Indigenous-Centered Forest Policy and Land Management: A Comparative Analysis of Brazil and British Columbia (2000-2023)

UBCO - Interdisciplinary Graduate Studies - Sustainability

PhD Research Proposal - March 2025

Project Title: Mapping the Relationship Between Forest Coverage and Policy Processes in Brazil and Canada: A Comparative Study of Indigenous Lands in Brazil and British Columbia (1980-Present)

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Integrating Policy Analysis, Land Cover Change Assessment, and Community-Based Evaluation

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Executive Summary

This proposal presents a 24-month PhD project that examines the relationship between forest policies and land coverage change within indigenous territories in Brazil and Canada. The research leverages existing research, open-source software, and publicly available data to conduct rigorous and cost-effective analysis, aiming to generate practical tools and insights for land managers, policymakers, and indigenous communities. It will consider Canadian areas in British Columbia due to the province's specific rules and management of lands and forests. It will also consider the Brazilian biomes Amazônia and Mata Atlântica as they are tropical forests in distinct stages of human influence.

The project builds directly on material gathered and papers produced for three comprehensive examinations: (1) Policy Analysis and Data, (2) Land Cover Change Analysis in Brazil and Canada, and (3) Evaluating land use concerning policy. The first paper establishes the theoretical framework for policy analysis, the second develops the technical methodology for land cover change assessment using remote sensing, and the third connects policy implementation to observable outcomes. By integrating these foundations, this research creates analytical tools and policy recommendations that can inform land management decisions across multiple stakeholder groups.

Working within Brazil and British Columbia, this study will analyze 4 to 6 indigenous territories using publicly available data, policy documents, and open-source technologies. The research leverages existing datasets and established methodologies, making it both cost-effective and reproducible while ensuring that all analytical tools and findings are accessible to diverse users, including indigenous communities, government agencies, conservation organizations, and academic researchers.

The core innovation lies in developing transferable methodologies and practical tools that can support evidence-based land management and policy development. The project aims to generate valuable insights for sustainable land management and indigenous land protection policies by comparing diverse case studies across different biogeographic regions and policy contexts. Community collaboration is a preferred pathway to enrich research outcomes. However, the project design ensures comprehensive deliverables regardless of the community participation levels achieved during the research period.

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Project Goals and Research Questions

This research aims to develop practical tools and evidence-based insights for land management and policy development supported by geospatial tools.

The research will develop accessible analytical tools, methodologies, and databases that support land management decision-making across diverse institutional contexts. Through systematic analysis and tool development, the project will build transferable capacity for ongoing land monitoring and policy evaluation, serving multiple user communities. It will evaluate Indigenous reserves and lands in comparison to their surroundings to understand how policies impact distinct locations and uses.

Four interconnected research questions guide this investigation:

How do formal policies interact with indigenous governance systems to influence forest conservation outcomes within indigenous territories in Brazil and British Columbia?

What land cover change patterns can be identified within Indigenous territories using remote sensing data, and how do these relate to policy implementation periods and approaches?

Can we understand the effectiveness of policy across different Indigenous territories and their surrounding areas to inform evidence-based policy development?

How can analytical methodologies and monitoring tools be designed to serve diverse user communities, including Indigenous land managers, government agencies, and policymakers?

Methodology

This research employs a practical three-phase approach over 24 months, designed to ensure project completion while maximizing opportunities for stakeholder engagement. The methodology prioritizes the development of analytical tools that can serve diverse users, with community collaboration pursued where feasible and appropriate.

Phase 1: Research Design and Case Study Selection (Months 1-6)

The initial phase establishes the analytical framework and selects 4-6 indigenous territories for comprehensive analysis. Case study selection considers data availability for the 1980-2023 analysis period, diverse policy contexts that enable meaningful comparison, and geographic representation across both Brazil and British Columbia.

Selection criteria require sufficient remote sensing data coverage through Hansen's Global Forest Change dataset and MapBiomas for Brazil, documented policy implementation history from 1980-present, contrasting forest cover patterns between indigenous territories and surrounding areas, representation of different legal recognition levels and governance arrangements, and geographic diversity across Brazil's Amazon and Atlantic Forest biomes and British Columbia's forest regions.

The research focuses on indigenous territories within distinct biogeographic regions that represent different policy environments and forest management challenges. Brazil's study areas encompass territories within the Amazon biome, the world's largest tropical rainforest characterized by high biodiversity, complex governance structures, and significant deforestation pressures, alongside territories within the Atlantic Forest biome, Brazil's most threatened forest biome that is highly fragmented and under intense development pressure, representing conservation challenges in densely populated regions. British Columbia's study areas encompass territories within the Montane Cordilleran (Cold Temperate Forest) and the Pacific Maritime (Cool Temperate Forest) zones. The Montane Cordilleran zone features high-elevation regions with complex terrain and distinct seasonal patterns. In contrast, the Pacific Maritime zone encompasses coastal areas with old-growth forests and significant commercial forestry activity.

