Transdisciplinary science for strengthening forest systems in British Columbia: Quesnel as a learning landscape

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Abstract

Forestry is becoming more complex as a result of diverging societal demands. Indigenous Peoples' reconciliation and the challenges of climate change call for research that embraces transdisciplinarity, reciprocity, and problem-focused learning at the landscape scale. Both globally and in Canada, forestry and forest research are struggling to keep pace with this growing complexity. Place-based collaborative research and learning initiatives, described here as "learning landscapes," offer an under-explored approach to meeting diversifying goals for forest landscapes. We describe recent progress in Quesnel, British Columbia, where researchers and local institutions are engaging to strengthen resilience and innovation in the forest sector. We first define the concept of learning landscape in the context of transdisciplinary sustainability science, and then illustrate this approach using the case study of Quesnel. We describe a process of systems diagnosis, including asset mapping and analysis of potential forestry pathways through a "best bets" framework. We propose a Theory of Change as a way forward, outlining opportunities for government, industry, and communities in developing regional capacity for integrated management and high-value forest products. We reflect on the contributions of learning landscapes to knowledge generation, experiential learning, and institutional development, and discuss implications for steering decision-making in locally driven sustainability transitions.

Key words: transdisciplinary science, British Columbia, knowledge co-production, learning landscape, Theory of Change

Introduction

Forest systems have been shaped by peoples' needs and desires since the emergence of humankind. Whether through cultural practices or consumer demands, forests and the landscapes within which they exist have been modified to meet the evolving values and aspirations of people. Today, the diversity of values demanded from forests poses a significant challenge for decision-makers at local, national, and global scales. Approximately 73% of the global forest area is publicly owned (FAO 2020), but in reality, a broad spectrum of tenure and management systems exist, many of which are in transition (RRI 2018). Decisions over forests must carefully consider the multi-dimensional elements of problems. In forest landscapes, resilience is a function of governance, rights, livelihoods, and prosperity. Cumulative impacts of climate change on forest systems, including wildfire, floods, and biodiversity loss, have demonstrated the adverse consequences of states failing to see forests as complex, dynamic systems (Simard 2009). Governments are now delegating greater responsibility to local institutions, creating space for local people and Indigenous communities to drive forest decisions. These new collaborative tenure arrangements call for a whole-of-society approach, respecting and drawing from rights holders, communities, and different knowledge systems (Zurba et al. 2016; McKay and Grenz 2021). To keep pace with shifting values, research and policy must be grounded in local settings and open to the breadth of pathways that could emerge to meet the diverse needs of people in forest landscapes (Chambers 1997).

The challenge of meeting local sustainability objectives within a global setting of change and complexity provides a strong incentive for transdisciplinary research and learning (Lang et al. 2012). Engaging different disciplines and ways of knowing to build understanding of shared problems and co-develop ideas offers numerous opportunities for mutual learning between practitioners, researchers, students, and societal actors (Smithwick et al. 2019; Margules et al. 2020). Many studies have acknowledged the difficulties of transdisciplinary science, such as sustaining cooperation and empowering local actors (Jakobsen et al. 2004; Brandt et al. 2013;). Notwithstanding this, the collaborative and cross-sectoral nature of transdisciplinary partnerships remains fundamental to addressing today's forest and land-use challenges (Creed et al. 2019). Forestry practitioners have long acknowledged

the need to expand the scope of forestry education to include competencies in areas such as collaborative problem-solving, communication, and social systems (Sample et al. 1999; Sample et al. 2015). Whilst the past few decades have seen forest research shift from species-specific to systems-based inquiry (Polinko and Coupland 2021), decisions on forests are often top–down and blind to complex local realities (Bull et al. 2018). Embedding research and learning at the landscape scale can help to overcome these blind spots, supporting institutions and scientists to engage in processes that lead to holistic and contextually appropriate pathways for forest systems (Langston et al. 2019).

Transdisciplinary research in forest systems is growing globally. There is still a knowledge gap in how research partnerships can contribute to experiential learning, enhance knowledge utilization among local actors, and respond to complex global challenges (Balvanera et al. 2017; Hoffmann et al. 2019). In this paper, we describe attempts to meet these objectives through a "learning landscape" approach. We provide a case study of a learning landscape in Quesnel, a small regional town in the Cariboo-Chilcotin region of British Columbia, Canada—a province with a long history of forestry that is now facing unprecedented challenges. We begin with a working definition of learning landscapes, drawing from the concept of boundary work in sustainability science (Clark et al. 2016). We then illustrate this approach in Quesnel, outlining learning pathways and synergies for strengthening regional capacity across the full spectrum of forest systems. Drawing from the Quesnel experience, we offer reflections on how embedding transdisciplinary learning systems into forest landscapes can enrich understanding and strengthen decision-making for locally driven sustainability transitions.

