcoal deposits, which reflect broader regional fire patterns and often show that fire is shaped by both climate and human presence (Marlon et al., 2008). Additionally, multiple-method interdisciplinary studies that integrate paleoecology, archaeology, fire history, ethnography, and TEK provide valuable insights into Indigenous fire use practices (Hoffman et al., 2016; Knight et al., 2022; Walsh et al., 2018). Future studies may benefit from considering alternative hypotheses, including the idea that, where ecologically appropriate, Indigenous Peoples may have used fire wherever and whenever suitable, even if such use is not currently documented.

Conclusions

While far from comprehensive, the geodatabase we produced in this study assessed ethnographic accounts of historical anthropogenic burning in a common descriptive framework and highlighted gaps in the literature. With 73 observations linked to 80 polygons within the PNW, we show that fire was commonly frequent with low severity, mostly occurred during summer and fall seasons, and was primarily prescribed for resource enhancement, hunting and game management, and ecosystem maintenance. The dataset provides a valuable, initial historical baseline for sustainable human use of landscape fire and demonstrates that anthropogenic fire was ubiquitous across our study region in pre-Settler time.

Our results may aid in the restoration of Indigenous burning in the PNW and will serve as a resource for simulation modelling. Similar approaches are already underway, as Greenler et al. (2024) demonstrated by conducting simulation modelling in collaboration with the Karuk Tribe Department of Natural Resources to assess the ecological impacts of cultural burning. The geodatabase will form a valuable input for regional-scale fire models that can estimate how different scenarios of anthropogenic fire application that are grounded in historical practices can be applied to influence vegetation dynamics, fuel accumulation, wildfire behavior, and other aspects of fire under current and future climate scnearios. To ensure the dataset remains relevant beyond the scope of this study, the geodatabase has been designed as a living, cross-disciplinary resource that can evolve through contributions from Indigenous nations, researchers, and fire practitioners representing diverse knowledge systems and disciplinary backgrounds.

We hope that our geodatabase may offer valuable insights for future researchers, policymakers, land managers, and Indigenous nations. The high frequency of low severity burns documented here offers a contrast to fire suppression regimes common over recent decades, which, in combination with climate change, have contributed to fuel buildup and more destructive wildfires (Boerigter et al., 2024; Turco et al., 2023). Reintroducing traditional burning practices has the potential to restore ecosystem resilience while honouring Indigenous sovereignty and knowledge.

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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.

Animal Care and Use

No permits or Animal Care Committee compliance were necessary.

Data Availability Statement

The geodatabase created in this study is available in geopackage (.gpkg) format in the Zenodo data repository (DOI to be provided upon upload).

Supplementary Materials

Supplementary tables and a full list of references used in the geodatabase can be found in the Supplementary Materials document.

Author Contributions

Holly Reynolds: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Jed O. Kaplan:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition.

