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EDITED BY
Breno Pietracci,
Environmental Defense Fund,
United States

REVIEWED BY
Coeli Hoover,
Forest Service, Northern Research Station (USDA), United States
Cathy Robinson,
Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
Silvia Laine Borges,
University of Brasilia, Brazil

*CORRESPONDENCE
William Nikolakis
William.Nikolakis@ubc.ca

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Diffusion of indigenous fire management and carbon-credit programs: Opportunities and challenges for "scaling-up" to temperate ecosystems

William Nikolakis[1]*, Clive Welham[2] and Gregory Greene[3]

[1]Department of Forest Resources Management, Faculty of Forestry, Gathering Voices Society, University of British Columbia, Vancouver, BC, Canada, [2]Faculty of Forestry, 3Greentree Ecosystem Services Ltd., University of British Columbia, Vancouver, BC, Canada, [3]Department of Forest and Conservation Sciences, Faculty of Forestry, University of British Columbia, Vancouver, BC, Canada

Savanna burning programs across northern Australia generate millions of dollars per year for Indigenous communities through carbon and other greenhouse gas (GHG) markets. In catalyzing Indigenous knowledge and workforce to mitigate destructive wildfires, these programs are considered a success story on a range of social, ecological and economic measures. Scaling-up to temperate ecosystems requires a focus on applying the architecture and governance of these programs, and accounting for fundamental differences in context. We examine the opportunities and challenges in applying the architecture of savanna burning to an Indigenous Fire Management (IFM) program in central British Columbia, Canada (the Chilcotin). The Chilcotin project involves Yunesit'in and Xeni Gwet'in First Nations, and we draw from eight key elements of the Australian savanna burning model to identify a project area that includes Aboriginal title and reserve lands. The area encompasses Interior Douglas Fir (IDF) and Sub-Boreal Pine—Spruce (SBPS) biogeoclimatic zones, or dry forest and grassland ecosystems where low intensity fires are applied by community members to remove forest fuels, with the goal of mitigating wildfires and associated GHG emissions. The multi-decadal intervals between contemporary fires in the Chilcotin region make it challenging to accurately document historical fire location, scale and intensity, and thus to establish an emissions baseline. If this issue can be resolved, the British Columbia Forest Carbon Offset Protocol version 2 (FCOPv2) offers promise for developing verified carbon credits for three reasons: first, carbon (CO_2), nitrous oxide (N_2O), and methane (CH_4), the three main GHG emissions from Indigenous fire management, are included in the protocol; second, credits under FCOPv2 are eligible for either compliance or voluntary markets, offering diversification; and third, a range of activities are eligible under the standard, including fire management and timber harvesting, which offers flexibility in terms of management practices. The Chilcotin project is likely to generate substantial co-benefits related to cultural, health and wellbeing, and livelihood values among First Nations participants. The

Australian experience suggests that getting governance right, and building community ownership through "bottom-up" governance, is critical to the success of these programs. From the Australian model, community-based planning, like the Healthy Country Planning approach, can be a positive step to take, engaging community in goal setting for the program to guide and take ownership of its direction.

KEYWORDS

Indigenous fire management, carbon credits, natural climate solutions, Indigenous peoples, British Columbia, Canada, Australia

Introduction

Each dry season, catastrophic wildfires impact vast areas of Australia's tropical savannas. This was not always the case. Traditional Indigenous burning practices that removed fuel loads in the early dry season (EDS) were critical to mitigating wildfires in the late dry season (LDS). These practices were described as "cleaning up the country, or breaking it up to be able to strategically manage fires that would occur later in the season" (Russell-Smith, 2019[1]). With the displacement of Indigenous peoples and their practices over large areas of the savanna landscape, that system of fine-grain management collapsed, resulting in large LDS wildfires. Frequent and extensive LDS fires significantly impact soil erosion, water quality, fire-vulnerable vegetation, faunal biodiversity (Russell-Smith and Yates, 2007; Yates et al., 2008), and related carbon dynamics (Russell-Smith et al., 2015).

Wildfires in savanna ecosystems (LDS fires) generate high GHG emissions, principally carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Between 1997 and 2016, LDS fires contributed 62% (4.92 Pg CO_2e yr^{-1}) of gross global mean fire related carbon emissions worldwide (van der Werf et al., 2017). In Australia, savanna fires are one of the major contributors of national GHG emissions, accounting for about 3% of the 2011 annual emissions reportable under the Kyoto Protocol (563.1 Mt CO_2e; Department of Climate Change and Energy Efficiency [DCCEE], 2011). Annual post-fire vegetation regrowth acts to replenish carbon stocks thereby removing CO_2 (Landry and Matthews, 2016), but CH_4 and N_2O emissions persist in the atmosphere, contributing to atmospheric warming (Le Quéré et al., 2013).

In the late 1990s and early 2000s, Indigenous fire management was supported across larger areas of northern Australia. Indigenous fire management, involving Indigenous peoples putting fire to the landscape (often as simple as using matches as ignition tools), can create mosaic landscapes in savannas, benefiting biodiversity through vegetation patchiness, maintaining species aggregated in habitats protected from fire, and supporting fire-dependent species (Russell-Smith et al., 2003; Andersen et al., 2012; Edwards et al., 2015).[2] Evidence shows Indigenous fire management programs have also been successful in mitigating the intensity of LDS wildfires, reducing GHG emissions, and producing socio-economic outcomes to their largely Indigenous participants (see Moura et al., 2019; Nikolakis and Roberts, 2020), which includes improved personal health and wellbeing and cultural maintenance (see Garnett et al., 2009). The sale of carbon credits has been an important source of revenue for some of these programs (Yibarbuk, 2009; Russell-Smith et al., 2013; Robinson et al., 2016b).