Transdisciplinary science in a learning landscape

Integrating knowledge and navigating boundaries has become central to understanding pathways for sustainability (Mattor et al. 2014; Karrasch et al. 2022; Zurba 2022). Transdisciplinary science can guide these transitions by shifting power dynamics, building local capacity, and providing a nexus between science, policy, and innovation (Pregernig 2006; Bréthaut et al. 2019). Embedding transdisciplinary science into landscape-scale learning systems, whether through formal education, informal relationships, or institutional development, can enrich cultural, ecological, and technical understanding (Tengö et al. 2017; Norström et al. 2020). We describe this approach as a learning landscape. Loosely defined, learning landscapes are places where scientists maintain long-term partnerships with diverse actors aspiring to learn about and influence the development trajectory of their landscapes, where people exchange ideas, their stories, and gain from otherwise unlikely experiences. The term landscape is used to capture both the geographic setting, defined by the problem, and the explicit attention given to understanding local social-ecological systems to steer decision-making processes.

Learning landscapes bring together researchers, local institutions, communities, students, and a diversity of other actors in recognition of the mutual benefits gained from new interactions or shared interests. Benefits might range from professional experience through hands on learning, grounding global research priorities in local contexts, or strengthening institutional capabilities through collaboration and resources. Learning landscapes may be more structured, such as the Nordic agroecology program described by Francis et al. (2020), or opportunistic, such as the sentinel landscape approach described by Langston et al. (2019). Past experiences of transdisciplinary partnerships in forestry have shown the value in embedding this learning in larger networks, such as the Canadian Model Forests program (Bullock et al. 2017). These approaches also offer important guidance on the challenges of engaging in collaborative learning, including representation of rightsholders and grappling with power and politics (Klenk et al. 2013). Here, we distinguish learning landscapes from the broader term of transdisciplinary science because of their emphasis on learning—exploration of questions and discoveries, rather than research focused on specific components of the landscape.

The intention of a learning landscape is reciprocity—breaking down boundaries and forming connections between people that may be otherwise separated by discipline, profession, or geography. For this reason, we liken learning landscapes to boundary work, a concept emerging from sustainability science that describes systems and processes aimed at crossing boundaries (Clark et al. 2016; Zurba 2022). In learning landscapes, boundary work involves interactions between researchers and local actors in ways that facilitate inquiry, exchange, and learning. We broadly categorize these interactions into three themes: (i) knowledge generation for policy and practice, (ii) experiential learning, and (iii) institutional development (Fig. 1).

Learning landscapes enable globally relevant research questions to be grounded in local settings to inform policy and practices, develop networks for collective action, and adopt problem-focused learning into practitioner and research institutions. They offer a pragmatic way to consider tele-coupled relationships between distant yet interconnected landscapes, fundamental to understanding and influencing global sustainability transitions (Hermans et al. 2023). In times of uncertainty, disruption, and transition, learning landscapes can help steer action through systems change, closing gaps between long-term ambitions and short-term practical needs (Frantzeskaki et al. 2012). In the case study that follows, we describe these processes in Quesnel landscape in British Columbia. Following a brief overview of the provincial forestry context, we present key components of the learning landscape, and reflect on the outcomes of our approach. We describe the potential gains from expanding transdisciplinary learning networks to meet diversifying goals of forest landscapes.

Case study: Quesnel, British Columbia

Indigenous stewardship has sustained the forests in the Pacific Northwest for thousands of years. The arrival of Euro-

Fig. 1. Boundary framework for a transdisciplinary "learning landscape" approach, adapted from Hoppe (2010).
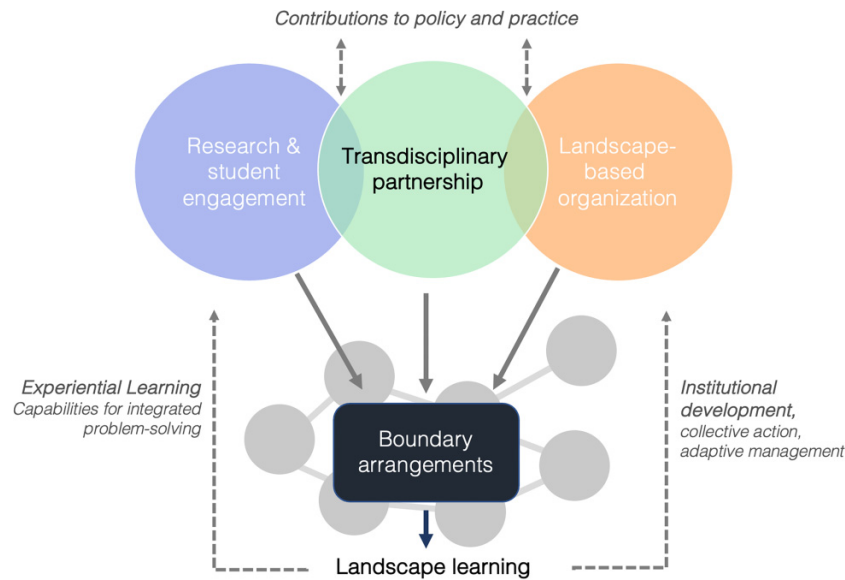
pean settlers and explorers in the mid-18th century disrupted traditional land-use systems and opened land for commercial logging and gold mining. Industrial forestry began in the late 19th century with the development of transportation networks across the province's vast and difficult terrain. Commodity products quickly became the foundation of the forest industry in British Columbia, primarily softwood lumber, with smaller contributions from pulp, paper, logs, and other wood products. For regional towns such as Quesnel, forestry was an essential part of life by the 1950s, the basis of local industry, settlement, farming, and culture. Despite their removal from the land, First Nations maintained their connection to forests throughout this period, managing and harvesting forest products for food, shelter, and ceremony. Today, First Nations continue to rely on the forest for sustenance, and engage in forestry through a variety of enterprises, partnerships, stewardship councils, and management operations (Nikolakis and Nelson 2015). Since the 1990s, forestry in British Columbia has faced several challenges, threatening the future of the industry. The Mountain Pine Beetle epidemic resulted in the loss of millions of hectares of pine forest, contributing to devastating wildfires in 2017, 2018, and 2021. In 2019, the provincial government passed the Declaration on the Rights of Indigenous People, committing to reconciliation across all laws, policies, and practices. The Declaration will significantly impact the forest sector, including new agreements, tenure rights, and decision-making processes still to be determined. Recent and planned policy changes include reduced logging of old growth forests, increasing forestry tenures available to First Nations and smaller operators, and establishing a new process for landscape-level planning (Government of British Columbia 2021). Forestry in British Columbia is entering a new paradigm, with greater involvement of local communities and stewardship that gives more emphasis to non-timber values.