The selection process prioritizes territories that exhibit contrasting patterns of forest cover between Indigenous lands and surrounding buffer zones, allowing for a comparative analysis of policy effectiveness across different contexts. The research framework systematically examines forest, land, and indigenous policies, with policy identification encompassing national, regional, and local levels that recognize multi-layered governance structures. The analysis covers policy objectives, target stakeholders, implementation mechanisms, enforcement procedures, and monitoring systems.

This phase establishes the computational framework for geospatial analysis, including the development of Python-based processing pipelines for handling large-scale remote sensing datasets. The framework utilizes

open-source technologies, including QGIS, PostgreSQL/PostGIS, R, and Python, while leveraging existing datasets such as Hansen's Global Forest Change, MapBiomas, and government policy databases to ensure reproducibility and cost-effectiveness.

Indigenous Data Sovereignty Implementation: Systematic outreach to Indigenous organizations and communities will explore opportunities for collaboration, following proper protocols for respectful engagement. Public data sources and processing results will be presented to Indigenous partners with invitations for corrections, contextual information, and guidance on interpretation. Communities will be offered multiple engagement options, from full collaboration to territorial exclusion, with all approaches respecting Indigenous data sovereignty principles.

Community Engagement Protocols: Research activities will adhere to Free, Prior, and Informed Consent protocols for all territory-specific analyses. Communities will have veto power over how their territories are represented, with options to opt out of case studies or request specific modifications to interpretations. Where communities decline engagement, territories will be excluded from analysis or included only with clear disclaimers showing non-endorsement.

Ethics Framework Declaration: Although this study relies on publicly available remote sensing data, we acknowledge that Indigenous rights extend beyond data ownership to encompass governance over knowledge interpretation. We will proactively engage affected Nations to contextualize findings, correct misrepresentations, and honour requests for exclusion. All outputs will undergo Indigenous review where possible, ensuring that research benefits Indigenous communities while advancing scientific understanding of forest policy effectiveness.

Community partnerships developed during this phase will enhance the research through local knowledge and validation. However, the analytical framework ensures meaningful outcomes for all stakeholders, respecting Indigenous rights and territorial authority, regardless of the engagement levels achieved.

Phase 2: Integrated Analysis (Months 7-18)

The analytical phase builds directly upon the comprehensive examination papers. This phase utilizes established technical methodologies to develop user-friendly tools for land management.

1. Policy Analysis (1980-Present)

The policy analysis component examines formal policies using established methodological approaches to identify implementation patterns, effectiveness indicators, and barriers to successful outcomes. This analysis creates detailed inventories of forest, land use, and indigenous rights policies from government websites, official publications, academic literature, and legal databases through comprehensive policy identification and compilation processes. The systematic extraction of key information encompasses policy objectives, target stakeholders, implementation mechanisms, enforcement procedures, and monitoring systems.

The historical analysis traces policy development from the 1970s onward, examining major policy shifts, the impact of colonialism on land tenure, and the influence of international agreements to provide a deeper understanding of contemporary policy contexts. The analysis examines the roles and perspectives of government agencies, indigenous communities, forestry industry, and environmental organizations.

2. Land Use Change Analysis (1985/2000-Present)

The land cover change analysis utilizes Hansen's Global Forest Change dataset and MapBiomas data for Brazil to conduct a comprehensive spatial analysis of forest cover changes within selected territories. This technical analysis begins with the acquisition of Hansen's Global Forest Change dataset at 30-meter resolution, spanning the years 2000-2023, and the MapBiomas Collection 9 data for Brazil, covering the period 1985-2023, as well as additional Landsat archives and other data for extended temporal coverage. The processing involves data preprocessing, including temporal alignment synchronizing policy data with satellite observations.

Time-series analysis quantifies deforestation and regeneration rates using advanced algorithms for pixel-by-pixel evaluation of forest disturbance and recovery patterns. The spatial analysis creates detailed maps of forest cover changes, identifies deforestation hotspots, conducts proximity analysis relative to infrastructure development, and calculates landscape metrics for comprehensive fragmentation assessment. A comparative analysis compares land-use change patterns within Indigenous territories versus surrounding buffer zones, proportional to territory size, enabling an evaluation of conservation effectiveness across different management regimes.