The success of Australia's savanna burning program is receiving worldwide interest and attention (Lipsett-Moore et al., 2018; Nikolakis et al., 2020; Nikolakis and Roberts, 2021), particularly in Latin America, Africa, and Asia. Griscom et al. (2020) estimated that natural climate solutions like proactive fire management activities (the application of EDS burns), could mitigate as much as 6.56 Pg of CO_2e per year. Adopting Australia's Indigenous fire management practices, however, comes with technical, political, governance, cultural, and legal challenges. Here, we examine the potential for Indigenous-led fire management programs, potentially supported through carbon markets, to be implemented in central British Columbia, a fire-dependent grassland and temperate forest ecosystem. Indigenous burning practices have been largely removed from this temperate landscape for over a century (Nikolakis et al., 2020). The frequency and impact of catastrophic wildfires in this area of British Columbia, resulting from an aggressive fire exclusion and suppression policy, and compounded by other drivers including landscape-scale insect outbreaks and climate change, has created a need for reintroducing Indigenous fire management practices back on the landscape (Nikolakis and Roberts, 2021). There is also a

1 Webinar 8: Fire and Carbon, Gathering Voices Society, Vancouver, BC. See: https://vimeo.com/user105935556.

2 Some studies argue for more information on the trade-offs between carbon emissions reduction and biodiversity conservation (Parr and Andersen, 2006; Andersen et al., 2012), to understand whether it is causing negative biodiversity outcomes (Corey et al., 2019).

need to understand the process of generating verifiable carbon credits to sustain these Indigenous fire management programs. Our goal in this paper is to examine the feasibility of such a program in temperate ecosystems, with the ambition of facilitating these programs in practice.

Assessment of policy/guidelines options and implications

Overview and background: Indigenous fire management

Fire has been removed as a dominant disturbance agent from many of the world's natural ecosystems. There is, however, a growing realization that the absence of fire undermines ecosystem integrity. One impact is the accumulation of dead organic matter that can serve as a fuel source. In these circumstances, ignition under hot and dry conditions can generate severe fires, with loss of surface organic layers and exposed mineral soil, leading to impaired regenerative capacity and productivity (Deal et al., 2010). Eliminating low-intensity fires can also result in overstocked stands with poor understory development, a predominance of uniformly older age classes, and reduced compositional diversity (Keane et al., 2002; Hessburg et al., 2019).

Paleoecological and oral evidence shows that for millennia, Indigenous societies used fire to manage landscapes (Kimmerer and Lake, 2001; Archibald et al., 2012; Huffman, 2013; Klimaszewski-Patterson et al., 2018). Anthropogenic fire is critical to many fire-dependent ecosystems (Marsden-Smedley and Kirkpatrick, 2000; Yibarbuk et al., 2001; Pellatt and Gedalof, 2014). Controlled burning, such as that produced through Indigenous fire management (IFM), serves to reduce fuel loading in forests and grasslands, though there are often significant legal, political and attitudinal barriers to this practice (Huffman, 2013; Lake and Christianson, 2019; Nikolakis and Roberts, 2020, 2021).

Record-breaking fires around the world have facilitated calls for more decentralized and proactive fire management—beyond the standard practice of fire suppression (Nikolakis and Roberts, 2021). It is generally recognized that fire management regimes often do not reflect the underlying ecological fire regime or take full account of available knowledge sources (Moura et al., 2019; Welch and Coimbra, 2019). IFM is increasingly seen as a way to bring fire back to landscapes, particularly on Indigenous tenured lands (Lake and Christianson, 2019; Moura et al., 2019; and mitigating destructive wildfire by bringing the right fire, to the right place at the right time. Nikolakis and Roberts (2020, p. 1) described IFM "[as] the proactive use of fire to achieve multiple and complex landscape-level objectives," which can include cleaning the landscape, mitigating wildfire, ceremony, promoting food security (Mistry et al., 2016; Lake and Christianson, 2019), guided by Indigenous knowledge,[3] practices, lore and customs. In addition to sustainable livelihoods, Indigenous fire management is increasingly being applied within the context of GHG emissions abatement (Russell-Smith et al., 2013; Moura et al., 2019).

In Canada, colonization and the expansion of the industrial logging model led to a decline in IFM practices, and with it, much of the knowledge around this practice (Nikolakis et al., 2020). A government-led report by Abbott and Chapman (2018) in British Columbia (BC), Canada, after the devastating 2017 wildfire season that impacted the Chilcotin, called for the prioritization of proactive fire prevention, prescribed burning, and better fire management coordination with First Nations (Indigenous peoples) (Nikolakis and Roberts, 2021).[4] Intentionally introducing fire back into Canada's landscape has its challenges: in addition to the risk of unintended consequences (escapement and air quality, for example), the knowledge to implement proactive fire management strategies needs to be re-learned (in modified landscapes with more people, property and tenure), and sufficient resources are required to do this. The well-established program in the savanna region of northern Australia could serve as a template for IFM within the Canadian context.

Developing Indigenous fire management as a nature-based climate solution: Australia's savannas

Savanna ecosystems are mixed woodland-grassland ecosystems that cover vast areas of northern Australia (**Figure 1**). They have two distinct seasons, dry and wet, the former typically occurring from May to October, and the latter occurring from December to March. Temperatures are relatively stable throughout the year, with monthly maximums averaging 32.5°C during the dry season, and 35°C during the wet season. In contrast, precipitation during the dry season averages only 65 mm, but averages 930 mm during the wet season (1985–2021 data from Darwin Airport, Tindal RAAF and Elliott weather stations; Australian Bureau of Meteorolog [ABOM], 2022). Forests tend to be primarily open canopied, with a ground layer consisting of herbaceous plants, primarily grasses. These ecosystems are the world's most fire prone landscapes and their flora and fauna show features adapted to,

3 Battiste and Henderson (2000) documented that Indigenous knowledge is underpinned by a principle of "totality or holism" (p. 42), and share a belief of "unseen powers" in ecosystems; that all things are interdependent; and that knowledge keepers teach morals and ethics to specific people, and this is passed down through generations.

4 There were also public calls for more Indigenous fire management in Australia after the devastating 2019 fire season, see Fuller (2020), New York Times.