The changes in forestry in British Columbia reflect shifting societal values towards more local stewardship, a lack of trust in the forest industry, and growing interest in conservation (Peterson St-Laurent et al. 2019; Riggs et al. In Press). Momentum towards these changes has been building for decades. Concerns over forest industry concentration, destructive forestry practices, and the lack of integrated land-use planning are voiced in the five forest commissions conducted over the past 105 years (Mitchell-Banks 2000). Whilst Sustainable Forest Management is highly regulated and practiced, ecosystem-based approaches that integrate economic, social, and ecological values into adaptive management regimes have been constrained by perceived political and financial risks of reducing timber production, incomplete knowledge inventories, and the difficulties of broadening participation in decisions over forests (Bourgeois 2008; Howlett et al. 2009). Inability to confront these challenges has led to an alarming situation. Issues of climate vulnerability and declining fibre supply extend across the province, creating an atmosphere of uncertainty and concern (Parkins and MacKendrick 2007). Markets and policy frameworks supporting bio-products, non-timber forest products, and carbon are still niche and under-developed, with lumber and pulp mills continuing to provide the majority of employment opportunities in the sector. The province is looking towards growth in the bioeconomy to enhance value, but investment and regulatory frameworks are in their early stages. Recreation and tourism are growing but are unlikely to replace forestry employment and revenues in remote areas. Faced with devastating effects of wildfires, conflicting societal values over forest resources means that municipalities, First Nations, and tenure-holders are anxiously navigating decisions over forests.

The City of Quesnel is located in the Cariboo region of British Columbia within the traditional, ancestral, and unceded territory of the Lhtako Dené Nation. Approximately

13 000 people live in Quesnel and the surrounding area, which also includes traditional territories of the Nazko, Lhoosk'uz Dené, and ?Esdilagh Nations. The region has a long history of gold mining, ranching, and forestry, which continues throughout the landscape today. Surrounding the city is the Quesnel Natural Resource District (Fig. 2), which covers approximately 1.28 million hectares, most of which is sub-boreal pine. The Quesnel landscape was hit hard by the mountain pine beetle epidemic and the 2017/2018 wildfires, greatly reducing the amount of timber available for harvest and leaving the landscape vulnerable to further ecological disturbance. The decline in fibre supply caused many companies to divest, leaving West Fraser Timber company, founded in Quesnel in 1955, as the only major company still operating in the area. West Fraser is important to Quesnel's competitive advantage, maintaining several integrated manufacturing facilities within the city limits. However, provincial trends indicate that West Fraser's long-term presence in the region is not guaranteed (West Fraser 2022). The decline in timber availability and increased wildfire risk has impacted industry, livelihoods, and communities closely entwined with their surrounding forests.

Learning landscape approach

The Quesnel municipal government established the Forestry Initiatives Program (FIP) in 2018. The purpose of the FIP is to work with First Nations, the provincial government, local forestry companies, and other actors to support a transition towards a resilient, innovative forest economy that aligns with broader landscape goals of reconciliation and sustainability. In British Columbia, municipal governments do not have authority to make decisions over forests outside of urban areas (i.e., in timber supply areas), but they can act as facilitators to support stakeholders and create enabling conditions for stewardship, investment, and fire management. The FIP is involved in several locally driven projects, including Fire-Smart wildfire prevention, community forestry, silvicultural trials, a biomass utilization scoping study, and an investigation into the potential for secondary wood manufacturing. Quesnel is also a pilot area for provincial government's new forest landscape planning process, set to replace forest stewardship plans in the forestry legislation and allow for greater negation of forest values at the local level. Each of these initiatives provides a platform for local actors to articulate and respond to local aspirations, whilst adapting to emerging markets, policies, and climate threats in British Columbia and internationally.

