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Canada's Green Gold: Unveiling Challenges, Opportunities, and Pathways for Sustainable Forestry Offsets

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Abstract: Forestry offsets, recognized for their diverse environmental and social co-benefits, are gaining a growing interest as nature-based solutions to combat climate change. Despite Canada's extensive forest resources, its potential for carbon credit remains largely untapped. This study aims to unveil the prevailing challenges in developing forestry offsets in Canada and propose potential solutions, drawing on insights from in-depth semi-structured interviews (SSIs) with 23 experts in the field. A qualitative thematic analysis highlighted 14 challenges under four major frequently discussed themes: methodological (37%), social (29%), economic (22%), and implementation challenges (12%). Our findings highlighted the urgency of addressing key obstacles, including the impermanent nature of forestry carbon offsets, substantial public knowledge gaps, uncertainties in the cost-effectiveness impacting financial viability, and the need for enhanced capacity for project implementation. Building on the discussions on the identified challenges, this study further presented a comprehensive analysis of the future directions for Canada, emphasizing the importance of addressing key methodological issues, enhancing public and Indigenous education and engagement, and leveraging advanced technologies and innovative approaches like ton-year accounting for economic viability. This paper delivers pivotal insights that have the potential to shape the direction and integrity of the forestry offset markets in both Canada and globally.

Keywords: Canadian forests; market mechanisms; carbon offsets; forest carbon; carbon credits; offset market; Indigenous participation; carbon market; expert interview

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1. Introduction

The Kyoto Protocol started the global efforts against climate change in 1997 and innovatively established a key market-based mechanism: the clean development mechanism (CDM) [1]. This mechanism bridged the emission reduction projects between developing and developed nations, setting the stage for the vibrant transactions and prodigious volumes of carbon credits evident in the current market landscape. Since its operation in 2006, the CDM has registered more than 1650 projects in various forms [2], ranging from renewable energy to energy efficiency improvement, afforestation and reforestation, and fuel switching [3]. The Paris Agreement (2015), adopted by 196 nations, set a milestone target of a global 1.5 °C temperature limit compared to the pre-industrial level through a bottom-up mechanism, 'nationally determined contributions (NDC) [4]'. This monumental accord boosted global awareness of the climate fight. An increasing number of businesses either directly reduce emissions via technological transformation or purchase carbon offsets in the voluntary markets. As a result, global carbon offset markets experienced noticeable growth, with a 475 million credit issuance in 2022, doubling from five years ago [5]. Amongst over 170 types of offsets, nature-based solutions (NbS) have stood out in the voluntary market, fueling the rising market price and size [6]. Forestry-related projects, encompassing 21 types, accounted for 46% of the voluntary market share in 2021 [6].

Forests, covering one-third (four billion hectares) of world terrene, have been valued as a pivotal natural ecosystem with various benefits [7]. The global forest aboveground biomass holds a significant carbon pool, reaching 522 Pg [8] with an average density of 210.09 Mg/ha [9]. This level can be further elevated by 15 to 16% if the human management of harvesting is eliminated [10]. A healthy species-rich forest ecosystem not only possesses high productivity and carbon benefits owing to the interspecific complementarity [11–13], but it also enriches the local biodiversity, regulates water provisioning, enhances air quality, and controls soil erosion [14–17]. With carbon finance, these invaluable forests can be transformed into offset projects to gain carbon credits in three general pathways: afforestation–reforestation (AR), improved forest management (IFM), and reducing emissions from deforestation and forest degradation (REDD) [18]. AR refers to the direct plantation or reforestation of trees on land where the forest is unlikely generated naturally, IFM refers to the better silviculture activities that optimize the additional carbon benefits, while REDD avoids the significant carbon emissions from deforestation and degradation [18]. Beyond ecological importance, these nature-based projects have cultural, recreational, and spiritual significance [15], and most importantly, they support local livelihoods [6]. Though outcompeted by renewable energy projects in 2022, they are anticipated to reclaim dominance in the voluntary market as renewable projects face a decline in financial additionality requirements, and buyers show a growing preference for the co-benefits associated with the forest offsets [5].

Nevertheless, developing forestry carbon offset projects faces a full spectrum of challenges, including additionality, permanence, cost benefits, monitoring, reporting, and verification (MRV) [19–22]. Additionality, a key criterion for forest offsets requires projects to have additional carbon benefits than the business-as-usual baseline scenario [23]. The IFM projects in the United States have been continuously questioned as research has demonstrated that these offsets have not reduced harvest rates nor increased the carbon accumulation as the signs of additionality [24] and have potentially been over-credited with 30 million tCO_2e [25]. Similar skepticism has sparked in deforestation-avoidance projects where 90% of these offsets may be 'ghost credits [26]', where it was further researched that out of 26 project sites, only one REDD project demonstrated a lowered deforestation rate [27]. Permanence, another key criterion, refers to the longevity and stability of the project with human or natural disturbances [23]. Under the current climate change, the incidence of climate-driven risks, encompassing forest fires, droughts, and insect outbreaks, becomes more frequent [28], significantly threatening permanence. A robust MRV system ensures the credibility of forest projects. Still, the trade-offs between robustness and the costs in the frequency, format, and level of details of monitoring, reporting, and verification process pose real-world conundrums [29]. While the world-leading carbon standards, namely the Verified Carbon Standard (VCS), the American Carbon Registry (ACR), the Climate Action Reserve (CAR), and Plan Vivo, have attempted to address most issues, the cost-effectiveness demands prompt solutions [20].

Canada, ranked third (9%) of global forestlands, possesses 347 million hectares of precious temperate and boreal forests [7], demonstrating significant potential for implementing nature-based projects. However, the forestry offsets remain nascent in the country. On the compliance side, the Canadian federal Government is still in the process of refining the 'Federal Offset Protocol: Improved Forest Management on Private Land' [30]. Provincially, British Columbia (BC) successfully implemented a 'BC Forest Carbon Offset Protocol' under the broader BC Offset Program in 2011 [31]. However, it only has five registered forestry projects in the BC Carbon Registry [32], partially owing to the development of the second version of the protocol in recent years [33,34]. Additionally, the Quebec province has established 'Carbon Sequestration Through Afforestation or Reforestation on Private Lands' but no active projects [35]. On the other hand, only two voluntary standards, VCS and ACR, have specific methodologies for Canadian forestry offsets [36–38]. Among 270 registered forestry projects under VCS, only four are developed in the Canadian landscape [39], while no project is under ACR [40].

The existing literature has discussed various aspects of forest carbon offsets in Canada, including their mechanisms, issues, and potential. Chen et al. [41] investigated the annual carbon potential of four types of forest offsets in Canada: (1) afforestation (~8 Tg C); (2) reforestation (~57 Tg C); (3) N fertilizer application (~58 Tg C); and (4) improved harvest (~11 Tg C). Golden et al. [42] preliminarily stated that stand-replacing disturbances of fire and insect infestations have been a long-discussed issue for Canada, especially when the monitoring period is 100 years. Provincially, St-Laurent et al. [43] summarized several key issues posed to BC forest offsets, including lack of carbon markets, restricted financial gains, doubtful efficacy in climate mitigation, adverse public perceptions, ambiguous ownership, and administrative challenges. Hope et al. [44] reported that the afforestation projects in Ontario present low economic feasibility if they involve wood harvests, considering the factors of high developing cost, unfavorable carbon price, and discount rate. In Quebec, Ménard et al. [45] found that forest plantations on unproductive, non-forested lands can gain 32 to 70% more carbon benefits with black spruce, white spruce, and jack pine, while only 4 to 12% for red pine. The natural succession of the abandoned clear-cut forest land is not significantly different from the afforestation scenario in Quebec [46]. However, there is limited research into the whole picture of the underlying difficulties and prospects for forest carbon offset development in the country. This study aims to address this research gap and unveil the multifaceted challenges, opportunities, and pathways for sustainable forestry offsets in Canada. By conducting qualitative semi-structured interviews with a diverse group of Canadian and international experts, we hypothesize that our thematic analysis will reveal a framework of challenges categorized into four key themes: methodological, social, economic, and implementation issues [20]. This framework will not only help categorize existing barriers but also aid in discussing comprehensive solutions and innovative approaches for the future. Ultimately, this research seeks to provide in-depth insights for the public, researchers, and policymakers, contributing to a more informed and strategic approach to enhancing the integrity and effectiveness of forest carbon offsets in Canada.

2. Materials and Methods

2.1. Study Area and Interview

We conducted interviews with 23 experts segmented into three primary categories: project specialists, governmental officials, and academic researchers, each of whom possessed in-depth experience and robust knowledge pertaining to forestry carbon offset projects in Canada (Table 1). Government officials, key in shaping and deploying provincial strategies, provided essential insights into the Canadian landscape of forest carbon offsets. Project specialists with hands-on experience in project implementation contributed practical experience and knowledge regarding the methodologies, standards, and challenges inherent in offset projects. Additionally, academic researchers, including university professors and renowned scholars, offered theoretical foundations and critical evaluations of current practices, enriching our understanding of this field. The scope of our study spanned five Canadian provinces: British Columbia (n = 8), Alberta (n = 3), Manitoba (n = 1), Ontario (n = 2), and Quebec (n = 4) (Figure 1). These provinces have sufficient experience and knowledge as they have either successfully implemented or are in the process of establishing the carbon offset tools. Additionally, to incorporate a global perspective, we engaged experts from California, the USA (n = 2), and other international experts (n = 3). Semi-structured interviews (SSIs) allowed researchers the latitude to explore emergent ideas while maintaining the focus, offering depth unattainable using quantitative data alone [47]. In line with contemporary qualitative research perspectives, typical interview studies often achieve data saturation between 9 and 17 interviews, with an average of 12–13 [48]. Given this benchmark, the input from our 23 participants, diverse in geographic scope and expert categories, ensured that we had adequately covered the necessary breadth of information for our study's inquiries, underscoring the robustness of our sample size.

