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First Nations reserve expansion and land cover dynamics since Treaty Land Entitlement in the Prairie region of Saskatchewan, Canada

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Since the 1990s, Treaty Land Entitlement (TLE) and Specific Claims settlements have significantly expanded First Nations reserves in Saskatchewan, Canada. Yet, the ecological impacts remain understudied, with limited systematic land-use data. This study employs geospatial analysis of open-source historical records, land cover data, and land capability assessments to evaluate reserve changes in southern Saskatchewan—a heavily agricultural region with dense First Nations populations. Between 1992 and 2024, reserve areas nearly doubled from 4,173.3 to 8,233.9 km^2, substantially increasing Indigenous land holdings. Land cover analysis reveals that reserves retained disproportionately more forests and wetlands than surrounding areas, functioning as vital biodiversity refuges and carbon sinks in a predominantly agricultural landscape. However, soil assessments indicate most reserve lands are marginal for high-yield crop production, reflecting historical inequities in allocation, and highlight systemic disparities in land quality. While expansion supports diverse land uses and priorities, limited indicated that most agricultural capability restricts economic opportunities in farming while minimizing potential environmental degradation, to the few areas of high-quality land available. Reserves' ecological value—particularly their role in preserving native habitats—contrasts with their constrained agricultural potential, underscoring the need for policies that address both sustainable management and alternative economic development. This study provides empirical evidence for Indigenous land rights discussions, illustrating how reserve lands simultaneously offer ecological benefits and face socioeconomic challenges and opportunities. Future research should prioritize community-led strategies to enhance sustainable development, ensuring land-use planning aligns with First Nations' goals and self-determination efforts.

KEYWORDS

First Nations, Treaty Land Entitlement, specific claims, land cover, agricultural land capability, Indian reserves, Saskatchewan

1 Introduction

Covering most of Western Canada, the Numbered Treaties (1871 and 1911) established reserve land bases for First Nations, which were to be proportional to their estimated populations. In many cases, however, the government failed to allocate a proportional land base, an error sometimes motivated by spurious and strategic interests (Daschuk, 2013). Reserve lands were also subject to later relocation or "surrender", where lands with high agricultural potential were subsumed by government and made available for sale to Settler populations (Martin-McGuire, 1998; Waiser and Hansen, 2023). Despite the treaty provisions for agriculture and conditions that reserve lands be set aside for farming, particularly in Treaty 4 and 6 (Morris, 1880; Jobin, 2023), the effects of reserve land under-allocation, relocation, and surrender have undermined the opportunities for First Nations in the Canadian Prairies to develop on-reserve economies, particularly in the commercial agricultural sector (Carter, 1990; Buckley, 1992).

First Nations across the Canadian Prairies have, especially since the 1990s, pursued restitution for historical land dispossession. This has been achieved through Treaty Land Entitlement (TLE) and Specific Claims processes, resulting in financial compensation to increase reserve land bases (Nestor, 2017). In Saskatchewan, the 1992 TLE Framework Agreement (TLEFA) enabled 25 First Nations (later expanding to 33) to acquire a minimum number of "short-fall acres"—lands that should have been allocated to their reserves—through purchase (Innes and Hubbard, 2014). Similar agreements exist in Manitoba (Alcantara, 2008). Specific Claims address a broader range of grievances than TLE, including instances where the federal government failed to fulfill treaty obligations, breached its fiduciary duties, or mismanaged Indigenous lands and assets (Crown-Indigenous Relations and Northern Affairs Canada, 2025b). In the Prairies, most of the Specific Claims stem from historical land surrenders or the federal government's failure to fulfill treaty obligations regarding agricultural assistance and benefits that were outlined in the Numbered Treaties (Crown-Indigenous Relations and Northern Affairs Canada, 2025a)—resulting in recent multibillion Canadian dollar "Cows and Plows" settlements between First Nations and the federal government (Dudha, 2025).

First Nations land expansion through TLE and other claims compensation was expected to increase agricultural land holdings, boosting capacity in the commercial agricultural sector (Pratt, 2006; Champ et al., 2010). However, publicly available data on the increases in reserve land bases since these settlements indicate that only 358,550 ha of land purchased by First Nations through TLE had been transferred to reserve status as of 2009 (Government of Saskatchewan, 2009)—falling short of the 930,800 ha minimum that First Nations were entitled to in the TLEFA (Garcea, 2014). More recent estimates from the Saskatchewan Aboriginal Lands Technicians (2024) report that approximately 1,000,000 acres (404,686 ha) of purchased lands have been transferred to reserve status. Whether these lands have supported the anticipated agricultural development or possess the capacity for economically viable agricultural production remains unclear.

While the agricultural potential of newly acquired reserve lands remains uncertain, it is crucial to recognize that First Nations—historically and contemporarily—selected lands not solely for farming, but for various uses to support livelihoods and culture (Musqua and Hubbard, 2014; Poitras, 2014). In recent decades, livelihood pursuits include resource extraction, tourism, renewable energy, and urban business development (Poitras, 2014). Traditional land uses that support hunting and fishing, medicine gathering, and ceremony—activities that depend on intact, undeveloped natural landscapes are also considered. In this context, land expansion through TLE and Specific Claims also presents an opportunity for Indigenous-led conservation and ecological restoration, particularly within Saskatchewan's intensively cultivated landscape, which accounts for over 40% of Canada's farmland (St. Pierre and Mhlanga, 2022) and retains less than 14% of its original native grasslands (Doke Sawatzky, 2019). Globally, Indigenous stewardship plays a vital role in preserving biodiversity and mitigating climate change by maintaining high-quality habitat (Garnett et al., 2018). Thus, reserve land expansion may offer not only economic opportunities but significant ecological and climate benefits, aligning with broader reconciliation and environmental conservation efforts (Chief-Morris, 2020). However, the ecological outcomes of Indigenous land restitution and the ways in which First Nations balance conservation with development remain largely unexamined.

This study investigates First Nations reserve land use and changes in land cover following critical land claims in the prairie-parkland region of southern Saskatchewan. We focus on the period defined by the 1992 TLEFA (Major, 2010)—which marks the initiation of the most significant expansion of reserve lands—and extending to the most recent data available in 2024. We test two hypotheses: (1) reserve lands support a higher proportion of perennial vegetation and are characterized by soils more marginal for agricultural production compared to surrounding areas; and (2) newly acquired lands exhibit more diverse cover than original reserves, reflecting a diversification of land use needs and goals. Using GIS, satellite imagery, and soil survey data, we first compare land cover on First Nations reserves vs. surrounding municipalities and then assess land use and cover changes both on original and newly acquired reserve lands. Our findings aim to inform policies and land use planning that balance sustainable economic development with ecological stewardship in First Nations land management.

2 Materials and methods

2.1 Study area

The study area includes southern Saskatchewan, extending south of the boreal forest to the Canada-US border to the south (Figure 1). This area represents the province's most productive agricultural land, which contains over two-fifths of Canada's total cropland (St. Pierre and Mhlanga, 2022). This agricultural region is vital to the province's economy, contributing $6.78 billion in 2022, or 11.05% of the provincial GDP (Government of Saskatchewan, 2024c). Southern Saskatchewan is covered by Treaties 2, 4, 5, 6, 8, and 10 (Figure 1). The region also contains 296 rural municipalities and 446 urban centers (Government of Saskatchewan, 2024a) (Supplementary Figure S1). The 58 First Nations within our study area (Supplementary Material, Supplementary Table S1),