The formation of the FIP in 2018 created a centre point within the Quesnel community to convene and collaborate on forestry issues. The agreed objective of the program is to "build home-grown solutions for Quesnel during its time of transition to be innovative, resilient and help grow a sustainable future for everyone who chooses to call the area home" (City of Quesnel 2022). The objective to strengthen resilience and innovation cuts across several areas, including the management of forests for timber, ecosystem services, biodiversity, and other values, the processing of forest products, the use of timber in construction and energy-efficient buildings in the community, education, reconciliation, and governance. The FIP hosted two think tanks in 2018 and 2019 to develop a strategy for action, inviting participants from local and provincial government, First Nations, forestry companies, small businesses, research organizations, and universities. A common vision emerged to strengthen resilience and innovation and address the social-ecological-economic vulnerability of the landscape. The FIP reached out to partner organizations to build their knowledge base and collective capacity. Several partnerships emerged, leading to the idea of a learning landscape. The core activities of our collaboration, described below, focus on examining assets, capabilities, and relationships within Quesnel to explore alternative investments and initiatives that would advance innovation and resilience in the forest sector. Collectively, we engage in various dimensions of FIP projects, using the boundary framework described in Fig. 1 to organize a holistic process for landscape learning.

Methods

From 2019–2022, we engaged in several small collaborative initiatives. We developed an inventory of assets (i.e., infrastructure, businesses, community initiatives) relevant to new diversification opportunities. Asset mapping draws from the asset-based community development approach, which encourages communities to identify strengths (asset mapping), articulate goals (visioning), and develop partnerships to strategize on how to meet goals (mobilizing) (Mathie and Cunningham 2003). The FIP think tanks in 2018 and 2019 enabled local actors to build consensus on goals for the Quesnel landscape. Asset mapping formed a logical next step to build understanding of assets, networks, and opportunities for collaboration. Information on assets was gathered from government sources, studies and organization websites. In 2021, we conducted 29 interviews with forestry actors, including small businesses, industry, government, and NGOs (Herdianti 2022; Valeri 2022). Interview questions focused on the challenges, opportunities, and partnerships to grow a diverse local forestry sector. Throughout this period, the FIP also hosted annual field trips for the Master of International Forestry program, where students engaged with different forest stakeholders to discuss perspectives on local issues, including wildfire management, community forestry, industry, conservation, and the flow of benefits from forests. These exchanges also bring new perspectives to people in Quesnel, exposing students to problem-based learning whilst allowing researchers to triangulate data.

To draw together key findings from scoping studies and short-term projects, we worked as part of a consultative team to evaluate optimal pathways for retaining and expanding the forest sector in Quesnel. The evaluation used a "best bets" framework to rank priorities for investment and action and outline key steps in research, funding, and partnerships (Gaston et al. 2021). Key considerations included fibre requirements, economic and environmental value, climate change risk, and availability of funding and infrastructure. The evaluation examined potential for bio-energy pathways and solid wood options, as-well as conditions for a thriving in-