Table 1. The detailed classification of experts interviewed.

Expert Category	Number of Interviewees
Project Specialists	13
Government Officials	4
Academic Researchers	6
Total	23

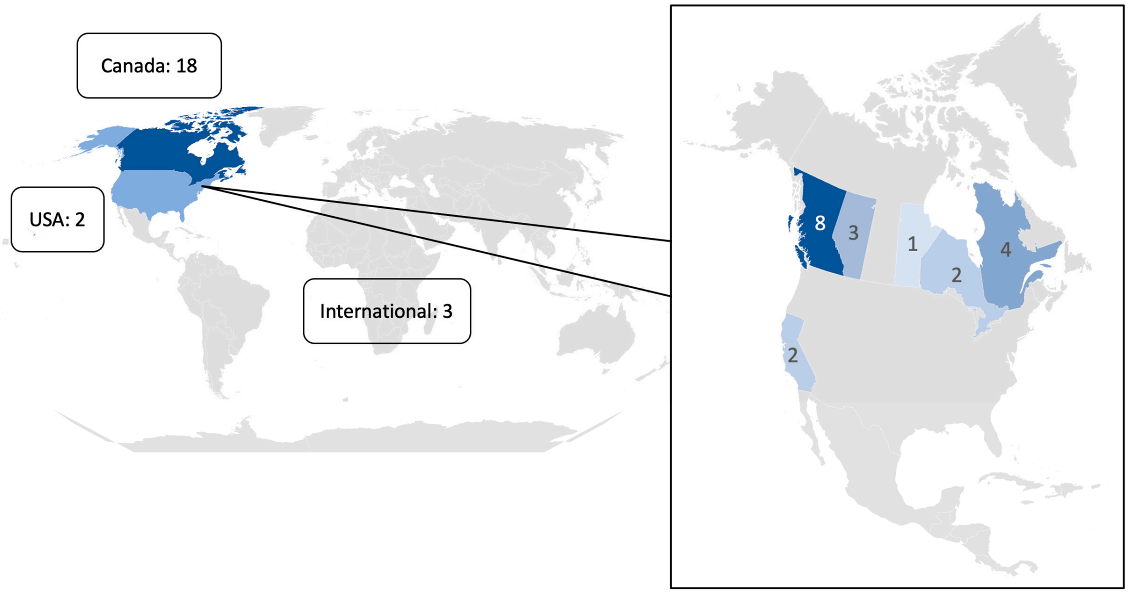

Figure 1. The location of the 23 experts interviewed. Map was generated via Excel (2023) of Microsoft Office 365 (© Australian Bureau of Statistics, GeoNames, Microsoft, Navinfo, Open Places, OpenStreetMap, TomTom, and Zenrin), powered by Bing.

2.2. Interview Procedures

An initial expert search was conducted based on a criterion-based sampling strategy [49], and our criteria focused on professional experience, contributions to the field, and affiliation with organizations of relevance, ensuring that participants had both theoretical knowledge and practical, on-the-ground experience. We identified more than 50 potential experts suitable for this study from the pertinent institutions, including project-developing companies, governments, and universities. We proactively contacted the potential interviewees or institutions via email, containing the project introduction and interview invitation, thereby ensuring their understanding of the scope and objective of the study. Due to constraints on time and capacity, some invitations did not result in successful engagements. The chosen organizations proposed representatives to participate, and the insights from these experts reflected both their personal expertise and the perspectives of their associated institutions. Before each interview, we provided participants with a package detailing the study's background, interview questions, and an informed consent form. Throughout the interview process, participants recommended additional potential interviewees. Subsequently, we extended invitations to these new candidates, employing a snowball sampling strategy [49]. The study culminated in 23 online interview sessions via Zoom, each approximately 60 min, a reasonable length to gather sufficient information while avoiding fatigue for both sides [50].

Our interview framework was crafted to engage experts comprehensively, beginning with their individual roles and experiences related to forestry carbon offset projects.

The interview encompassed 14 main questions, categorized under two primary themes. The first section consists of ten questions about the challenges and potential solutions in forestry carbon offsets, including general, methodological, social, economic, and implementation aspects. The subsequent part highlighted the prospects and sustainability, featuring four questions that explored opportunities, trade-offs, policy integration, and the future outlook of these offsets. Each primary question was open-ended, and in line with the semi-structured interview format, subsequent probing questions were followed for in-depth, personalized responses drawing upon the interviewee's professional knowledge and individual experiences. This approach captured a thorough, diverse set of insights, enhancing the robustness of our research findings.

2.3. Thematic Analysis

All interviews were audio-recorded, transcribed (anonymized), and imported to NVivo 14 for qualitative thematic analysis (TA). NVivo 14 is a software tailored for qualitative analysis, offering tools to organize, retrieve, and interpret qualitative information [51]. TA, widely used in qualitative research, enables researchers to identify, analyze, and interpret the patterns and themes across the vast interview data by generating codes [52]. We meticulously followed the six-phase TA (Table 2) proposed by Braun and Clarke [53], supplemented by guidelines for ensuring the trustworthiness added by Nowell et al. [54].

Table 2. The six-phase thematic analysis [53].

Phase	Process Description
I. Familiarizing with Data	Transcribing data (if necessary), reading and re-reading the data, and noting down initial ideas.
II. Generating Initial Codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
III. Searching for Themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
IV. Reviewing Themes	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
V. Defining and Naming Themes	Ongoing analysis to refine the specifics of each theme and the overall story the analysis tells, generating clear definitions and names for each theme.
VI. Producing the Report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating the analysis back to the the research question and the literature, producing a scholarly report of the analysis.

We thoroughly engaged in the primary data and deeply examined the transcribed content. Integrating with previous research that forestry offsets primarily consisted of methodological, economic, social, and implementation challenges [20], an initial thematic network for coding was inductively formed (Figure 2). This network was continually referenced during the subsequent coding process, serving as a fundamental guide to the theme generation [54]. In phase II, a deductive approach was employed, under which we coded all pertinent phrases, sentences, and paragraphs in alignment with the thematic network. The NVivo software recorded the number of experts and references for each coded topic. We meticulously reviewed the themes generated and merged several into larger themes. For example, issues related to 'forest longevity', 'long monitoring period', and 'land tenure' were integrated into 'permanence'. After several rounds of peer debriefings, our team established an initial thematic coding framework regarding the challenges in developing forest carbon offset projects in Canada (Figure 3a). We further immersed ourselves in all the coded information and refined the thematic framework (Figure 3b). For instance, the 'unique forest inventory' was moved under 'quantification' since conducting forest inventories is part of the quantification process in project development. We renamed the 'general unfamiliarity (new market)' to 'lag in knowledge' for better alignment in the coded information and conciseness. Also, the 'wrong attitude for fires' was subsequently switched to 'lag in knowledge' for suitability.

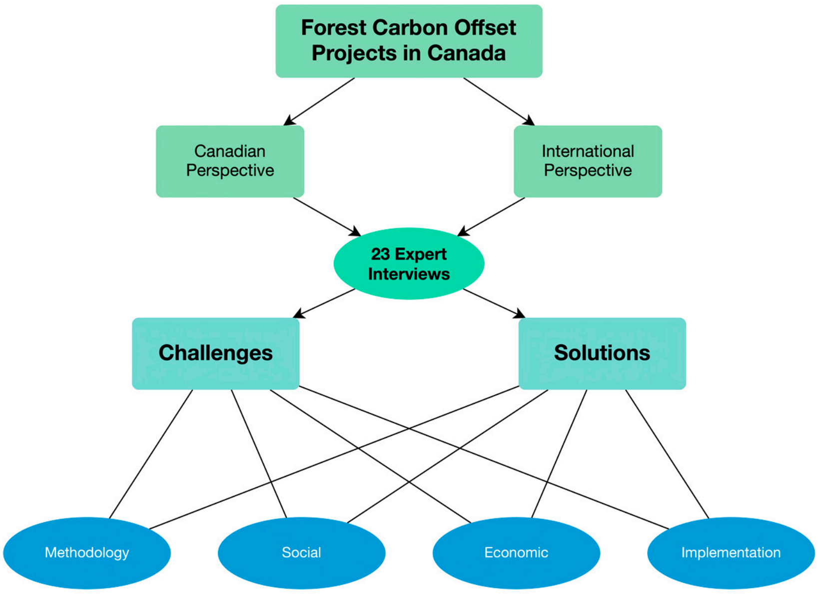

Figure 2. The thematic framework.