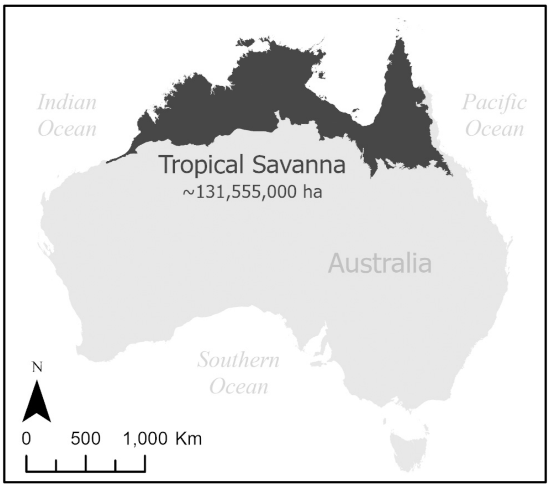

FIGURE 1
The location and size of the tropical savanna ecosystems in Northern Australia.

and dependent on, the dry season fire regime. Without fire, savanna communities exhibit profound changes in composition (Andersen et al., 2012) as they transition to a predominance of tree cover with attendant losses in understory structural and compositional diversity (Lipsett-Moore et al., 2018; though see Veenendaal et al., 2018).

In northern Australia, landscape fire management played an integral role in traditional Aboriginal society (Nicholson, 1981; Bowman, 1998; Yibarbuk, 1998). Indigenous peoples typically burned savannas during the EDS, with small, less intense fires, thereby reducing litter and mitigating LDS fire occurrence, intensity, and extent.[5] European settlement of northern Australia in the nineteenth century disrupted and largely prevented traditional fire practices. The resulting buildup of fuels led to an increase in the frequency, severity, and extent of higher-intensity fires occurring late in the dry season.

In 2000, the 28,000 km^2 West Arnhem Land Fire Abatement (WALFA) project in northern Australia was implemented, incorporating Indigenous knowledge into savanna burning (Russell-Smith, 2016). Compared to the pre-project 10-year emissions baseline, WALFA activities reduced wildfire-related GHG emissions by 37.7% over 7 years (Russell-Smith et al., 2013). The WALFA transitioned to a voluntary carbon offset project in 2006, with the credits purchased by ConocoPhillips per a 17-year off-take agreement to abate 100,000 t CO_2e $year^{-1}$ (Russell-Smith et al., 2015; Morley et al., 2016). A savanna burning emissions abatement methodology based on Intergovernmental Panel on Climate Change rules was formally approved in 2012, under the country's agricultural carbon offsets program, the Carbon Farming Initiative (Russell-Smith et al., 2013).

The Australian *Carbon Credits (Carbon Farming Initiative) Act 2011* broadened the scope of activities and enabled crediting of GHG abatement by reducing or avoiding emissions, or removing CO_2 from the atmosphere by sequestration in soil or trees. In 2014, the Act was amended by the *Carbon Farming Initiative Amendment Act 2014*, to establish an Emissions Reduction Fund (ERF). The ERF has three elements: Crediting; Purchasing; and Safeguarding emissions reductions. The Clean Energy Regulator is the Australian independent statutory authority responsible for developing the technical rules (methods) associated with emission reductions, administering the ERF, and making emissions reduction purchases on behalf of the Federal Government. To participate in the ERF, a project must be registered with the Clean Energy Regulator. When properly verified and registered under an approved methodology, these offsets are referred to as Australian Carbon Credit Units (ACCUs). A government-approved savanna burning program provides the vehicle for Indigenous savanna landowners to sell the carbon credits produced through EDS fire management to the ERF.

In the case of savanna burning, the government mandates use of the Carbon Farming Initiative—Emissions Abatement through Savanna Fire Management Methodology Determination 2018. By January 2018, a total of 75 projects were registered under the ERF and 52 of these projects secured contracts with the Australian Government to abate 13.8 Mt CO_2e over an average of 8.5 years (Lipsett-Moore et al., 2018). This includes the WALFA project, which transitioned into the ERF program in 2015. In 2019, the ERF program was extended with an additional $2 billion (Australian dollar) funding injection and rebranded as the Climate Solutions Fund. An Indigenous-based project verification process is utilized with individuals, preferably Aboriginal Rangers and farmers, who have completed nationally accredited training. Projects require maps of vegetation fuel-types and fire scars for each fire season of each year in the baseline and reporting years (see **Table 1** for the eight key elements of these programs). Typically, these are derived from satellite data in conjunction with ground-truthing. The vegetation and fire scar maps are overlaid to derive the potential area burnt in each fire season of each year. This also allows for calculations of "years since last burnt" (YSLB).[6] YSLB maps determine fine fuel loads in each map pixel. The potential emissions of CH_4 and N_2O for each fire season, given the vegetation fuel type and YSLB, can then be estimated from fuel loads and parameters defining combustion efficiency. Emissions in the reporting year must also account for any fossil fuels consumed to establish and maintain the project activity.

5 This situation in northern Australia is distinct from the southern temperate context, where the fire regime has longer intervals, and IFM programs have been focused on hazard reduction (Robinson et al., 2020).

6 In North America this is referred to as Time Since Last Fire (TSLF).

Key enabling factors in the Australian program

One of the elements that must be satisfied under any carbon credit program and project approval process is additionality. A GHG emission reductions project is considered "additional" if its emission reductions exceed what would have happened had the project had not been carried out (a continuation of business-as-usual practices). Only carbon credits from projects that are additional represent a net environmental benefit. The number of credits generated is the difference in emission reductions as compared to a business-as-usual baseline. In a burning program, then, net emissions from pre-emptive combustion (the project activity) must be less than emissions from uncontrolled fire in its absence (the baseline). Table 1 outlines how additionality is achieved within the Australian Indigenous-led savanna burning programs.

The other enabling factors were:

1. Legislation to support the compliance market for EDS fire management, which established the framework for the national carbon market (the ERF). This was a followed by the government-approved methodology for participation in a market. The federal government was also willing to purchase credits, committing $2.55 billion (Australian

TABLE 1 Key elements and characteristics of savanna burning.