Fig. 2. Map of the Quesnel Natural Resource District, roughly depicting the Quesnel forest landscape. Source: Province of British Columbia (2023).
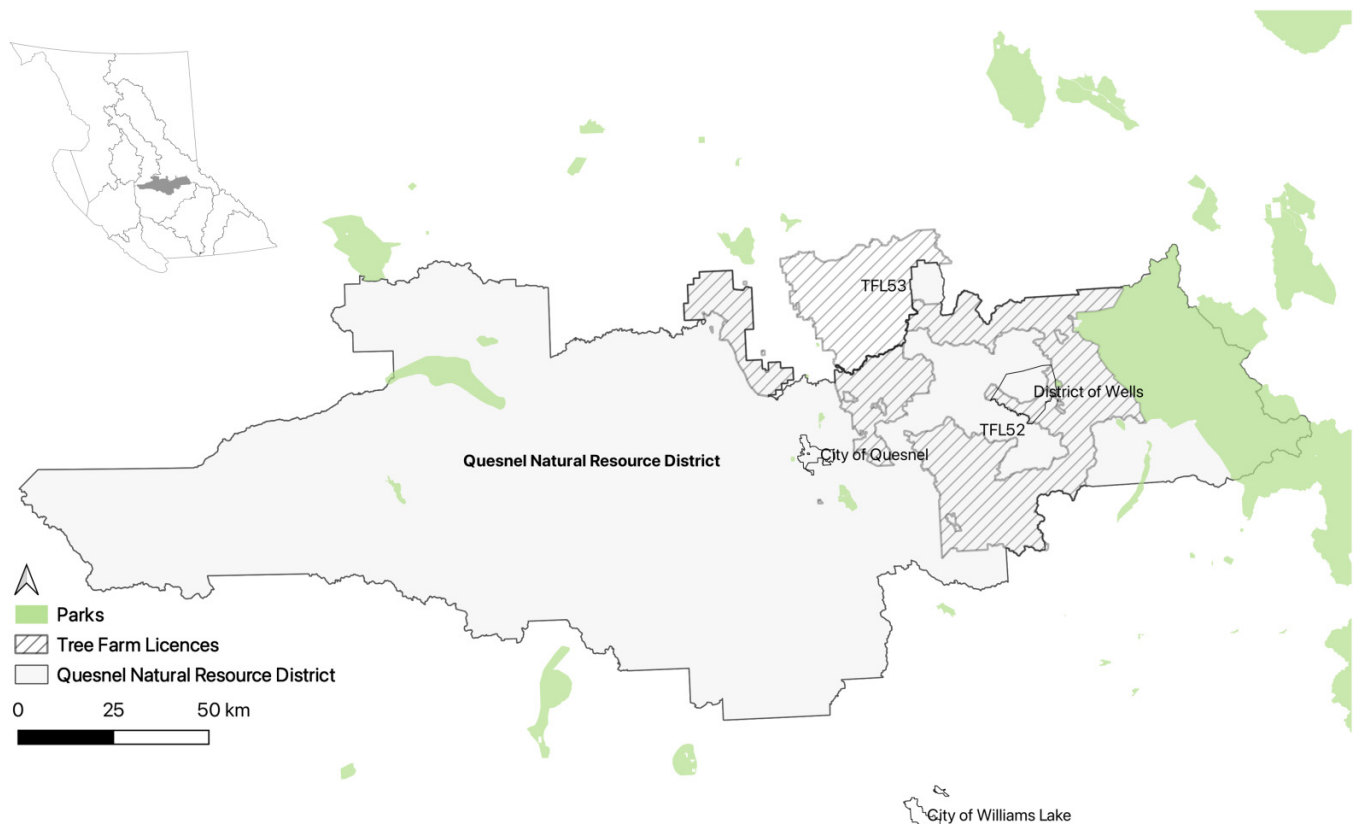
dustry, such as landscape-level planning, securing fibre supply, and training and education. Results of the evaluation were shared with the City of Quesnel in October 2021, and subsequently became a core part of our analysis.

Results

Diagnosis: key assets and opportunities

In interviews and think tanks, priorities for addressing knowledge and resource gaps focused on ecological resilience, fibre utilization and diversified manufacturing, training and education, and landscape-level processes. The asset-mapping exercise identified four key assets that could play an important role in meeting these objectives through future forest initiatives, summarized in Table 1. These included (1) cultural and recreational assets to enhance public engagement and support emerging markets, (2) physical infrastructure and labour force conducive to growth in manufacturing industries, (3) regional universities with a strong interest in local education and training, and (4) municipal and First Nations governments engaged in forestry partnerships. Across each of these assets, the municipal government, First Nations governments, West Fraser, and universities emerged as key players for their contributions to diverse and complementary capabilities in the landscape, including political leadership, Indigenous Knowledge, expertise in forestry and manufacturing, ability to engage and mobilize society, and re-

search capacity. Collaboration between these actors has been essential to mobilizing resources for ongoing initiatives, including wildfire risk reduction, exploration into the potential for district heating systems, and the Three Rivers Community Forest—a joint initiative between the Lhtako Dene, Nazko, ?Esdilagh, and Lhoosk'uz Dene Nation Governments and the City of Quesnel.

Prognosis: evaluating potential pathways

Using the "best bets" framework, the consultative team identified four potential pathways to strengthen resilience and innovation in the Quesnel forest landscape. The four pathways were (1) bio-energy (i.e., district energy and combined heat and power, renewable natural gas production, bio-crude oil production), (2) expansion of secondary wood manufacturing, (3) training centre for trades and careers, and (4) regional forestry management. Each of these pathways was considered feasible under current resource constraints (limited fibre supply) and to contribute positively towards ecological resilience and regional development. Growth in bio-energy products is favourable for meeting local clean energy needs and is in line with interest in growing the bioeconomy in British Columbia, such as using residual waste from logging in small-scale combined heat and power production. Expansion of secondary wood manufacturing responds to growing demand for municipal and First Nations housing in the Quesnel region, as well as objectives for enhancing innovation and

Table 1. Key assets in the Quesnel forest landscape.