Name	Files	References
Challenges	0	0
Economic Challenges	0	0
Cost Effectiveness	18	34
Revenue and Demand	14	22
Limited Credits	4	8
Scale of Projects	2	2
Policy Change	1	1
Implementation Challenges	0	0
Lack of Capacity and Difficulties	14	22
Credit Integrity	7	11
Long Monitoring Period	5	6
Lack of Verifiers	4	4
Methodological Challenges	0	0
Additionality	15	25
Lack of Protocols and Methodologies	11	18
Leakage	6	11
Wrong Atitude for Fires	5	8
Quantification	3	3
Unique Forest Inventory	2	2
Permanence	0	0
Forest Longevity	13	18
Long Monitoring Period	9	14
Land Tenure	2	2
Public Land	0	0
Carbon Rights	6	11
Land Tenure	3	3
Social Challenges	0	0
Genral Unfamiliarity (New Market)	16	29
Public Critiques	13	22
Timber Trade-off	12	20
Indigenous Participation	8	10

(**a**)

Name	Files	References
Challenges	23	306
Methodological Challenges	21	113
Permanence	18	40
Forest Longevity	13	18
Long Permanence Period	9	14
Long Monitoring Period	5	6
Land Tenure	2	2
Additionality	15	25
Lack of Protocols and Methodologies	11	18
Public Land	7	14
Carbon Rights	6	11
Land Tenure	3	3
Leakage	6	11
Quantification	5	5
Unique Forest Inventory	2	2
Social Challenges	22	89
Lag in Knowledge	18	37
Wrong Atitude for Fires	5	8
Public Critiques	13	22
Timber Trade-off	12	20
Indigenous Participation	8	10
Economic Challenges	22	67
Cost Effectiveness	18	36
Scale of Projects	2	2
Revenue and Demand	15	31
Limited Credits	4	8
Policy Change	1	1
Implementation Challenges	17	37
Lack of Capacity and Difficulties	14	26
Lack of Verifiers	4	4
Credit Integrity	7	11

(**b**)

Figure 3. The thematic coding framework: (**a**) the coding framework (before aggregating child codes to parent codes) of the challenges in forest carbon offset projects in Canada after phase III; (**b**) the refined coding framework after phase V. The number of files represents the total number of experts referring to the specific codes, and the number of references denotes the total number of times all experts discuss a particular code.

2.4. Relative Frequency Analysis

In the final phase of the thematic analysis—Producing the Report—we sought to emphasize the most prominent themes underscored by our expert participants. We recorded the total number of references for each sub-theme, denoting the specific insights and pivotal points underscored by the experts. We then determined the relative frequency (%) of each sub-theme by dividing its count by the total references across all sub-themes. Additionally, to assess the importance of each sub-theme within its broader theme, we divided its count by the total references of all related sub-themes. This approach highlighted the relative importance and consensus of specific challenges and insights among the experts. It facilitated the selection of compelling evidence to relate our analysis to the research question and the relevant literature, ensuring a thorough and insightful scholarly discussion.

3. Results

3.1. Thematic Framework of Challenges

Throughout the thematic and relative frequency analysis, we found that the challenges in developing forest carbon offset projects in Canada can be broadly segmented into four broader themes: methodological, social, economic, and implementation challenges (Figure 4). This classification aligns seamlessly with our hypothesis and the previous research [20]. Methodological challenges included six sub-themes: (1) Permanence in Canada's forests, vulnerable to disturbances like wildfires and insects, especially considering the mandated 100-year monitoring period. (2) The challenge of additionality from accurately establishing credible baselines versus exaggerated climate benefits. (3) The lack of forest carbon protocols and methodologies with slow governmental responses. (4) The intricate relationship between the First Nations and crown forests, confusing the carbon ownership for public land. (5) Uncertainties surrounding accounting for international leakage and adjustments in the government's annual allowable cut. (6) Complexities in forest inventories, disturbance rates, and carbon modeling complicate carbon quantification. Social challenges were classified into four sub-themes: (1) The knowledge lag reflected in public unfamiliarity, governmental incapacity, and complexities in project development concepts. (2) Public criticisms for potential greenwashing from Indigenous communities, news agencies, and academia. (3) Reduced timber harvests as the primary trade-off to carbon offsets, affecting local communities and economies. (4) Complex rules and standards, posing concerns for Indigenous participation in reduced control over ancestral lands and equitable benefit sharing. Economic challenges had two sub-themes: (1) Cost-effectiveness challenges due to high initial costs, lengthy and complex developing processes, and the small forest holders of many Canadian owners. (2) Market demand and revenue uncertainty due to public criticism, limited compliance demand, and conservative protocols. Lastly, the implementation challenges were categorized into two sub-themes: (1) The lack of capacity for skilled forest carbon analysts, governmental resources, project implementation, and available verifiers. (2) The credit integrity from untransparent verification.

3.2. Relative Frequency Analysis of Challenges

During the interview process, most experts discussed four broader themes: methodological, social, economic, and implementation challenges (Table 3). Methodological challenges emerged as the predominant challenge, most frequently discussed (accounting for 37% of mentions), followed by social (29%), economic (22%), and implementation challenges (12%).

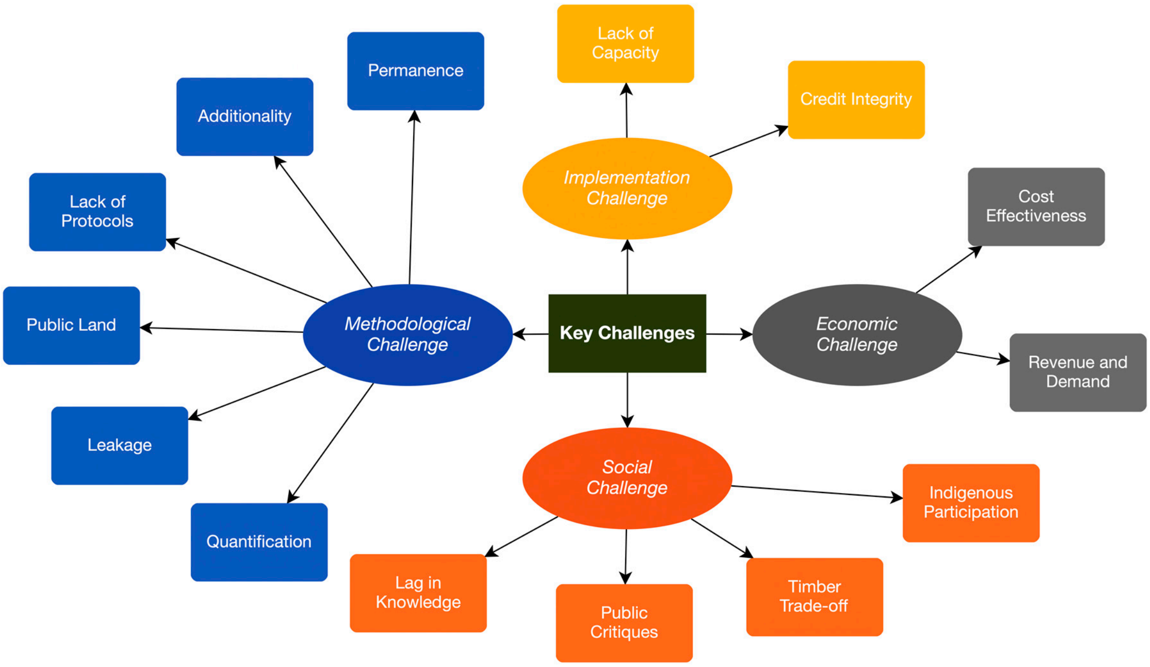

Figure 4. The thematic framework of the challenges identified from the thematic analysis.

Table 3. The number of experts, frequency, and relative frequency for the broader thematic challenge categories.

Challenges	Number of Experts	Frequency	Relative Frequency
Methodological	21	113	37%
Social	22	89	29%
Economic	22	67	22%
Implementation	17	33	12%
Total	23	302	100%

From 23 respondents, 14 distinct challenges emerged (Figure 5). The 'permanence' issue, a methodological concern, was paramount, constituting 15.0% of the challenges discussed within the Canadian context. Significant challenges also included 'lag in knowledge' (13.9%) within the social challenges and both 'cost-effectiveness' (13.5%) and 'revenue and demand' (11.7%) in the economic domain. These four challenges represented over half (54.1%) of the discussions. Six other challenges had a moderate mention rate, ranging from 5% to 10%, such as 'lack of capacity and difficulties' (9.8%) to issues with 'public land' (5.3%). A subset of four challenges was less frequently mentioned, falling between 1.9% and 4.1%. When categorizing all these challenges, methodological ones were most abundant in number (6), followed by social (4), economic (2), and implementation (2) (Figure 6). In each broader category, one challenge was predominant. Specifically, within methodological challenges, 'permanence' accounted for 35%, while 'lag in knowledge', 'cost-effectiveness', and 'lack of capacity and difficulties' were the dominant issues in their respective categories, comprising 42%, 54%, and 70%.

