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Socioeconomic framework and indicators for assessing cumulative effects of resource development on indigenous nations

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ABSTRACT

The development of natural resources, particularly mining and associated infrastructure, has profound impacts on ecosystems and people, particularly on host communities, with Indigenous people often bearing unequal burdens. Mainstream impact assessments continue to be disproportionately directed towards evaluating mostly biophysical impacts, usually neglecting the critical issues of cultural, social, health and economic aspects that impact Indigenous ways of knowing and being. In this paper, we provide a conceptual contribution to the search for a holistic socio-economic assessment of the cumulative impacts of resource development on Indigenous people. Drawing upon existing research and direct engagement with Indigenous people, we propose a holistic framework for regional cumulative socio-economic effect assessments of resource development. We anchored our framework in the concepts of environment, place, and space linked to the Indigenous concept of wellbeing. To operationalize the framework at the regional level, we recommend building Indigenous representation and capacity by adopting Indigenous governance systems, legal principles and values based on the concepts such as the *mino pimatisiwin*. Our approach provides a holistic, relational, interrelated, and interdependent view that is culturally sensitive, responsible, and reciprocal and provides a relevant foundation for selecting appropriate socio-economic indicators to assess regional cumulative effects of mining on Indigenous people.

1. Introduction

Historically, the development of natural resources, including mining and associated infrastructure, has disproportionately affected host communities, particularly remote and Indigenous people in many parts of the world. Most policies and values guiding resource development are created by and for the benefit of industry and the State, often marginalizing Indigenous people (Perrault et al., 2025). A review of the impact of natural resources on Indigenous communities between 1979–2020 argued that the combined impacts of past and ongoing effects of colonization, increased globalization, industrialization, and trade liberalization has made most Indigenous people more vulnerable to displacement, alienation, cultural erosion, and social exclusion (Mishra et al., 2021). Thus, in most cases of resource development, the expectations of Indigenous host communities overlap and sometimes conflict with those of resource development actors, namely the state and industry (Antwi et al., 2017; Hilson & Basu, 2003).

Evidence regarding the benefits of resource development for Indigenous communities is mixed and unclear, as baseline data are often lacking (Winter et al., 2021; Public Policy Forum, 2006). However, it is generally agreed that mine development has had several developmental advantages, particularly the modernization of community

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infrastructure, such as sanitation, electricity, and running water, as well as economic development opportunities, including financial compensation (Winter et al., 2021). Yet, continuous extraction of resources on the lands and territories of Indigenous peoples has led to several concerns being raised, often focusing on the physical environment (e.g., the air, soil, water, food, and plant and animal species) and a wide range of social, economic, and cultural issues including cultural conflicts (Parlee and O'Neil, 2007; Winter et al., 2021). For instance, although resource development is associated with employment opportunities, they tend to be short-term, and Indigenous Peoples are disadvantaged due to lower educational attainment (Gibson & Klinck, 2005; Angell & Parkins, 2011; Amnesty International, 2016). Thus, mine development can worsen Indigenous host communities' health and wellbeing by perpetuating the health, social, and cultural impacts of historic environmental dispossession.

Canada, a major resource extraction country and home to Indigenous people, has had long-standing issues with resource extraction on Indigenous reserve lands and the impacts on their health and wellbeing. Several studies have shown that the loss of Indigenous reserve lands to mining has had several negative consequences for Indigenous ways of knowing and being. For instance, in 1987, Loney (1987) documented that when Chemawawin First Nations in Manitoba were displaced from their traditional territory and could not hunt, fish, or trap, they resorted to drugs and alcohol; others contracted tuberculosis, while others committed suicide. In the recent past, Windsor and McVey (2005) documented how the displacement of the Cheslatta T'En First Nations in British Columbia damaged the established social relationships of the people and destroyed their sense of group identity, loss of both place and sense of place. Richmond et al. (2005) also reported a strong link between reduced access to environmental resources and declining 'Namgis First Nation's health and wellbeing. Amnesty International's (2016), study on the social impacts of gas development in BC's northeast region reported loss of access to lands, gendered violence, and increased competition for land use with non-Indigenous recreational users and social strain from an influx of non-residents leading to inflationary increases in local housing prices and the cost of living. Stockwell (2015) also reported gendered violence in resource communities, with Indigenous women and girls particularly vulnerable to increased risk of violence. Additionally, Indigenous women and their families have faced homelessness and a lack of financial resources to sustain their households. These challenges have led to the breakdown of marital relationships and caused families to become disconnected from their extended support systems.

Besides impacts reported on health and wellbeing, a limited number of studies have reported the weakening of Indigenous governance systems, including limited participation in impact assessment (IA) processes, and the inception of internal conflicts between and among Indigenous communities because of resource development. For instance, Whitelaw, McCarthy & Tsuji (2009) reported that mine resource development has been a source of tension/disagreements within and among an Indigenous community. The study also found that Elders and adults, as well as young people, felt that youth were not being included in the IA process and that more should be done to ensure they are heard in community decision-making processes, such as public meetings. More recently, technical and capacity issues such as limited community capacity and knowledge in the IA process and a lack of resources to acquire the help needed to participate in the IA process have been reported (Arnold et al., 2023). This asymmetrical distribution of resources, power and negotiation skills often does not favour Indigenous people (Larsen et al., 2017), creating a power imbalance between States and corporations at one end and host communities at the other end (Parlee & O'Neil, 2007). The power imbalance faced by Indigenous people in the resource sector is exacerbated by a lack of capacity, formal education, and differing values around resource development. These also limit the ability of Indigenous communities to fully grasp and document how resource development affects their communities and wellbeing, as well as how non-Indigenous partners' understanding of how mining changes host communities (Perrault et al., 2025).

Generally, while IA have evolved to consider the lack of consideration for Indigenous wellbeing and broader socio-economic issues (see Vanclay et al., 2015), emerging evidence on the ground suggests that IA assessments often do not comprehensively and interactively address ecological, social and governance issues in Indigenous communities (see Antwi et al., 2024; O'Faircheallaigh, 2015; Whitelaw, McCarthy & Tsuji, 2009; Parlee & O'Neil, 2007; Antwi et al., 2022) and fail to account for the self-determining rights of Indigenous peoples (O'Faircheallaigh, 2007). Most often, environmental and social impact assessments are conducted to meet regulatory standards and as separate studies, often excluding communities' wellbeing (Leyton-Flor and Sangha, 2024). Moreover, States and project proponents have a narrow scope of socio-economic and human health indicators during impact assessments (Parlee & O'Neil, 2007; Whitelaw, McCarthy & Tsuji, 2009; Kryzanowski & McIntyre, 2011; Arnold et al., 2023) and often fail to provide adequate funding and time to enable inclusive and robust Indigenous participation (O'Faircheallaigh, 2007; Gibson et al., 2016; O'Faircheallaigh and MacDonald, 2022). For instance in Canada, although attempts have been made to explicitly incorporate Indigenous concerns and broader socio-economic issues in the new Impact Assessment Act (2019), emerging research suggests that there are several obstacles (e.g., failures to engage best practices, financial limitations, underlying power structures, imbalanced decision making power, knowledge incompatibilities, effects of colonization, etc.) that prevents the Act from meaningfully engaging Indigenous communities (Eckert et al., 2020). Moreover, a recent assessment of 37 Hydroelectric projects for social impact in Canada showed that despite improvements in methods and approaches for social impact assessments, 'baseline assessments and anticipations of social impacts remain focused on the implications of population growth, physical infrastructure, and socio-economics with minimal consideration for the livelihoods, culture, and wellbeing of host communities' (da Silva, Parkins, & Sherren, 2021). For instance, Gunton (2015, p.17) argued that the incorrect characterization of benefits and burdens of the Transnational Mountain Pipeline Energy project (i.e. "incorrect assumption that regional or local costs and benefits should be discounted relative to benefits deemed national") by Canada's National Energy Board highlights the challenges Indigenous Peoples continuous to with impact assessment.

The continuous disregard for Indigenous perspectives/concerns in contemporary impact assessments echo the practices of the 1970s – before Canada had a statutory impact assessment regime or the constitutionally mandated duty to consult – when environmental impact assessments were largely absent, and decisions regarding projects were driven solely by technical and economic considerations (Antwi et al, 2024). For instance, in 1975, the James Bay hydroelectric project in northern Quebec, often referred to as the "project of the century" proceeded without the knowledge or consent of the Eeyou (Cree) and Inuit peoples living in the affected areas (Côté et al., 2017). This lack of consultation led to significant controversy (Marsh, 2023; Antwi et al., 2024) and eventually triggered a legal action leading to what is regarded as Canada's first known modern treaty. While this event reshaped Crown-Indigenous relations, the project's exclusionary decision-making and the enduring cultural and environmental harm foreshadow challenges that echo through contemporary times, serving as a reminder of the persistent challenges Indigenous peoples face when their voices and legal orders are marginalized in resource development.