Element	Characteristics in savanna
Zonal designation	Project are restricted to those located in either of two rainfall zones in northern Australia: • High rainfall zone (1,000–3,200 mm annual average) • Low rainfall zone (0–800 mm annual average)
Seasons	For management purposes, two seasons are defined: • Early dry season (EDS)—1 January to 31 July. • Late dry season (LDS)—1 August to 31 December. • EDS burning is the project activity along with avoided burning in the LDS. A predominance of burning in the latter season constitutes the baseline scenario.
GHG gases	Methane (CH4) and Nitrous oxide (N_2O). CO_2 is included only if fossil fuel is used to establish and/or maintain favorable project conditions.
Additionality	Must meet the definition of a savanna fire management project—(a) aims to reduce the emission of CH4 and N_2O from fire by using fire management primarily in the early dry season; and (b) is carried out in a savanna that includes land in either or both of the high-rainfall or low-rainfall zone. Fire management for the primary purpose of reducing emissions from fire cannot be mandated by law.
Project area	A savanna fire management project may be declared as a single project area, or across multiple project areas (the latter are referred to as grouped or aggregated projects). Within an area, there are specified fuel types that must be present to qualify as a valid carbon project. Once a project has been declared eligible, the project proponent is able to add further project areas. Grouped projects are composed of multiple parties and thus are more complex to manage and have added risks of default. Default refers to a decision by one, or more, parties to the project of ceasing participation and fulfilling requirements and obligations. Depending on the default circumstances, this could compromise the entire project though, at the very least, the remaining parties will incur material costs. These risks are counterbalanced by a reduced risk of catastrophic reversal affecting the entire project, and potential cost-savings from scale since expenditures are amortized over multiple parties. Note that having non-contiguous parcels with a single owner is not considered a grouped project. Including specified fuel types narrows the scope to ensure that only appropriate ecosystems are included; this could be addressed through specifications derived from applying the BEC system.
Project Activity	Fire management typically involves the application of a strategic EDS fire regime to reduce the risk of occurrence and extent LDS fires. This includes the planning for, and implementation of, burning practices that reduce fuel loads. Planned burnt patches form a mosaic across the landscape, such that they reduce the potential for fire spread in the late dry season.
Net abatement amount	The basic method for working out the CO_2e net abatement amount for a reporting period of a savanna fire management project. • Requirement to create vegetation fuel type map for the project area that is validated by field surveys and verified. • Map must be validated by field surveys to confirm vegetation. • Calculation of net annual abatement includes an annual buffer contribution or withdrawal, depending on whether the annual abatement is positive or negative. • Annual abatement = Baseline emissions—Annual project emissions • Annual project emissions = Fire emissions + Fossil fuel emissions Baseline period is either 10 or 15 years, depending on the rainfall zone. • Fire emissions are calculated annually for the project area from geospatial mapped areas burnt, by vegetation type, and season (early or late), each of which have associated default emission values.
Reporting, record-keeping and monitoring	Reporting is required and must correspond to the time period over which offsets are claimed.

dollars) to carbon farming programs (seven project types, including savanna burning).

2. Structural support from companies to broker credits to third parties, and support from well-known Australian enterprises, such as the Commonwealth Bank, the TSA Group, and the City of Sydney.
3. Simplification of project verification, which can be complex and costly. An Indigenous-based project verification process was developed using a "Core Benefits Verification Framework."[7] The Framework provides for independent verification of the environmental, social, and cultural values associated with a project. The verification teams are made up of individuals who have completed nationally accredited training, with a preference for Aboriginal Rangers and farmers, and who have the responsibility for assessing the core benefits.
4. Strong carbon credit prices. Once a registered project has generated ACCUs, it can attempt to secure a contract with the national government (specifically, the ERF) by bidding in a reverse auction. Historically, auction prices have varied between $10.23 and $14.17 AUD ($9.78–$13.55 CAD) per t CO_2e (i.e., per ACCU). Spot prices for ACCUs ranged between $16 and $18 AUD in the past several years but have fluctuated considerably of late. Prices peaked around $56 AUD early in 2022 but have settled in the $30–35 AUD range.

The Australian Indigenous fire management program: Concluding comments

Evidence from the north Australian programs not only shows reductions in wildfire and GHG emissions, but by drawing on Indigenous knowledge and participation, these generate positive social outcomes, such as motivating social cohesion (Burgess et al., 2005; Berry et al., 2010), strengthening local governance structures (Campbell et al., 2011), reaffirming cultural identity, and supporting community decision-making authority and land tenure (Garnett et al., 2009; Robinson et al., 2016b). There are also positive employment and livelihood opportunities in remote areas (Green and Minchin, 2012; Greiner and Stanley, 2013; Robinson et al., 2016a), income diversification (Campbell et al., 2011; Robinson et al., 2016b), knowledge transfer from elders to youth (Green and Minchin, 2012; Robinson et al., 2016a), enhanced food security, and improved physical and mental health (Burgess et al., 2005; Garnett et al., 2009; Nikolakis et al., 2022). As Jeremy Russell-Smith observed, the outcomes are critical to the self-governance goals of Indigenous communities:

> "They're absolutely a success story. Because they've met the aspirations of the traditional owners; and that's not to do with the emissions reduction targets being met, it's been all the ancillary benefits that have come with being able to support cultural land management programs. The setting up of schools, the employment of people, especially of young people, in culturally appropriate sorts of ways" (Russell-Smith, 2019; see text footnote 1).

There have been extensive planning processes to support these "co-benefits" from Indigenous fire management—carbon programs (as well as other environmental stewardship programs). The level of planning is critical, as Russell-Smith described:

> ". . .a lot of the Indigenous communities across Northern Australia employed a framework which is called Healthy Country Planning. And that's really to sit down right at the start, think through where people want to be in the future. . . So is this [program] actually resulting in more time people are spending on country with their families? Are people healthier? Are people getting culturally educated? In fact, those are all criteria within a lot of these Indigenous plans, and they're ticking them off against those aspirations, not just a commercial set of criteria" (Russell-Smith, 2019; see text footnote 7).

There have been concerns expressed by Indigenous fire experts, such as Victor Steffensen, around commodifying IFM practices, and these practices being driven by carbon related contracts rather than landscape needs.[8] This suggests there are important trade-offs such as managing for ecosystem integrity and meeting commitments in carbon contracts that must be worked through in establishing these programs—paying heed to what Robinson et al. (2016b) argue, carbon arrangements should "focus on the reflexive and active human–environment relationships that "service" one another" (p. 27). In addition, there are a number of barriers for Australian Indigenous communities to participate in carbon markets, identified by Robinson et al. (2014), such as land tenure, geography, capacity, resources and recognition of Indigenous knowledge and responsibilities.