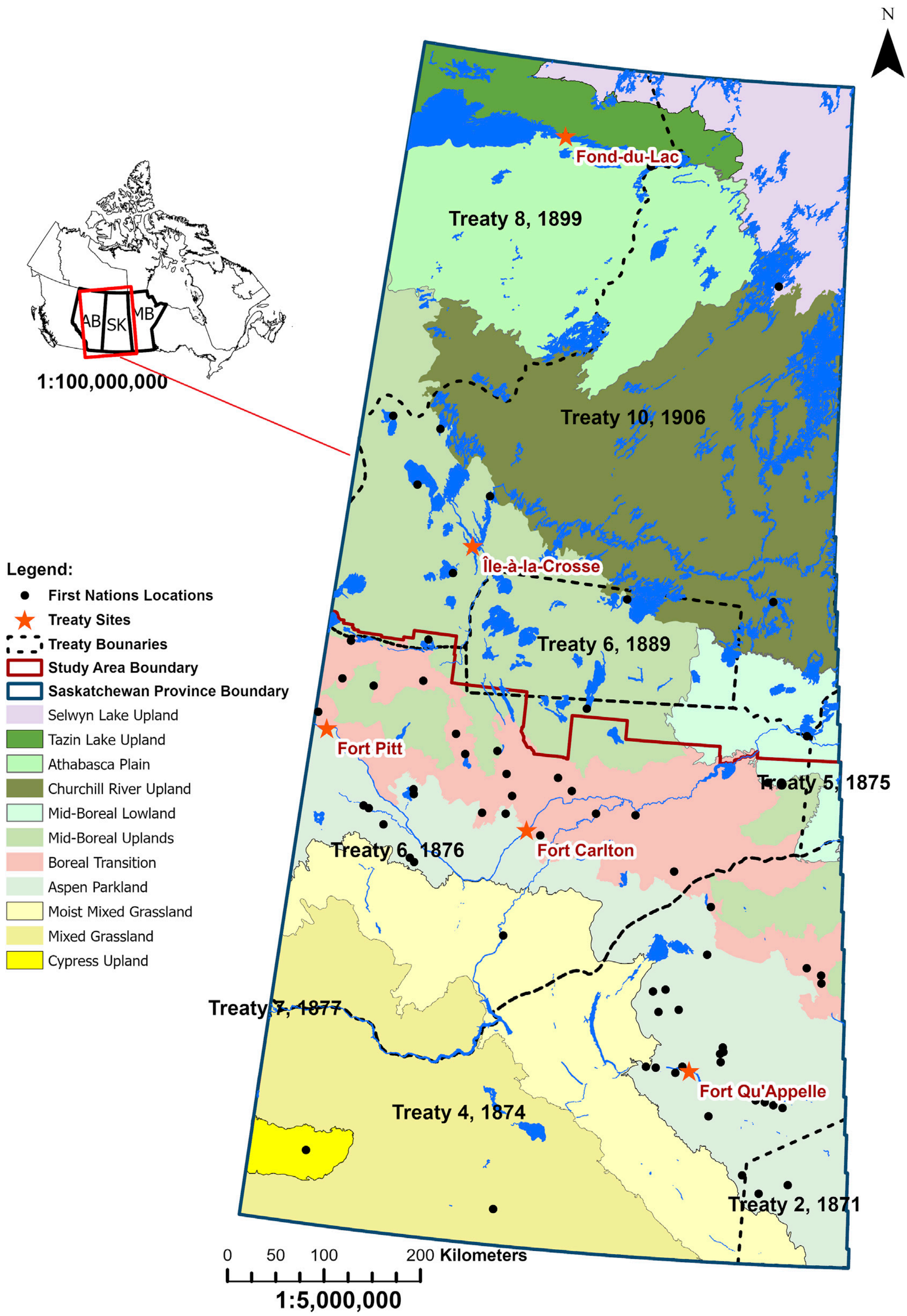

FIGURE 1
Map of the study area (below the red boundary line) encompassing 43% of Canada's farmland (St. Pierre and Mhlanga, 2022), First Nations locations, Treaty Boundaries, and Ecoregions within Saskatchewan, Canada. (Map created by the author using data from First Nations Locations (Indigenous Services Canada, 2016), 2021 Census Boundary files (Statistics Canada, 2021), and Saskatchewan GeoHub (Government of Saskatchewan, 2024b).

are primarily distributed within the aspen parkland and boreal transition ecoregions, with fewer in the mixed and moist-mixed grassland ecoregions (Figure 1), each with varying soil types (Supplementary Material, Supplementary Table S2) (Centre for Land and Biological Resources Research, 1996). In this area, the type of agriculture practiced closely aligns with soil zone and agricultural land capability, influencing agricultural land use patterns (Supplementary Material, Supplementary Figure S1).

2.2 Data utilized

This study examines shifts in First Nations reserve boundaries and associated land cover data across two temporal periods: the Pre-Land Claims era (prior to 1992) and the Post-Land Claims era (up to April 2024). For consistency, the terms Treaty Land Entitlement (TLE) and Specific Claims—distinct legal mechanisms addressing historical grievances—are collectively referred to as "Land Claims" throughout this analysis.

The Pre-Land Claims period is demarcated by events preceding 1992, marking the signing of the TLE Framework Agreement in Saskatchewan, while the Post-Land Claims period encompasses the timeframe from 1992 up to April 2024, when this research was conducted, capturing the contemporary status of reserve boundaries and land cover. It is recognized that First Nations acquired lands before the 1992 period through Specific Claims, including 41,654 ha from TLE claims preceding the TLE Framework Agreement (Garcea, 2014). We focus on 1992 as a critical period, after which most reserve land expansion occurred.

2.2.1 Delineating Pre- and Post-Land Claims reserve boundaries

The boundaries of Post-Land Claims First Nations reserves were derived from the Aboriginal Lands of Canada Legislative Boundaries, a product of Natural Resources Canada (Natural Resources Canada, 2024a), which outlined the boundaries used in this study as of April 2024. The specific scope of the definition can be found in (Natural Resources Canada, 2010). This monthly updated digital boundary data layer is prepared to represent the changes in First Nations lands when land is converted to reserve status through the Additions to Reserve Policy (Government of Canada, 2018).

The boundaries of Pre-Land-Claims First Nations reserves were determined by analyzing all new reserve additions from 1992 to 2024. First, the list of reserves associated with individual First Nations was confirmed by referencing the boundaries of Post-Land Claims First Nations reserves, as previously described. This verification was further supported by the First Nation Profiles provided by Crown-Indigenous Relations and Northern Affairs Canada (2024b).

We then identified the parcel identification numbers (PINs) (Martin, 2011) for land parcels within each reserve belonging to individual First Nations using the Electronic Registry Index Plan (eRIP) (Crown-Indigenous Relations and Northern Affairs Canada, 2024a). These PINs were then examined in the Indian Lands Registry System (ILRS) and the First Nations Land Registry System (FNLRS) (Government of Canada, 2024) to obtain Parcel Abstracts, which contain land registry records. This process allowed us to determine when First Nations added new reserve areas to their land base (Indigenous Services Canada, 2017).

Additionally, we cross-referenced our findings with records of Approved Additions to Reserve from 2011 to 2023 (Indigenous Services Canada, 2024) and the proceedings of the Indian Claims Commission—an intermediary and advisory body that assisted in resolving First Nations' claims against the Government of Canada between 1991 and 2009 (Government of Canada, 1994). This step ensured that all new reserve additions were accounted for in the land registration system. Furthermore, we reviewed Canada Lands Survey Plans (Natural Resources Canada, 2024b) to clarify boundary information for land parcels with uncertain delineations.

Finally, land parcels added to reserves between 1992 and 2024 were removed from the boundaries of Post-Land Claims First Nations reserves, restoring the original appearance of the Pre-Land Claims First Nations reserves' boundaries.

Other datasets employed in this study include the SaskGrid Township Fabric Map and boundary data for rural municipalities (RMs) and population centers. These datasets were obtained from the Saskatchewan Geohub (Government of Saskatchewan, 2024b) and the Census Profile of Canada (Statistics Canada, 2022).

2.2.2 Historical Landsat imagery and ancillary data

For the land cover classification, the primary imagery dataset comprises data from the Landsat 5 Thematic Mapper (TM), spanning 1984 to late 2011, and from the Landsat 8 Operational Land Imager (OLI), operational since 2013. Only "Level 2, Tier 1" products were utilized for both sensors, ensuring the highest quality imagery through stringent radiometric and geometric accuracy standards. Data processing and overall management were conducted using Google Earth Engine (GEE), with the datasets referenced in the analysis code as LANDSAT/LT05/C01/T1_SR for Landsat 5 TM and LANDSAT/LC08/C02/T1_L2 for Landsat 8 OLI. To reduce computational demands, the analysis was restricted to selected spectral bands. Specifically, for Landsat 5 TM, bands 1 (blue), 2 (red), 3 (green), 4 (near-infrared), 5, and 7 (shortwave infrared) were used, while for Landsat 8 OLI, bands 2 (blue), 3 (red), 4 (green), 5 (near-infrared), 6, and 7 (shortwave infrared) were utilized.

In addition to the historical Landsat archive, several ancillary datasets were employed as reference data for the training and validation of the classification, including: high-resolution satellite or aerial imagery from the Saskatchewan Geospatial Imagery Collaborative (SGIC): FlySask2 (ISC, 2023); visual interpretation using Google Earth Pro (Wuthrich, 2006); and Annual Crop Inventory data (Agriculture and Agri-Food Canada, 2023).