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Figures

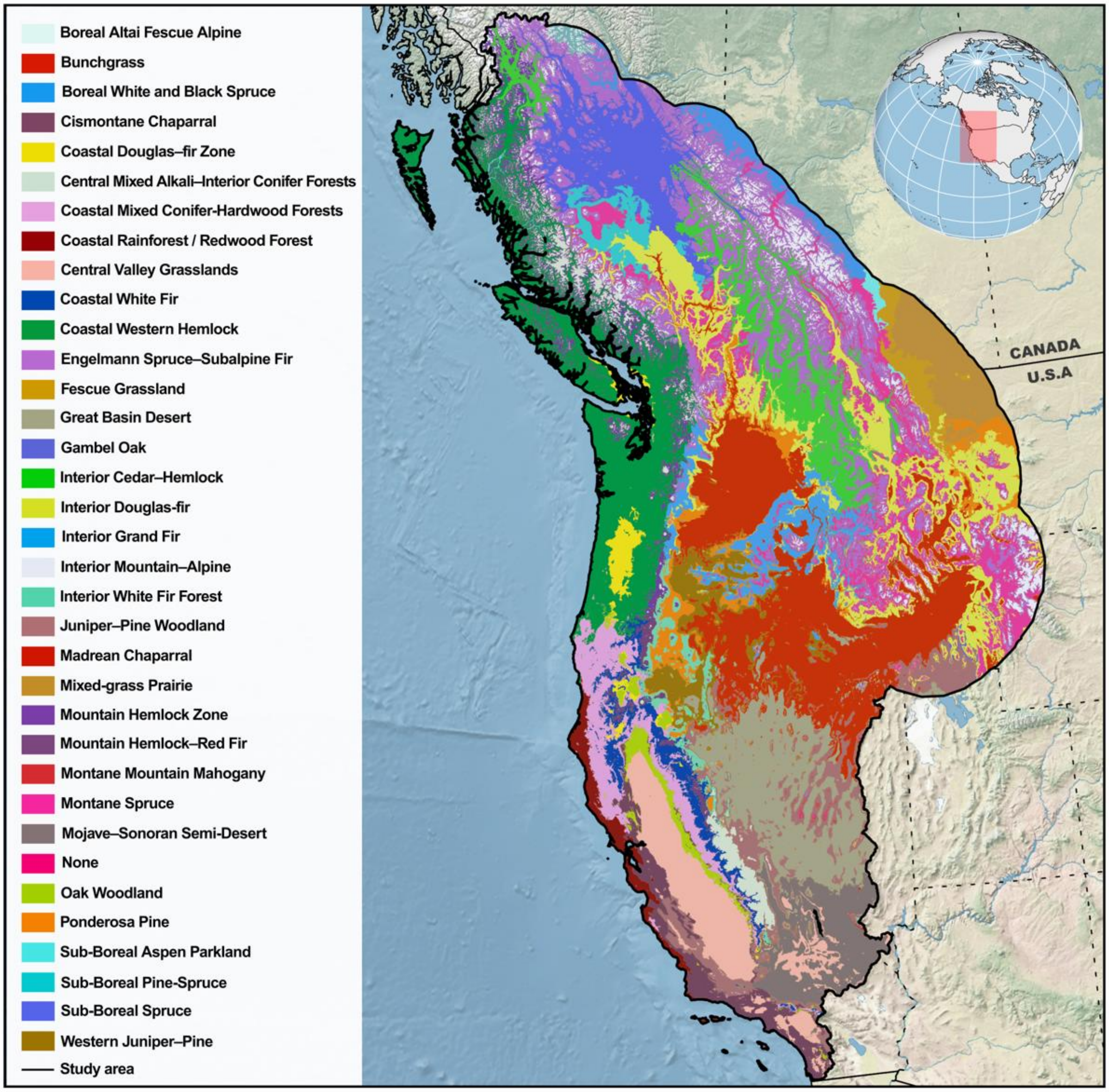


Figure 1. The 36 Biogeoclimatic Ecosystem Classification (BEC) zones included in our study area, representing distinct ecosystems defined by climate and dominant vegetation (MacKenzie & Mahony, 2021). Spatial data from the Forest Carbon and Climate Services Branch, BC Ministry of Forests (2025). Base map: Natural Earth (Natural Earth, 2014).