In summary, existing IA methodologies and practices inadequately address issues of concern for Indigenous communities. Yet, due to a lack of capacity and resources, Indigenous communities are often unable to address issues ignored by proponents, such as limited interpretation of the links between socio-economic and biophysical attributes and Indigenous wellbeing and the relationships between mining and historical colonial legacies. Indigenous people are again forced to rely on colonial settlers' knowledge, which fails to accurately reflect the deep,

authentic knowledge held by Indigenous people and their people and continues to undermine and erase Indigenous ways of knowing and being. Therefore, there are significant knowledge gaps relative to our understanding of the long-term effects of resource extraction on Indigenous communities (O'Faircheallaigh, 2007; Centre for Indigenous Environmental Resources, 2009), particularly, how it impacts the health and wellbeing of Indigenous communities (Parlee & O'Neil, 2007; Rohr, Blakley, and Loring, 2021; da Silva, Parkins, and Sherren, 2021). This gap further perpetuates the marginalization of Indigenous worldviews in crucial areas such as resource development and environmental stewardship (Nadon, 2018) .

Over time and influenced by "resurgence and revitalization in place-based Indigenous laws and legal orders, interest and expertise in Indigenous-led impact assessment (IA) models have grown in recent years" (Scott, Sankey & Tanguay, 2023, p.3). Indigenous community leaders and researchers have advocated for a holistic assessment of the socio-economic effects of resource development from a host community perspective (Lockie et al., 2009; Arnold et al., 2023). Several Indigenous communities affected by resource development are seeking a holistic assessment of the impacts of resource development on their health and wellbeing (Luginaah, Smith & Lockridge, 2010; Windsor & McVey, 2005 Richmond, Elliott, Matthews, & Elliott, 2005). Such calls have either advocated for greater value to be placed on Indigenous Knowledge (IK) in impact assessment (e.g., Eckert et al., 2020) or effective braiding of IK and Western science for better understanding of environmental change, improved decision-making, and recognition of Indigenous rights (e.g., Abu, Reed, & Jardine, 2019). These calls are not only about recognizing Indigenous rights but also about respecting Indigenous laws and traditional ways of knowing and being, which existed long before colonial contact and continue to thrive outside of colonial structures.

In this paper, we propose a framework to guide regional-level socio-economic cumulative effect assessment of the impact of resource development on Indigenous Peoples. Cumulative effects are the "successive, incremental and combined impacts (both positive and negative) of one or more activities on society, the economy and the environment" resulting from the aggregation and interaction of impacts, which may be a product of the past, present, or future activities (Franks et al., 2013, p.646). We draw on Vanclay's conceptualization of social impacts to define socio-economic impacts as changes to people's way of life, their culture, their community, their political systems, their environment, their health and wellbeing, their personal and property rights and their fears and aspirations arising from planned interventions (Vanclay, 2002).

Fig. 1 provides a graphical overview of the research approach guided by the research question. We begin by reviewing existing literature on the impacts of resource development on Indigenous Peoples and their territories to identify indicators and measures relevant to assess the impacts of resource development. In selecting the indicators and measures, we were guided by specific Indigenous led concepts and frameworks on relationships between Indigenous Peoples and with the land and resource use. While the framework integrates indicators and measures from different countries, most of our examples are from Canada. As such, we also engaged two Indigenous scholars, an Elder and community members from the Apitipi Anicinapek from the Algonquin Anicinapek Nation of the First Nation Indigenous people to develop the framework and indicators. This engagement and consultation are not meant to represent the diversity of Indigenous voices and Peoples of Canada. Our research builds on previous studies (see Parlee and O'Neil, 2007; Parlee and O'Neil, (2007; Kryzanowski & McIntyre, 2011; Marks, Cargo MD, Daniel, 2007) that have used an Indigenous lens to develop culturally appropriate framework and indicators for monitoring the impacts of resource extraction on the health and wellbeing outcomes of environmental exposure. Moreover, our framework aligns with Indigenous led assessments (see Nishima-Miller, 2021; Sacred Trust Initiative, 2015). It is important to note that, in addition to information derived from published literature, the views shared in this research study are those of Indigenous community members, Indigenous scholars and an elder from the Apitipi Anicinapek Community. The Indigenous scholars and an elder co-designed the study, contributed to the drafting and revision of the manuscript, and are recognized in this paper as co-authors. In the following section, this paper shares the conceptual and methodological approach adopted in the identification and development of the indicators and framework for assessing the socio-economic cumulative effect. We proceed to present the proposed indicators and framework for assessment, discuss the outcome of the study, and conclude on the study.

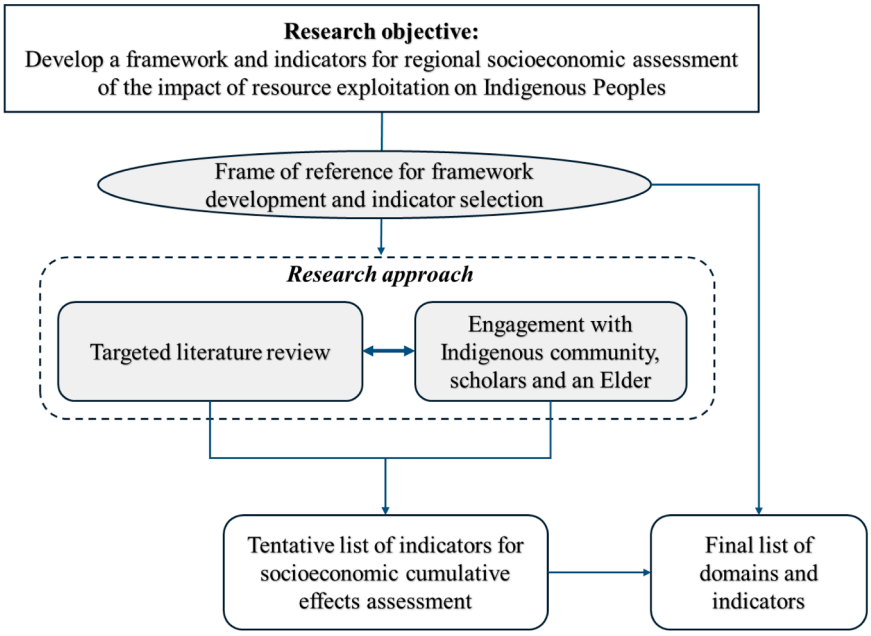

Fig. 1. Research approach.

2. Conceptual and methodological approach

2.1. Conceptual approach

Researchers and Indigenous communities have advocated for a holistic approach to the impact assessment, particularly one that captures the cumulative effects from impacts experienced during exploration and extraction activities of combined development of several resource facilities within commuting distance (Braid et al., 1985; Uhlmann et al., 2014). Measuring cumulative social impacts is very challenging because it is often impossible to delineate the specific social impacts that may occur in any situation (Vanclay, 2002), but also social impacts are potentially 'wicked problems', where linear relationships between cause and effect may not be evident (Uhlmann et al., 2014). As the practice of cumulative effects assessment evolves, new tools (see Antwi et al., 2025) and approaches for measuring and assessing cumulative effects have emerged.

To address complex and wicked problems, researchers have advocated approaches that promote the interaction of different knowledge systems while respecting each other (Abu, Reed and Jardine, 2019; Westwood et al., 2023). For instance, Miller et al. (2008) advocate for the use of epistemological pluralism, an approach that recognizes and accommodates the plurality of multiple valuable ways of knowing in different contexts. To do this, Rathwell et al., (2015) propose four settings that can facilitate the bridging of knowledge systems: the epistemological arena, methods and processes, brokerage mechanisms, and governance/institutional arrangements. In this study, we use the epistemological arena and methods and processes as the lens to braid Indigenous and Western knowledge systems in the development of a framework and selection of indicators for socio-economic impact assessment of resource development on Indigenous Peoples (See Fig. 2).