The policy evaluation component employs systematic approaches to link observed land cover changes to policy implementation periods through temporal correlation analysis examining relationships between policy implementation dates and forest cover change patterns. Spatial overlay analysis maps policy boundaries against areas of significant forest loss or gain, while effectiveness assessment evaluates policy impacts through quantitative metrics of forest conservation outcomes. Cross-case comparison develops frameworks for comparing policy effectiveness across different territories and contexts, enabling the identification of transferable best practices and policy innovations.

The analysis utilizes a custom Python-based geospatial processing framework that can handle high-resolution data across large regions through tile-based parallel processing with chunked array storage. Automated polygon-based extraction enables the detection of temporal changes across 39 annual land cover maps, facilitating the calculation of transition matrices. The customized system generates automated land cover maps, Sankey diagrams for land use transitions, and interactive visualizations supported by robust error handling, automatic recovery mechanisms, and comprehensive validation procedures.

Validation and quality assurance incorporate systematic accuracy assessment using available ground truth data and statistical methods, cross-validation through multiple dataset comparison to identify and correct systematic errors, uncertainty quantification using statistical approaches to characterize and communicate uncertainty in results, and complete reproducibility through comprehensive documentation of analytical procedures and open-source code availability.

Phase 3: Tool Development and Knowledge Transfer (Months 19-24)

The final phase focuses on turning research findings into practical tools for various user groups. This includes creating user-friendly analytical software, methodological guides, and decision-support tools for land managers, policymakers, and researchers. The tools will cater to different technical skill levels, offering basic visualization for policymakers and advanced analytics for researchers.

Knowledge transfer includes creating policy briefs, technical reports, training materials, and open-source software to make research accessible to different audiences. Academic dissemination via peer-reviewed publications and conference presentations ensures that innovations reach the broader research community, while policy outputs provide practical guidance for government agencies and land management organizations.

Where community partnerships exist, we can develop together specific tools and resources to support community-based land management and monitoring activities. However, the primary focus remains on creating transferable tools and methodologies that can support evidence-based land management across diverse institutional contexts.

Data Sources and Technical Infrastructure

Primary Data Sources

The research leverages Hansen's Global Forest Change dataset, which provides consistent, global-scale forest cover change information at a 30-meter resolution from 2000 to 2023, accessed through Google Earth Engine for efficient pre-processing. MapBiomas Collection 9 provides annual land cover maps for Brazil from 1985 to 2023, offering a detailed historical context and finer classification than Hansen's data, with over 35 land cover classes. The Sentinel and Landsat Archives supplement this with higher temporal or spatial resolution imagery for detailed analysis of specific areas or events, extending temporal coverage back to 1985.

Policy documentation draws from government sources, including policy documents from Brazilian federal and state governments, as well as British Columbia provincial sources, encompassing Forest and Range Practices Acts, National Forest Strategies, and indigenous land management policies. Legal databases, including LexisNexis, HeinOnline, and FAOLEX, provide comprehensive access to legal documents, while academic literature offers peer-reviewed sources for policy analysis and implementation studies.

The technical infrastructure employs QGIS for spatial data processing, analysis, and visualization, while PostgreSQL with PostGIS extension enables efficient spatial data storage and querying. R and SciPy/Numpy handle statistical analysis, time-series processing, and hypothesis testing, with Python providing automated data processing, machine-learning applications, and custom analytical tools. Google Earth Engine facilitates large-scale remote sensing data processing through cloud computing capabilities.

The research utilizes a custom Python-based geospatial processing framework that can handle high-resolution data across large regions while maintaining fine-scale detail. The processing architecture utilizes tile-based parallel processing with chunked array storage, leveraging Zarr for enhanced memory efficiency. It implements advanced algorithms, including spectral trajectory analysis, for pixel-by-pixel evaluation. Automated polygon-based extraction enables the detection of temporal changes across 39 annual land cover maps and facilitates the calculation of transition matrices. Additionally, the automated generation of land cover maps, Sankey diagrams for land use transitions, and interactive visualizations support comprehensive analysis.

The computational framework operates on a desktop system with 20 cores, 98 GB of RAM, and 8 GB of CUDA GPU capability, supported by 3 TB of SSD storage with auxiliary external storage for large datasets. This configuration enables the processing of 800x800 kilometer regions in a single operation, with a tested capability to complete batch processing of 138 example areas in 70 minutes, validating the computational efficiency required for comprehensive multi-territorial analysis.