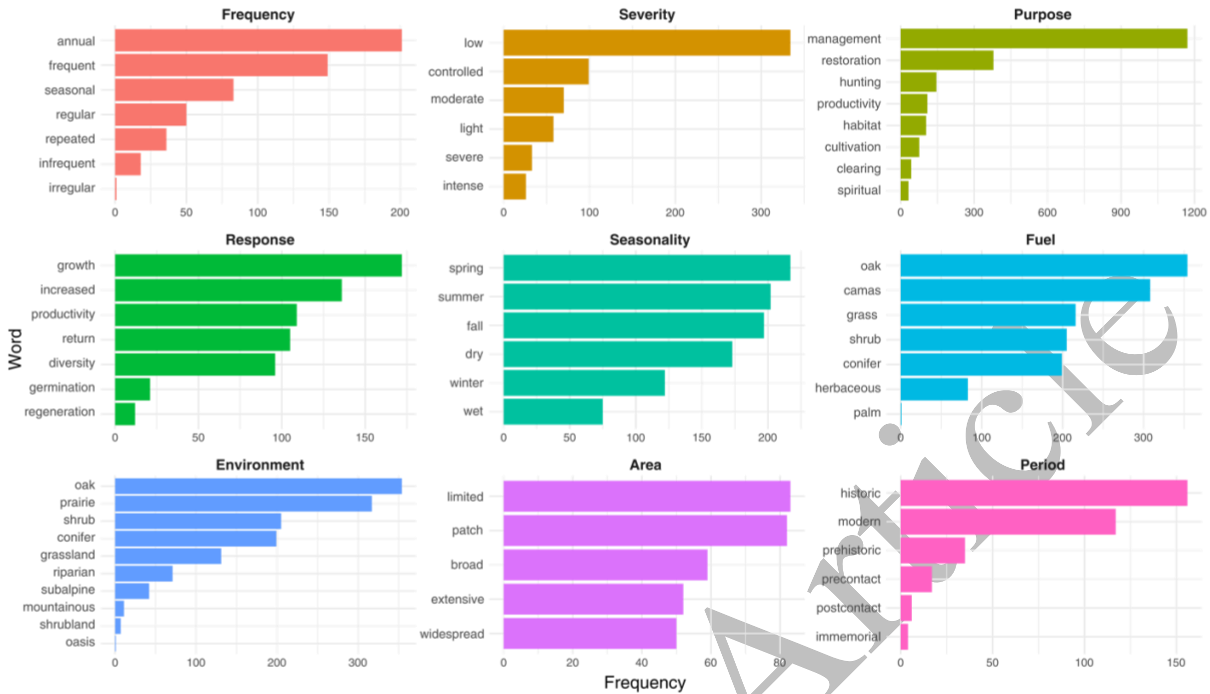
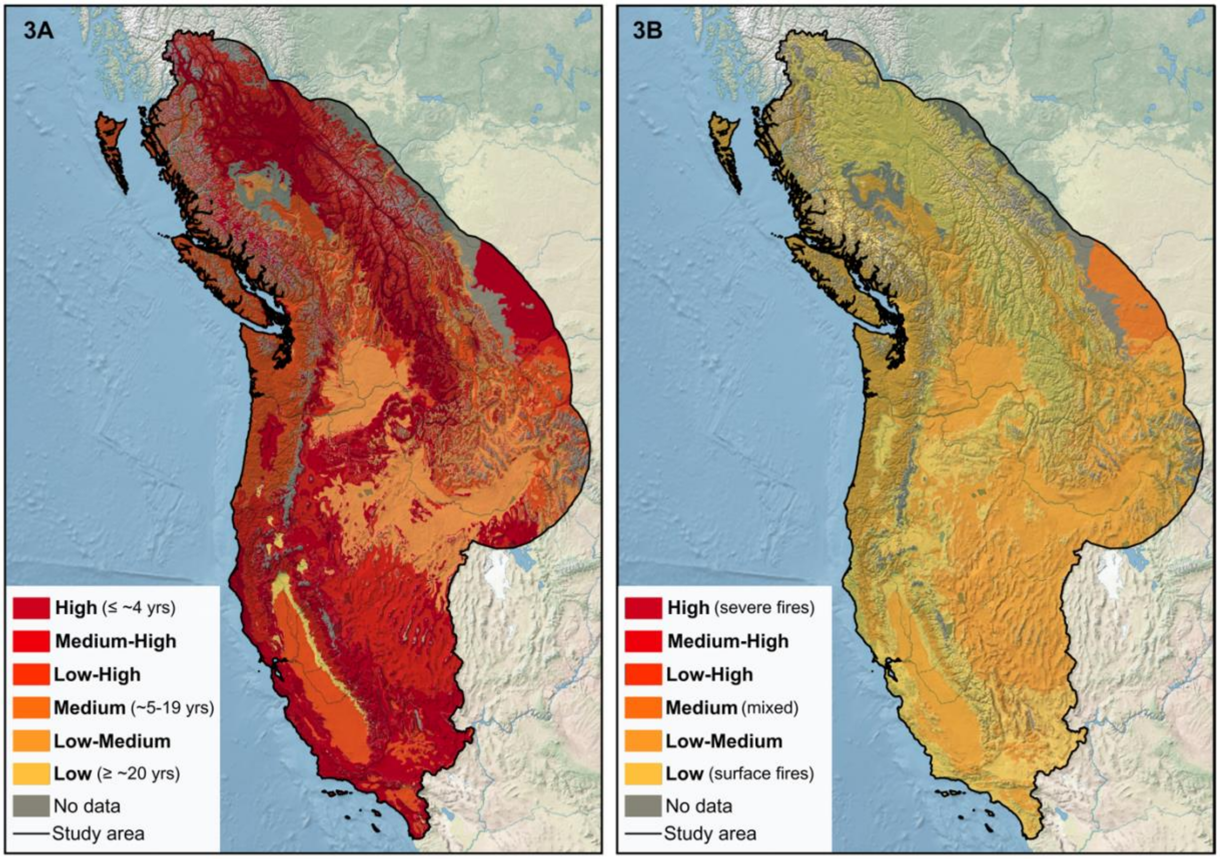


Figure 2. Frequency analysis of the most common descriptive terms by attribute category based on our lexical analysis of the sources describing historical Indigenous burning practices. The attribute terms were manually selected in advance, and only those that appeared in the sources are shown.