2.2.3 Canada land inventory data

The study region falls within Canada's primary agricultural zone, where assessing land capability for agriculture is essential for determining land value. To quantify this capability, we analyzed the Canada Land Inventory (CLI) 1:250,000 Land Capability for Agriculture dataset for both reserve and non-reserve lands (Agriculture and Agri-Food Canada, 1998). The CLI dataset evaluates agricultural potential by classifying mineral soils into seven categories for field crop production (See Supplementary Table S3), while treating organic soils separately. These agricultural capability maps serve as valuable tools at the regional scale for guiding decisions related to land improvement, farm consolidation, land-use planning, and equitable land assessments (Munn, 1986). Soils in Classes 1 and 2 are typically considered prime

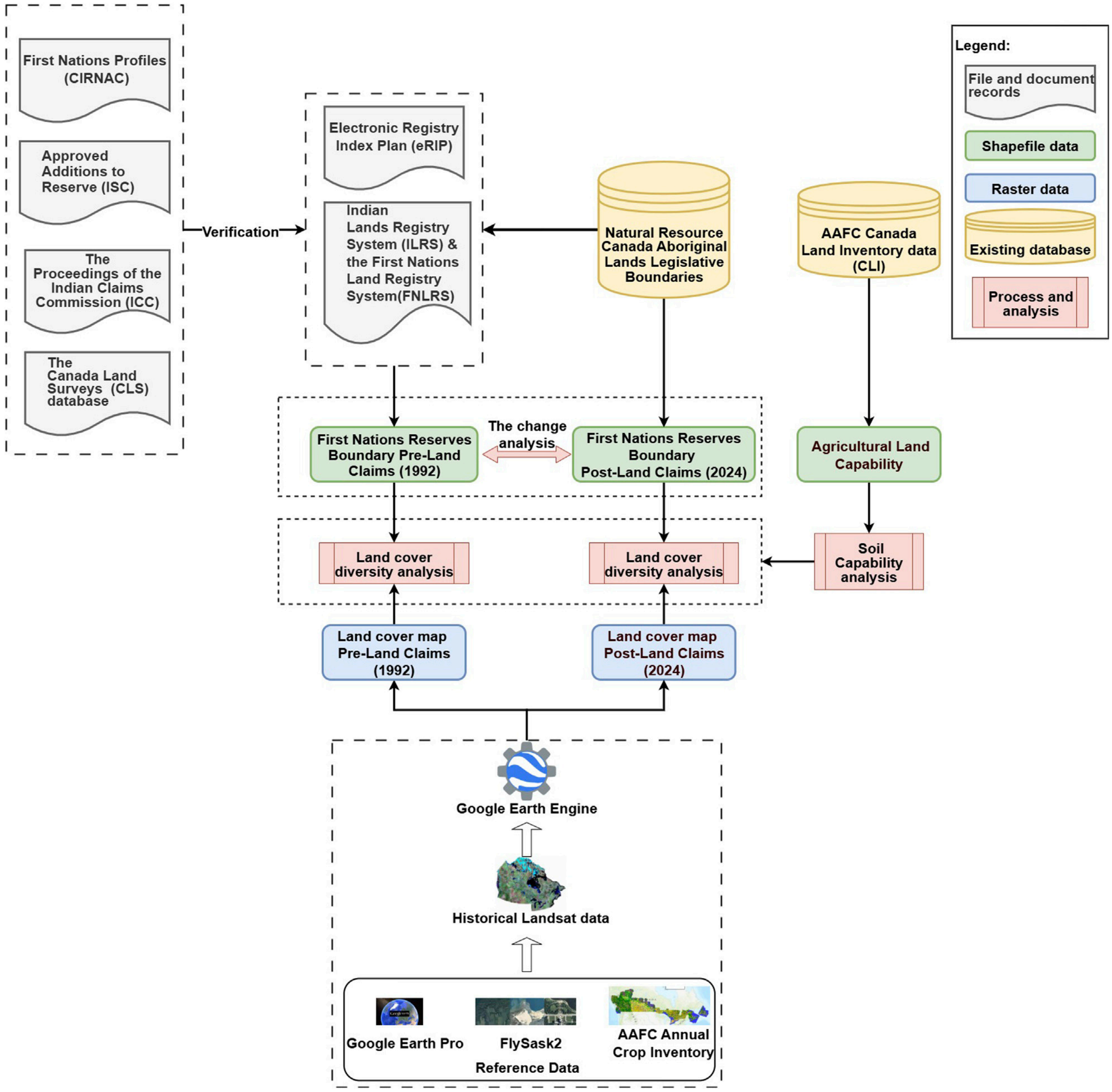

FIGURE 2
Overview of the methodology and data sources for mapping changes in land use and soil agricultural capability in First Nations reserves. Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC); Indigenous Services Canada (ISC).

or high-quality agricultural land, whereas Classes 4 and 5 are identified as marginal or less suitable for crop production. Furthermore, soils in Classes 5 and 6 are generally restricted to forage crops and grazing because of severe limitations. Class 7 soils are unsuitable for both arable farming and permanent pasture (Liu et al., 2017). A detailed description of these capability classifications is provided in Supplementary Table S3.

2.3 Geospatial data analysis

This study integrates geospatial analysis tools and systematic processes to map and analyze changes in land use and soil agricultural capability within selected First Nations Reserves Pre-Land Claims (1992) and Post-Land Claims (2024) periods (Figure 2). The analysis relies on verified boundary data and land-related records sourced from land registry systems and agricultural land inventory databases as previously described. First Nations Reserve boundaries for the Pre-Land Claims (1992) and Post-Land Claims (2024) periods were delineated and verified against these registry systems. Historical Landsat data was processed using Google Earth Engine (Mutanga and Kumar, 2019), while reference data from Google Earth Pro, FlySask2, and the AAFC Annual Crop Inventory facilitated the creation of land cover maps. These maps underwent land cover diversity analysis to quantify changes in land use patterns over time. Concurrently, AAFC Land

Inventory data was overlaid with the reserve boundaries to support a soil capability analysis, evaluating shifts in soil productivity and agricultural suitability between the Pre- and Post-Land Claims periods. Finally, a comprehensive change analysis integrates findings from both the land cover diversity and soil capability assessments to highlight the spatial and temporal dynamics of land use changes and their resulting impact on soil agricultural capability within these First Nations Reserves. This methodological framework provides a robust assessment of land use and soil capability changes, offering valuable insights for land management and understanding agricultural potential.

2.3.1 Land cover classification for Pre- and Post-Land Claims

For both the Pre-Land Claims and Post-Land Claims eras, imagery was processed in GEE using FMask cloud removal (Sundberg, 2020) and aggregated into median composites in a 5-year window (Pre-Land Claims: 1988- 1992, Post-Land Claims: 2000–2024), which can diminish the data missing and cloud (or snow and ice) cover issue. Seven land cover classes were distinguished: (1) settlement (built-up areas with >50% impervious surfaces), (2) cropland (actively managed annual crop production), (3) grassland (herbaceous vegetation with <10% tree cover, including hay land), (4) forest (>10% canopy cover of trees >5 m height), (5) wetland (permanently or seasonally saturated soils), (6) water (permanent water bodies), and (7) other lands (barren, ice, or non-vegetated areas). Classification parameters and accuracy metrics are detailed in Supplementary Material Section 2.

2.3.2 Spatial analysis of land cover change and agriculture capability dynamics in the First Nations reserves

To examine patterns of reserve land expansion and agricultural capability (AC) dynamics, we implemented a multi-stage analytical approach. First, agricultural potential was assessed using the Canada Land Inventory (CLI) 1:250,000 Land Agricultural Capability dataset, with detailed ratings provided in Supplementary Table S3. The AC analysis was conducted both within reserve boundaries and across the broader study region to enable the comparative assessment of soil productivity. Spatial integration procedures, including data resampling and boundary alignment for both Pre- and Post-Land Claims periods, are fully documented in Supplementary Material Section 3.

Secondly, the spatial dynamics of reserve expansion were analyzed using the Getis-Ord Gi* analysis (Bajjali, 2023) to identify significant clusters of reserve land growth. This approach detected hotspots (areas of concentrated reserve expansion) and coldspots (areas with limited expansion) across the study region. The spatial analysis of reserve expansion patterns incorporated a formal neighbourhood definition to assess clustering tendencies. We implemented queen's-case contiguity weights to establish spatial relationships between rural municipalities (RMs) (Cressie, 2015), where any RMs sharing either a common boundary (rook's case) or a single vertex point (bishop's case) were considered neighbours (Scott and Janikas, 2009). This comprehensive adjacency matrix ensured that all potentially influential spatial relationships were captured in our analysis of reserve land expansion patterns. The Getis-Ord Gi* statistic was then applied to this neighbourhood structure to identify statistically significant ($p < 0.05$) spatial clusters of reserve expansion. Hotspots (z-score >1.96) indicated RMs with higher-than-expected reserve land growth surrounded by similarly high-growth neighbours, while coldspots (z-score < −1.96) revealed areas of limited expansion surrounded by similarly low-growth regions. This approach allowed us to distinguish between random spatial patterns and meaningful clusters of reserve land development.