Choosing indicators for impact assessment without theoretical or conceptual guidance developed a priori can lead to overlooking existing or desirable indicators representing particularly key determinants of community wellbeing (Marks, Cargo, & Daniel, 2007). Thus, using an Indigenous concept of wellbeing and the concept of space and place as the lens through which to select indicators allows us to create a comprehensive, holistic, culturally relevant, and responsible set of indicators that align with the values, concerns, and issues faced by Indigenous people in resource development. Moreover, specifying a frame of reference for indicator development a priori enables consistent, theoretically sound, and policy-relevant consideration of options for management of regional development (Kulig et al., 2010). This approach also creates space for Indigenous knowledge to be utilized, considering that the socio-economic impacts directly affect Indigenous people. Next, we discuss two concepts that are relevant to Indigenous wellbeing: the Indigenous concept of wellbeing and the environment, place, and space.

2.1.1. Indigenous conceptualization of wellbeing

Different societies have different culturally constructed conceptions of what it means to be well, healthy, or satisfied. Although Indigenous peoples have no word that directly translates into English as health or wellbeing, studies of First Nations, Inuit, and Métis in Canada (e.g., Adelson 2000; Wilson 2003; Parlee et al. 2005; Richmond et al. 2005 Turner and Clifton, 2009) and other Indigenous communities within and outside Canada (e.g., Izquierdo 2009; Heil 2009) reveal that wellbeing, as articulated by Indigenous peoples, is linked to lives lived on the land. Adelson (2000) found that among the James Bay Cree of northern Quebec in Canada, the concept of *miyupimaatisiiun*, translated as "being alive well," is the closest concept to health and wellbeing. *Miyupimaatisiiun* is "less determined by bodily functions than by the practices of daily living and by the balance of human relationships intrinsic to Cree lifestyles" (Adelson, 2000, p.15). According to Adelson (2000), to "be alive well" means that one can hunt, pursue traditional activities, eat Cree foods, and keep warm. Similarly, Parlee et al. (2005) described how berry harvesting connected Teetl'it Gwich'in women in the Northwest Territories to their mental, emotional, physical, and spiritual selves, and to each other and their land. Turner and Clifton (2009) highlight the high nutritional and medicinal value of, and the physical work involved in, the Nuxalk Nation's traditional food system that keeps the natives healthy, active, and fit.

Thus, for Indigenous peoples, the connection to healthy ecosystems, meaning Indigenous wellbeing, is also a reflection of the quality of the environment and a proper sense of place (see Windsor and McVey 2005; Snyder et al. 2003). Wilson (2003) explored how First Nations peoples' connection to the land and meanings of place maintain their physical, emotional, mental, and spiritual health and identity. Thus, for Indigenous Peoples, the health of the land and the health of the people are considered inseparable (Parlee et al. 2005). Many studies on the health

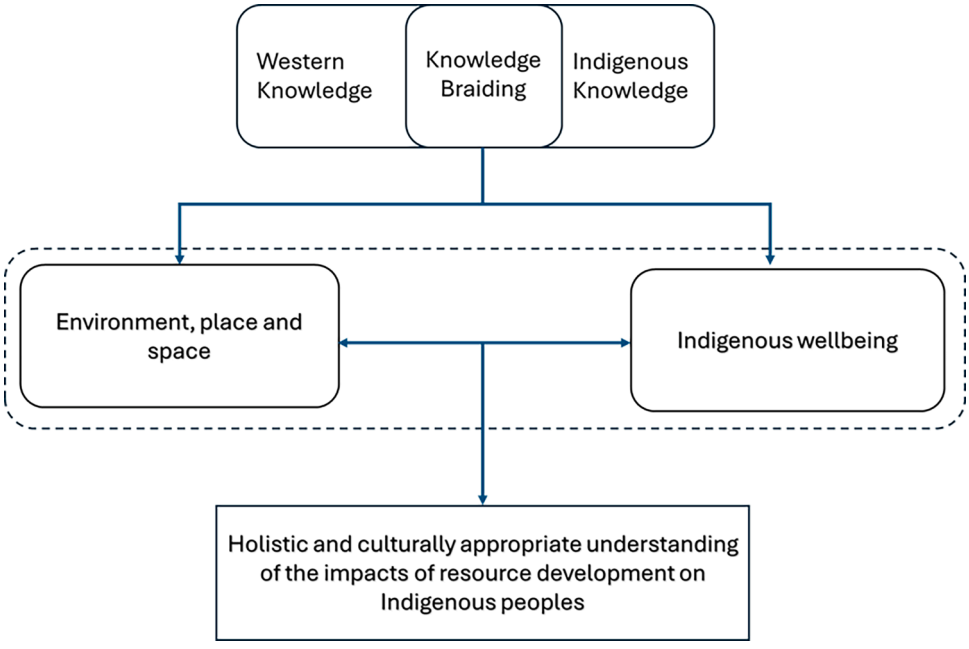

Fig. 2. Braiding indigenous and Western knowledge systems in impact assessment.

of Indigenous People in Canada have found that Indigenous culture protects the health and wellbeing of Indigenous People in many ways (Bartlett et al., 2012; Beatty, 2022; Cooper et al., 2020). The protective factors existing in Indigenous communities include a connection with their traditional land, traditional medicine, local foods, spirituality, and traditional activities (Beatty, 2022; Tobias, Richmond, & Luginaah, 2013; Willox et al., 2012). Adelson (2000) recounts that one Elder summarised the Cree conception of wellbeing by saying, "If the land is not healthy, then how can we be?" This is because for the northern Cree, a healthy land not only supports one's ability to harvest food but also defines who they are, including their cultural identity.

Beyond the connection to the land, Indigenous notions of wellbeing are expressed through an immersion in a closed network of kin, particularly in the social obligations of sharing (Adelson, 2000 ;Richmond and Ross, 2009), engaging in traditional and social practices, and responding to kin and social obligations (Heil, 2009).

In sum, the Indigenous concept of wellbeing focuses on the ability to live off the land, the nature of social and environmental relations, and cultural identity (Abu, 2018). However, as Indigenous Peoples are integrated into wage-based economies or transition to mixed economies, using either Western or an Indigenous lens alone to understand how resource developments impact Indigenous wellbeing may be inadequate. This view is supported by current literature that advocates braiding Indigenous and Western knowledge systems or approaches (see Abu, Reed & Jardine, 2020; Lawrence & James, 2019) to understand long-term changes in Indigenous lands and territories. Thus, bringing both Western (e.g., resource sector and market dependency measures) and Indigenous lens (e.g., traditional and cultural measures of wellbeing) to guide assessments on how resource developments impact Indigenous wellbeing is deemed a more appropriate frame of reference.

2.1.2. *Environment, place, and space and indigenous wellbeing*

Across the world, Indigenous worldviews often emphasize the interconnectedness and interrelatedness of all aspects of life that integrate human relationships' spiritual, emotional, environmental, and intellectual dimensions. This perspective sees every element, including people, animals, plants, land, water, and beyond, as part of a larger, interdependent web. Thus, to examine how mining affects Indigenous people, a conceptual basis or frame of reference rooted in Indigenous worldviews becomes an important starting point. On the other hand, because of the longstanding integration of Indigenous cultures and lifestyles in modern economies, an Indigenous lens alone would not sufficiently unravel the full range of impacts mining poses to the socio-economic life of Indigenous peoples. Thus, combining Indigenous worldviews and Western scientific concepts could aid in strengthening the relevance, breadth, and appropriateness of indicators used to assess the cumulative impacts of mining on Indigenous communities.

We draw on the concept of environment, space, and place and Indigenous holistic worldviews and ways of knowing and being as a respectful approach and entry point to examine how Indigenous communities connect holistically to the land and their environment and how disruptions in this relationship affect their health and wellbeing.

Human geographers have employed the concept of space and place to understand people's relationship with their local and immediate surroundings. The concept of place is defined as any locality, or space made meaningful through human experiences or attachments (Tuan, 1977). Places are differentiated by the cultural and subjective meanings through which the place is constructed and understood (Creswell and Poth, 2018), suggesting "intimate, personal, and emotional relationships between self and place" (Gregory et al., 2009, p. 676). People often ascribe different meanings, including peace, relaxation, aesthetic, economic, and spiritual, to places that are important to their health and wellbeing (Williams & Kitchen, 2012). For Indigenous peoples, a sense of place encompasses the complexity of meanings attached to places, including how "all entities of nature … rivers, plants, mountains, animals, lakes, stones, trees, among others, are embodied in relationships that must be honored" (Cajete, 2000; p.178). Thus, for Indigenous People, the land is the meeting point for meaning, health, and wellbeing (Watson, 2009), an essential aspect of place attachment.