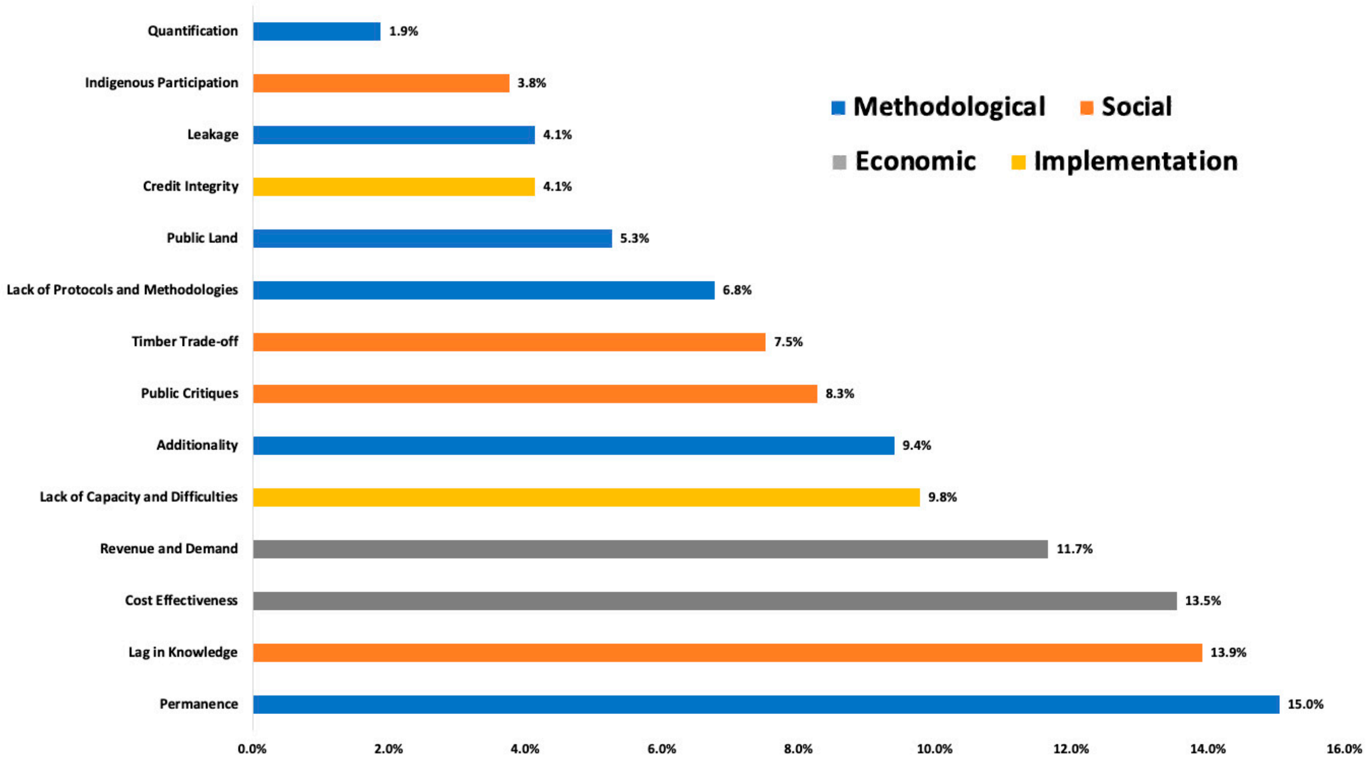

Figure 5. The relative frequency (%) of the 19 individual challenges under four broader categories.

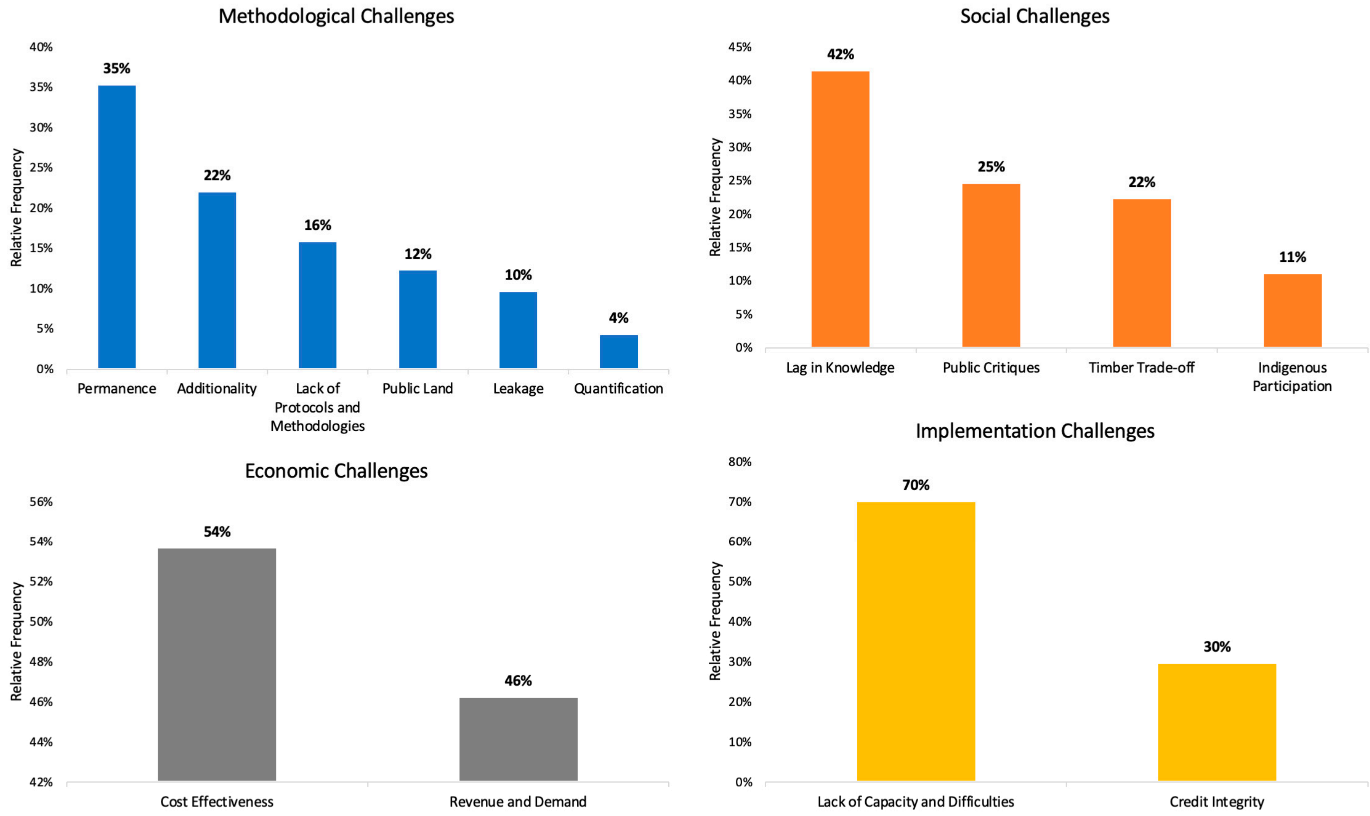

Figure 6. The relative frequency (%) of individual challenges under each broader challenge category.

4. Discussion

The following sections were based on the insights, perceptions, and opinions of the interviewed experts, combined with the existing literature, studies, and reports.

4.1. Methodological Challenges

Permanence, the forefront methodological challenge, denotes the longevity of forest carbon offsets from their susceptibility to reversal risks [55]. Numerous experts stressed that most forest ecosystems in Canada are particularly vulnerable to natural disturbances such as wildfires and insects. The few milder exceptions include the temperate rainforests in coastal British Columbia (BC) and the old growth in southern Ontario, which can live for millennia. Conversely, forests in the rest of Canada exhibit shorter disturbance cycles. For example, the boreal forests in northern Alberta experience fires every 39–96 years [56]. The year 2023 witnessed a surge in wildfires, significantly surpassing the occurrences in the past decade [57]. With climate change, predictions suggest that Canada will face more frequent and intense wildfires, peaking around 2040–2045 [58]. However, respondents further emphasized that regulatory forest protocols in Canada require a crediting period to accompany an additional 100-year monitoring period, which considerably exceeds the usual fire cycles. Suppose an IFM project adopts a 25-year crediting framework, and the forest's age starts at 50; the project developer is responsible for monitoring the forests until they are 175 years old. This extended duration heightens the susceptibility of forests to fires as the fuel load accumulates over time. Methodologically, this natural risk poses a significant challenge to project permanence, as the emissions from global forest fires can reach 1.8 Gt CO_2e annually [28]. Beyond the threat of fires, some interviewees expressed concerns related to insect outbreaks. For instance, between 2000 and 2020, disturbances caused by mountain pine beetles in interior BC resulted in the release of an estimated 270 Mt of carbon [59].

The mandated long permanence period (100 years) set by regulatory entities poses substantial obstacles, encompassing not only natural disturbances but also issues related to commitment and land tenure. Interviewees emphasized the challenge for organizations, whether businesses or non-profits, to maintain operations over a century. Such a long-term commitment to modify harvesting practices is a deterrent for potential project developers, notably when revenue assurance is lacking. Another point of contention highlighted by experts is the typical duration of forest licensing in Canada, which is generally confined to 20–25 years for public lands, with rare exceptions extending to a century. BC, for instance, allows a maximum of 20 years for a forest license [60]. However, 90% of the vast forest resources in Canada are publicly owned by the provinces and territories [61], thereby introducing additional layers of complexity and challenges in forest projects.