Timeline

24-Month Milestone-Driven Schedule

Phase & Milestones	Months 1-6	Months 7-12	Months 13-18	Months 19-24
Phase 1: Research Design	✓ Analytical framework established Case studies selected Data sources identified			
Phase 2: Integrated Analysis		✓ Policy analysis completed Land cover analysis initiated	✓ Comparative analysis completed Tool development initiated	
Phase 3: Knowledge Translation			✓ Analytical tools developed Initial dissemination	✓ Final deliverables completed Thesis defense
Ongoing Activities	Literature review, stakeholder outreach	Data processing, community engagement	Analysis refinement, writing	Publication preparation, dissemination

Detailed Activity Timeline

Activity	Months 1-3	Months 4-6	Months 7-9	Months 10-12	Months 13-15	Months 16-18	Months 19-21	Months 22-24
Literature Review	✓	✓	✓					
Policy Document Collection	✓	✓						
Case Study Selection	✓	✓						
Indigenous Engagement Protocol	✓	✓	✓	✓	✓	✓	✓	✓
Data Acquisition	✓	✓	✓	✓				
Data Processing		✓	✓	✓	✓			
Methodology Development		✓	✓	✓	✓			

Activity	Months 1-3	Months 4-6	Months 7-9	Months 10-12	Months 13-15	Months 16-18	Months 19-21	Months 22-24
Community Consultation		✓	✓	✓	✓	✓		
Case Study Analysis			✓	✓	✓	✓		
Indigenous Review Process				✓	✓	✓	✓	✓
Comparative Analysis				✓	✓	✓	✓	
Tool Development					✓	✓	✓	
Thesis Writing					✓	✓	✓	✓
Publication Preparation						✓	✓	✓
Community Feedback Integration						✓	✓	✓
Defense Preparation							✓	✓

Key Milestones:

- **Month 3**: Complete initial Indigenous community outreach and protocol establishment
- **Month 6**: Complete research design, case study selection, and community engagement agreements
- **Month 12**: Complete policy analysis, initiate land cover analysis, and conduct community verification of preliminary findings
- **Month 18**: Complete integrated analysis, begin tool development, and conduct comprehensive Indigenous review
- **Month 24**: Complete all deliverables with community approval and defend thesis

Budget and Resource Allocation

This research is designed to be cost-effective while prioritizing the development of practical tools and evidence-based insights. The budget leverages open-source software and publicly available datasets, with strategic investments in knowledge transfer and capacity building.

Budget Category	Amount	Justification

Budget Category	Amount	Justification
Indigenous Engagement and Protocols	$6,000	Community consultations, protocol development, and respectful engagement processes including travel for territory visits, interpretation services, and culturally appropriate meeting facilitation
Travel and Conferences	$4,000	Additional travel for stakeholder meetings, field validation, and conference participation for knowledge dissemination
Publication and Dissemination	$5,000	Open-access publication fees for peer-reviewed journals and conference registration/presentation costs, including Indigenous-authored publications
Equipment and Technology	$3,000	Hardware upgrades, computing resources, and technology infrastructure maintenance
Training and Capacity Building	$2,500	Specialized training programs, workshops, and community-based skill development opportunities
Total Estimated Cost	**$20,500**	

Resource Optimization Strategy:

This research leverages exclusively open-source datasets including Hansen's Global Forest Change, MapBiomas, and government policy databases while utilizing complete open-source software infrastructure through QGIS, PostgreSQL/PostGIS, R, and Python platforms with existing institutional access to cloud computing resources. The approach maximizes existing computational infrastructure with minimal additional investment and prioritizes partnerships with academic institutions and government agencies to share resources and expertise.

Budget Flexibility:

The budget structure allows for reallocation between categories based on project development and opportunity identification. Travel funds can be redirected to enhance digital collaboration tools if community engagement occurs primarily through virtual platforms, while publication funds can support additional open-access dissemination if research generates more outputs than initially planned.

| **Data acquisition and processing** | $3,000 | Access to computational resources for comprehensive analysis including cloud computing resources for large-scale remote sensing analysis and subscription access to specialized databases | | **Tool development and software** | $2,500 | Creation of user-friendly analytical tools and decision-support systems including software development tools, hosting costs for online platforms, and technical support for accessible interfaces | | **Community engagement and outreach** | $2,000 | Respectful stakeholder engagement where communities express interest in collaboration including travel costs for community meetings, interpretation services, and culturally appropriate communication materials | | **Knowledge transfer and dissemination** | $2,000 | Ensuring research findings reach diverse audiences through multiple channels including conference presentations, workshop materials, policy brief

development, and open-access publication costs | | **Training and capacity building** | $1,500 | Development of training materials and technical documentation for methodology and tool application including user guides, video tutorials, and technical documentation | | **Equipment and materials** | $1,000 | Essential computing resources, software licenses, and materials for field validation reflecting reliance on existing data sources and open-source technologies | | **Research travel and fieldwork** | $2,000 | Site visits for validation activities, conference participation for dissemination, and stakeholder meetings throughout the research process | | **Academic dissemination** | $6,500 | Publication fees for three peer-reviewed journals, conference presentation costs, and open-access publication expenses to ensure wide accessibility | | **Equipment and infrastructure** | $1,000 | Commitment to using existing computational resources and open-source software, relying on open-access datasets including Hansen's Global Forest Change data, MapBiomas collections, and publicly available government policy documents | | **Total** | **$21,500** | |

Expected Outcomes and Impact

This research will generate comprehensive outcomes that serve indigenous communities, land managers, policy makers, and the broader academic community. The project is designed to produce practical tools and evidence-based insights that will have lasting impact beyond the doctoral timeline.