Adapting the Australian experience to British Columbia

The Tsilhqot'in fire management program

The Chilcotin, a fire-prone area of BC, Canada, is the traditional territory of the Tsilhqot'in Nation, who, in 2014,

7 See Aboriginal Carbon Foundation: https://www.abcfoundation.org.au/.

8 Webinar 7: Indigenous Fire Management, Gathering Voices Society, Vancouver, BC. See: https://vimeo.com/377668806.

had Aboriginal title declared on almost 1,700 km^2—they have constitutional rights to exclusive possession and control of their title lands (Nikolakis et al., 2016; Nikolakis, 2019), including jurisdiction to create fire laws for this area. Parts of the Chilcotin experienced intense wildfires in 2017 and 2018, with over 800,000 hectares burned and tens of thousands evacuated (British Columbia Wildfire Service, 2022). It is here that the fire-suppression approach, extinguishing fires as they arise, is being disrupted (Abbott and Chapman, 2018; Verhaegue et al., 2019). This study provides insight into two member First Nations of the Tsilhqot'in, Yunesit'in and Xeni Gwet'in, both of whom are looking to restore their traditional fire practices and the feasibility of carbon credit revenues to support this activity.

The Chilcotin plateau ranges 1,000 m above sea level, and lies west of the Fraser River and east of the Coast Mountain ranges (**Figure 2**). The plateau is cool and dry, with annual temperatures averaging 0–2°C, but only 250–350 mm of precipitation (1961–1990; Dawson et al., 2008). Summers are warm, with average maximum temperatures ranging from 22 to 28°C (June-August, 1981–2010; PCICS, 2014). The Chilcotin region encompasses a broad range of pyrophytic ecosystems, but is predominantly comprised of savanna-like grasslands, woodlands, and dry forests within the Bunchgrass (BG), Interior Douglas Fir (IDF), Sub-Boreal Pine—Spruce (SBPS), and Montane Spruce (MS) biogeoclimatic zones (Meidinger and Pojar, 1991). Historical fire regimes were variable across these biogeoclimatic zones, with frequent low- and moderate-severity surface fires dominating in the BG and IDF zones (Gayton, 2013; Harvey et al., 2017; Copes-Gerbitz et al., 2022), and a less frequent mix of low- to moderate-severity surface fires and high-severity crown fires dominating in the remaining zones (Cochrane, 2007; Marcoux et al., 2015). Many of these fire regimes were influenced by Indigenous fires (Turner, 1999; Harvey et al., 2017), which amplified fire frequencies and reduced severities relative to the background lightning-ignited wildfires (Copes-Gerbitz et al., 2022). The dominant plant species in this region are adapted to these historical fire regimes. Grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata*), spreading needlegrass (*Achnatherum richardsonii*), Rocky Mountain fescue (*Festuca saximontana*), prairie junegrass (*Koeleria macrantha*), and pinegrass (*Calamagrostis rubescens*) are passively pyrophytic to low-intensity surface fires; their aboveground tissues are consumed, but new shoots quickly resprout from below-ground tissues that survive the fires (Abrahamson, 2022). Douglas-fir [*Pseudotsuga menziesii* (Mirbel) Franco var. *glauca* (Beissn.) Franco] has thick, fire-resistant bark and self-prunes its lower branches to lift crowns above the ground. It is adapted to survive low-intensity surface fires (Hermann and Lavender, 1990). Conversely, Lodgepole Pine (*Pinus contorta* Douglas Ex Louden) is highly susceptible to crown fires and fire-driven mortality. It reproduces by seed released from serotinous cones that open when heated (Logan and Powell, 2001). Organized

FIGURE 2
The location and size of the Chilcotin region in central British Columbia, Canada.

fire suppression began around the 1940s, altering the structure and composition of forests and grasslands, and resulting in fuel buildup (Blackstock and McAllister, 2004), woody species encroachment into grasslands, and densification of woodlands and open forests (Bai et al., 2004).

As in other parts of BC's dry interior, the Tsilhqot'in people used fire to encourage ungulate browsing, thin understory vegetation, and prevent conifer and sagebrush encroachment into grasslands (Turner, 1999; Blackstock and McAllister, 2004). Hence, IFM shaped the region's historical fire regimes, creating a fire-adapted landscape (Kay et al., 1999). However, colonial fire exclusion through the forced relocation of Indigenous peoples onto reserves, and the prohibition of Indigenous burning, fundamentally altered the historical fire regimes and forests (Greene, 2021; Copes-Gerbitz et al., 2022). Several fire history reconstructions in central BC have documented the absence of low- to moderate-severity fires following colonization in the mid- to late-1800s, which altered forest structure and composition, leaving the landscape vulnerable to high severity fires (Harvey et al., 2017; Brookes et al., 2021; Copes-Gerbitz et al., 2022). Hence, revitalizing Indigenous fire practices offers an important landscape stewardship tool missing for almost a century (Nikolakis et al., 2020).

To address the increasing wildfire risk, the Yunesit'in and Xeni Gwet'in, two of six members of the Tsilhqot'in National Government, have taken over fire management on their lands from the British Columbia government (Nikolakis et al., 2020; Nikolakis and Roberts, 2021). Both First Nations are revitalizing their fire practices through a pilot program that commenced in April 2019, with support by the Gathering

Voices Society, an organization that facilitates Indigenous environmental stewardship programs.[9] This program aims to strengthen landscape stewardship, and to train local people in Indigenous fire practices that are rooted in Indigenous knowledge. Communities determine where and when to burn, and establish the rationale for burning specific areas. There are two burning periods each year, early spring (April and early May), and late fall (October), and each specific site is burned once a year. The program has now been expanded, and employs and trains dozens of community members in fire stewardship, from a combined population of around 500 people, and over a total area of more than 1,700 square kilometers held under Aboriginal title and reserve lands (Nikolakis and Roberts, 2021; Nikolakis and Myers-Ross, 2022). In April 2022, some 250 hectares of forest and grassland was burned.