Indigenous People in Canada have lived off the land for centuries and maintained a sacred relationship with their traditional lands for their health and wellbeing (Tobias et al., 2013; Willox, Harper, Edge, et al., 2013). This involved dependence on the resources of their lands for survival, including food, shelter, spiritual enrichment, cognitive development, reflection, and aesthetic experience (Lines, 2019), suggesting that the health and wellbeing of Indigenous peoples are integrally connected to their traditional lands (Greenwood et al., 2018). For instance, the capacity of an individual to be out on the land is vital for maintaining balance among the physical, social, emotional, and spiritual domains of health and wellbeing (Willox, Harper, Edge, et al. 2013). Consequently, the health and wellness of Indigenous People reflect the health of their land (Ballard et al., 2020; Cardinal & Hildebrandt, 2000). For instance, the Cree in Saskatchewan describe themselves as Iyiniwak, meaning the "people made healthy by the land" (Cardinal and Hildebrandt, 2000); thus, the Cree measure their health and wellbeing through healthy land (Adelson, 2000). Moreover, Ballard et al. (2020) observed that the strong relationship between Indigenous People and their traditional lands underpins their ways of knowing. Knowledge of how to successfully live off the land has been transmitted over generations through Oral Tradition and experiential teachings (Tobias et al. 2013; Tobias & Richmond, 2014). Therefore, for Indigenous People, there is an obligation to respect and look after the land for the land to look after them (Richmond, 2015).

Due to the strong reciprocal relationship with the land, any disturbance to the land can have significant impacts on the health and wellness of Indigenous Peoples. The establishment of the reserve system and signing of treaties often dispossessed and alienated many Indigenous Peoples from their productive lands, which supported traditional practices, and forced them onto lands that barely supported those practices (Burkhart, 2019; Tobias & Richmond, 2014). Also, the imposition of the residential school system stripped Indigenous Peoples of their Traditional Knowledge, culture, ceremonies, language, and healing systems, which are often passed on through experiential learning on the land (Bartlett, 2003). Because of the historical legacies of colonization, including historical trauma and ongoing racism, the general health status of Indigenous People is poor compared to the general Canadian population across the lifespan (Frohlich, Ross, & Richmond, 2006). The prevalence of chronic conditions including high blood pressure, obesity, diabetes, and respiratory diseases is higher among First Nations and Métis populations when compared to the general Canadian population (Reading & Wien, 2013; Waldram, Herring, & Young, 2006;Young, 2000). These suggest that a health crisis exists among Indigenous Peoples, which could be further worsened by resource developments. Hence, an assessment of the impacts of new resource developments on Indigenous communities should not lose sight of the existence and perpetuation of historical health inequities so as not to be worsened when new developments set in.

2.2. *Methodological approach: engagement process*

Informed by the conceptual framing, we employed a mixed-method approach, combining an Indigenous subject matter expert and community consultation and a targeted review of literature (Grant & Booth, 2009). The approach enabled the weaving of scientific Western data and local perspectives from Indigenous people in the development of the framework and identification of indicators for socio-economic cumulative effect assessment. Local Indigenous subject matter experts and community members of the Apitipi Anicinapek from the Algonquin Anicinapek Nation (AAN) of the First Nation Indigenous people were engaged. The Apitipi Resource Belt of Quebec and Ontario is a forest-dominated ecosystem with several ongoing and planned natural resource developments and is home to this First Nation. The Apitipi

Anicinapek Nation is a small component of the AAN Traditional territory created in 1906 through treaty No.9 (Apitipi Anicinapek Nation 2024). Resource development affects over a dozen Indigenous communities in the region, including the Algonquin Anicinapek people. Indigenous subject matter experts, including two scholars and an Elder, selected community members who had knowledge on the topic and were available for an in-depth discussion. Some of the participants include community leaders, council members and representatives of different socio-demographics in order to capture varying views of the community. The community engagement was led by the Indigenous scholars and six representatives, who also discussed with other community members. The discussion was informed by to identify community-designed prompts to identify and validate local indicators of socio-economic importance in relation to resource management. This was then used to create an initial list of indicators for socio-economic cumulative effects assessment.

Next, we undertook a targeted literature review to identify indicators relevant for measuring the impacts of resource development on Indigenous peoples and lands. The targeted literature review focused on peer-reviewed papers that (a) discuss the impacts of mining/resource development on Indigenous Peoples, (b) propose or develop indicators for social impact assessment, and (c) develop concepts or frameworks for social impact assessment and Indigenous health and wellbeing. We approached the literature review focusing on key papers and their references. Examples of papers that were used include: Vanclay (2002); Uhlmann et al. (2014); Fedorova and Pongrácz (2019); Joseph, Zeeg, Angus, Usborne, & Mutrie, (2017); Winter et al. (2021); Stockwell (2015); Amnesty International, (2016); Owusu (2020); Abu (2018); Whitelaw, McCarthy & Tsuji, (2009); O'Faircheallaigh (2015); Parlee & O'Neil, (2007). We also undertook an additional review of the Indigenous specific cumulative effects assessment to validate and identify additional indicators (Gunton, 2015; Sacred Trust Initiative, 2015). See Tables 1–5 in the appendix for the full list of papers. The outcome of these two approaches was a final list of domains and indicators for socio-economic cumulative impacts assessment. In addition, the use of both methods is complementary in providing a holistic picture of the elements to be considered (Grant & Booth, 2009).

The results of the in-depth discussion with the community members and the literature review were combined to form a complete set of indicators. Next, we engaged in targeted outreach with an Indigenous Elder and a selected Indigenous scholar. During the engagement, we discussed the framework and frame of reference for our assessment, the appropriateness and relevance of the list of socio-economic indicators, and the challenges of developing and implementing socio-economic cumulative effects assessment in an Indigenous context. For instance, the engagement enabled us to group and re-categorize the indicators into four domains (social and community wellbeing, economic, human health, social wellbeing, and governance). Further discussions enabled us to include additional indicators of relevance and recategorize and reframe how some of the indicators are selected. For instance, instead of the original social wellbeing domain, the engagement enabled us to create an additional domain called the cultural wellbeing domain and change the governance domain to the leadership domain. Also, the discussions highlighted some challenges and opportunities to the development of effective and culturally appropriate impact assessment.

Table 1
Indicators for social and community wellbeing domain.

Sub-indicator categories	Description	Source
Infrastructure	Investment by State/industry/ local business in accommodation, health care centres, child-care centres, etc., as a total or per capita figure.	Uhlmann et al. (2014)
Housing	Average rents for a given size house.	Uhlmann et al. (2014); Lawrie, Tonts, and Plummer (2011); Ryser and Halseth (2011).
	The average price of housing in the community hosting resource development	Joseph, Zeeg, Angus, Usborne, & Mutrie (2017).
	Variety of affordable accommodations available for vulnerable groups.	Fedorova and Pongrácz (2019)
	Cost of construction labour in the First Nation community.	Joseph, Zeeg, Angus, Usborne, & Mutrie (2017).
Health	Availability of addiction/suicide prevention programs and assistance to vulnerable people.	Fedorova and Pongrácz (2019)
	Suicide rate.	Winter et al. (2021)
Crime	Number of criminal offences per 1000 people	Joseph, Zeeg, Angus, Usborne, & Mutrie (2017).
Education	Number/per cent of new trainees & apprentices supported by the resource industry.	Fedorova and Pongrácz (2019)
Population growth	Growth of 10–15% suggests the onset of boomtown dynamics.	Uhlmann et al. (2014)
Social services	Waiting times for doctors.	Uhlmann et al. (2014)
Safety	Number of child-care places available per household.	Uhlmann et al. (2014)
	Crime rate and general perception of safety.	Uhlmann et al. (2014)
	The number of company trucks that travel regional roads	Uhlmann et al. (2014)
	Changes in the frequency, severity, and nature of traffic incidents,	Uhlmann et al. (2014)
	The extent of road deterioration	Cheshire et al. (2014)
Safety of women and girls	Number of gender-related violence against women and girls	Stockwell (2015); Amnesty International (2016)

3. Results: conceptualizing socio-economic cumulative impacts in indigenous contexts

3.1. Challenges and opportunities for developing an indigenous-inspired framework for socio-economic impact assessment

During our engagement, Indigenous scholars and the elder argued that the biggest barrier to guaranteeing Indigenous wellbeing and sovereignty in resource development in First Nations communities is ineffective governance, including local and regional capacity. They argued that industry and the State have taken advantage of First Nations communities by neglecting the specific needs of each community situated near industrial or mining sites. To illustrate this, the contamination of clean water due to pollution from nearby mines represents a blatant disregard for the health of the land and the people. In several mining host communities, necessities for thriving—clean water, clothing, shelter, and education—could be better secured if First Nations had the capacity to mine and manage their own resources, rather than allowing external entities to extract them. When other Nations or companies are contracted to mine resources, they become complicit in the harm done to First Nations from whose lands these resources are taken. The concerns of First Nations are often ignored, further complicating issues of rights, health, and sovereignty over their lands and resources. This exploitation highlights the ongoing marginalization and neglect faced by Indigenous communities about resource extraction.