Key asset	Category	Description	Strategic advantage
High number of community groups, recreational facilities, and community support services.	Cultural and recreational	18 Religious institutions, 12 community halls, 8+ annual events, recreational clubs, support services for family, health, education, employment, First Nations, and community housing.	Opportunities for advocacy and public engagement, demand for facilities and construction (potential end-market for timber and clean energy), attractive community for families (labour market).
Existing industrial infrastructure and transport	Physical, human (labour), social	Transportation services include highway, rail, and commercial airports, same-day shipping to major ports and metropolitan centres (Vancouver and Prince Rupert), permitted routes for 9-axle trucks. Industrial infrastructure includes timber processing facilities (six major mills and processing facilities) and 20.7% of the labour force work in manufacturing (Census). West Fraser Timber was founded in Quesnel and headquarters are located in the city.	Foundation for expanding forest manufacturing hub, potential demand for clean energy, social capital in the form of past and present relationships, culture, and families linked to forestry.
Post-secondary institutions	Human (education)	The College of New Caledonia and The University of Northern British Columbia share a campus in Quesnel, offering diverse programs including in trades and industry and Aboriginal studies.	Willing partners in providing education and training to strengthen community resilience and forest sustainability. Land and learning spaces available for expanding facilities and programs.
Quesnel City Council, Lhtako Dené, Nazko, Lhoosk'uz Dené, and ?Esdilagh Governments	Political	The Quesnel municipality and governments of Lhtako Dené, Nazko, Lhoosk'uz Dené, and ?Esdilagh First Nations have entered into an application for a community forestry partnership. The municipality launched The Forestry Initiatives Program in 2018.	Affirmed government support for improving forest systems, existing avenues for communication and partnerships, access to provincial and national funding schemes.

resilience through diversification of the forest sector. The development of a training centre is closely linked to expanded secondary wood manufacturing, providing a space for innovation, entrepreneurship, and partnerships. Strengthening regional forest management underpins each of these pathways, expanding research partnerships, exploring local leverage points for increasing value, and promoting an integrated approach to forest management.

To examine the fit of each of these pathways to Quesnel, we explored how each of the key assets contribute or detract from each pathway (Table 2). The analysis showed Quesnel assets offered multiple advantages for the potential pathways, with support from local leadership bodies and post-secondary institutions offering positive contributions across all four pathways. Existing industrial infrastructure and transport, whilst an important asset for attracting new business and investment, could generate challenges due to the limited supply of fibre. High-value forest products that require minimal fibre, such as cellulose, could circumvent this problem but require substantial investments in technology and market development. The pathways of expanding secondary wood manufacturing and establishing a training centre are more feasible, concentrating on mature markets and regional needs instead of novel technology. Quesnel is well-positioned to attract new workers and develop training programs aimed at expanding skilled labour and opportunities for First Nations. A 2019 study of the labour market in the Cariboo Chilcotin region identified a lack of skilled workers as a critical issue in the regional economy (Cariboo Regional

District 2019). In addition, recent changes to legislation on energy-efficient construction in BC (known as the BC Energy Step Code) have led to an increased demand in prefabricated construction, requiring skilled workers trained in engineered wood products and prefabricated wood building systems.

Rather than isolate pathways, the analysis shows complementarity, indicating benefits from pursuing multiple pathways in parallel or integrated into a cluster. For example, a training centre focused on contemporary skills in forest management, such as managing for climate change, wildfire, and diverse forest products, is likely to be complementary to growth in the secondary wood manufacturing sector, supporting a gradual shift towards value-added production. A training centre for trades and careers adds another dimension to a learning landscape, where education opportunities purposefully target societal needs within the local setting. Matching these pathways to provincial programs, such as growing the bioeconomy, could help to mobilize resources, connecting practice with research and innovation. The convening power of the FIP could help align the needs of regional employers with training programs provided by post-secondary institutions, growing the region's capabilities in secondary wood manufacturing.

Diversity in stakeholders and the high number of community groups is noted as both a strength and a challenge. Narrowly defined land-use objectives focused on access to timber and single sector industry-driven economic pursuits contributed to Quesnel's current vulnerability. However, diversity of interests may also slow-down consensus building. We

Table 2. Asset contributions to potential pathways to innovation and resilience in the Quesnel forest landscape.

Asset\Pathway	Bio-energy	Expansion of secondary wood manufacturing	Training centre for trades and careers	Regional forest management
Community groups, recreational facilities, and support services	(+) Local energy needs for community buildings and recreation facilities	(+) Local construction needs for community buildings and recreational facilities	(+) Attractive living for young families and short-term visitors in the region	(+) Opportunities for community engagement
		(+) Attractive living for consumers (ageing population) and workforce (young families)		(+) (−) Diverse and competing interests
Existing industrial infrastructure and transport	(+) Local energy needs for production	(+) Industrial infrastructure and accessibility	(+) Industry support in funding, resources, expertise	(+) Engaged stakeholders
	(−) Competition for fibre	(−) Competition for fibre and labour	(+) Employees	(+) Interest in innovation
				(+) Interest in stability
Post-secondary institutions	(+) Local energy needs for campus	(+) Interest in developing training programs to meet local needs	(+) Interest in developing training programs to meet local needs	(+) Research partnerships
		(+) Potential construction of student residence	(+) Aboriginal Resource Centre to support Aboriginal students	
			(+) Local campus to serve regional community	
Quesnel City Council, Lhtako Dene, Nazko, Lhoosk'uz Dene, and ?Esdilagh Governments	(+) Advocacy and leadership in provincial-level discussions	(+) Convenors	(+) Convenors	(+) Advocacy and leadership in provincial-level discussions
	(+) Potential for First Nations led combined heat and power	(+) Affordable housing development is a priority for municipality and First Nations	(+) Access to Federal and provincial funding	(+) Existing partnership as platform for collaboration
	(+) Access to Federal and provincial funding	(+) Access to Federal and provincial funding		