Fire is used in this program for a variety of goals, including removing fuels to mitigate wildfire risk, to regenerate vegetation such as grasses and berries for people and animals, to clean the landscape and maintain forest health (Nikolakis et al., 2020). Yunesit'in and Xeni Gwet'in took active steps to learn from the Australian savanna experience, engaging with Indigenous fire practitioner, Victor Steffensen, in 2018 and 2019,[10] and formed a working group to investigate the feasibility of carbon credits to support their program. This working group included leading carbon and fire scientists and Indigenous fire practitioners, many from Australia. Under their guidance, field work is currently being implemented to develop rules and guidelines for generating carbon credits from the fire programs. Revenues from the sale of carbon credits could strengthen land stewardship and ecological outcomes, and provide jobs and income to community members.

It is important to account for the differences in landscapes and fire regime between the Chilcotin and Australia's northern savannas, as well as in the economic, political, and legal systems that influence how fire can be applied. "There is definitely. . . information and links and indicators that are going to help put the pieces back for [Indigenous knowledge and practice in] any fire prone country in the world. . ." A lot of them are going to have a lot of differences. But it goes back to that old saying, "Same but different" (Victor Steffensen, 2018; see text footnote 8). Hence the architecture of the Australian savanna programs can be used to guide the development of a fire-carbon program in BC. **Table 2** details the elements and characteristics of a project in the BC context.

Applicable methodologies in British Columbia

In contrast to Australia, no specific methodology or legal framework is currently available to underpin an Indigenous fire management program in British Columbia. Several grassland methodologies have been published with management practices that include biomass burning, but their applicability conditions are not suitable. Suitability refers to the accepted project activities. The most common example of an inappropriate activity within the context of this paper are projects that generate credits through cessation of active burning. It is important to note that Grassland burning projects in British Columbia, like those grasslands in the Chilcotin, are likely to be of only modest size, generating perhaps several thousand t CO_2e per annum. This is also the case for the Verified Carbon Standard (VCS) REDD methodology, VM0029 (Methodology for Avoided Forest Degradation through Fire Management). Though it applies to projects that implement preventative early burning activities to minimize late season burning emissions, it is only approved for application to the miombo woodlands in the Eastern Miombo ecoregion of Africa. Furthermore, the Australian and VM0029 approaches reference a baseline burning schedule that occurs predictably over one or several years. In BC, the baseline would be a probabilistic analysis of the risk of a catastrophic wildfire occurring over a time interval of decades, though with the possibility of smaller fires occurring more frequently. The empirical data used in Australia and in VM0029 to establish the baseline will therefore not be suitable for a project in BC, simply because the frequency, severity, and extent of fires are so different. Canada is in the early stages of developing a national compliance-driven cap-and-trade program. This includes development of methodologies for large emitters to offset a portion of their emissions deficit. Currently, BC is in the late stages of developing its Forest Carbon Offset Protocol (FCOP v2) as an equivalent in-province methodology, and to replace a version withdrawn in 2015. Early indications are that it may be able to accommodate cultural burning.

The BC government manages a portfolio of Carbon Offset Units[11] on behalf of all provincial public sector organizations in support of commitments to carbon neutrality. Organizations that have regulated operations under the Greenhouse Gas Industrial Reporting and Control Act or a desire to meet emissions reduction or net-zero targets can also purchase these units. Assessing the suitability and integrity of a project to generate Carbon Offset Units is a multi-stage process and involves an evaluation of the project attributes and a clear demonstration of carbon sequestration, whether from enhanced removals or emission reductions.[12] As an activity that

9 See: www.gatheringvoices.com.

10 See: https://vimeo.com/377626207.

11 A B.C. Offset Unit represents a tonne of carbon dioxide equivalent that was either removed from the atmosphere or not released into the atmosphere as the result of direct, beyond business-as-usual action by a project proponent. These actions are validated and verified by an independent, accredited third-party to ensure they are real, permanent and additional. See: https://www2.gov.bc.ca/gov/content/environment/climate-change/industry/offset-projects.

12 Developing a new offset project involves a. Assessing feasibility, b. Creating, and c. Validating a project plan, followed by d. Developing and implement a project management plan.

TABLE 2 Elements and characteristics of BC fire-carbon programs.

Element	Characteristics and application in BC
Zonal designation	Australian savannas have well-defined zones of high and low rainfall. In BC, the provincial Biogeoclimatic Ecosystem Classification (BEC) system could be used to identify fire-dependent ecosystems based on precipitation and temperature regimes. In the Chilcotin region these are Bunchgrass, Interior Douglas-fir (IDF xm, dk 3,4), and Sub-boreal spruce (SBS dw 1,2).
Seasons	Whereas the savanna has one EDS burn period, there are two potential burn periods in the Chilcotin, after snow melt (March/April), and late summer or fall (October/November). Under the right climate conditions, these two periods should generate fires of reduced intensity ("cool burns").
GHG gases	The main greenhouse gas abated in the Australian program are CH_4 and N_2O. These are also applicable in BC. CO_2 will be included in terms of fossil fuel emissions or if significant tree loss occurs due to fire.
Additionality	Activities anticipated within the BC burning program will be consistent with the additionality principle articulated above.
Project area	A single project area will initially be developed as a pilot and located within Chilcotin, Xeni Gwet'in and Yunesit'in territories. The tenure holders are the Xeni Gwet'in (title lands) and Yunesit'in First Nations (Yunesit'in—Stone Reserve), both part of the Tsilhqot'in Nation.
Project activity	In Australia, EDS fires are a temporal substitute for LDS fire events because the former reduces occurrence and severity in the latter within the same year. In BC, burning is anticipated to occur in both spring and fall but its occurrence is designed to mitigate the overall risk of catastrophic wildfire.
Net abatement amount	Net abatement from burning in Australia can be demonstrated annually because of the very high natural fire frequency. The positive impacts of Indigenous fire management will be subtler in BC because of longer fire return intervals (several decades, or more). In this case, net abatement will need to be demonstrated using regionally calibrated fire models.

reduces emissions through the protection, transformation, or restoration/enhancement of land or water features, the burning program may be well suited as a mechanism to enhance carbon sequestration.

A second attribute is that a BC project must realize one or more of eight desirable outcomes:

1. **Supports reconciliation with Indigenous groups**
2. **Enhances public infrastructure or services**
3. Advances clean technology
4. **Provides employment opportunities to diverse people and groups**
5. **Encourages economic development in rural and remote areas**
6. **Increases resilience to the effects of a changing climate**
7. **Advances innovative offset opportunities, and**
8. **Introduces a new offset project to the Portfolio**

The bolded items listed above are those of particular relevance to the proposed IFM program, which would thus have many desirable outcomes within the BC offset program.