Additionality, another crucial methodological challenge, requires demonstrating additional carbon benefits after the project implementation compared to the credible baseline (business-as-usual) scenarios [55]. This counterfactual baseline, delineating the trajectory of emissions of the hypothetical reference case [55], is complicated to establish in the first place, particularly in regions that lack historical records of forest inventories. There are also incentives for project proponents to avoid setting a conservative baseline due to asymmetric information, leading to exaggerated climate benefits and overestimated carbon credits. A study conducted in Quebec investigated the additionality of white spruce plantations over abandoned agricultural lands [46]. The findings indicated that the carbon sequestration of afforested forests (project scenario) did not surpass that of abandoned lands (baseline scenario), mainly owing to the carbon accumulated in the soil and vegetation biomass from the natural succession. Has Earth truly benefited from this afforestation activity? This is challenging for Quebec, given that the province restricts its forest-offset efforts to afforestation and reforestation projects alone [35]. Some projects in BC have been operating since 2011, and experts stressed that with the evolution of carbon modeling and accounting technology over the years, it may become imperative to recalibrate baselines for optimal accuracy concerning additionality.

A salient case study of additionality is the controversial Darkwoods Forest Carbon Project in BC, which gained credits for conserving the forests. A number of respondents expressed concerns regarding Darkwoods' chosen baseline, which assumes the imminent harvests of mature timber by a so-called liquidation logger within a few years. However, it does not align with the sustainable forest management requirement under the Forest Stewardship Council (FSC). The insight aligns with the findings from the Office of the Auditor General of British Columbia, arguing that the Darkwoods' baseline was not conservatively and appropriately configured [62]. This overestimated baseline could have exaggerated the real additionality by over sixfold, as the most probable baseline activities are historical practices instead of unrealistic mass logging (Table 4). The Darkwoods forest, in its original sale terms, was destined for a buyer committed to sustainable forestry and prioritizing wildlife biodiversity, essentially excluding the possibility of the liquidation logging for maximum financial return [62]. Also, sustainable forestry was an ineligible baseline since the project proponent, the Nature Conservancy of Canada, bears legal obligations to stay lower than historical practices due to Darkwoods' inclusion in the federal Ecological Gifts Program [62]. Thus, the credible baseline for Darkwoods would fall below the 57,000 m^3 annual harvest, far below the claimed liquidation logging scenario.

Table 4. Harvesting volume comparisons between different baseline scenarios for the Darkwoods Forest Carbon Project [62].

Scenario	Volume of Forest Harvested (m^3/year)	Additionality (m^3/year)
Project	11,000	
Historical Practice	57,000	46,000
Sustainable Yield	150,000	139,000
Liquidation Logging	300,000	289,000

The scarcity of protocols and methodologies, regardless of compliance or voluntary markets, poses another critical methodological challenge for Canada. These protocols serve as the fundamental blueprint to convert forests into viable projects. Throughout the interviews, we learned that there are six methodologies for the Canadian landscape, but only one is active for both the compliance and voluntary markets (Table 5). On the regulatory front, the BC province has been the lead player in forest carbon offsets, holding five projects under the first version of the 'BC Forest Carbon Offset Protocol [31,32]'. Nevertheless, the BC government retracted the first version in 2016 and published the drafted second version in 2021 [34]. Though the public consultations have concluded, the methodology remains in the developmental stage [33]. Only Quebec has an active methodology but with a limited scope on afforestation and reforestation on private lands [35]. Although several experts did highlight proactive protocol development by provincial governments like Alberta and Manitoba, they raised concerns about the pace at which Canadian federal and provincial governments are reacting to climate change. For example, the public consultation period for the BC Forest Protocol 2.0 could take several years. On the voluntary side, only two international standards, the Verified Carbon Standard (VCS) and the American Carbon Registry (ACR), have developed methodologies for Canada. Partially owing to the growing pressure from the press and scholarly criticisms [26,27,63,64], Verra, the body overseeing VCS, is currently re-evaluating all its IFM methodologies, including the VM0034 and VM0012, to ensure quality and credibility [65]. Thus, these methodologies are temporarily on hold. While VCS holds four forest projects in Canada [39], there is no project under the American Carbon Registry (ACR)'s methodology [40].

Table 5. Status quo of the forest carbon protocols and methodologies in Canada.

Jurisdiction	Name	Ownership	Scope	Status
Federal Government [30]	Improved Forest Management on Private Land	Private	Compliance	Under Development
BC [34]	BC Forest Carbon Offset Protocol 2.0	Private and Crown	Compliance	Under Development
Quebec [35]	Carbon Sequestration Through Afforestation or Reforestation on Private Lands	Private	Compliance	In Force
VCS [36]	VM0034—Canadian Forest Carbon Offset Methodology	Private and Crown	Voluntary	Pending Update
VCS [38]	VM0012—Improved Forest Management in Temperate and Boreal Forests (LtPF)	Private and Crown	Voluntary	Pending Update
ACR [37]	Improved Forest Management (IFM) on Canadian Forestlands	Private	Voluntary	In Force

Another fundamental challenge is the scope of the regulatory forest carbon protocols. Except for BC, all others have been targeting the private forests but overlooking the 90% of public crown forests in Canada [61]. Respondents noted that since carbon credits originate from the atmosphere, determining the rightful ownership of carbon stored in forest biomass remains challenging, given that traditional forest tenures do not encompass carbon rights [43]. Particularly, experts stated that the relationship between the First Nations and crown forests is complex and has been shaped by historical treaties, unceded territories, and ongoing negotiations. The Indigenous peoples have been managing the lands for generations, but there are conflicts in the property rights of forests, forest management, and carbon. BC is the sole province permitting project development on crown lands, primarily due to the Atmospheric Benefit Sharing Agreements (ABSAs) established between the First Nations and the government. ABSAs are designed to clarify carbon ownership and enable Indigenous communities to sell and trade carbon credits [66]. However, comparable agreements are absent in other provinces/territories. On the other hand, since the timber industry is one of the pillar industries, Canada has set an upper limit for the annual wood harvest from public forests, termed the annual allowable cut (AAC), to safeguard economic sustainability [67]. Project developers may reduce the AAC from 100,000 to 50,000 cubic meters to demonstrate additionality, but experts questioned if government policy shifts in the future, a reduced AAC may lead to fewer additional projects. Most critically, the presence of AAC introduces a subsequent challenge–leakage.

Carbon leakage is defined as the emissions outside a project area directly resulting from its activities, encompassing both internal and external leakages [18,68,69]. At the micro level, internal activity shifts occur when a landowner increases harvesting in forests outside the project area in response to a reduction in harvest within the project's boundaries [69]. On the other hand, external leakage refers to the emission transitions beyond the landowner's control, influenced by market dynamics [18]. Respondents emphasized Canada's significant challenges with external leakage. For example, the government determines the AAC yearly; if a project developer reduces their AAC, the government might reallocate the spared portion to other tenure owners to achieve economic goals. Leakage issues also arise internationally, lacking comprehensive accounting techniques [70]. Experts shed light on the complexities and difficulties of evaluating global supply–demand shifts following project implementation. There is an inherent challenge in balancing increased wood demands abroad with forest conservation efforts in Canada.

Quantifying the carbon emission reduction or avoidance is central to determining the carbon credits a project can generate. However, this process can be challenging for forest offsets in Canada, as experts depicted. The forest inventory is measured and controlled provincially in Canada, and its national forest inventory program was only established in the 2000s [71], contrasting the US's nationwide approach since 1930 [72]. This lack of historical records may affect the level of accuracy in baseline determination and credit quantification. Other than inventory, many other parameters, including disturbance rates, harvest activities, species biomass functions, growth and yield functions, and carbon modeling, would add layers of complexity [24,25,27,73]. Further, an expert raised concerns regarding the omitted emissions from logging activities in IFM projects, which should be meticulously and holistically accounted for in the quantification, particularly given that global timber harvest-related greenhouse gas emissions can peak at 4.2 Gt CO_2e yr^{-1} [74].

4.2. Social Challenges

A significant social challenge in Canada is the lag in knowledge, given the market's infancy and limited exposure within the country. Respondents stressed that the public remains largely unaware of forest carbon credits due to the sparse number of projects and methodologies available. This knowledge deficit extends beyond the public; several experts noted that even government bodies, whether provincial or federal, have limited staff with the expertise to understand the concept. The limited government capacity would significantly lower the speed of developing protocols and methodologies. Compared to less than 10 Canadian projects [32,39,40], 130 forest offset projects were already under the California carbon offset program in 2020 [25]. There is an educational lag in the concept within the First Nations, where the Indigenous peoples remain uncertain about continuing traditional activities, such as cultural practices, timber harvesting, firewood collection, and gathering herbs and medicines after the project implementation. Also, changing the behaviors of land management can always lead to skepticism. Experts also warned that a misrepresentation of the carbon credits their forests can create may emerge as the carbon consultants tend to exaggerate and overestimate the climate benefits owing to asymmetric information. A consultation fee is paid in that case, but the proposed projects may not reach the stated additionality.