To explore these issues further, Indigenous scholars and the Elder provided reasons why issues and concerns related to Indigenous people are less considered and prioritized in impact assessments. The responses are thematically summarised below:

- *Differing Value Systems*: The Elder and Indigenous scholars argued that Indigenous communities often approach issues from a perspective that integrates land, spirituality, community, and intergenerational knowledge. This contrasts with the Western focus on economic

Table 2
Indicators for economic impacts domain.

Sub-indicator categories	Description	Source
Employment	The number of residents, disaggregated by gender, employed by the resource industry.	Fedorova and Pongrácz (2019); Sacred Trust Initiative (2015)
	The number of additional mining-related jobs created.	
	Overall rate of Indigenous workforce participation and unemployment levels disaggregated by gender	Fedorova and Pongrácz (2019); Uhlmann et al. (2014)
Direct/indirect economic benefits	Emergence of new locally/ Indigenous-owned businesses.	Sacred Trust Initiative (2015)
	Income, e.g., individual or household income distribution before and after the mine.	Fedorova and Pongrácz (2019)
	Number of new vehicle registrations	Uhlmann et al. (2014)
Education & training	The percentage of residents and target groups (e.g., women, youth) enrolled and completing training or apprenticeships	Fedorova and Pongrácz (2019)
Cost of living	Cost of a basket of food for a local household	-
Regional economic development:	Number of Indigenous companies hired for contract work	Fedorova and Pongrácz (2019); Uhlmann et al. (2014)
	Number of Indigenous actors involved in the production supply chain	Fedorova and Pongrácz (2019); Sacred Trust Initiative (2015)

Table 3
Indicators for human health domain.

Sub-indicator categories	Description	Source
Noise	Levels and times of noise from traffic and equipment	-
Water quality	Number of households/communities without access to potable water	Uhlmann et al. (2014)
Occupational health and safety:	Number of mine-related accidents, worker injury rates and traffic-related injury	Fedorova and Pongrácz (2019)
Air quality	Health hazard from emissions, e.g., Human Toxicity Level indicator in life-cycle assessment	Fedorova and Pongrácz (2019)
	Increase in the number of respiratory or gastrointestinal illnesses	Gunton (2015)
Food quality	The extent of human exposure to contaminated fish/wildlife	Fedorova and Pongrácz (2019)
	Animal health (fish and wildlife contamination).	Fedorova and Pongrácz (2019)
	Effects on diet and nutritional outcomes	Gunton (2015)
The health of vulnerable groups	Social and health inequities that are experienced by seniors and aging populations	
	Increase in demand for mental health and addiction services	

and scientific measurements. As a result, Indigenous recommendations may be dismissed as "non-scientific" because they do not conform to Western academic standards, despite being deeply rooted in lived experience and ecological sustainability. Western knowledge systems tend to prioritize quantitative data, formal structures, and decision-making processes, which can undervalue Indigenous knowledge systems that are more holistic, relational, and qualitative. As a result, recommendations coming from Indigenous people often lack the influence necessary to be heard in these dominant systems. The lack of consideration for Indigenous worldviews often leads to the marginalization of Indigenous voices, even when these

Table 4
Cultural wellbeing domain and indicators.

Sub-indicator categories	Description	Source
Cultural sovereignty/ maintenance	Number of archaeological and cultural heritage sites preserved/protected	Owusu (2020); Sacred Trust Initiative (2015)
	Access to traditional/cultural food by households (#/week)	Owusu (2020); Abu (2018)
	Being able to pass knowledge and skill sets to the younger generation	Owusu (2020); Abu (2018)
	Number and attendance at cultural events and practices	-
	Ability to organize social and cultural activities related to the land	-
	Ability to perform burial and ceremonial sites	-
Closeness to nature	Ability to access spaces/places to connect spiritually with the land	Owusu (2020); Abu (2018)
	Ability to find peaceful spaces/ places on the land to heal and be free	Owusu (2020); Abu (2018)
Kinship bonds	Number of households that are able to share and receive traditional food	Owusu (2020); Abu (2018)
Livelihoods	Ability to pursue land-based activities – fishing, hunting, trapping, berry-picking, trips to a cabin (#/year)	Owusu (2020); Abu (2018)
Protection of traditional rights	Number of agreements achieved on the management of land use and Indigenous cultural heritage	-
	Level of satisfaction with those agreements	-
	Preservation/protection of spaces to access traditional medicinal plants	Owusu (2020); Abu (2018)
Recreation and physical strength	Ability to enjoy land-based recreational activities	Blueberry First Nation BC, (Supreme Court Decision, 2021)
	Ability to eat nutritious, healthy, and culturally relevant food	Abu (2018)
	Ability to actively collect bush/ traditional food	Abu (2018)
	Ability to use the land for camping, including travel and traditional routes	
Relationship building	Ability to connect and socialize with other communities	Owusu (2020); Abu (2018)
	Ability to maintain good human-animal relations	Abu (2018)
Eldercare	Ability to age well on the land	Abu (2018)
Cultural transmission	Ability to access sites for activities (e.g., resource harvest, trails) that foster intergenerational knowledge transfer (e.g., elder-youth interaction)	Sacred Trust Initiative (2015)

communities are deeply affected by the socio-economic issues being discussed.

- *Research Methodology Differences*: Western research methodologies often prioritize data that can be quantified and measured, whereas Indigenous research methodologies may place greater importance on storytelling, lived experiences, and relational knowledge. These methodologies offer valuable insights, but they may be disregarded by systems that demand standardized, scientific metrics.
- *Lack of Representation in Decision-Making*: Indigenous voices are often underrepresented in formal decision-making bodies, such as State boards, corporate decision-making, or research institutions. Even when Indigenous communities are consulted, the process may be tokenistic, without a genuine attempt to integrate their perspectives into the final decisions.
- *Power Imbalances*: Power dynamics between States, corporations, and Indigenous people often lead to recommendations from Indigenous people being overlooked or downplayed. The lack of political and economic power held by many Indigenous people can contribute to

Table 5
Leadership and local capacity.

Sub-indicator categories	Description	Source
Community engagement/ participation	Number of meetings held per year and number of people attending.	Booth and Skelton 2011
	Representativeness of participants.	Whitelaw, McCarthy & Tsuji, (2009).
	Inclusiveness of consultation opportunities provided	Whitelaw, McCarthy & Tsuji, (2009).
Social acceptance	Relationship between the mining company and communities.	Uhlmann et al. (2014)
	Perceptions of company responsiveness.	Uhlmann et al. (2014)
Community knowledge and capability	Community capacity to negotiate with external actors.	O'Faircheallaigh (2015)
	Capacity to understand the links between socio-economic and biophysical attributes	Whitelaw, McCarthy & Tsuji (2009); Parlee & O'Neil, (2007)
	Availability of community-generated resource mapping	Whitelaw, McCarthy & Tsuji (2009)
Information	Public availability of documents that supply information about the community aspirations and impacts on the community.	Parlee & O'Neil (2007)
Community/ regional leadership	Community perceptions that leaders represent their interests in negotiations with the resource industry and the State.	O'Faircheallaigh (2015)
	Tension/disagreements related to mine development among leaders within	Whitelaw, McCarthy & Tsuji (2009)
	Tension/disagreements among different Indigenous communities	Whitelaw, McCarthy & Tsuji (2009)
Institutional capacity of local States	The ability of local States to meet demands for an increase in infrastructure provision for locals	Cheshire et al. (2014)
	Ability to meet demands placed by transient workers on a range of local infrastructure and services (e.g., temporary accommodation, recreational facilities, health, and allied services)	Cheshire et al. (2014)
	Ability to manage competing (between mining firms and community actors) interests and represent diverse community interests	Cheshire et al. (2014)

their voices not being taken seriously in critical discussions on land use, resource extraction, and social policies.

- *Differences in conceptions of time*: The differing concepts of time between Indigenous communities and States, and industry groups present significant challenges. While the State and industry view time in terms of production and financial gain, Indigenous people see time through a lens of sustainability, ensuring that nature can endure ongoing development. These conflicting priorities further exacerbate tensions and impede the creation of equitable and culturally respectful solutions.