828

829 Figure 3. Frequency (3A) and severity (3B) of historical fire use by Indigenous Peoples in the
830 study region. Combination categories (e.g., low-medium) indicate polygons where more than one
831 observation type was reported. Base map: Natural Earth (Natural Earth, 2014).

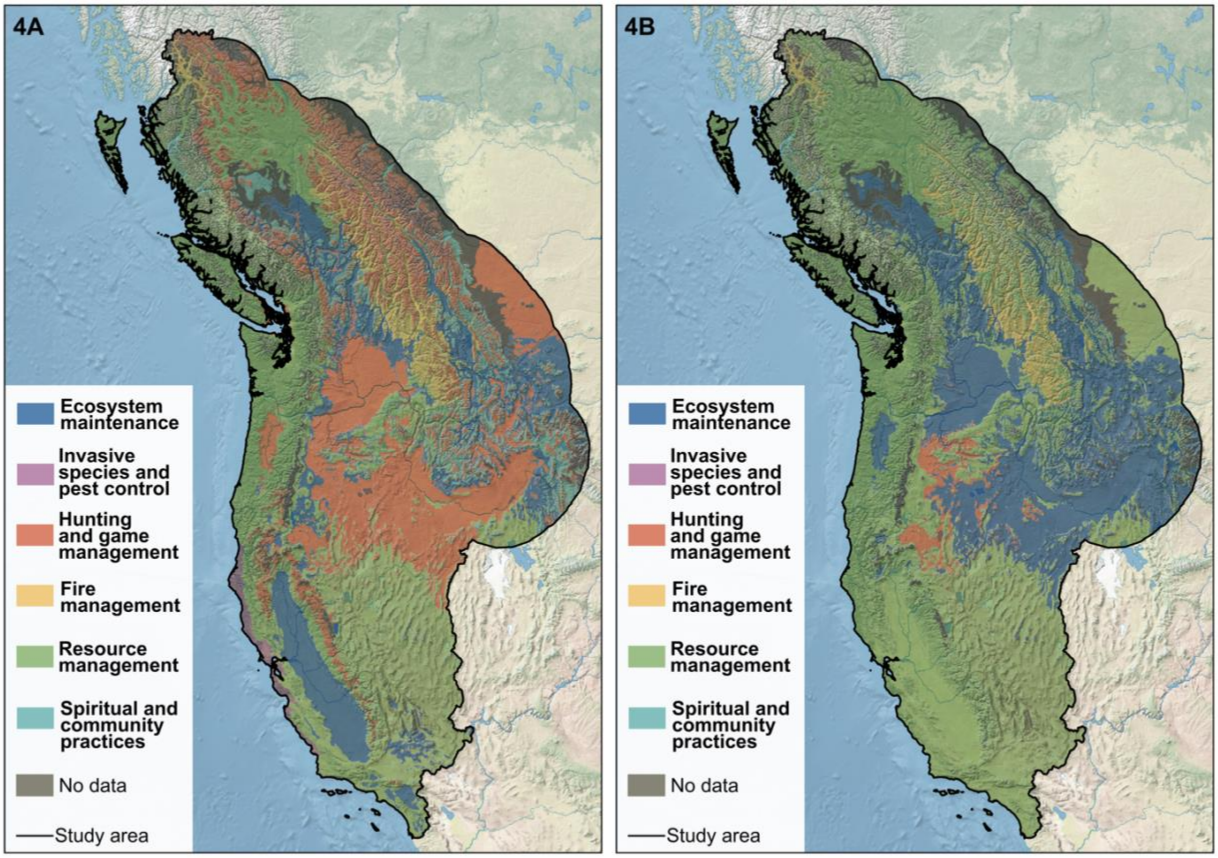


Figure 4. Primary purpose of burning (4A) and primary post-burn response (4B) for the fire use by historical Indigenous Peoples in the study region. Base map: Natural Earth (Natural Earth, 2014).