However, the rules and standards for the project development are complicated by nature. Basic concepts like additionality, permanence, and leakage are already challenging to comprehend before reaching the MRV phase. Thus, the local communities will likely play passive roles due to this complexity and, hence, invest more time and capital to address the lag in understanding [75]. Ultimately, it would take a lengthy time to develop such projects. The lack of participation in the project, especially Indigenous participation, can potentially harm the local community by reducing control of the land [20]. An interviewee brought up an example: if project developers aim to maximize the carbon benefits, critical habitats for keystone species, such as deer and moose, valued by the First Nations, may be significantly impacted. Moose tend to avoid newly cut blocks due to shifts in vegetation and growth conditions, disrupting their natural habitats [76]. Extreme social conflicts of forced eviction from the forest, violence, and lawsuits have occurred to the Indigenous peoples in the tropical projects [77], providing lessons for Canada. Experts were questioned about the benefit-sharing: where does the money go? Right now, it is difficult for society to examine the fairness of revenue sharing to the local communities. Some First Nations, already committed to sustainable forest management, are disadvantaged because they cannot earn carbon credits due to the lack of additionality.

There is a general misunderstanding that frequent fires destroy the forests, hence criticizing the necessity of having a forest project. Experts have been continuously emphasizing that although with destined emissions, fire is a critical component of the forest ecosystems, especially the fire-dynamic boreal forests in Canada. The Indigenous peoples have been practicing cultural burnings with traditional knowledge for thousands of years, as fire is vital to contain the fuel loads, limit forest encroachment to grassland, safeguard biodiversity, and build a more resilient and healthy forest [78–81]. Many boreal species have adapted to periodic fires for regeneration, such as jack pines and black spruce since they rely on fires to melt the cones and release the seeds, provide a mineral soil seedbed for seedling survival, and clear the overstorey for optimal growth conditions [78]. Fire is one part, but the public criticizes many other aspects of forest offsets.

Forest credits' potential greenwashing issue has been a long-discussing topic [82]. Through the expert interview, we learned that a fair portion of the public and Indigenous communities perceive carbon credits as excuses for oil and gas companies to continue to emit carbon, appearing as greenwashing, especially since there is general uncertainty in the integrity. This negative public perception has deterred potential developers and buyers. The resistance is significant when a typical oil and gas company approaches to explore forest credit opportunities, even if there is a tangible added income stream for the Indigenous communities. The year 2023 has been marked as the bear-market year since the release of the Guardian article in January, which argued that almost all tropical forest carbon credits have no climate benefits [26]. The cooling effect was visible: at the beginning of the year, the global nature-based credits were priced at around USD 7/t, and it sharply dropped to USD 2/t after the Guardian critique and is now priced at USD 1.82/t in October after months of fluctuation [83]. More people started to believe that forest credits are not real, especially in Canada, where there is already a lack of public knowledge. The public in BC did show a positive attitude towards switching forest management activities for mitigating climate change before [84]. However, an expert argued that the balance of public perception of forest credits may tilt towards the negative side now, indicating that a larger proportion of the public believes that forest carbon credits are ineffective. Concerns have also been raised across academia regarding forest carbon integrity and credibility [63,64]. California's forest carbon offset program has over-issued about 30% of the credits [25], and those in California have not been additional [24]. Similarly, most REDD+ projects targeting reducing deforestation across the globe have not significantly reduced deforestation [27].

There are always trade-offs from different forest management approaches among numerous ecosystem services: carbon sequestration, timber production, water supply, biodiversity, and many more [85,86]. They are also unavoidable in forest carbon offsets. From this interview study, the biggest trade-off for Canadian forest project implementation falls into timber revenue. The forest sector is central to Canada's economy, communities, and livelihood. Globally, Canada has consistently been a leading exporter of forest products, reaching a value of USD 44.9 billion in 2021, constituting 7.3% of national exports [87]. The forest industry has contributed a USD 34.8 billion (1.5%) value of gross domestic product (GDP) for the country, along with 205,365 direct jobs in 2021, involving around 12,000 Indigenous peoples [87]. Many experts emphasized a phenomenon in Canada: many communities reliant on timber production have been negatively impacted by the forest carbon offsets, particularly those involving reducing the timber harvests. Taking the Great Bear Rainforest (GBR) project in BC as an example, a forest conservation project, Indigenous communities have traditionally relied on stable, well-paying logging jobs. Some have the chance to stay in the industry, but some have lost these income sources. Some may become 'Guardians', including the roles in forestry, fishery, and wildlife. The Guardians program was an initiative of the BC government to work with the First Nations to manage the land and resources better, and these guardians will undertake various stewardship activities in traditional knowledge [88]. However, the reality remains that some lose their jobs due to such projects, and additional support and mitigation measures are needed.

4.3. Economic Challenges

Cost-effectiveness is the core challenge for forest project development in Canada. The experts have thoroughly discussed the high cost, the unstable price, the uncleared revenue, and the uncertain demand throughout the interviews. The investment into the project initiation is huge before receiving the credits, involving information search, approval, project management, monitoring, reporting, verification (MRV), and insurance [89–91]. Although projects can vary significantly in conditions, a global meta-regression model showed that the marginal cost for forest credits is around USD 25/tCO_2e [92], which would be economically unviable if the carbon price was lower. Zooming into the tropics, the transaction cost to develop forest offset can reach USD 7.71/tCO_2e, equivalent to 270% of the anticipated project revenue [93]. This economic pattern, agreed by the interviewees, is mirrored in the Canadian context.

The entire process of project development is intricate and lengthy, with expenditures incurred at almost every stage. To illustrate, consider the procedures under the VCS by Verra (Figure 7) [94]. Project proponents begin by selecting a suitable methodology and drafting a project design document. These steps involve information searching and possible consultant hiring [91,93] and can cost varying amounts according to the project size and conditions, up to USD 147/ha [95]. Given their knowledge deficit, as highlighted in the interviews, most Canadian landowners may find themselves relying on hiring project developers. Following a successful public comment period, this design document is subject to validation by an approved validation/verification body (VVB)—a substantial approval cost of around USD 18,000 [95]. Additionally, the experts suggested that validation could take half a year and an additional three months of internal review in the registration bodies. Once registered, the project enters its active phase with planned activities involving monitoring costs, site preparation, and field data collection [95]. The proponent then monitors the project's activities for typically five to ten years before submitting a monitoring report to the VVB for verification, another significant approval cost. The time here is a considerable commitment, while the verification could cost USD 20,000 to USD 100,000, as indicated by several respondents. After verifying the project, the proponent finally receives the carbon credits. The respondents argued that it is challenging for many Canadians to obtain the project financed, to raise the initial capital, and to find the proper methodologies, models, tools, and consultants, especially since the country is still digesting the concept of carbon credits. This system naturally sets a threshold that few project proponents are financially qualified to participate.

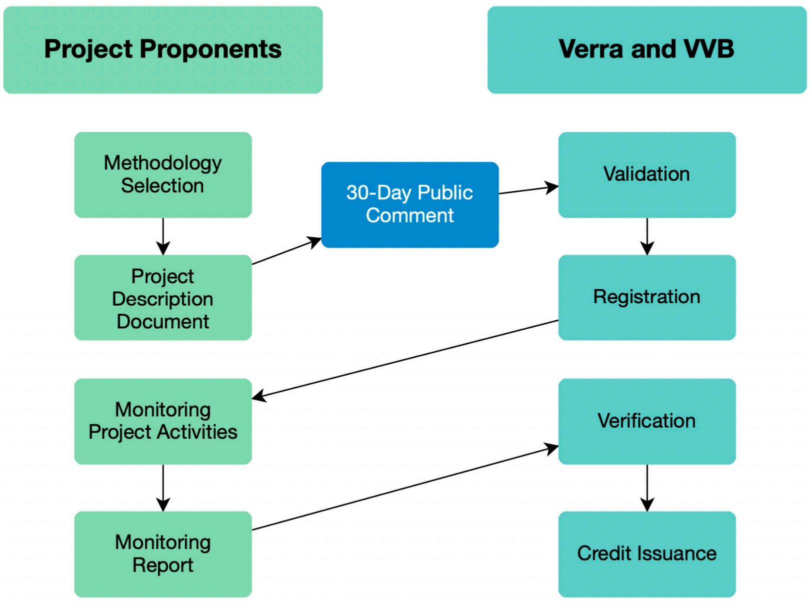

Figure 7. The illustration of the project development process under the VCS standard [94].

The forest plantation projects are rare in Canada, regardless of the markets. The experts explained that most protocols work on an ex-post crediting system, which VCS adopts (Figure 7). Despite the benefits of ensuring credit integrity, the project proponent is required to experience complex procedures with significant time and capital spent before the credit revenue. This project type is a natural victim of the ex-post system in Canada, where the trees grow slowly, especially in the boreal region [96]. Experts emphasized that it might take up to 20 years to retrieve the carbon credits with many uncertainties in growth conditions and natural risks, while the regular costs of tree planting, monitoring, measurement, and verification still apply. IFM projects are more financially viable in Canada as they are based on the existing carbon stocks, and with the assumption of adjusting or reducing the harvests, people obtain the carbon revenue in a shorter timeframe, and there are still some timber revenues. Another point brought up by the respondent is that many landowners in Canada are smallholders owning 25–50 acres of forests, but a viable project size needs to be several thousand to offset the enormous costs.