According to the Elder and Indigenous scholars engaged, addressing these challenges requires a shift toward decolonizing research and decision-making processes. This can include:

- *Integrating Indigenous Knowledge Systems:* Making space for Indigenous methodologies in research and policy development, acknowledging their value alongside Western approaches.
- *Capacity Building and Education:* Educating decision-makers on the validity of Indigenous worldviews and knowledge systems, while building capacity within Indigenous communities to navigate and challenge Western systems.
- *Partnerships and Representation:* Ensuring that Indigenous peoples have equal representation and decision-making power in areas that affect them and that their recommendations are given the same weight as those from Western experts.

These steps are crucial for creating a more equitable and inclusive approach to measuring the socio-economic cumulative impacts of resource development for Indigenous people.

3.2. Proposed domains and indicators for socio-economic cumulative effect assessment of resource development on indigenous people and local communities

Based on the outcome of the review and engagement process, we propose five domains and associated indicators for assessing the cumulative impacts of mining on Indigenous people and local communities. These domains are: (1) social/community wellbeing, (2) economic impact, (3) human health, (4) cultural wellbeing, and (5) leadership and local capacity.

Appendix 1 provides the full list of the domains and indicators, the source and type(s) of data needed to assess these indicators, the level or scale at which assessments need to be undertaken, and the stage or cycle in the mine development that assessments need to cover for the indicator in question. For instance, depending on the specific indicator, data can be collected at the community or regional level or both. While we do not provide a specific indication of who should collect the data, however, the diversity and multi-scalar nature of the data needed to come to a holistic understanding of the cumulative impacts of resource development suggests that data would come from diverse sources but could be centrally managed. In addition, some of these data types, particularly community-level data on Indigenous wellbeing and resources, should be managed in accordance with ownership, control, access, and protection (OCAP) principles (First Nations Information Governance Centre, 2021).

Also, for any of the proposed list of indicator data sources, it would be important to determine if baseline data is available and in what format. In the absence of this, a decision has to be made on the adequacy of available data for the assessment. For instance, during impact assessments, managers of CEA need to evaluate whether the natural capital is the right baseline data and adequate for analyzing the impact on present and future generations (Bond and Dusík, 2020). Also, depending on the context, the temporal boundaries for specific indicators are likely to be informed by the pre-contact environment (cultural baseline) or the way of life when it was protected via Indigenous-settler treaties (relational baseline), or a combination of both (Muir et al., 2023). Finally, overlaps among the domains and indicators are to be expected, as the Indigenous way of life cannot be easily partitioned given the likelihood of connectivity among the elements (Muir et al., 2023). Below, we describe each of the domains and associated indicators.

3.2.1. Social and community wellbeing

The social/community wellbeing domain focuses on indicators that examine the impacts of mining on the social infrastructure and wellbeing of the community. Specifically, we focus on the impact of mining on tangible and intangible community assets as well as other aspects of community social life, such as population growth, and the safety of women and girls against gender-based violence (Table 1). The tangible assets include community-level infrastructure such as accommodation, healthcare, and child-care centres. This is because major mining projects often lead to increased population and the consequent demand on social services and infrastructure can be huge. The social and community wellbeing domain focuses on examining how much investments have been made to improve social infrastructure. Table 1 provides a list of all the social and community wellbeing domain indicators, their descriptions, and the literature from which they were derived.

3.2.2. Economic impacts

The economic impacts domain focuses on the changing economic landscape at the regional and community levels and the impacts on economic self-sufficiency and sustainability at the community level including opportunities to practice wage economy, benefit from the emerging resource industry, and potential for new local business to emerge as well as other economic factors important to living a dignified life (see Table 2). This is consistent with Indigenous led framework that recognizes the right to derive benefit from the territory and pursue economic development opportunities in a variety of ways, related or unrelated to natural resources (Sacred Trust Initiative, 2015). Understanding the economic impacts must also require specific institutional arrangements to monitor and mitigate adverse impacts. Employment is a major issue for Indigenous people or host communities. In most instances, concurrent construction of multiple projects would require individual projects to employ more of its labour force from outside the local area than would be necessary if only one large construction project took place. Thus, the assessment must recognize the potential for boomtown effects to occur and create considerable disruption in communities existing infrastructures (Braid et al., 1985). However, because of the limited capacity to respond rapidly in rural areas to the fast changes induced by mining, the negative impacts on the supply and affordability of accommodation can be significant (Uhlmann et al., 2014). Table 2 provides descriptions of the various economic impact indicators considered.

3.2.3. Human health

The human health domain focuses on biomedical indicators of health associated with environmental exposures from mining-related impacts. The main indicators under the human health domain focus on impacts related to noise, air, and water pollution as well as mine-related accidents. This domain is different from the cultural domain, which includes other health indicators, but from an Indigenous conception of health that goes beyond biomedical indicators of health and wellbeing (see section 5.1.4). Table 3 describes the various human health indicators and sub-indicators to be considered in understanding the impact of mining among Indigenous people.

3.2.4. Cultural wellbeing

The cultural wellbeing domain focuses on many aspects of the day-to-day life of Indigenous people and how they are connected to health and wellbeing at the individual, household, and Nation levels. A wide range of indicators measure how mining affects the ability of individuals to maintain their sense of identity, continue traditional and religious practices, protect traditional rights, maintain kinship bonds, and live and age well on the land. The cultural wellbeing domain is consistent with Indigenous led framework that advocates for the "right of Indigenous Peoples to access important places with the assurance that they will be physically and culturally intact, without disturbances of the view, violation of privacy, noise intrusions, polluted water, or contaminated sediment" (Sacred Trust Initiative, 2015, p.25). Details of the various cultural wellbeing indicators and sub-indicators have been provided in Table 4.

3.2.5. Leadership and local capacity

From a broader governance perspective, Indigenous led frameworks have suggested the need to account for the right to possess, occupy and use their territories and the responsibility to steward environmental resources (Sacred Trust Initiative, 2015). Within the context of resource extraction, we illustrate this through leadership and local capacity of Indigenous Peoples to participate in consultation, provision of information, equity/inclusiveness, Indigenous capacity, and knowledge to participate and scrutinize project impacts and transparency in decision-making and governance processes. In broad terms, the governance domain contributes to operationalizing the promotion of free, prior, and informed consent (FPIC) to reshape the suit of governance regimes designed to address the local consequences of extractive industry development in Indigenous territories (Mahanty & McDermott, 2013). It is important to emphasize that the application of the governance domain within a specific region is conditioned on contextual factors such as State laws and policies, the socio-political environment, and the overall distribution of rights and resources (Mahanty & McDermott, 2013). Table 5 shows various governance domains and indicators, and a detailed description of what has to be considered under each domain.

4. Discussion

4.1. Our approach and outcomes within the broader context of impact assessment

Researchers, particularly from Indigenous, health, and impact assessment fields have long intimated the limited understanding of how resource development activities impact the health and wellbeing of Indigenous and local communities given the narrow range of socio-economic issues often considered in impact assessments (see Luginaah, Smith & Lockridge, 2010; Windsor & McVey, 2005; Richmond et al., 2005). To address this gap, we used an integrative, multi-dimensional, and culturally appropriate approach to arrive at domains and indicators for regional socio-economic cumulative effect assessment.

Our approach is inspired and consistent with growing interest in Indigenous-led or inspired impact assessment (Scott, Sankey & Tanguay, 2023) and also aligns with Vanclay's (2002) domains of the social change process for social impact assessment. However, our domains and indicators are targeted and specific to Indigenous contexts. More importantly, our proposed list of domains and indicators is not meant to be complete. Rather, we present an indicative list of examples of conventional and culturally relevant indicators rooted in the concept of Indigenous wellbeing and governance. Consequently, there may be overlaps within these categories, even though the indicators remain culturally appropriate and robust.

The multidimensionality of the indicators illustrates the complex issues constituting cumulative impacts and the need to select indicators that represent overall impacts across the social system rather than discrete changes. Our approach is unique and innovative as the frame of reference that guided the domain and indicator selection blends scientific and traditional Indigenous worldviews. This enables us to focus on several priority socio-economic issues that may often not be covered sufficiently by proponents in formal IA processes. However, the wide-ranging indicators chosen should be seen not as an end, but as providing opportunities for actors to engage in dialogue and priority setting since consideration of a large set of indicators can be a complex task in planning and governance (Uhlmann et al., 2014). Consistent with Uhlmann et al. (2014) and Vanclay (2002), the outcomes of our work can serve as a starting point for discussions on local and regional goals and priorities in the context of mine sustainability in Indigenous and remote communities. While not all the indicators may be relevant at a specific point in time or context, the resulting indicators need to be operationalized to make them relevant within these specific contexts. For instance, the domains and indicators can be used as baselines to understand how local-regional socio-economic Value Ecosystem Component (VEC) conditions will change in the future with the onset of cumulative effect stresses. By this, the domain and indicators provide information that can enable decision-makers and stakeholders to be better informed on the selection of potential VECs and conditions, what factors shape VEC conditions, and where mitigation efforts should be directed towards, and provide a basis for regional-level monitoring. As noted by Uhlmann et al. (2014), indicators with a time dimension and potential application at multiple scales (e.g., local, and regional) are needed in the broader discussion of cumulative impact. At the same time, the domains and indicators can enable broader debates about the meaning and measurement of progress in not just Indigenous communities but also remote and local mineral-rich communities.