Primary Deliverables:

This research will produce an Indigenous Land Management Toolkit consisting of user-friendly geospatial analysis tools specifically designed for community use. The toolkit will include automated land cover change detection systems that enable communities to monitor their territories independently, along with interactive mapping applications that provide real-time visualization of land use patterns. Policy impact assessment tools will allow communities to evaluate the effectiveness of different management approaches, supported by comprehensive training materials and technical documentation that ensure accessible application across varying technical skill levels.

The research will generate evidence-based policy recommendations through comprehensive analysis of land management practices and indigenous land protection policies in both countries. These recommendations will emerge from comparative analysis of policy effectiveness across different contexts, enabling identification of best practices for sustainable forest management. The analysis will produce guidelines for strengthening indigenous participation in decision-making processes and develop frameworks for adapting successful policies across different jurisdictions, ensuring transferable insights that can inform policy development beyond the specific case studies.

Publicly accessible maps and visualizations will provide detailed land use change maps for all case study areas, creating visual documentation of landscape transformations over time. Interactive Sankey diagrams will illustrate land cover transitions, while comparative visualizations demonstrate policy impacts across different territories and time periods. Time-series animations will capture forest cover change patterns, making complex analytical results accessible to diverse audiences including policy makers, land managers, and community members.

The research will establish a complete open-source analytical framework that enables replication and adaptation of the methodology across different contexts. This framework will include Python-based processing pipelines capable of handling large-scale remote sensing data, along with database schemas and data management protocols that ensure efficient data organization and accessibility. Statistical analysis scripts and methodological documentation will provide transparent analytical procedures, while quality

assurance and validation procedures ensure robust and reliable results that can inform critical land management decisions.

Academic Contributions:

The research will produce three peer-reviewed publications in high-impact journals addressing indigenous governance and conservation outcomes, participatory remote sensing methodology, and comparative policy analysis. A comprehensive PhD thesis will integrate all three comprehensive exam papers with methodological innovations and policy recommendations. Academic conferences and professional workshops will provide platforms for sharing findings with diverse audiences, while methodological documentation through technical reports and white papers will describe analytical approaches and tool development.

Direct engagement with policy makers in Brazil and British Columbia will ensure research findings and recommendations reach decision-makers, while contributions to international forums will advance global discussions about indigenous rights and land management through relevant international conferences and policy networks. Evidence-based resources will support indigenous land rights and self-determination efforts through advocacy channels.

The research will establish comprehensive training programs for geospatial analysis techniques, land monitoring, and policy assessment. User guides, video tutorials, and technical manuals will support ongoing tool application, while partnership development will establish ongoing research relationships that support long-term land monitoring and management activities. Documentation of approaches for integrating traditional and scientific knowledge systems will contribute to broader methodological advancement in collaborative research practices.

Long-term Impact:

The project outcomes will support evidence-based land management and policy development across diverse institutional contexts. The open-source tools and methodologies will enable ongoing monitoring and analysis beyond the research period, while the policy recommendations will inform forest conservation and indigenous rights policies in both countries. The transferable nature of the analytical framework will facilitate application in other regions and contexts, contributing to global efforts in sustainable forest management and indigenous land protection.

Technical Limitations and Considerations

This research acknowledges several technical and methodological limitations that inform the analytical approach and interpretation of results. The analysis inherits any misclassifications present in source datasets including Hansen's Global Forest Change and MapBiomas, requiring validation procedures and uncertainty assessment. Annual snapshots may miss seasonal changes, short-term disturbances, or rapid recovery patterns that occur within single years, while 30-meter resolution may not capture fine-scale degradation processes, edge effects, or small-scale management interventions. Satellite-based analysis is limited to 1985-present, missing earlier policy impacts and long-term historical baselines.

Full analysis requires substantial computational resources with 32GB+ RAM recommended and specialized technical expertise. Boundaries between land cover classes may show classification instability over time, requiring careful interpretation of transition patterns. Limited availability of ground-truth data for validation

exists, particularly in remote areas and historical periods, while variations in policy documentation quality and accessibility occur across different jurisdictions and time periods.