observed this in the recent community consultations on two new developments in the region: the Three Rivers Community Forest and the Cariboo Gold Project.[1] The Cariboo region has a long history of forestry, mining, and ranching that continue to contribute to culture and livelihoods. Both the community forest and gold mine aim to harness this strength but both face opposition due to concerns over social and environmental impacts (Barkerville Gold Mines Ltd. 2020). These debates, whilst difficult, have led to new dialogues on how local values are reflected in forest and land-use management. The need to articulate values and engage in discussions has helped to build capacity among communities, Nations, and local leaders. Although hard to measure, progress in these initiatives offer guidance for future initiatives, both in terms of clearer understanding of local values and the relationships needed to navigate change.

Discussion

The assets and pathways discussed above provide a brief overview of the breadth of discussions held over the 3 years of interacting through a learning landscape. Whilst many of these discussions led to research and learning outputs (i.e., graduate theses, news articles, presentations, and internships), there is an emerging need in Quesnel for a locally driven Theory of Change (ToC) (van Noordwijk 2017). A ToC outlines intended impacts (of an organization, policy, or initiative) and the changes that need to happen to achieve them (Sayer et al. 2017; Oberlack et al. 2019; FSC 2022). ToCs help to clarify goals, make assumptions explicit, define actions, and evaluate progress in ways that are context appropriate (Weiss 1995). In Quesnel, the chosen forum for a ToC is the think tank, which began in 2018 as a multi-stakeholder process. In May 2023, the FIP convened another think tank, focused on the future of forestry in Quesnel. The forum invited industry, small businesses, First Nations, municipal and provincial government, NGOs, and researchers to reflect on the knowledge gained over the past five years and determine how best to translate knowledge into action. The outcome of the think tank, currently in preparation, will aim to connect local ac-

[1] In 2022, the Cariboo Gold Project (owned by Osisko Development) began production on Lhtako Dene territory about 80 km outside of Quesnel. The underground gold mine is expected to employ 500 people during its 16-year operation.

tors in a cohesive strategy for change, as well as continue dialogue and collaboration.

Our evaluation shows potential to grow the Quesnel learning landscape into a regional learning hub, fulfilling needs across the full spectrum of the forest sector. Potential training programs include wood product manufacturing, equipment operation for harvesting and thinning, prefabricated wood construction, LiDAR application and digital technology, bioproducts, and a range of other short- and long-term courses designed for future employees in the forestry sector. Collectively, these programs offer benefits in forest management for ecological resilience (i.e., managing fire risk) and innovation (competence and knowledge in product development and trends) (Gaston 2014; Keenan 2015). Quesnel is already the provincial hub for a 5-year federally funded *Silva21* research project (silva21.com) on advanced forest management practices. The think tank aims to draw from these experiences to generate buy-in and expand through a coordinated effort, highlighting the advantages of Quesnel as a pilot landscape for trialing regulatory and operational approaches to innovation and learning.

The direct engagement of policymakers in the think tanks creates an opportunity for feedback to higher political levels, influencing decisions whilst gaining relevant insights into emerging policy agendas. The challenges facing the Quesnel landscape, such as climate vulnerability, improving recognition of Indigenous Peoples, and reconciling economic and environmental objectives, exist across forest landscapes in Canada. At both the provincial and national level, policymakers are seeking to learn from collaborative local arrangements on pathways for maintaining resilient, healthy forests that support vibrant communities (CCFM 2019). Learning landscapes provide a platform for in-depth place-based and problem-focused learning, but must also be cognizant of broader drivers of social-economic-environmental change. In British Columbia, the recent Declaration on the Rights of Indigenous People Act (DRIPA) adopted by the provincial government in 2019 means that First Nations in British Columbia are re-positioning themselves in forest and land-use decisions. A recent amendment to the Forest Planning and Practices Regulation places non-timber values equal to timber values in management objectives—symbolic of impending change. In Quesnel, the Lhtako Dené, Nazko, Lhoosk'uz Dené, and ?Esdilagh Nations are already strengthening partnerships within the forest sector and exploring new arrangements for co-managing resources. Together with the FIP, the Nations have submitted a community forestry application, intended to enhance forest stewardship in line with local values. These opportunities to frame and respond to policy agendas have proven essential to gaining networks and resources to close local knowledge gaps. Difficulties lie in the pace of change; the urgency of the problem versus the benefits of a long-term adaptive process.