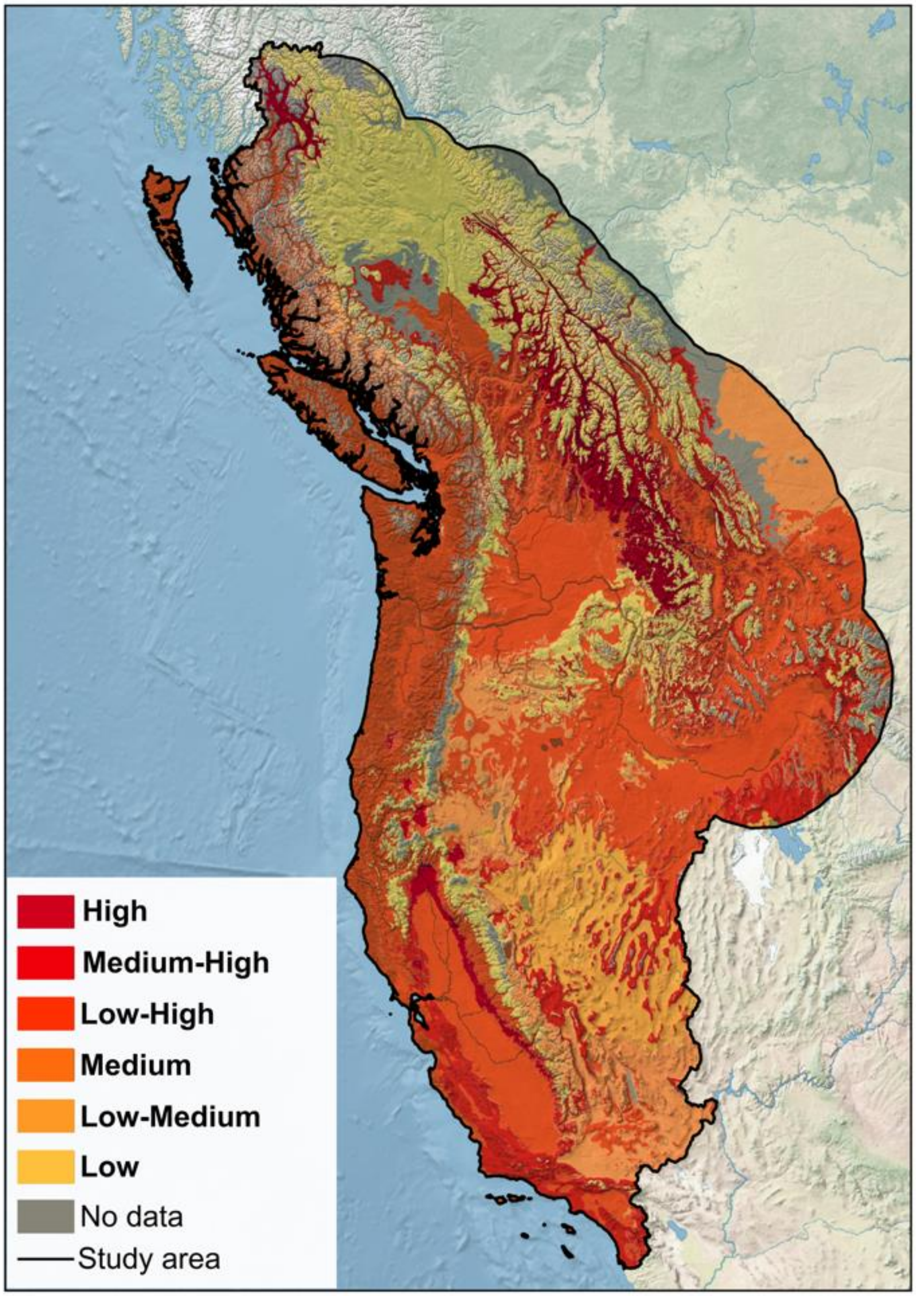


Figure 5. Map of estimated uncertainty in the geodatabase. Uncertainty was defined qualitatively into three categories based on the source's own assessment, language used, and specificity of the Indigenous Peoples described. Combination categories (e.g., low-medium) indicate polygons where more than one observation type was reported. Base map: Natural Earth (Natural Earth, 2014).