Establishing direct causal relationships between policies and land cover changes requires careful consideration of confounding factors and alternative explanations. Effects may vary at different spatial scales, requiring multi-scale analysis approaches, and policy impacts may occur with significant time delays, requiring extended observation periods. Local environmental, economic, and social conditions may influence policy effectiveness independently of policy design.

The research implements systematic accuracy assessment and uncertainty quantification while combining multiple datasets and methodological approaches to cross-validate findings. Appropriate statistical methods account for uncertainty and control for confounding variables, with complete documentation of methodological choices, limitations, and assumptions ensuring transparency.

The preliminary computational framework has been developed and tested using MapBiomas Collection 8 data for Brazilian indigenous territories. The analysis framework is documented in a 1,205-line Python script available under MIT license, demonstrating the feasibility and scalability of the proposed approach. Initial processing of 138 indigenous territories was completed in 70 minutes using desktop computing resources, validating the computational efficiency of the methodology. The framework is capable of processing 800x800 kilometer regions with 30-meter resolution, with complete technical documentation including processing architecture, validation procedures, and visualization capabilities available through the GitHub repository at https://github.com/leandromet/nlp_project_cuda.

Integration of Comprehensive Exam Papers

This PhD proposal builds comprehensively on insights from three comprehensive examination papers, each contributing essential theoretical frameworks, methodological innovations, and empirical foundations that collectively inform the proposed research design. The three papers together represent a sophisticated progression from policy analysis theory, through technical spatial analysis capabilities, to integrated methodology development that directly shapes the proposed research.

Paper 1: Policy Analysis for a Changing Forest Region

The first comprehensive paper establishes a robust analytical framework for understanding forest governance in the colonized Americas, with particular attention to the evolution of policies from resource extraction to sustainability paradigms. This paper establishes a sophisticated framework for understanding policy boundaries that considers geographical scope, affected stakeholders, and temporal evolution, recognizing that boundaries are contingent and shaped by the analyst's disciplinary background and historical context. The framework provides comprehensive analysis of how colonial legacies continue to shape contemporary forest governance, including the systematic dispossession of Indigenous peoples and the prioritization of European legal frameworks over customary law systems.

The paper offers detailed examination of the relationship between customary Indigenous land rights and formal legal systems, drawing from comparative analysis across Australia, Brazil, Canada, and South Africa to understand legal pluralism potentials and challenges. This analysis extends to examining policy development drivers including ecological concerns, economic considerations, international agreements, and evolving social values toward climate change awareness. The paper develops multi-stakeholder behavioral analysis that recognizes forest owners as vital ecosystem service providers whose responses to policy changes vary widely based on their classification from "optimizers" to "traditionalists."

This approach creates a framework for examining interest groups that drive policy change, including governments, local communities, Indigenous populations, forest industry, financial institutions, and consumer demand patterns. The methodological contribution includes historical trajectory analysis that traces policy evolution from initial European settlement through industrialization, World Wars, and contemporary environmental awareness. This systematic approach to data collection combines policy document review, stakeholder interviews, spatial data analysis and modeling, and historical context examination.

The paper establishes a framework for evaluating policy objectives that distinguishes between explicit goals such as economic efficiency, sustainable timber production, and biodiversity conservation, and implicit aspirations that reflect deeper societal values. This analysis addresses policy implementation challenges including bureaucratic inertia, competing interests, and the temporal disconnect between ecological changes and political cycles, while recognizing that policy success depends on practical implementation, public acceptance, enforcement mechanisms, and long-term evaluation and adaptation cycles.

Paper 2: Land Cover Change, Forest Analysis in Brazil and Canada

The second paper establishes sophisticated technical foundations for spatial data analysis and remote sensing applications, providing the methodological backbone for empirically evaluating policy effectiveness through landscape change detection. This paper demonstrates deep technical expertise that creates comprehensive mastery of land cover classification methodologies using multiple satellite platforms including Landsat with 30m resolution and multi-decadal archive, MODIS with 250-1000m resolution and high temporal frequency, along with SPOT, Sentinel-3, PROBA-V, and AVHRR systems. This technical foundation includes advanced understanding of remote sensing preprocessing including geometric correction, radiometric calibration, atmospheric correction, and temporal normalization techniques essential for consistent time-series analysis.

The methodological contributions encompass sophisticated classification algorithms including both supervised approaches such as Random Forest, Classification and Regression Trees, and Neural Networks, and unsupervised learning approaches, with deep understanding of their appropriate applications and limitations. The paper develops time-series analysis capabilities using temporal segmentation algorithms like LandTrendr, spectral trajectory analysis, and change detection methods that can capture both abrupt disturbances and gradual recovery processes.