Thirdly, to quantify changes associated with the Land Claims process, we employed the Wilcoxon Rank Sum test (Wilcoxon et al., 1963) to compare: (1) temporal changes in reserve land characteristics between Pre- (1992) and Post-Land Claim (2024) periods, and (2) spatial differences between reserve and adjacent non-reserve lands within each period. This non-parametric approach accounted for non-normal data distribution while controlling multiple comparisons through established correction methods (Bridge and Sawilowsky, 1999). The analysis focused on the median values of key land characteristics to identify significant shifts attributable to the Land Claims process and regional land-use trajectories.

Spatial data processing and statistical analyses were performed using QGIS 3.28 and MATLAB R2023a, while map generation was performed using ArcGIS Pro 2.0. The data sets used in this study, as described in Section 2.2, were obtained from open-source repositories.

3 Results

3.1 The spatial expansion of reserve lands Post-Land Claims

Overall, reserve lands in the study region have increased significantly, nearly doubling from 1992 to 2024. In the agricultural region of Saskatchewan, which encompasses over 70% of all the First Nations reserves in the province, the total area of reserve lands expanded from 4,173.3 to 8,233.9 km^2 (Table 1), with the proportion of reserves in the study region doubling over the past 3 decades, rising from 1.28% to 2.51% (Figure 3). The expansion is decentralized relative to the original reserves; notably, the new additions are not adjacent to the original Pre-Land Claims reserves (often the primary residential and administrative centers, commonly known as "home reserves"), resulting in a dispersed, "checkerboard-like" pattern across the landscape (Figure 3).

Furthermore, the proportion of reserve lands varied significantly across RMs, with substantial disparities in their spatial distribution (Figure 4). Following the conversion of land to reserve status after the Land Claims, five RMs—Tullymet, Elcapo, Willowdale, Battle River, and North Qu'Appelle—contained more than 20% reserve lands, with Tullymet having the highest percentage at 34.1% (Figure 4B) while only Tullymet and Elcapo had more than 20% before the Land Claims (Figure 4A). On average, the proportion of reserve lands within affected RMs increased from 4% to 8%, representing a doubling of First Nations land holdings in these jurisdictions. Rural municipalities without reserve land declined

TABLE 1 Land cover composition of the whole study region, the home reserve lands, new additions to reserve land, current reserve lands, and non-reserve lands for Pre- and Post-Land Claims (1992 vs. 2024).

Spatial extent	Whole study region		Home reserve land boundaries		Additions to reserve land		All reserve land	Non-reserve	
Periods	1992	2024	1992[a]	2024	Pre-reserve creation 1992	Post-reserve creation 2024	2024	1992[b]	2024
Land cover type (%)									
Settlement	0.97	2.88	0.60	2.53	1.16	1.36	1.93	0.97	2.91
Water	3.94	4.25	2.95	3.47	2.96	5.29	4.40	3.95	4.25
Forest	17.33	14.03	42.10	37.62	33.95	23.49	30.41	17.01	13.60
Cropland	55.31	62.13	30.19	37.74	37.10	47.48	42.71	55.63	62.63
Grassland	16.48	11.33	15.26	10.55	19.59	11.32	10.94	16.50	11.34
Wetland	5.97	5.27	8.90	8.08	5.24	11.06	9.60	5.93	5.16
Other Lands	<0.01	0.11	<0.01	0.01	<0.01	0.01	0.01	<0.01	0.11
Area	3.27×10^5 km^2		4,173.3 km^2		4,060.6 km^2		8,233.9 km^2	3.23×10^5 km^2	3.19×10^5 km^2

[a]The home reserve land cover composition in 1992 was identical to that of all reserves' land cover composition in 1992.
[b]The land cover composition closely resembles that of the non-reserve areas due to the small proportion of reserve land.

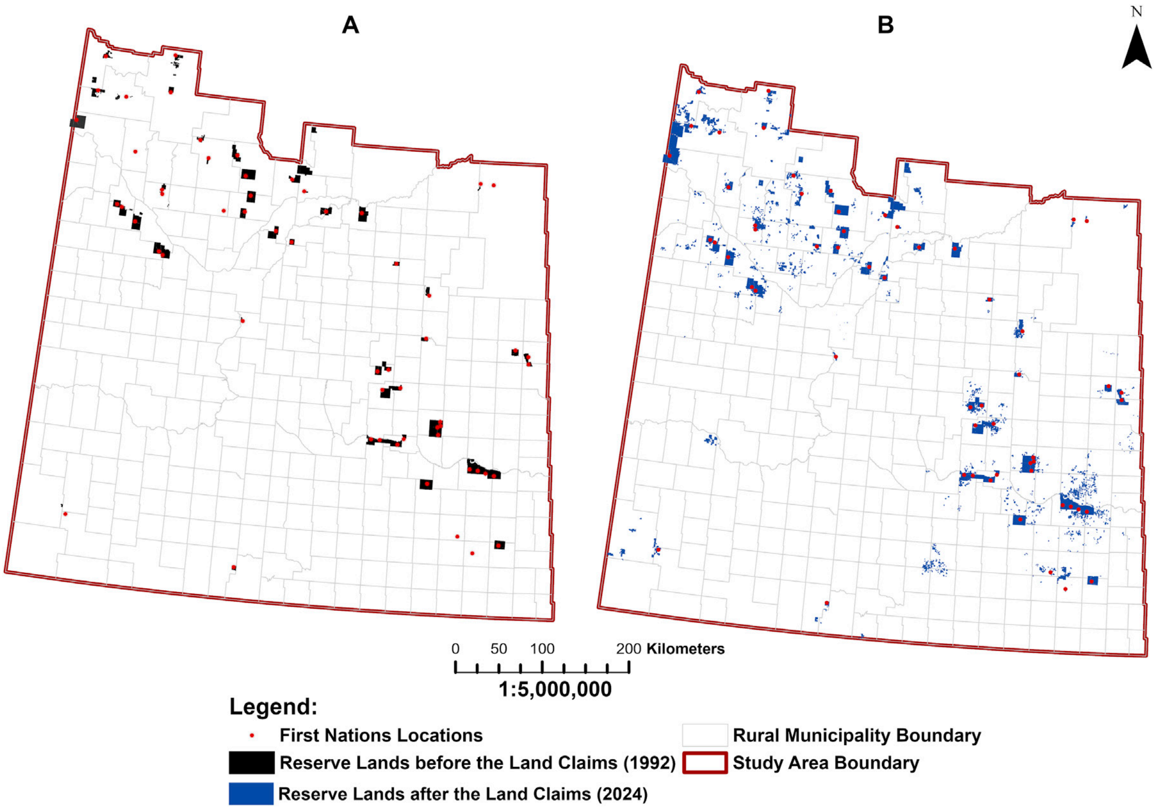

FIGURE 3
Comparison of First Nations Reserves spatial distribution **(A)** Pre- and **(B)** Post-Land Claims. (Noted that Makaoo 120 is a reserve of the Onion Lake Cree Nation in Alberta and Saskatchewan, located between the County of Vermilion River and the Rural Municipality of Frenchman Butte No. 501).