Tables

Table. 1. Primary search terms used to locate relevant sources and their approximate number of relevant results from Web of Science and Google Scholar.

Search term	Web of Science	Google Scholar
Indigenous burning practices in the Pacific Northwest	5	100
Cultural burning Pacific Northwest	21	70
“Traditional ecological knowledge” “Pacific Northwest" "fire"	6	30
Indigenous fire management Pacific Northwest	28	60
Indigenous burning practices in British Columbia	11	40
Indigenous burning practices in California	31	70

Table 2. Total number of observations of fire frequency and severity.

	Low	Medium	High
Fire frequency	6	15	59
Fire severity	63	17	0

Table 3. Total number of observations for categories of purpose of burning and post-burn response.

Category	Purpose of burning observations	Post-burn response observations
Resource enhancement	62	60
Ecosystem maintenance	36	29
Hunting and game management	36	14
Fire management and land clearing	25	7
Invasive species control and pest reduction	18	11
Spiritual and community practices	13	0
Soil replenishment	0	3
Increased water flow	0	1

Table 4A. Total number of observations for fuel type category.

Category	Number of observations
Grass	65
Shrubs	38
Understory vegetation	21
Berry bushes	16
Herbaceous ground cover	16
Oak	13
Conifer	11
Forest litter	11
Camas	2
Palm	1

Table 4B. Total number of observations for environment category.

Category	Number of observations
Prairie/grasslands	48
Oak woodlands	23
Forested areas	22
Meadows	21
Shrublands	20
Mixed conifer	16
Riparian zones	12
Mountainous	5
Subalpine	4
Oasis	1