The paper demonstrates expertise in integrating diverse data sources including satellite imagery, ground surveys, aerial photography, LiDAR data, and ancillary databases containing information on disturbances, management activities, and socioeconomic factors. This integration approach includes rigorous validation methodologies combining ground truthing, statistical accuracy assessment through confusion matrices, and comparison with independent reference datasets. The technical framework addresses data quality challenges including cloud cover, atmospheric interference, and the need for robust interpretation techniques to translate imagery into meaningful land use and management information. The paper establishes proficiency with cloud computing platforms such as Google Earth Engine and NASA Earth Exchange for processing large-scale datasets and automated analysis workflows.

The paper provides comprehensive understanding of ready-to-use land change products from initiatives like Hansen's Global Forest Change dataset, Copernicus Climate Change Service land cover maps, Global Forest Watch, and TerraClass for the Brazilian Amazon. This technical knowledge encompasses change detection methods for monitoring deforestation, forest degradation, forest recovery, and understanding the

relationship between these changes and policy interventions. The methodological framework establishes capability to work across multiple spatial and temporal scales, from local 30m Landsat resolution to regional 300m Copernicus resolution to global 1km AVHRR resolutions, with understanding of appropriate applications for each scale and their implications for policy analysis.

Paper 3: Evaluating Changes in Forest Land Cover, Concerning Policy

The third paper represents a sophisticated synthesis that creates an integrated methodology directly applicable to the proposed PhD research. This paper advances beyond the individual contributions of the first two papers to create a comprehensive framework for policy-landscape analysis that bridges theoretical policy analysis with technical spatial data capabilities.

The paper develops systematic approaches for linking policy analysis with spatial data analysis using GIS tools, incorporating overlay analysis, spatial correlation techniques, policy boundary mapping, and land use change modeling under different policy scenarios. This framework establishes cause-and-effect relationships between policy interventions and landscape outcomes, including appropriate timeframe selection that aligns with policy implementation periods and enables detection of policy impacts. The methodological innovation includes scenario-based approaches for evaluating policy effectiveness over time, incorporating climate change projections and land use change dynamics while addressing methods for analyzing policy interactions and unintended consequences, recognizing that income support might encourage production on sensitive lands or that deforestation reduction in one area might shift pressures to regions with weaker regulations.

The paper provides detailed examination of three distinct forest governance contexts through comparative case study analysis. The Brazilian Amazon case focuses on PPCDAm implementation and its 66% reduction in deforestation rates between 2004-2015, while the Brazilian Atlantic Forest examination analyzes conservation-focused policies in a heavily degraded biome with only 10% of original cover remaining. British Columbia represents the evolution from revenue-focused timber extraction to sustainable forest management frameworks. This comparative analysis documents how different policy approaches, historical contexts, socioeconomic factors, and Indigenous land rights considerations influence land use outcomes across diverse contexts, encompassing policy instruments including command-and-control regulations, economic incentives, protected area strategies, monitoring systems, and multi-stakeholder engagement approaches.

The paper establishes a comprehensive framework for incorporating Indigenous land rights and customary law systems into contemporary forest management policy evaluation, recognizing the critical role of Indigenous Peoples as original stewards and knowledge holders. This framework analyzes how colonial legacies continue to impact policy effectiveness, including the historical dispossession of Indigenous peoples and the imposition of European legal frameworks that often ignore traditional governance systems. The methodological contribution includes framework development for understanding how Indigenous Peoples' traditional knowledge and management practices can inform more effective and equitable forest policies, establishing pathways for meaningful integration of Indigenous governance systems with contemporary policy frameworks.

The paper develops comprehensive tools for policy coherence and effectiveness analysis through policy gap analysis identifying areas where current policies fail to address specific challenges, policy mix evaluation recognizing that coordinated strategies across multiple sectors are necessary for sustainability, and policy coherence assessment ensuring alignment within and between different policy areas and governance levels.

This analytical framework includes methods for evaluating both intended and unintended policy consequences, considering implementation challenges, stakeholder engagement effectiveness, and long-term landscape outcomes while incorporating international policy influences including UN SDGs, Paris Agreement, and Convention on Biological Diversity, and their translation into national and local policy contexts.

Synthesis and Innovation for PhD Research

Together, these three comprehensive papers create a robust foundation for PhD research that advances significantly beyond existing scholarship through methodological integration and scaling that establishes capability for multi-scale analysis integrating rigorous policy analysis frameworks with sophisticated spatial data analysis techniques. This enables evaluation of policy effectiveness from local implementation to regional landscape change to global policy influence, using both qualitative stakeholder analysis and quantitative remote sensing change detection.