4.2. Proposed new framework for regional socio-economic cumulative impact assessment

In Fig. 3, we provide a framework for regional socio-economic cumulative impact assessment through an Indigenous and western lens. At the heart of the framework is the need to integrate Indigenous and Western science as a lens to understand the wellbeing impacts of resource governance. However, we argue that whether such integration would happen depends on the governance system in place. Thus, governance is a critical mediating factor in arriving at a culturally relevant approach for impact assessment. This realization is informed by experiences shared by the Indigenous scholars and the Elder we engaged as part of this research who all argued that the current impact assessment fails Indigenous peoples because of prevailing governance systems that do not consider Indigenous values and knowledge as legitimate sources of evidence despite being rooted in lived experiences and ecological sustainability. This, combined with the fact that Indigenous voices are often underrepresented in formal decision-making bodies, including the impact assessment process and the asymmetrical power relationships, means that recommendations from Indigenous people are overlooked. Thus, without a governance system that understands and values Indigenous knowledge systems and enhances Indigenous representation and power in decision-making, Indigenous issues and values are less likely to be considered and adopted in the impact assessment process.

From an Indigenous perspective, all forms of impact assessment of a policy or project must begin and end with concerns for the Nation's way of knowing and being (Bice, 2020). Where community perspectives are poorly understood, addressing social impacts, and delivering local benefits mostly fail those communities (Bice, 2013). Indigenous peoples and Nations are deeply connected to their traditional ways of knowing and being, guided by Elders who carry and share Ancestral Knowledge, ensuring the continuity of cultural wisdom and responsibilities across generations. Thus, Indigenous people have a deep-rooted connection and responsibility to the land, which sustains all living and non-living entities. Indigenous people recognize that they do not exist in isolation, and they carry an innate duty to care for Mother Earth and all creation. This relationship goes beyond simply breathing the air; it is a sacred ideology that connects Indigenous peoples to the land across all Nations.

Indigenous people impacted by resource exploration approach resource development from a worldview that allows for a greater understanding of the whole/entire impacts that are created as a result of development exploration. To elaborate on the concept of holism, it is essential to recognize that Indigenous philosophy and traditional legal frameworks are grounded in the principles of interconnectedness and interrelatedness. These guiding legal values and concepts reflect a worldview in which the spirit, emotions, physical body, and intellect are understood as integral parts of the whole person. This holistic view extends beyond the individual, encompassing their relationship with the environment and the biodiversity that surrounds them. From this interconnected worldview emerges the concept of Natural Law, which Indigenous peoples have long used as a source of governance. This law, derived from observing the natural world, informs both traditional and contemporary governance structures, particularly about the sustainable management of natural resources. Through this lens, Indigenous governance is not just a legal system but a reflection of deep ecological and spiritual ties to the land and its living systems. To achieve a state of holistic wellbeing, it is essential to recognize that this journey extends beyond the individual, encompassing our families, communities, and Nations. A key aspect of this understanding is the concept of *mino pimatisiwin*—a principle representing the constitution or governing law for many Indigenous peoples, particularly the Anicinapek and other related linguistic groups. *Mino pimatisiwin*, often translated as "the good life," serves as the foundation of an Indigenous holistic worldview, emphasizing balance, harmony, and interconnectedness. At its core, this worldview is grounded in the principle of relational accountability, which posits that all beings —human and non-human—are interconnected and responsible to one another. Thus, Indigenous philosophies recognize that wellbeing is not an isolated or an individual experience but one that is intrinsically tied to relationships with the broader world, reinforcing a sense of accountability to all living systems and entities.

Thus, reframing how resource development impacts Indigenous people through Indigenous worldviews may be a critical step for fostering equitable collaboration between knowledge systems and resource developers and Indigenous people. Such a reframing offers the potential to create fairness, equal access, and meaningful opportunities for Indigenous participation in resource development. This approach must honor Indigenous ways of knowing and being while respecting the deep relational ties Indigenous peoples maintain with biodiversity. By seeking a balance between environmental protection and economic benefits, resource development can align more closely with Indigenous values, creating pathways for sustainable, respectful engagement that upholds both ecological integrity and cultural principles.

The guiding principles found in the concept of governance of *mino pimatisiwin* include all of those elements and should be considered in resource exploration negotiations. The Western concept of governance

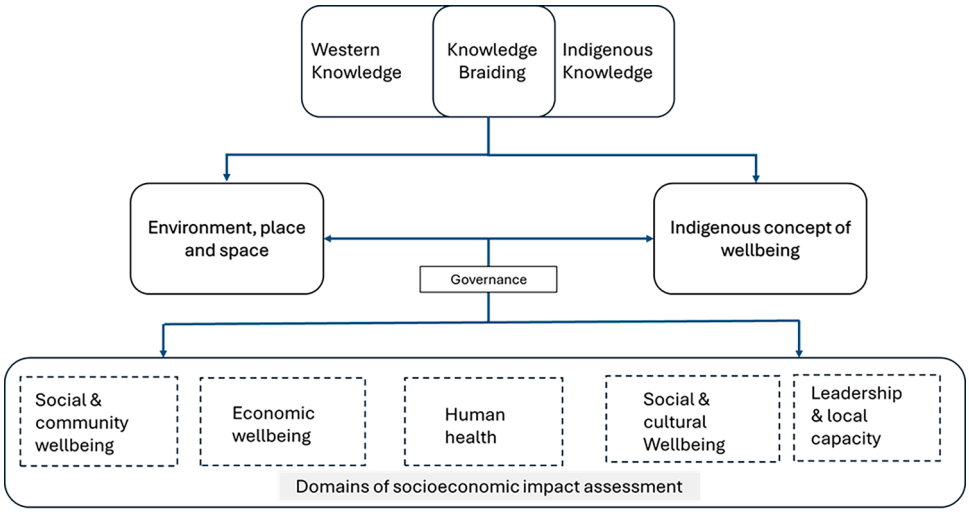

Fig. 3. New framework for socioeconomic cumulative impact assessment through an indigenous lens.

structure is not compatible with the *mino pimatisiwin* governance system common to Indigenous people. Some communities, especially Indigenous communities in Ontario and Quebec, are beginning to explore ways of replacing this governance system inherited from the Indian Act, with its negative impacts of colonialism. It is important to understand the concept of Indigenous governance (mino pimatisiwin) and Indigenous legal orders and how they relate to natural resource extraction (Napoleon, 2007). Indigenous people would not only like to see the legal principles, the legal values, and the legal concept of mino pimatisiwin being considered, but also accepted and incorporated within the legal and policy framework that deals with extracting natural resources. This governance system addresses all aspects of human and land health. Borrows (2005) has classified Indigenous legal orders into five categories of law, namely, sacred law, natural law, positive law, deliberative law, and customary law. The concept and elements of mino pimatisiwin are also associated and considered within these five categories of Aboriginal law. Thus, it is important to use the *mino pimatisiwin* governance concept with its components as part of the legal and policy framework that deals with extracting natural resources among Indigenous people to truly understand and appreciate the meaning of wellbeing.

4.3. Operationalizing the proposed framework

Indigenous mining host communities' access to accurate information on cumulative impacts is important to better negotiate with project proponents and States and serve as a justifiable basis for securing financial relief and developing locally appropriate mitigation and adaptation plans. Hence, our proposed regional framework would be adopted in part or whole by different resource-rich Indigenous communities as well as project proponents. However, we refrain from offering specific steps to operationalize our framework of domains and indicators and the mediating influence of the *mino pimatisiwin* governance concept since this may differ by Nation and the type and stage of resource development. Ultimately, a regional impact assessment approach will only be beneficial if it reflects local priorities; therefore, our framework is not meant to replace Indigenous community-led approaches but should serve as a guide and complementary to Indigenous community-led processes of identifying priorities and indicators.