Supplemental Materials

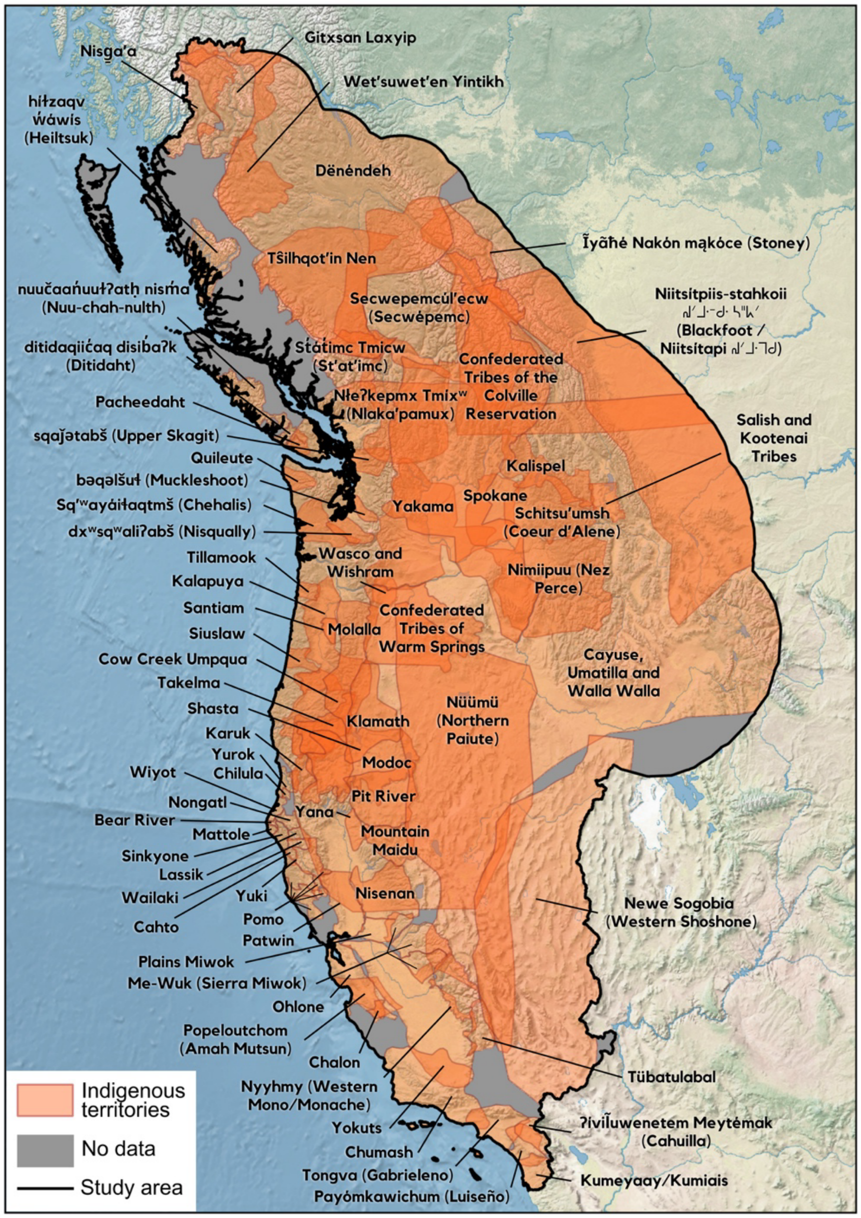


Figure S1. Traditional territories of the 73 Indigenous Peoples for which we found descriptions of historical burning practices in the literature. Territory boundaries are adapted from the Native Land Digital database (2015) and represent approximate, community-informed areas rather than official or legal boundaries. This map is intended for illustrative purposes and was not used as a basis for extrapolating local information over larger areas. Base map: Natural Earth (Natural Earth, 2014).

Table S1. Uncertainty classification system

Low	Medium	High
Indigenous group explicitly mentioned in the source with all or almost all attribute information provided.	Indigenous group mentioned in the source, but only some attribute information is explicitly stated.	Indigenous group only mentioned by name, most attribute information derived from details in overall paper.

Table S2. Purpose of burning coding scheme

Category	Description
Ecosystem maintenance	Maintain open prairie landscapes, maintain habitat for native plants, promote species diversity, support rare species, reduce litter, moss, competition from pasture grasses
Invasive species control and pest reduction	Reduce invasive species and insect pests
Spiritual and community practices	Spiritual practices, signaling, travel and trade
Hunting and game management	Hunting and maintaining wildlife and/or game habitats and food sources
Fire management and land clearing	Fire management, managing fuel loads, clearing village sites, managing tree densities, reducing catastrophic fire risks
Resource enhancement	Improving the productivity, accessibility, and quality of critical resources including tobacco, tarweed, grasshoppers, hazel, berries, roots, acorns, camas, and medicinal plants, and basketry or fiber materials such as willow, deergrass, sourberry, and redbud.

Table S3. Post-burn response coding scheme

Category	Description
Ecosystem maintenance	Return of green fire-adapted plants, maintenance of early-successional plants, enhanced resprouting of California black oak, reduced conifer encroachment, improved multiple-leaf flowering densities, enhanced grass growth, increased species richness, maintained prairie ecosystems, enhanced vegetation regrowth
Hunting and game management	Enhanced hunting success, maintained open habitats for game, increased habitat diversity, increased available food for wildlife
Fire management and land clearing	Improved site access
Resource enhancement	Increased grassland productivity, improved forage plants, resource productivity, increased camas productivity, extended flowering-fruiting period, improved huckleberry productivity, increased berries, improved forage quality, stimulated seed germination, increased productivity of edible roots, increased productivity of lowbush blueberry patch
Soil replenishment	Improved soil replenishment and replenished soil nutrients
Increased water flow	Increased water flow

Table S4. Fuel type coding scheme

Category	Description
Grass	Grassland and prairie
Berry bushes	Berry bushes, huckleberry
Understory vegetation	Oak and conifer understory
Shrubs	Shrubs, heather, snowbrush, red osier, rose willow, brush
Conifer	Moist and dry mixed conifer
Oak	Oak savannah, oak
Camas	Camas
Forest Litter	Forest litter, hardwood litter
Herbaceous vegetation	Herbaceous vegetation, clovers, meadow groundcover
Palm	Palm

Table S5. Environment coding scheme

Category	Description
Prairie	Grassland, prairie, temperate grasslands, valley-bottom grasslands
Riparian zones	Riparian zones, marsh-edge environments
Mountainous	Mountainous areas, mountains
Shrub-steppe	Shrub-steppe plains, shrublands
Mixed conifer	Moist mixed conifer (MMC) and dry mixed conifer zone (DMC)
Oak woodlands	Oak woodlands, hills with some oak trees, oak groves, oak savannah
Subalpine	Subalpine slopes, zones, and forests
Forested areas	Coastal forests, bog woodlands, upland forested areas, lower elevation forests dominated by ponderosa pine, Douglas-fir or western larch
Meadows	Meadows
Oasis	Desert oasis, palm oases

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