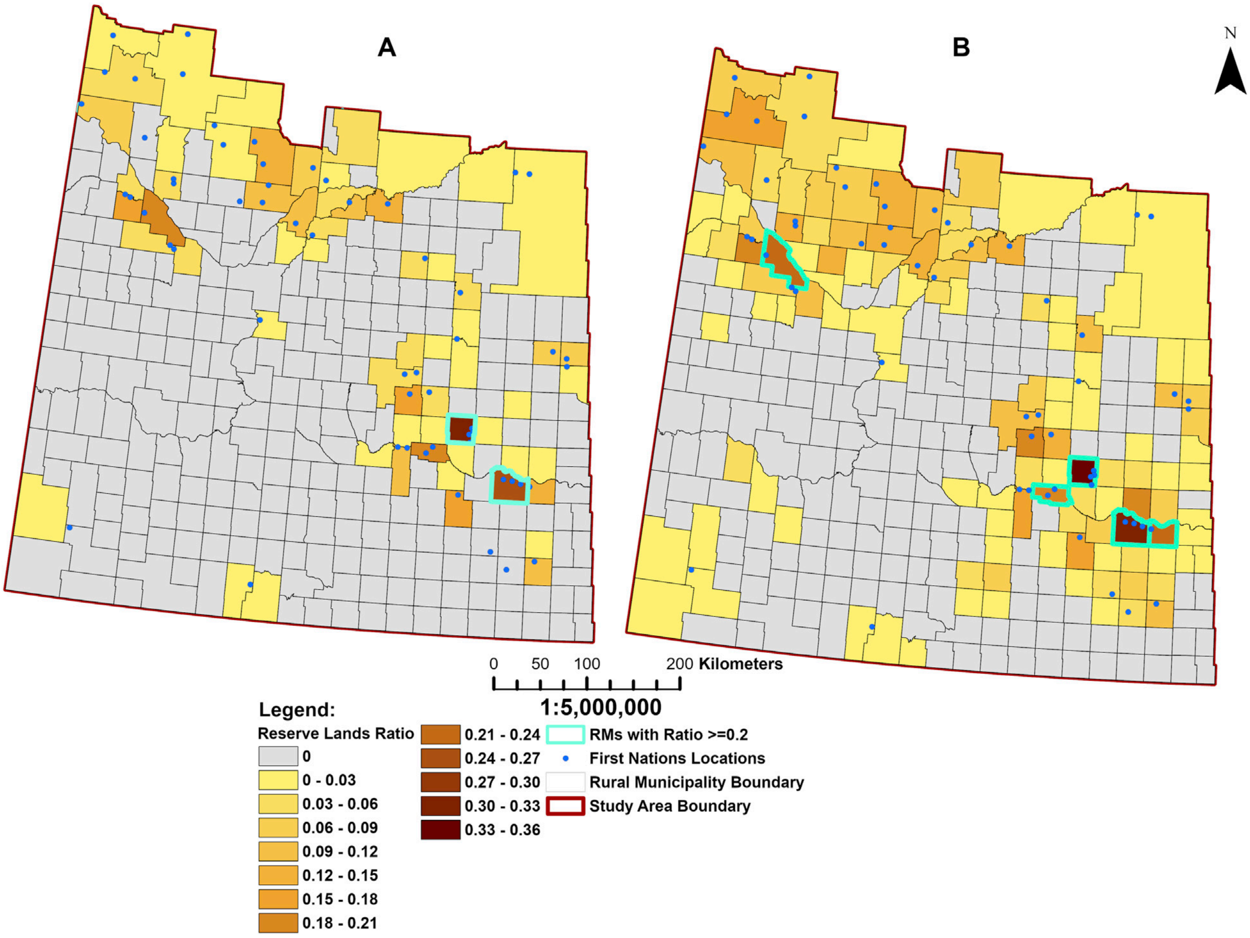

FIGURE 4
The proportion of First Nations reserves in central and southern Saskatchewan that comprise the defined local rural municipality (polygons) **(A)** Pre- and **(B)** Post-Land Claims. For cartographic clarity, proportions below 0.1% were excluded from the map representation.

from 235 before the Land Claims, to 178 after (Figure 4). Additionally, the hotspot analysis based on the occurrence of new reserve additions revealed that the aspen parkland ecoregion (Figure 1) had a high prevalence of new reserves (Supplementary Figure S4). In contrast, the region's central location remained unchanged. For example, only one reserve—Carry the Kettle 76-33 was added to the Miry Creek municipality, after the Land Claims (Figure 4B).

This dispersion extended not only within rural areas, but also to urban centers, where reserves, though proportionally small, expanded substantially since Post-Land Claims. Initially limited to three cities (Saskatoon, Yorkton, Prince Albert) (Figure 3A), urban reserves now exist in seven additional municipalities (Regina, North Battleford, Fort Qu'Appelle, Swift Current, Meadow Lake, Duck Lake) (Figure 3B).

3.2 Land cover differences between First Nations reserve lands and non-reserve lands

Land cover classification results for Pre- and Post-Land claims eras are shown in Supplementary Figure S3. Accuracy assessments for both Pre- and Post-Land Claims periods demonstrated robust classification performance ((Supplementary Tables S4 and S5)). The Pre-Land Claims classification achieved an overall accuracy (OA) of 86.9% with a Kappa of 81.7%, indicating substantial agreement. F1-scores ranged from 92.7% (cropland) to 77.4% (grassland), with similarly high UA/PA metrics across most classes. The Post-Land Claims classification showed comparable reliability (85.5% OA, 81.5% Kappa), maintaining high cropland accuracy (92.0% F1-score) but with reduced performance for grassland (76.9%) and wetland (72.0%). The slight accuracy decline in specific classes likely reflects increased landscape heterogeneity during the later period.

A comparative analysis of land cover classifications between the two periods reveals significant shifts in distribution across the entire study region, encompassing both reserve and non-reserve lands (Supplementary Figure S3). Cropland, while remaining the predominant land cover, increased from 55.31% to 62.13% across the study region (Table 1). Conversely, grassland decreased from 16.48% to 11.33%, and forest cover declined from 17.33% to 14.03%. Water bodies and wetlands showed minor variations, whereas settlements expanded approximately threefold, from 0.97% to 2.88% (Table 1). These regional patterns closely

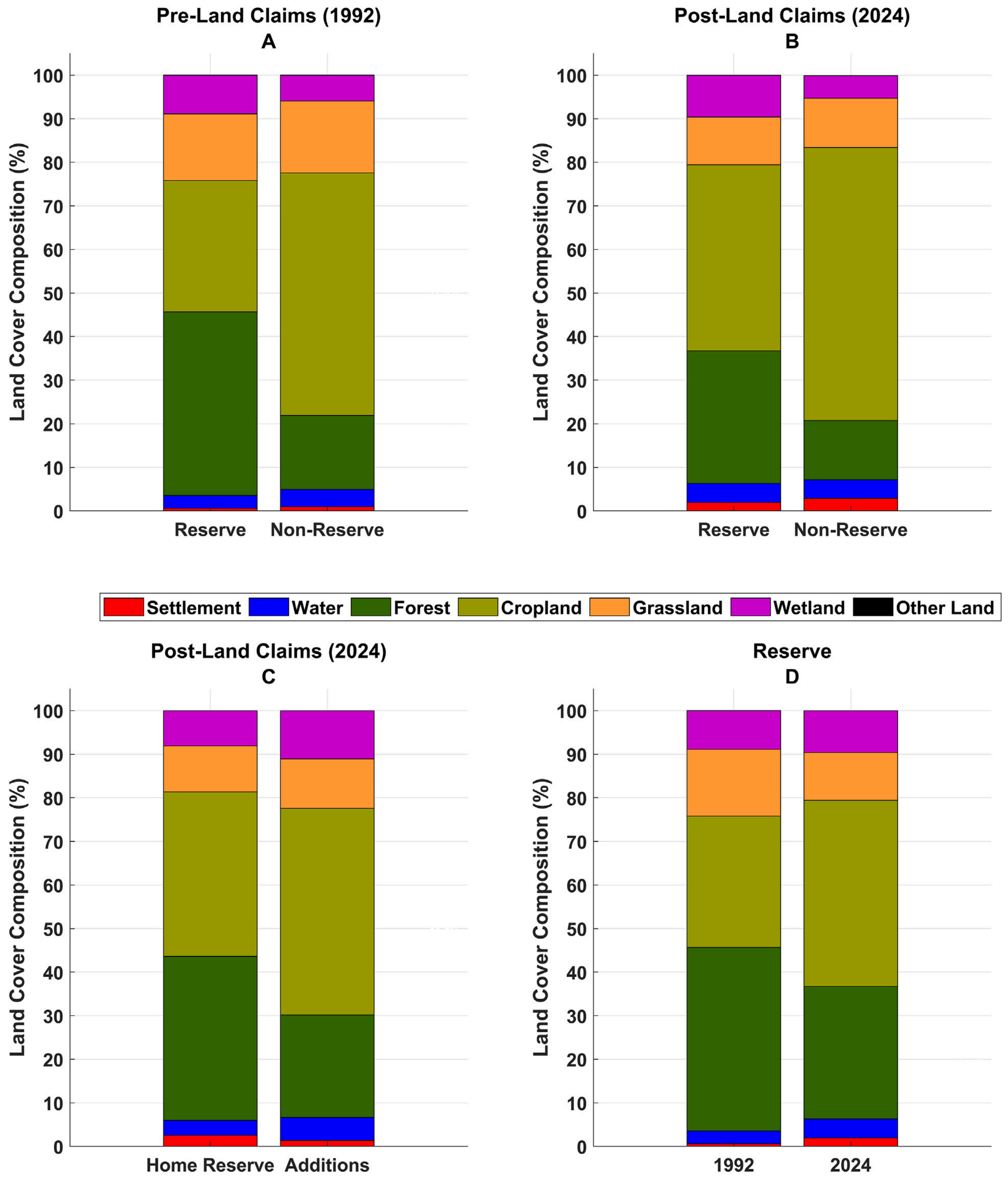

FIGURE 5
Land cover composition (%) for **(A)** Reserve vs. Non-Reserve, Pre-Land Claims, **(B)** Reserves vs. Non-Reserve, Post-Land Claims, **(C)** Home Reserve vs. Additions, Post-Land Claims, **(D)** First Nation Reserves, Pre-Land Claims vs. Post-Land Claims.

mirrored non-reserve lands, which comprised over 98% of the study area before the Land Claims (1992) and over 97% after the Land Claims (2024) (Table 1).