Market price and demand challenges arise when a forest project is developed in Canada. Currently, there is significant market uncertainty due to public criticism, creating the issue of liquidity. Sometimes, buyers may also bypass the option for forest credits due to the perceptions of natural impermanence [97]. The experts commented that the compliance demand is not rigid in Canada. For example, BC has a regulatory forest protocol but only has a carbon tax scheme that does not necessarily require offsets. Only Quebec has a compliance cap and trade market that allows the offset usage of up to 8% of the compliance obligations [98]. However, there are no active forest projects in Quebec because there have not been any forest protocols for years until recently [35], and people can purchase the credits from California, the carbon market linked with Quebec since 2014 [98]. Less demand means a lower carbon price. It was found that the sale price of forest carbon credits might reach only 25%–50% of their anticipated market value [97]. The economic benefits of such forest projects are significantly limited. Furthermore, several experts stressed that the BC forest protocol has been fairly conservative, leaving more constrained carbon revenue. A large portion of the credits has been assigned to the contingency account, acting as insurance, for the financial, fire, drought, pest and disease, wind, hydrological, or flooding risks in the following 100 years [34]. Also, the provincial default leakage rate for interior BC is about 70% [34]. These measures ensure the quality of offsets, but the financial viability is further reduced.

4.4. Implementation Challenges

There are also numerous difficulties in the Canadian context during the project implementation phase. As the forest carbon offset market is nascent in the country, the interviewees emphasized the challenge of lack of capacity. Despite the criticisms, many landowners are interested in entering the market for the co-benefits and additional incomes. Still, finding forest carbon analysts with the skill sets to perform the forest carbon inventory and modeling is challenging. These forest carbon consultants need to have the capacity to set up sample plots and measure the trees. They need to apply the proper biomass models, estimate the growth rates, and then derive the estimated carbon credits. Conversely, governments and global standards are also often short of capacity. For example, staff power is limited for most provinces, such as BC, where few specific roles, departments, or divisions are tailored to take charge of the forest carbon offsets, further slowing down the progress and development. It took five years for the BC government to develop the new version of the forest protocol (June 2016–March 2021), two rounds of public consultations until April 2023, and the 2.0 protocol is still under revision (October 2023) [34,99]. VCS under Verra, on the other hand, has an increasingly slower processing time due to the unmatching capacity under growing demand. For example, there might be 20 projects to review for registration ten years ago, but it could be 200 today. In 2023, the registration review time may take up to 100 business days after a 30-day public commenting period on the pipeline and up to one year of validation [100,101].

Regarding the project activities, several experts raised the issue of inaccessibility of forests. Canada has more than 75% of its forests located in the boreal zone, spanning 282 million ha, but the majority is highly remote with significantly low accessibility [87]. The principal activities for forest offsets are the actual forest tending and management [102], but the remoteness and the lag in the infrastructure create fundamental issues in establishing the local forest management team. For example, an Ontario project developer can have difficulty initiating the project activities in the remote northern BC forests, even the initial work in the local community consultation. When a registered project is ready for verification, there are further challenges in finding the available verifiers. Experts have revealed that the current wait time to verify forest offset projects is about six to twelve months. Also, they reported that there are occasions when the verifiers are not skilled enough to conduct credible verification work, leading to integrity challenges.

Credit integrity has been a global, long-criticized issue, which we have discussed in the social challenge section, but experts reported further problems in the implementation phase. There are incentives for the verifiers to certify more projects to keep their business liquidity, leading to incompatible claims of over-qualified credits and the ultimate corruption issue [103]. The Darkwoods project is an excellent representation of the overestimated climate benefits certified by such a verifier [62]. The experts further question the credit integrity as the project lacks transparency in baseline establishing, carbon accounting, and benefit sharing, and the documents are obscure.

5. Approaches and Recommendations

The experts have also suggested possible approaches for addressing the identified challenges, but these may not cover the whole picture. The following sections will discuss approaches and recommendations from the insights from the interviewees incorporated with the published resources and studies.

5.1. Strengthening the Integrity

Appropriately setting up a buffer pool is an effective tool against the permanence issue, regardless of compliance or voluntary markets, through the non-permanence risk analysis [20,55]. A buffer or contingency account is an estimated proportion of the issued credits on hold in case of reversal events, including fires and pests [34]. For example, if the buffer is determined as 25%, a quarter of the credits issued will be withheld. Nevertheless, we need more active approaches. As fire will still play a role in Canadian forests in the coming years [57,58], the interviewed experts suggested an active monitoring and management strategy for forest offsets in Canada. First, the enhancement in the monitoring plan can actively detect fires and disturbances. For example, projects can leverage novel science and technologies to detect fires and changes, including using satellite images [104] and airborne LiDAR [105]. In the meantime, more high-quality ground sample plots are essential in assessing the health and dynamics of the forests. Active fire management practices of prescribed burnings incorporating local fire ecology should be aligned with the project implementation to prevent future larger fires [80,81].

Experts have jointly agreed that a dynamic baseline accounting approach is a potential way of addressing additionality. The idea originated from the methodology published by Verra in 2022, *Methodology for Improved Forest Management Using Dynamic Matched Baselines from National Forest Inventories* [106]. The dynamic baseline approach uses a number of matching control groups, calculated using K-nearest-neighbor algorithms, to represent baseline scenarios with highly similar initial conditions to the matched plots in the project sites [106]. These matched plots can be continuously monitored to reflect the real conditions of the additional climate benefits accurately, but there may be issues of adverse selection that will lead to over-crediting [73]. For example, landowners may choose to preserve the forests in the project sites when matched control plots under harvest activities, creating less-quality credits from the asymmetric information between project developers and verifiers [73]. Verra recently (3 October 2023) published the new *Afforestation, Reforestation, and Revegetation* (ARR) methodology, which also uses the dynamic matching method to test the additionality but relies on remote sensing data [107]. This innovative approach is projected to ensure high-quality and high-integrity ARR credits [107]. Similarly, advanced remote-sensing technologies, including multi-resolution optical imaging, synthetic aperture radar (SAR), and LiDAR (light detection and ranging), have been employed to effectively detect changes in canopy cover and quantify shifts in above-ground biomass (AGB) in REDD+ projects [108].

Regarding better accounting leakage, experts have mentioned innovative economic trade models combining both additionality and leakage, aligning with the research from Filewod and McCarney [109]. The researchers also outlined three principles to avoid carbon leakage by design [109]: (1) if a nature-focused project indicates possible market leakage consequences, we should employ the most conservative potential leakage estimates; (2) nature-based credits, when encompassing market leakage risks, should not replace direct emission reductions in regulated markets; and (3) outside of compliance markets, the degree of uncertainty in a nature-based offset should be determined by the specific action it aims to replace. International leakage was the problem for leakage accounting in forestry offsets [70], and recent research has suggested that implementing multiple monitoring approaches, such as combining production-based accounting (PBA) with the technology-adjusted balance of emissions embodied in trade (TBEET), can provide a comprehensive understanding from international leakage [110]. However, the interviewees stressed the need for an international leakage methodology. Moreover, the interviewed experts proposed government actions to ensure that the reduced AAC caused by the forest project is not compensated to other logging companies.

The respondents have recommended that the forest protocols or programs in Canada should strive to meet the criteria of several standards or initiatives to ensure credit integrity. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) under the International Civil Aviation Organization (ICAO) is an initiative to reduce emissions from the aviation sector with minimized market distortion [111]. It set stringent inclusion criteria for eligible offset units with a rigorous assessment of program design elements and carbon credit integrity [112]. The Core Carbon Principles (CCPs) developed by the Integrity Council for the Voluntary Carbon Market (ICVCM) offer a globally recognized benchmark for credible carbon credits, ensuring transparency, sustainable development, and verifiable climate impact [113]. CCPs have ten core principles, broadly including governance, emission impact, and sustainable development, to ensure the high integrity of the carbon credits [113]. The International Carbon Reduction and Accreditation (ICROA), initiated by the International Emission Trading Association (IETA), endorses high-integrity carbon standards from a stringent review with criteria ranging from governance, verification, and environmental impact to social impact [114]. Although the BC provincial government has been endorsed by ICROA, the rest of Canada still lags.

5.2. Addressing Social Barriers

Education and knowledge building are key to addressing the social barriers to forest carbon credits. The educational materials for introducing how a carbon credit market works and how to turn a forest into a carbon project with pros and cons should be publicly accessible and easily approachable. The public fear of climate effectiveness and additionality could be remediated by a transparent educational program [43,115]. Thus, the landowners and the First Nations can understand, confidently judge, and make rational decisions about using their forests as offsets. Public cooperative programs are also vital for public education. For example, the Family Forest Carbon Program in the US, developed by the American Forest Foundation and the Nature Conservancy, allows family forest owners to enroll and finance them with annual payments for implementing improved forest management activities [116]. In October 2023, the program gathered more than 35 thousand acres of family forests [117], and one interviewee said nearly all the forest landowners now in the US understand forest carbon credits very well, due to the presence of the program. Similarly, the government-led Liangshan Bamboo Forest Carbon Program in Anji County, China, collects the forest land rights of smallholders, implements the management activities uniformly by a professional team, and pays the carbon credits back to the farmers [118]. The experts also suggested that the provincial and federal governments expand their capacity in the forest carbon teams, host more workshops and training sessions, work more closely with the academia, and establish more forest carbon programs.