Reflections on learning landscapes for forest sustainability

Transdisciplinary learning emphasizes mutual exchange, long-term partnerships, and integration of knowledge across boundaries. The case study in Quesnel briefly highlights how these ideas can come together to support development pathways in forest landscapes. For forestry and related sciences, the integration of collaborative, holistic approaches into existing research and learning agendas mirrors the expanding and evolving needs of forest systems. A large body of work now exists encouraging universities to promote integrated, place-based research and learning, aimed at enhancing societal capabilities for sustainability (Francis et al. 2008; Yarime et al. 2012). Forestry educators recognize a growing need to foster capabilities for addressing profound challenges of global sustainability, including epistemological agility, political astuteness, and strategic engagement (Kanowski 2020). In Quesnel, experiential learning encouraged students to build empathy and emotional intelligence as part of their professionalism. In the Nordic region, the learning landscape approach proposed by Francis et al. (2008) targets competencies in observation, dialogue, participation, reflection, and visioning (Francis et al. 2020). These competencies match a global demand for expanding capabilities in forest restoration (van Oosten et al. 2019). Demand for "soft skills" are also reflected in the changing labour market; the 2020 Business Council of Canada Skills Survey found that the most desirable attributes for mid-level hires include collaboration, teamwork, relationship-building, and interpersonal skills (Business Council of Canada 2020).

In Quesnel, our research is inductive but purposeful, intended to enable governments, civil society, and industry as leaders, with researchers participating as co-learners (Roux et al. 2017). This type of "slow research" often seems incompatible with the urgency of a problem, but allows for careful consideration of policy pathways and feedback loops (Sewerin et al. 2022). Learning landscape encourage reflexivity, with research activities guiding incremental rather than transformative change. Concrete initiatives can act as boundary objects for confronting larger issues, such as more inclusive policymaking and appropriate ways of framing knowledge and participation (Diver 2017; Zurba et al. 2019). In Quesnel, these focus points included community forestry and wildfire protection planning, encouraging landowners, First Nations, and management bodies to express values and commitment to change. Both in Canada and globally, there is widespread interest in strengthening the incorporation of culturally diverse values into forest management decisions (Baumflek et al. 2021). Examples of First Nations led transdisciplinary partnerships are emerging across British Columbia (Copes-Gerbitz et al. 2021; Smith and Bulkan 2021), emphasizing the value of long-term, iterative collaboration built from trust. Learning landscapes create spaces to explore both how knowledge is translated into policy and practice, and how it is conceived, valued, and shared amongst different people.

Whilst transdisciplinary partnerships can help to frame problems and develop strategies for action, there are also limitations to research impact. A slow, non-normative approach

makes it difficult to assess progress. Developing competencies in a long-term process of institutional development is notoriously difficult (Andrews et al. 2017). Innovation and resilience are not skills to be acquired; they emerge through culture and policies led by pro-active companies and governments (Hansen 2010). In Quesnel, the learning landscape encouraged muddling through seeking solutions from the ground–up, rather than top–down planning for development (Easterly 2006). Local decision-makers now have a richer understanding of the landscape, rather than a prescriptive pathway to meet externally defined goals. We observed the partnerships in Quesnel directly contributing to new capabilities and relationships to advance innovation and resilience in the landscape. Local initiatives such as the think tank, forest landscape planning pilot, and community forest have led to strategic alliances that promote collaborative land management and community resiliency. The most recent think tank hopes to translate landscape knowledge into action, advancing Quesnel as a regional learning hub, including regulatory and operational pathways towards bioeconomy cluster development. As First Nations and local institutions gain more influence in forest governance, these forums could provide opportunities to heal and repair relationships. Documenting both how this process unfolds and what solutions emerge will offer important insights to addressing challenges of climate resilience, biodiversity loss, and innovation in Canadian forest landscapes.

Conclusions and implications

Understanding how to best contribute to addressing local problems, seek solutions to global challenges, and enable learning pathways is fundamental to research across all disciplines. Learning landscapes offer a platform for collaboration that is problem-focused, confronts boundaries, and creates space for linking local and global research questions. The case of Quesnel in British Columbia as a learning landscape demonstrates the opportunities and challenges of this approach in a complex forestry setting, emphasizing the breadth of research, policy, and decision-making involved in initiating regional sustainability pathways. While all forest landscapes have unique attributes, the experiences in Quesnel have direct implications for municipalities, industry, communities, and researchers wanting to strengthen community and ecological resiliency. For municipalities seeking similar initiatives, early engagement with stakeholders and First Nations to develop priorities and collective action is fundamental to building trust, buy-in, and leadership. Proactive sharing of expertise from industry, private land managers, and local government bodies with community groups and leaders can help to strengthen understanding of the land base, grounding policy decisions in local conditions. Even if starting small, partnerships that enable First Nations and communities to see their values represented on the landscape provide a platform for developing capacity and a shared vision. Universities and researchers that facilitate and co-learn through these processes can offer important insights into the ways in which local institutions manage sustainability transitions (Henry et al. 2022). Policies that enable these collab-

orations by making resources and funding available to local governments and businesses can provide the stimulus, fostering collective action towards concrete actions. In Canada and globally, there is significant momentum towards local control of forests and strengthening capacity for dealing with complexity at the landscape scale. Learning landscapes enable these experiences to nurture the next generation and strengthen the knowledge base for action.

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