Before the Land Claims and contemporary additions to the reserve land bases, there were significant differences in land cover composition between the pre-claim reserve and non-reserve lands (Wilcoxon Rank Sum test, $P < 0.001$, Table 1; Figure 5A). Despite reserve lands constituting only 1.28% of the total study area, the concentration of forest and wetlands was notably higher within the reserves than in non-reserve areas. The reserves comprised 42.12% forest land and 8.90% wetlands, whereas non-reserve lands comprised 17.01% forest land and 5.93% wetlands (Table 1). The

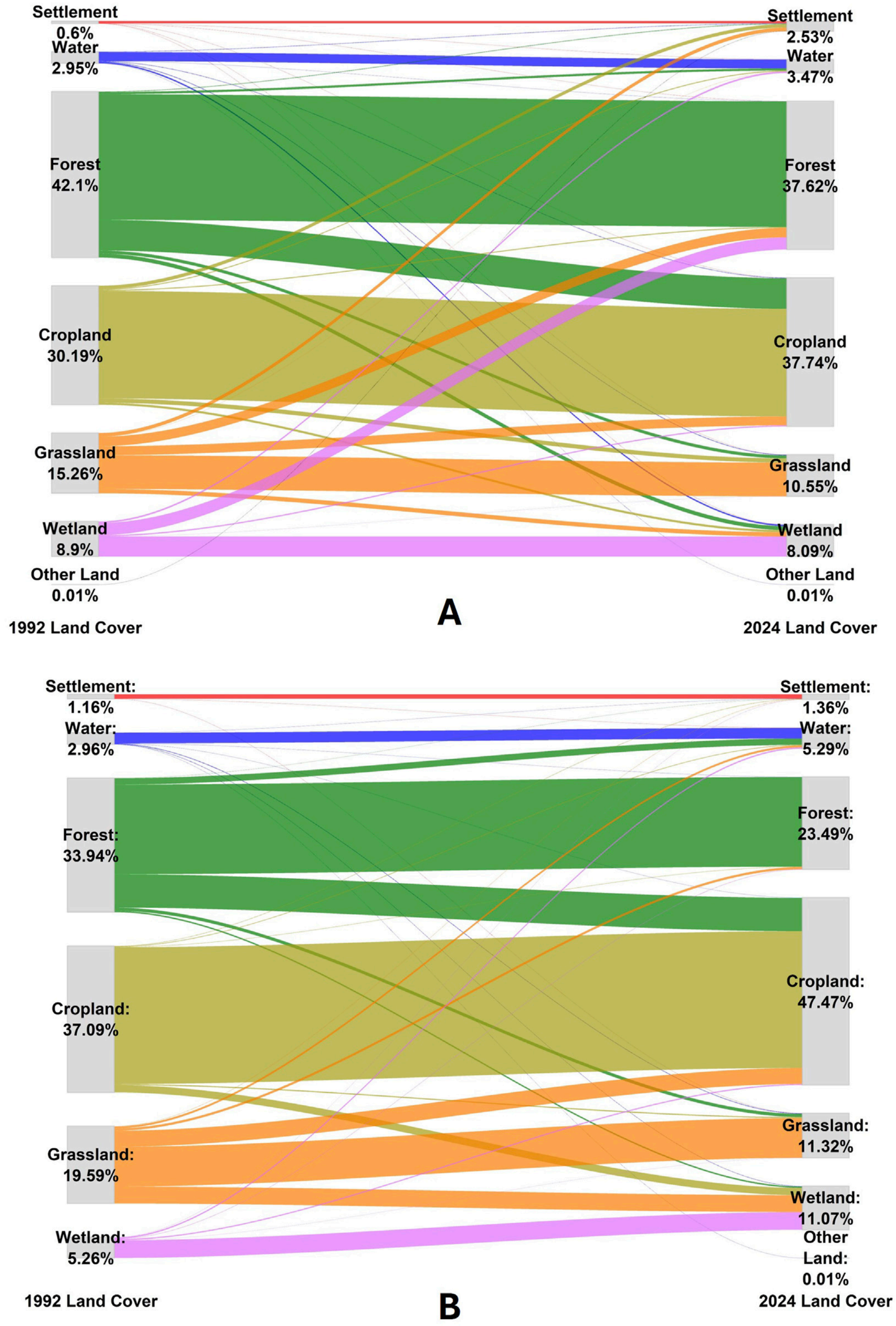

FIGURE 6
Land cover change flows between Pre- and Post-Land Claims for **(A)** the original Reserves and **(B)** the Additions (see the land use change matrix in Supplementary Tables S6 and S7).

proportion of grasslands, however, was quite similar, constituting 15.26% and 16.50% on reserve vs. non-reserve lands, respectively (Table 1).

After the addition of 4,060.6 km^2 (1,003,396 acres) to reserve lands since 1992 (Table 1), the diversity in land cover composition persisted between reserve and non-reserve lands (Wilcoxon Rank

Sum test, $P < 0.001$, Table 1; Figure 5B). 1,928.0 km^2 of cropland was added to the land cover types of reserves, increasing the proportional cover of cropland from 30.19% to 42.71% on reserve lands (Table 1). The new additions had a higher proportion of cropland than the Pre-Land Claim original reserves (Wilcoxon Rank Sum test, $P <$ 0.001, Table 1; Figure 5C). Still, compared to non-reserve areas, the Post-Land Claims reserves had a lower proportion of cropland (42.71% compared to 62.63%; Table 1). Despite the increase in cropland on reserve lands, the proportion of forest and wetland areas remained higher within the reserves than in non-reserve areas, while grasslands also remained similar (Table 1; Figures 5A,B).

3.3 Land cover changes of reserve lands Post-Land Claims

In the Post-Land Claims period in the original reserve land bases, the land cover change analysis shows that the interchanges between different categories were significant (Figure 6A). Among these interchanges, the proportion of land occupied by settlements increased from 0.6% to 2.53% (Table 1), primarily at the expense of cropland and grassland areas prior to the land claims (Supplementary Table S6). The proportion of wetlands slightly decreased from 8.90% to 8.09% (Table 1), with the major transitions being conversions to forest and water (Supplementary Material, Supplementary Table S6). At the same time, a comparable portion of forest and grassland transitioned back to wetland (Figure 6A). The cropland portion increased from 30.19% to 37.74% (Figure 6A), primarily from the transition of grassland (2.27% converted) and forest (7.78% converted; Supplementary Material, Supplementary Table S6).

Moreover, the new reserve additions had a higher proportion of cropland than the home reserves (Table 1; Figure 5C). Notably, the additions experienced a substantial land cover change from 1992 to 2024. Forest decreased from 33.95% to 23.49%, with 8.42% converted to cropland, and grassland changed from 19.59% to 11.32%, with 4.28% converted to cropland (Figure 6B; Supplementary Material; Supplementary Table S7). The increase in cropland on the additions from 37.10% to 47.48% was greater than the change on the original home reserve (30.19%–37.74%). The conversion of grasslands to cropland was more severe in the additions than in both the original home reserves and the non-reserve lands. Interestingly, land composition of the additions experienced an increase for wetlands (5.24%–11.06%), whereas both the home reserve and the non-reserves experienced a slight decline (Table 1). Overall, the First Nations reserve lands in 2024, following the legal designation of newly acquired land to reserve status, exhibit markedly different land cover composition compared to the Pre-Land Claims period of 1992 (*Wilcoxon Rank Sum test*, $P < 0.001$, Table 1; Figure 5D).

3.4 Agricultural capability of First Nations reserve lands

The derived dominant agricultural capability score was grouped into three categories based on cropland suitability: high (Classes 1–2), marginal (Classes 3–4), and limited (Classes 5–6) (Supplementary Material, Supplementary Table S3). For the Pre-Land Claims era, 9.6% of reserve land was classified as prime or high quality for agriculture, 66.8% was marginal or limited suitability, and 19.1% had limited capacity for cropland (Table 2). Following the contemporary expansion of reserve lands since 1992, these proportions shifted to 8.5% high, 58.4% marginal, and 21.6% limited. In comparison, the agricultural capability scores for these three categories across the entire study region were 11.7%, 51.7%, and 20.7%. Notably, 10.7% of the new reserve land additions were classified as Organic soils (O) (Table 2), coinciding with the relatively high proportion of wetlands. Overall, the high-quality soil in the reserves, both home reserve and new additions, remained significantly lower (9.6% and 8.5%) than that for the entire region (11.7%). Conversely, the proportion of soil with marginal agricultural capability for cultivation was higher in the home reserves (66.8%) than the regional average (57.4%). No differences were observed in the proportions of lands with marginal agricultural capability for cropland in the new additions (Table 2). Cropland primarily occupied prime lands, covering 83.91% of Class 1 and 71.66% of Class 2 soils within the original reserves, and 90.89% of Class 1 and 80.61% of Class 2 soils within the additions (Supplementary Material, Supplementary Tables S8 and S9). There was a higher proportion of cropland in Class 3 (76.84%) and Class 4 (52.16%) soils on additions than on original reserves (48.06% and 29.08%, respectively, Supplementary Material, Supplementary Tables S8 and S9). In contrast, lands with marginal and limited soil agricultural capability were predominantly used as grassland, while organic soils were mainly covered by forests, water bodies, and wetlands (Supplementary Material, Supplementary Tables S8 and S9).