Moving forward: Recommendations

Once a final version is released, the BC FCOPv2 methodology may have applicability to the communities' fire management project. FCOPv2 includes the three main GHG emissions (CO_2, N_2O, and CH_4) and has considerable flexibility in terms of permitted (and desired) activities. The largest obstacle to overcome in this approach will be the derivation and application of the additionality principle, which requires a comparative analysis of emissions under both the baseline and project scenarios. Additional challenges include an updated and accurate vegetation map, methods to quantify emissions, and the timing for prescribed burning. In Australia, emission reductions are achieved by shifting annual burning from the LDS (the baseline) to the EDS. This differs from circumstances in BC, where fires are not currently set deliberately (the baseline). In this case, fire will be re-introduced intentionally as a means of reducing fuel loads, thereby mitigating the risk of larger, more intense wildfires. This analysis relies on a probabilistic assessment of the change in fire risk, as determined using an appropriate computer model calibrated for the region. Another consideration is that savanna fires in northern Australia occur with sufficient frequency, intentionally and naturally, that an accurate retrospective record of emissions can be documented as per baseline requirements, as well as any immediate and actual emission reductions resulting from project activities (EDS burning, in particular). Natural fire return intervals in BC are much more protracted, in the order of decades, or longer. This is, in part, due to the natural fire cycle but is also a statistical consequence of fire suppression. Documenting historical baseline emissions on the project area with any reasonable accuracy will thus be a challenge, as will quantifying the impact of project activities on emission reductions. These are distinct and important differences that characterize the Canadian context, and will require a more complex approach than is utilized in Australia.

How the baseline and project activities are established, and whether these will achieve a degree of rigor sufficient to be verifiable, remains an open question. A key first step will be to develop the procedures for establishing the baseline and project activities, and then engage in a pre-validation audit (PVA). Under a PVA, the approach and associated calculations are subject to independent review and opinion of compliance to a given standard and its associated methodology. PVA can provide confidence that a fully developed project will achieve the rigor necessary to acquire certified carbon credits.

There is also the potential to broaden the management activities within the project, beyond just fire management. For instance, Yunesit'in and Xeni Gwet'in could integrate forest management and harvesting into the project areas. These "mixed" project types are more complicated to administer, but offer flexibility around land use and economic development on Indigenous lands over longer time frames, which has been identified as important to First Nations governments (Nikolakis et al., 2016).

Carbon credit ownership and permanence

All methodologies include a provision for unequivocal documentation of credit ownership. This determination can arise either from uncontested land title or from a right assignment granted to the project proponent. Ownership needs to be established and documented at the beginning of the project and throughout the crediting period (CP). One approach used in British Columbia is an Atmospheric Benefit Sharing Agreement (ABSA), a government-to-government arrangement which sets out ownership of carbon and revenue sharing.[13]

In the savanna burning program, all sequestration projects are subject to permanence obligations, which maintain carbon stores for which ACCUs have been issued. The Australian methodology requires proponents of sequestration projects to choose a permanence period of either 25 or 100 years. The minimum CP associated with an International voluntary standard is 20 years (VCS) and the minimum project length must be 30 years (i.e., carbon stocks must be maintained for 10 additional years beyond the minimum CP). The American Carbon Registry allows for a minimum 30-year CP, but carbon stocks must be preserved for 100 years after the final year for which credits were issued; the same requirement is expected under the BC Forest Carbon Offset Protocol. The 100-year time limit may be an issue for some First Nations governments, being viewed as too constraining for land use among future generations (Nikolakis et al., 2016).

13 While there is no jurisprudence around who owns carbon, five ABSAs have been concluded in BC, sharing ownership to carbon and revenues from the sale of carbon credits between First Nations and the Crown. See BC Government: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/consulting-with-first-nations/first-nations-negotiations/atmospheric-benefit-sharing-agreements#:~:text=Atmospheric%20Benefit%20Sharing%20Agreements%20(ABSA,local%20or%20international%20carbon%20markets.

Communication

Carbon credit buyers often prefer projects that are of a particular scale and deliver a suite of environmental, cultural, and social co-benefits. These will be a predominant feature of the Chilcotin project, and includes improved health and wellbeing among participants, enhanced connection to country and cultural knowledge transmission, and increases in biodiversity. These outcomes will create a "charismatic" carbon project that may command premium prices from individuals and organizations purchasing carbon credits, for whom Indigenous wellbeing and development are priorities. Hence, an effective marketing program is essential in order to reach prospective buyers and tell a story consistent with their corporate and/or social responsibility objectives. A strong marketing program targeting BC businesses, as well as government, could drive demand and should be a priority for the Chilcotin project.

Next steps

The concept of generating carbon credits through planned burning needs to be codified, with clear goals and objectives, and further government engagement with a view to potentially developing an ABSA or whether, in the context of Aboriginal title, an ABSA is necessary.

Important advice, from fire scientist Jeremy Russell-Smith, who has established these programs in Australia are that it must:

> "...start with Indigenous communities, thinking through their aspirations, and the aspirations are probably very similar in Canada to north Australia. It's got to involve First Nations people who have a lot of intellectual knowledge to bring to the table. [And] then approaching like-minded colleagues who can assist the process thinking through where an abatement program could be generated... Then you certainly have to think about developing an accountable methodology which has to be credible, has got to be transparent; if you're going to have people buying your product, you have to be able to deliver on your arrangements with commercial buyers and it wouldn't just be in Canada, there are international markets that people would be interested. Especially in supporting Indigenous economic development aspirations" (Jeremy Russell-Smith, 2019; see text footnote 1).