Ensuring Indigenous participation is the top mission after the education work. The experts have recommended that Canada adopt the Climate, Community, and Biodiversity (CCB) standard when developing or revising their protocols. CCB aims to ensure the benefits to the local communities and conserve biodiversity while addressing climate change with the offset projects; it requires project developers to identify stakeholders, respect rights, obtain informed consent, evaluate costs, benefits, and risks, and uphold high conservation values [119]. Additionally, it is generally agreed by the experts that a legislative change to define carbon rights across the country is required to realize the optimal climate benefits of the vast crown forest. Currently, only BC has the capacity to host projects on crown land thanks to the Atmospheric Benefit Sharing Agreement (ABSA) that clarifies the ownership of carbon to the First Nations [66]. In this way, the Indigenous peoples, who have been managing the land since time immemorial, have the entitlement to the land and now have the carbon rights to sell and trade carbon credits. The respondents have appealed to all other provinces and territories to establish similar mechanisms that will define the clear carbon rights on crown lands, reaching the greater potential of Canadian forestland to offset development.

Experts suggested a full spectrum of compensation measures should be in place to address the timber trade-off. The developers should design the project holistically, ensuring a balance between carbon and timber. If the project does cause timber production to drop, such as the GBR project, many Indigenous workers will be affected. The provincial government should first work with the First Nations to provide as many job opportunities as possible, such as the Guardians in BC [88]. The federal and provincial governments should strive for sufficient funding for some inevitable unemployed workers. The Coast Opportunity Funds, worth USD 118 million, were provided by the Province of British Columbia, the Canadian Government, and six private foundations, creating significant job opportunities for the Indigenous peoples [120].

5.3. Reaching Cost-Effectiveness

The direct approach to addressing the high development costs is funding from government and non-profit organizations, aiding in covering the expensive transaction costs. Although there are concerns about financial additionality, the project developers can provide an assessment to prove that the project can only be funded if the forests are planned to gain credits [55]. Government subsidies are efficient incentives for project implementation, especially for afforestation-type projects, to cover the significant initial cost [121]. Also, programs aggregating small forest holders are emerging across the world, such as the Family Forest Carbon Program (US) [116] and the Liangshan Bamboo Forest Carbon Program (China) [118]. They provide annual payments to the small forest owners, merge the individual land pieces into large projects, and mitigate the cost issues by the economy of scale. BC's newest draft forest protocol has provisions of the small project merger in the approach called 'Program of Activities', allowing multiple individual eligible projects to combine [34].

Technological advancements to cost-effectiveness have been discussed throughout the interview. They stressed the need for a balancing point between integrity and practicality. Incorporating advanced technologies, such as remote sensing, to reach high integrity may increase costs, but the costs may be reduced when the field data are less relied upon as the technology popularizes. Also, the costs surrounding monitoring, reporting, and verification (MRV) can be optimized with the technologies employed. A digital MRV system, incorporating 'smart sensors, satellites and drones, cloud computing, artificial intelligence, the internet of things, and blockchain encryption', can smoothly enhance the efficiency of 'data collection, processing, and quality control [122]'. Several experts suggested that a comprehensive digital MRV system helps build a more standardized platform, significantly reducing costs for project developers. For example, a project developer can visit the registry website to find a pre-validated template with embedded formulas and dropdown menus, ensuring consistent and accurate carbon calculations. This not only eliminates the need for each project to undergo individual auditing of their formulas but also streamlines the verification process, making it more cost-effective.

In Canada, there is a growing interest in the 'ton-year accounting' approach for carbon credits that could potentially reach cost-effectiveness [123] and alleviate the permanence issue [124]. A ton-year denotes the amount of carbon kept in a particular reservoir (land or air) for a set period [124]. Ton-year accounting awards credits to short-term carbon storage efforts based on the concept of cumulative radiative forcing [125,126]. Quebec released the afforestation and reforestation protocol based on the ton-year accounting approach [35], which only accounts for the climate impact before the credit issuance date [123]. Quebec defines that one carbon credit represents the climate benefit, based on cumulative radiative forcing, of one ton of CO_2 removed over 100 years, and if the project period is under 100 years, that one credit will be proportionated [123]. For example, a 30-year forest project can accumulate 40% of the climate benefits [123]. Quebec's innovative approach reduces the cost of MRV as the monitoring is only required when there are natural or human disturbances while maximizing the carbon incomes as the impacted forests can still gain credits due to the ton-year accounting [123]. Also, no permanence buffer pool is required as there will be no such issue under this scheme. However, there are debates about Quebec's approach. It may overestimate the benefits of temporary carbon storage because it disregards the prolonged presence of emitted CO_2 in the atmosphere and neglects the albedo changes associated with reforestation [127]. The wide application of ton-year accounting in Canada and the world needs further discussions and future studies.

There are opportunities regarding the future demand in Canada. Voluntarily, the new Paris Agreement Article 6.2 and Article 6.4 have established a platform for Canada to collaborate the forest carbon credits internationally, potentially enlarging the voluntary demand. Article 6.2 of the Paris Agreement outlines provisions for exchanging internationally transferred mitigation outcomes (ITMOs) between governments, allowing Canada to transfer their ITMOs from forest activities bilaterally to another country to fulfill its NDC [128]. Additionally, Article 6.4 introduces a multilateral mechanism similar to the previous CDM, allowing Canada to generate forest credits to trade internationally [128]. On the regulatory side, many provinces now fortify the compliance demand for offsets by introducing the Output-based Pricing System (OBPS). For example, BC, which has been implementing carbon tax since 2008, plans to adopt the OBPS in 2024 to regulate high-emitting facilities, promote emission reductions, and support carbon offset markets [129]. This system allows a maximum of 30% usage of offset credits to comply with the compliance obligations [130], posing a significant future demand for forest offsets in BC.

6. Conclusions

This paper presented a comprehensive analysis of the ongoing challenges and potential future paths for developing forest carbon offset projects in Canada. Following a thematic analysis of the expert interviews, multiple themes emerged, including methodological, social, economic, and implementation challenges. Methodological challenges were most frequently discussed by the experts, with a 37% mention rate. These challenges encompass issues like permanence, especially given Canada's vulnerability to disturbances such as wildfires and pests. The challenge of additionality, the intricacies of relationships between the First Nations and crown forests, and uncertainties in accounting for international leakages were other significant concerns in this category. Social challenges, sharing 29% of discussions, highlighted the substantial knowledge gap in the public. The criticisms of greenwashing, trade-offs in reduced timber harvests, and complex standards that might limit Indigenous participation were also noted as primary concerns. The economic challenges (22%) highlighted cost-effectiveness concerns due to high initial costs and the uncertainty in market demand and revenue, given public criticism and conservative protocols. Implementation challenges, while less frequently discussed at 12%, raised concerns about the lack of skilled analysts, governmental resources, and potential issues with credit integrity in the verification processes. Zooming in on individual challenges, the methodological issue of 'permanence' was predominant, accounting for 35% within its category. Likewise, 'lag in knowledge', 'cost-effectiveness', and 'lack of capacity and difficulties' emerged as the dominant challenges in their respective categories.

Building on these challenges, this paper conducted an in-depth analysis of the potential approaches the country could adopt, leveraging insights from expert interviews and the existing literature. While addressing the conventional issues of permanence, additionality, and leakage is paramount in upholding integrity, future research could examine the role of advanced monitoring plans using satellite imagery and LiDAR, particularly in their capability to detect disturbances effectively. Also, adopting and adhering to standards like CORSIA, ICVCM, and ICROA is advocated. We need to address the social barriers by enhancing education and knowledge building for the public, ensuring Indigenous participation, building agreements like ABSA, and actively addressing the employment issues from timber income loss. There is a pressing need for scaling up the ABSA to the country, which needs future research. On the economic front, providing sufficient funding, employing advanced technologies, exploring new schemes such as ton-year accounting, and securing future market demand are potential solutions. Future studies could investigate how to leverage technological advancements, such as remote sensing and digital MRV systems, to balance project integrity and practicality, optimizing monitoring, reporting, and verification costs. Central to all these is capacity building. Governmental actions, such as expanding the forest carbon team, can augment awareness, elevate governmental capability, and foster programs in education, Indigenous collaboration, funding, and job creation. There is also a pressing need for capacity development for standards and registries, especially to harness cutting-edge technology and digital MRV systems. The collaboration between academia, carbon standards and registries, and governments could motivate innovation, such as exploring the ton-year approach. While this paper might not capture the whole picture, it provides a foundational understanding of the intricacies tied to Canadian forest offsets. It is pivotal for bridging research gaps in the Canadian forest offsets and guiding policymakers in Canada and globally to navigate the challenges and future. Given the anticipated demand, the prospect of forest offsets in Canada and the world remains substantial.

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