The process of collectively establishing local indicators is an exercise in inclusive dialogue and learning that must be focused on adaptation to the local context (Uhlmann et al., 2014). For adoption in specific Indigenous communities, this can take the form of facilitated workshops with diverse representations of Indigenous actors (e.g., Knowledge keepers, Elders, youth, and women) and other stakeholders working collaboratively to identify their interests and develop pathway models linking these indicators with the projects. The inclusion of a broad range of stakeholders to operationalize the indicators can help affirm and include missing community values and impact concerns, provide an interdisciplinary lens to validate the outcomes, and enhance learning (Rutherford and Campbell, 2004). For mining companies, the indicators can be used to engage in dialogue and discussions with communities beyond the legal requirements, as this could be important to obtain the needed social licence for mineral development and better outcomes for both the environment and community wellbeing. Our framework also aligns and supports various CEAM approaches and methods developed in various studies (see Noble et al., 2017; Atkinson and Canter, 2011; Bidstrup et al., 2016; Bonnell and Storey, 2000; Canter and Atkinson, 2011) . Particularly, the indicators could be very useful in the scoping phase of CEA, where the focus is on selecting VECs and identifying the spatial (geographic nature of VECs and extent of effects) and temporal (how far to look into the past and future) boundaries.

As an essential part of the operationalization process, stakeholders can agree to set significance thresholds (also known as management triggers, management thresholds, management objectives, regulatory limits, and decision thresholds (see Joseph et al., 2017), although for some indicators this may require the use of standard measures of change. Thresholds provide context for interpreting baselines, effects, and their significance, and they make practitioners' value judgements explicit (Hegmann et al., 1999; Wood, 2008; Hegmann and Yarranton, 2011). Setting significant thresholds is important because they communicate the point where one feels that action needs to be taken to prevent unacceptable deterioration of a VEC's condition (Kennett, 2006; Antoniuk et al., 2009). Hence, thresholds are deeply connected to stakeholders' views about what level of change is acceptable (Wood, 2008; Ehrlich and Ross, 2015). At the core of deciding a threshold is the principle that Indigenous and local communities should not be worse off than others in the region (Joseph et al., 2017). As our framework of domains and indicators is informed by an Indigenous worldview, the identification of significant thresholds for most of the indicators first needs to be grounded in Indigenous values, and second, by available Indigenous and non-Indigenous scientific knowledge of how associated systems function (Joseph et al., 2017). In some cases, there would be a need to use specific quantitative measures to define thresholds, while for some, the thresholds would need to be informed by a conceptual approach to enable available evidence that is accepted by the Indigenous and non-Indigenous lens to guide interpretation. For instance, for indicators under the economic and social domains, such as employment, health, and crime, thresholds can be derived from regional or national averages. In sum, grounding thresholds in stakeholder values, specifically Indigenous values, fulfils the IA principles of participation, supports the principle of free, prior, and informed consent and ensures that it is the values of those affected by projects, that shape significance determinations (Lawrence, 2003; Vanclay, 2003; Wood, 2008; Ehrlich and Ross, 2015). However, the capacity for stakeholders to minimize biases and achieve sufficient consensus, factors often difficult to achieve in arriving at significant thresholds (Hegmann et al., 1999; Duinker and Greig, 2006; Mitchell and Parkins, 2011; Noble et al., 2011) would be key to the operationalization of the domains and indicators.

Irrespective of the benefit our framework offers to build Indigenous capacity in resource exploration negotiations, the internal organizing capacity of Indigenous communities is critical to any effective engagement outcome. Resource exploration problems can be exacerbated unless the communities are organized from within to address expectations, power dynamics, and diverse interests; less it will struggle to honour all needs equitably and honourably. A governance and management mechanism that prioritizes conflict resolution and that promotes fairness and transparency may be essential. Without such internal organization, the community will face ongoing internal conflicts, which industry and the State can exploit. This could result in leadership that contradicts traditional First Nations governing systems, where the wellbeing of all people and the interconnectedness with all creation are not valued, respected, or honoured.

4.4. Limitations

Despite the robustness of our approach, there could be several limitations. The first limitation of our approach is the inability to capture into the framework uncertainties that may be associated with projects, since impacts may occur at different time periods and gathering accurate and reliable information can present considerable difficulty. The second limitation relates to the assignment of responsibility, such as which impacts are caused by who and who should be responsible for addressing which mitigation, which we do not address in our framework. The third concept recognizes that Indigenous worldviews are not static but rather dynamic, evolving in response to the continuous changes experienced by Indigenous peoples. Just as nature is fluid and ever-changing, so too are Indigenous perspectives, adapting like the wind to new realities, challenges, and opportunities. To overcome this, the assignment of responsibility of who caused what and who needs to address which mitigation depends on the existence of a structured institutional arrangement for joint cumulative effect management at the regional

level (Braid et al., 1985). Fourthly, while the list of indicators is comprehensive, we do not account for those that might occur because of exogenous influences outside the regional context of resource development. Yet, we believe that the indicators could be operationalized and contextualized to examine net effects in areas outside the regional context of resource development. Fifth and finally, limitations in Indigenous capacity, data gaps, as well as budget and time constraints, can hinder the effective operationalization of our framework. These challenges must be acknowledged and addressed to ensure the framework's success in fully reflecting Indigenous priorities and worldviews.

5. Conclusion

Cumulative effects are inherently politically wicked problems that require careful management of power imbalances, but at the same time need to be guided by the best available knowledge and science from both Indigenous and non-Indigenous people. Traditionally, Western science worldviews have held greater power and influence over Indigenous views in environmental decision-making (Spak, 2005). This power dynamic is particularly evident in the assessment and management of cumulative effects resulting from resource development.

In this paper, we integrate the concept of Indigenous wellbeing and the place and space to inform the development of a suite of indicators for cumulative socio-economic assessment. This framework informed our selection of holistic and culturally appropriate impacts to measure, allowing us to explicitly address the connections between environmental displacement and the social determinants of health and wellbeing. From a First Nations perspective, the effects of resource development and governance decisions often reach deeply into fundamental aspects of life, including cultural survival, land stewardship, and spiritual wellbeing. Historically, and in contemporary times, States have systematically devalued First Nations peoples, their values and their knowledge systems, leading to under-representation in decision-making. This ongoing disregard undermines the inherent dignity, identity, and sovereignty of First Nations, failing to acknowledge the spiritual and cultural rights that all Indigenous people hold as rightful stewards of their lands and cultural heritage.

While traditional assessment measures provide evidence on how Indigenous people may be affected by opportunities in a new wage-based economy, the Indigenous lens provides evidence of the deeper meanings of how environmental change affects the health and overall wellbeing of Indigenous peoples. This diversity of perspectives and knowledge complementarity is reflected in the selection of diverse and multiple domains and indicators for cumulative socio-economic effect assessment. The proposed holistic framework we proposed serves as an initial step toward fostering meaningful dialogue, understanding, facilitating information sharing, and promoting forward-thinking approaches to protect Indigenous people's ways of knowing and being. The vision is to develop a culturally responsive and respectful tool that incorporates the *mino pimatisiwin* concept of Indigenous governance, along with its fundamental components, to address and understand the cumulative socio-economic effects of mining.

Our approach aligns with the emerging recognition that practical assessments of long-term environmental changes require the integration of diverse knowledge systems (Abu, 2018). Understanding such changes is a complex endeavour that necessitates multifaceted and transdisciplinary dialogues. Therefore, the domains and indicators developed in this paper should not be seen as an endpoint but rather as a starting point. They are intended to stimulate discussions, facilitate information exchange, and foster forward-thinking regarding the ideal approach to assess and monitor the health and wellbeing of Indigenous and remote communities in mineral-rich regions within the context of sustainable regional development. Ultimately, if Indigenous peoples themselves are not given the space and opportunity to express their self-determination and sovereignty within the resource development regime, the legacy of colonialism or neocolonialism will continue. Consequently, operationalizing our approach is underpinned by the need to promote Indigenous self-determination and rights, recognition of the greater role of Indigenous peoples in CEA, alongside significant investments to build capacity in Indigenous communities.

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CRediT authorship contribution statement

Effah Kwabena Antwi: Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **John Boakye-Danquah:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Denyse Donna Mary Nadon:** Conceptualization, Data curation, Supervision, Writing – original draft, Writing – review & editing. **Maurice Joseph Kistabish:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Tanya Matthews:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Akua Nyamekye Darko:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Priscilla Toloo Yohuno (Apronti):** Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Felicitas Egunyu:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.exis.2025.101735.

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