Russell-Smith noted there will always be "bureaucratic hurdles," but he was "surprised continuously about how the hurdles have just broken down, basically cause it's such a good news story" (Jeremy Russell-Smith, 2019; see text footnote 14). He also stated that:

> "Governance is the big issue, because you've got community governance, how families actually want to see this work, and they have to deal with the national requirements over how businesses should be run, and all the taxation issues that go with that. So, there are obviously complications about how you get the bottom-up governance effectively working in with the top-down corporate requirements. With the WALFA project, the formal governance arrangements really took about 10 years, even after the contract was signed, to get everybody on the same page. . .So there's a whole lot of different carbon projects that now operate under one arrangement, that's called Alpha Limited, Arnhem Land Fire Abatements Limited, it's an Indigenous owned enterprise. But all the directors are Indigenous people, representative of the different groups. It's got a very small and tightly focused corporate structure" (Jeremy Russell-Smith, 2019; see text footnote 1).

Getting governance arrangements right is critical for supporting the development of fire-carbon projects, and may involve an integration of Indigenous-led governance and more western style governance structures to bring this to reality.

Discussion and conclusion

The success of the Australian savanna burning program in mitigating destructive LDS fires, reducing GHG emissions, and delivering socio-economic and cultural outcomes to Indigenous participants, has garnered interest in adapting this approach to other contexts (Lipsett-Moore et al., 2018; Moura et al., 2019). In this study, we evaluate the potential for transferring the Australian savanna burning program to the temperate, arid ecosystems of the Chilcotin region in British Columbia, Canada. There are fundamental ecological, political, socio-cultural, legal, and economic differences to be overcome—what we focus on is the architecture for developing rules and guidelines for a suitable fire-carbon program. The Yunesit'in and Xeni Gwet'in are subject to wildfires that threaten their communities, and the integrity of their rights and title (Nikolakis et al., 2020). In response, both are seeking to revitalize their communities by restoring traditional fire management practices. Our goal is to use the Australian savanna burning program to inform the process in BC, determine whether a similar program is feasible in the Chilcotin, and whether carbon markets can bring revenues to strengthen the communities' stewardship roles on the landscape (and if so, what the key issues are).

In the savanna burning program, where fire intervals are short and predictable, the use of EDS fire in tropical open canopy forests has delivered reductions in N_2O, CH_4 and CO_2. These savanna burning programs were enabled by:

- The development of a national compliance market (supported through legislation);
- A federal government infusion of $2.55 billion (Australian dollars) to the carbon farming program;
- A broker market to facilitate the trade of carbon credits from producers to corporate buyers;
- An uncomplicated Indigenous-based project verification process, the "Core Benefits Verification Framework," which certifies the environmental, social and cultural values associated with a project; and,
- Strong carbon credit prices.

The Australian savanna burning programs have been well planned, with communities sometimes engaging in Healthy Country Planning, a bottom-up form of governance, to identify holistic goals through engagement with a fire-carbon program. There is a concern that land and fire stewardship could be too "carbon-centric," and lose sight of the Indigenous land stewardship ethic that includes responsibilities to care for the land, driven by ecological indicators. Nikolakis et al. (2020) examined the goals from Indigenous fire management in the Chilcotin, and these were indeed broader than simply carbon, including supporting ecological restoration (and food security) and maintaining Tsilhqot'in laws and responsibilities to the land. A planning process to align community and project goals is a critical step for building a "bottom up" governance approach.

Low-intensity fires will be applied two times a year to the Chilcotin project area, in spring and fall, to reduce fuel loads that have accumulated from fire suppression, and mitigate summer wildfire (often ignited by lightning). Compared to the Australian model, the effect of Indigenous fire management will likely be less pronounced for the Chilcotin program, primarily because of the longer fire intervals, though, as we note, an increasing trend of more high-intensity fires underscores the importance of implementing the program now. Work will need to be conducted on net abatement using regionally calibrated fire models. There will be limitations in documenting historical baseline emissions for the project area with accuracy, which will make determinations of reductions in emissions from project activities more complex. These issues around baseline and project activities bring into question whether the project can achieve a high degree of rigor in terms of establishing additionality. However, exploring this is necessary to bring vital revenues to the landscape level to mitigate wildfire and subsequent emissions.

The Chilcotin project will advance an important goal of supporting Indigenous reconciliation. Although there is no specific methodology or legal framework underpinning this program province-wide, on title lands the Tsilhqot'in Nation and Xeni Gwet'in can develop their own institutional framework, and the project is already galvanizing this. If project additionality can be validated, the FCOP v2 methodology appears to offer promise for building a carbon project: (1) It includes the three main GHG emissions (CO_2, N_2O, and CH_4); (2) Credits could be marketed in either a compliance market (under development in Canada) or voluntary markets, offering diversification; and (3) It offers the potential to include other forms of forest management activities (such as timber harvesting), which provides flexibility to the First Nations.

IFM practices have considerable potential but there are practical issues that have yet to be resolved. We identify four areas for attention: 1. Generating carbon credits through IFM needs to be codified, with clear goals and objectives. 2. Ownership: Do the First Nations need to share carbon credit revenues with the Crown (through the ABSAs), or is this precluded by Aboriginal title declarations that recognize the underlying ownership of First Nations to their lands and resources (which may include carbon)? 3. Project length: what periods are preferable? Decadal length commitments allow for flexibility in management practices and resource allocation, while longer periods are consistent with an intergenerational vision for the landscape, yet contracts that restrict land use may also constrain the self-governance of First Nations. 4. Community level planning. As with the planning processes that support IFM and carbon programs in Australia, like the Healthy Country Planning in Australia, bottom-up governance relies on grass-roots participation, promotes local engagement and leverages traditional ecological knowledge. This is preferable to top-down processes that tend to be prescriptive, one-size-fits all that do not account for local context and do not empower community members to take ownership over the program. When properly implemented, Indigenous-led fire-carbon programs can deliver a suite of co-benefits encompassing livelihood, ecological, cultural, health and social outcomes. However, following Robinson et al. (2014), who called for more information on the risks and opportunities from carbon offset trading to Indigenous communities and for greater attention to the capabilities required to harness the opportunities, we call for further research on the kinds of governance approaches that can generate positive outcomes in this context.

Author contributions

WN contributed to funding, project management, support conceptualization, writing and editing, analysis, and recommendations. CW contributed to conceptualization, writing and editing, analysis, and support recommendations. GG contributed to writing, editing, and analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

WN was a senior officer with the Gathering Voices Society, which supports the Chilcotin project. CW was employed by the 3Greentree Ecosystem Services Ltd.

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

Publisher's note

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