4 Discussion

Based on a spatially explicit analysis of multiple open-source data, this study provides new insights into land use patterns on First Nations reserves in the southern region of Saskatchewan, where ecological value, agricultural potential, and development pressures intersect in complex ways. We found that 4,060.6 km^2 (406,060 ha) of land has been added to the First Nations reserve land base in Saskatchewan's agricultural region since 1992—nearly doubling the total to 8,233.9 km^2 (823,390 ha) and increasing its share from 1.28% to 2.51%. Our findings align closely with the 1,000,000 acres (404,626 ha) reported by the Saskatchewan Aboriginal Land Technicians (2024). Newly acquired lands were dispersed throughout the region, and lands under perennial cover faced greater rates of conversion to cropland than non-reserve and home reserve lands. We also confirmed that reserve lands support a higher proportion of perennial cover—dominated by forest and wetlands—offering ecological benefits, yet they face systemic barriers to agricultural development due to the predominance of soils with more marginal agricultural capability that risk degradation and biodiversity loss through conversion pressures.

4.1 Perennial vegetation on reserve lands dominated by forest

Our findings reveal that First Nations reserve lands consistently support a greater proportion of ecologically valuable land cover—namely forests and wetlands—than surrounding non-

TABLE 2 Soil agricultural capability (AC) scores for the whole study region, the home reserve lands, and new additions to reserve land (Group percentages: 1-2 = high, 3-4 = marginal, 5-6 = limited; O = Organic soils; UN; unclassified; see Supplementary Table S3 for details).

AC score	Home reserves			Additions			Whole study region	
	Area/km^2	%	Group %	Area/km^2	%	Group %	%	Group %
1	62.6	1.5%	9.6%	31.4	0.8%	8.5%	1.6%	11.7%
2	337.7	8.1%		309.7	7.7%		10.1%	
3	1705.0	40.9%	66.8%	1,286.4	31.9%	58.4%	35.9%	57.4%
4	1,084.2	26.0%		1,070.1	26.5%		21.5%	
5	401.8	9.6%	19.1%	609.0	15.1%	21.6%	14.1%	20.7%
6	397.1	9.5%		263.0	6.5%		6.6%	
7	1.0	0.02%		0.2	0.01%		0.03%	
UN	33.6	0.8%		38.1	1.0%		4.0%	
O	150.3	3.6%		430.6	10.7%		6.2%	

reserve areas, underscoring their critical role in regional biodiversity and habitat. Specifically, during the Pre-Land Claims period, forests and wetlands within the reserves accounted for approximately two times the corresponding percentages found in the non-reserves (51% vs. 23%, respectively). While moderately diminished, this disparity remained notable in the Post-Land Claims period, with reserves still exhibiting nearly double the percentages of these land cover types relative to the non-reserves. We anticipated that grassland would be more represented within reserves, but grassland proportions were relatively similar between reserve and non-reserve lands. In fact, our results showed considerable shifts from grassland and wetlands to forest, particularly in the home reserves (2.43% and 3.10%, respectively). This aligns with previous studies, which suggest that a combination of fire suppression policies, climate change, and land use changes is driving woody species encroachment in Saskatchewan's prairie region (Schutz, 2010; Ratajczak et al., 2012; Archer et al., 2017).

The high proportion of forest and wetlands highlights the crucial role of First Nations reserves as *de facto* conservation areas, safeguarding biodiversity and providing essential wildlife habitats in a region dominated by agricultural expansion and habitat fragmentation (Hobson et al., 2002; Lesbarrères et al., 2014). Our findings demonstrate that reserve lands diversify land cover across this region, lending support to research elsewhere and at a broader global scale that shows enhanced biodiversity within Indigenous-managed lands (Garnett et al., 2018; Schuster et al., 2019). In addition to their ecological significance, forests and wetlands serve as vital carbon sinks, capable of capturing and storing substantial amounts of atmospheric carbon dioxide over long periods (Hopkinson et al., 2012; Houghton and Nassikas, 2017; Ruehr et al., 2023). By preserving intact natural landscapes, such as forests and wetlands, First Nations reserves exemplify how Indigenous land stewardship can complement broader conservation efforts (Garnett et al., 2018), reinforcing the importance of integrating Indigenous land stewardship into regional and national biodiversity policies (Sangha, 2020). This role is critical in southern Saskatchewan, where agricultural expansion has reduced the extent of natural habitats, particularly grasslands, and released previously sequestered carbon into the atmosphere (Wang et al., 2014). In this context, reserve lands act as natural buffers against land-use change, helping to sustain biodiversity and mitigate climate impacts.

While reserve lands offer significant ecological and climate benefits, First Nations should not be disproportionately burdened with conservation responsibilities. To do so risks placing unfair constraints on wanting to develop land for economic opportunities, especially when surrounding non-Indigenous lands have been extensively developed. Further, nature-based climate solutions have been met with criticism, particularly if implementation is externally driven and in conflict with or undermining Indigenous rights to self-determination (Townsend et al., 2020; Reed et al., 2022; 2024).

4.2 Cropland on First Nations reserves is proportionally smaller and more marginal

Despite expectations that reserve land expansion following TLEFA and Specific Claims would expand First Nations' agricultural capacity (Pratt, 2006; Champ et al., 2010), our findings reveal persistent disparities—both in the overall share of cultivated reserve land as well as their productive capacity—that continue to constrain First Nations agricultural development. While cropland dominated the broader regional landscape—accounting for 60% of the total land cover—this proportion was notably lower within First Nations reserves, with cropland comprising 30.19% during the Pre-Land Claims period. Since the Post-Land Claims period, cropland comprised a greater share of new reserve additions compared to the home reserves (47.48% vs. 37.74%) but remains well below earlier projections. Despite increases in cropland through acquisitions and land cover conversions, reserve agricultural land holdings have reached 351,670 ha (868,995 acres) as of April 2024, falling short of previous estimates that agricultural land holdings could reach as much as three to four million acres (Pratt, 2006; Champ et al., 2010). This disparity highlights the contrasting land use priorities and patterns between reserve lands and the surrounding agricultural region, emphasizing the importance of understanding how land claims and subsequent land use changes impact agricultural productivity potential.

To better understand potential agricultural development, we examined the land's agricultural capability during the Pre-Land Claims period (the original home reserves) and the new additions to the reserves. Both periods showed a lower percentage of prime or high-quality agricultural land (Classes 1–2) and a higher percentage of marginal or less suitable land (Classes 3–4) (Table 2). These findings highlight a crucial barrier to agricultural development for First Nations, as much of the lands allocated historically, as well as recent reserve additions, have marginal agricultural potential. This reflects a longstanding challenge for First Nations agriculture, where lands granted through historical treaties and modern acquisition often lack the fertility or infrastructure needed for high-yield farming (Arcand et al., 2020). Land tenure issues, fragmented land parcels, and the absence of substantial investments further exacerbate these challenges (Desmarais and Wittman, 2014; Robson, 2020). The predominance of marginal croplands within reserve boundaries underscores systemic barriers rooted in historical dispossession and inequitable land allocation.

From an Indigenous agroecological perspective, soil capability may encompass not only suitability for conventional agriculture but also the land's potential to support diverse, place-based food systems and ecological stewardship. Indigenous knowledge systems often emphasize adaptive practices—such as polycultures, rotational grazing, and selective harvesting—that respond to the limitations of marginal soils while promoting soil health, biodiversity, and long-term resilience (Morrison, 2011; Whyte, 2013). Initiatives like the Indigenous Food Sovereignty movement and the restoration of native prairie ecosystems by various Indigenous Nations point to the potential for Indigenous Traditional Ecological Knowledge (TEK) to inform the revitalization of traditional food systems and sustainable land management (Coté, 2016; Martens et al., 2016). While our preliminary engagement with community partners highlights promising directions, more research is needed to understand how these Indigenous-led approaches might reshape land management priorities—particularly in terms of shifting from short-term yield maximization to long-term ecological and cultural sustainability. Future studies should explore these community-led strategies further to assess how TEK can contribute to sustainable stewardship practices, especially on lands currently classified as marginal (Jessen et al., 2022).

4.3 First Nations grassland and forest conversion to agriculture is greater on new reserve lands

Newly acquired reserve lands exhibited higher grassland and forest conversion rates to cropland (8.42% and 4.28%) compared to home reserves (7.78% and 2.27%), likely driven by the economic incentive of renting cropland. This trend reflects the systemic pressures to maximize revenue, as cropland leases often command premium rates, exacerbated by rising farmland values and tight rental markets (Michaud and Shepherd, 2024; Arnason, 2025).

These land-use transitions carry significant ecological implications. The conversion of grassland and forest—especially on marginal soils—reduces biodiversity, diminishes carbon sequestration, and increases risks of erosion and long-term productivity decline. Marginal lands are more vulnerable to the negative impacts of intensive agriculture, yet they also provide valuable ecosystem services. Institutional frameworks may reinforce these patterns. For example, the Reserve Land and Environment Management Program (RLEMP), administered through Indigenous Services Canada, supports land management in 29 Saskatchewan First Nations (and over 100 nationally). However, its current funding structure—with allocations tied to cropland and grazing lease transactions, and cropland generally valued higher—may inadvertently incentivize conversion over conservation, regardless of ecological suitability (Indigenous Services Canada, 2023). This can constrain more holistic land-use planning and prioritize short-term income generation over long-term ecological resilience.

These patterns point to a fundamental tension between economic development and environmental stewardship of reserve lands. While cropland expansion, especially through leasing, can generate short-term revenue, it may come at the cost of biodiversity, carbon storage, and long-term soil health, particularly on marginal soils that are common in newly acquired reserves. However, not all these lands are marginal; 74,140 ha of class 1-2 lands possess high agricultural potential and readily support sustainable crop production, while more careful management is required on the 299,140 ha of class 3 lands found on reserves. Moreover, class 4 and 5 lands offer suitable grazing opportunities. This raises important questions about how to distinguish lands appropriate for agricultural use from those better suited for conservation. Future research could explore how land management programs, such as the Reserve Land and Environment Management Program (RLEMP), might be restructured to align economic incentives with ecological sustainability. Alternative models—such as diversified land use, crop-sharing agreements, or conservation-compatible leasing—may reduce financial risk while maintaining critical ecosystem functions (Ingram et al., 2023). Ultimately, addressing these challenges requires adaptive frameworks that align Indigenous sovereignty, economic viability, and environmental sustainability (Darvill and Lindo, 2016; Coyne et al., 2022; Ingram et al., 2023).

4.4 First Nations reserve land additions are dispersed and diverse

While our results showed an increase in the density of reserve lands within clusters of RMs where reserve lands already existed, there was also a dispersion of new reserve additions in RMs further away. Indeed, many of the new reserve additions are located far from the administrative base of the home reserve, which may be opportunistic, strategic, or both. First Nations can be constrained to find suitable land available for purchase close to their home reserves due to land price increases and other challenges, including resistance from rural municipalities to support the conversion of purchased land to reserve status (Garcea, 2014; Poitras, 2014; Iwama, 2018). Thus, they may purchase land further afield if it is affordable and the administrative hurdles of reserve land designation are more easily overcome. The distance can pose challenges for land management, including monitoring land use activities and enforcing environmental regulations. In some cases, distant land purchases are strategic, such as reclaiming traditional territories, extracting resources for economic development, or pursuing urban commercial opportunities (Poitras, 2014). Our results also demonstrated an increase in the "Settlement" land cover within the home reserve from 0.6% to 1.93%, accounting for 55.0 km^2 of build-ups in First Nations. This increase reflects a significant shift in land use priorities, driven by demographic pressures, infrastructure development, and evolving community needs (Assembly of First Nations, 2025). First Nations in Saskatchewan have experienced notable population growth; for instance, the on-reserve population has been growing at an average annual rate of 1.1% from 2019 to 2023 (Statistics Canada, 2022). However, the expansion of reserve land has not kept pace with this demographic increase, resulting in limited space for new housing developments (Clatworthy, 2009; Pasternak, 2023). Addressing these challenges necessitates collaborative efforts focused on sustainable and culturally respectful development strategies.

5 Limitations of the study

This study's findings should be interpreted considering several data constraints. The exclusion of Additions to Reserve (ATR) lands from the Aboriginal Lands of Canada Legislative Boundaries dataset underrepresents Indigenous-held territories, particularly given the chronically delayed ATR process described as "broken" by the Assembly of First Nations (2025). The 30 m resolution of Landsat imagery, while suitable for broad-scale analysis, fails to detect small ecotones (e.g., riparian buffers <30 m wide) and fine-scale Indigenous land management practices (e.g., cultural burns, agroforestry patches) that are ecologically and culturally significant. Furthermore, the Canada Land Inventory's agricultural capability ratings prioritize conventional crop productivity, potentially misaligning with Indigenous agroecological systems where "low capability" soils may support culturally vital species like medicinal plants or berry shrubs. These limitations highlight the need for Indigenous community-engaged ground studies to capture both biophysical details and socio-cultural land use drivers omitted by standardized datasets incorporated with higher-resolution temporal earth observation data.

6 Conclusion

This study demonstrates that First Nations reserve lands in the prairie-parkland region of Saskatchewan serve as crucial ecological landscapes while facing persistent agricultural limitations. Three key findings emerge: (1) reserve expansion through TLE and Specific Claims has nearly doubled Indigenous land holdings (4,173.3–8,233.9 km^2), yet these gains remain spatially fragmented and disproportionately concentrated in agriculturally marginal areas (66.8% Class 3–4 soils); (2) reserves maintain significantly higher proportions of forests (30.41% vs. 13.60%) and wetlands (9.60% vs. 5.16%) than surrounding areas, functioning as vital biodiversity refuges and carbon sinks in an intensively farmed region; (3) new reserve additions show accelerated conversion of grasslands to cropland (4.28% vs. 2.27% in home reserves), reflecting economic pressures from higher cropland rental values despite ecological trade-offs.

These patterns reveal an unresolved tension between the treaties' agricultural promises and the reality of land allocation. While financial compensation through TLE and Specific Claims has expanded reserve boundaries, the perpetuation of marginal land quality continues to constrain First Nations' agricultural potential—a systemic inequity requiring policy redress, where sustainable agricultural development is targeted on high-quality lands and marginal lands are preserved for their ecological value, or developed for non-agricultural purposes. The dispersed "checkerboard" pattern of new additions further complicates cohesive land management. In some cases, the dispersed land is strategic in nature, offering diversified economic opportunities not available on lands closer to the administrative home base and that are outside the agricultural sector. At the same time, the demonstrated conservation value of reserves presents opportunities. Indigenous-led stewardship maintains ecosystems that simultaneously support cultural practices, biodiversity, and climate mitigation—benefits that could be better supported through Indigenous-led policy reform and conservation program development. Ultimately, land use decisions on First Nations reserves—whether oriented toward development or conservation—should be at the discretion of the Nations themselves, supported by access to relevant data and information that can enhance informed decision-making and strengthen self-determination.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: Annual Crop inventory: https://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9 Canada Land Inventory: https://sis.agr.gc.ca/cansis/nsdb/cli/index.html Electronic Registry Index Plan (eRIP): https://geo.sac-isc.gc.ca/erip-prre/index-eng.html First Nations: https://fnp-ppn.aadnc-aandc.gc.ca/fnp/Main/Search/SearchFN.aspx?lang=eng Reporting Centre on Specific Claims: Status Report on Specific Claims. Available at: https://services.aadnc-aandc.gc.ca/SCBRI_E/Main/ReportingCentre/External/externalreporting.aspx Indian Claims Commission proceedings. Available at: https://publications.gc.ca/site/eng/9.504816/publication.html Indian Lands Registry System (ILRS). Available at: https://services.aadnc-aandc.gc.ca/ILRS_Public/Home/Home.aspx Approved Additions to Reserve. Available at: https://sac-isc.gc.ca/eng/1466532960405/1611939046478 SGIC Ortho Imagery. Available at: https://www.isc.ca/MapsandPhotos/Imagery/Pages/SGICOrthoImagery.aspx Aboriginal Lands of Canada Legislative Boundaries. Available at: https://open.canada.ca/data/en/dataset/522b07b9-78e2-4819-b736-ad9208eb1067 Canada Lands Surveys: Tools and data. Available at: https://clss.nrcan-rncan.gc.ca/clss/plan/search-recherche.

Author contributions

XY: Formal Analysis, Visualization, Methodology, Data curation, Writing – original draft, Writing – review and editing, Conceptualization, Investigation. DN: Writing – review and editing, Conceptualization, Investigation, Writing – original draft, Supervision, Funding acquisition, Resources. CM: Investigation, Conceptualization, Supervision, Funding acquisition, Resources, Writing – review and editing. MA: Project administration, Investigation, Writing – original draft, Conceptualization, Funding acquisition, Supervision, Writing – review and editing, Resources.

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Conflict of interest

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

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2025.1642641/full#supplementary-material

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