The research prioritizes Indigenous-centered knowledge co-production by building on the policy analysis framework's attention to customary law and Indigenous land rights, moving beyond extractive research models to create genuine partnership frameworks that center Indigenous knowledge, sovereignty, and governance innovations. Extending the integrated methodology developed in Paper 3, the proposed research will create user-friendly, transferable tools that can be applied by land managers, policy makers, and communities across different geographical and political contexts, bridging the gap between sophisticated academic analysis and practical decision-making needs.

Leveraging the remote sensing expertise demonstrated in Paper 2, the proposed research will conduct multi-temporal analysis spanning decades of policy implementation, capturing both immediate policy impacts and long-term landscape transformations. This temporal depth enables understanding of policy lag effects, cumulative impacts, and landscape recovery dynamics while using the comparative framework established across Brazilian and Canadian contexts to develop transferable insights about policy effectiveness across different political systems, ecological contexts, and Indigenous governance relationships.

The proposed PhD research thus represents not merely an application of these comprehensive papers, but a sophisticated synthesis that creates new knowledge at the intersection of Indigenous governance innovation, evidence-based forest policy evaluation, and landscape science. The comprehensive papers provide both the theoretical foundation and the technical capabilities necessary to conduct research that can inform more effective, equitable, and sustainable forest governance approaches that serve both Indigenous communities and broader society through systematic approaches for comparing policy effectiveness across different institutional contexts, legal frameworks, and geographic regions. While maintaining the technical rigor established in the comprehensive papers, the PhD research focuses on creating methodologies and tools that can be accessed and applied by communities and organizations with varying technical capacities.

Research Design Coherence

The three comprehensive papers together establish a research design that is both academically rigorous and practically applicable. Historical and institutional understanding from Paper 1 provides context for contemporary policy challenges and opportunities, while technical analytical capabilities from Paper 2

enable systematic and reproducible analysis across different scales and contexts. The integrated evaluation framework from Paper 3 connects policy intentions with spatial outcomes and stakeholder needs.

This foundation ensures that the PhD research can proceed efficiently while serving the needs of land managers, policy makers, and indigenous communities through the development of practical tools and evidence-based recommendations. The comprehensive examination process has established not only the theoretical foundations but also the practical capabilities necessary for successful completion of this research agenda.

Ethical Considerations and Indigenous Data Sovereignty {#ethics}

Indigenous Data Sovereignty Principles

Research involving Indigenous territories requires careful attention to Indigenous data sovereignty principles, even when utilizing publicly available datasets. Indigenous rights extend beyond data ownership to encompass territorial representation, cultural interpretation, and policy implications that may affect Indigenous communities regardless of data source.

CARE Principles

The research framework embraces **Collective Benefit** by designing research to benefit indigenous communities and ensuring that research outcomes support Indigenous self-determination and land stewardship goals. **Authority to Control** is respected by ensuring indigenous communities maintain meaningful control over how their territories are represented and analyzed, including the right to review and modify interpretations of publicly available data affecting their lands.

The approach emphasizes **Responsibility** by holding researchers accountable to indigenous communities for research conduct, interpretation, and dissemination, while maintaining **Ethics** by aligning research with indigenous values and ethical frameworks, including traditional governance systems and cultural protocols.

OCAP Principles

The research acknowledges **Ownership** by recognizing that indigenous communities have inherent rights to their territories and the knowledge generated about them, while respecting **Control** by allowing communities to control how their territories are represented in research, even when using public datasets.

Access principles ensure that communities determine who can access territory-specific analysis and findings, while **Possession** rights guarantee that communities have the right to possess and control territory-specific data products and analytical outputs.

Public Data Ethics Framework

Risks of Extractive Research with Public Data

Using publicly available satellite imagery and government datasets without Indigenous engagement can lead to significant harm through misinterpretation, such as labeling culturally managed lands as "degraded" or "unused," and harmful policy impacts including conservation policies that restrict Indigenous land use or development policies that ignore traditional governance systems.

The research recognizes that Hansen's Global Forest Change data and MapBiomas datasets, while publicly available, still depict Indigenous territories subject to inherent rights and jurisdiction under UNDRIP and national frameworks. Interpretations and policy recommendations derived from these datasets can significantly impact Indigenous communities, creating ethical obligations regardless of data source.

Legal and Ethical Precedents

Canada's DRIPA (Declaration on the Rights of Indigenous Peoples Act) and Brazil's ongoing Marco Temporal debates demonstrate that even public land-use data can become contested in Indigenous rights cases. Academic best practices increasingly require Indigenous engagement for research affecting Indigenous lands, as reflected in SSHRC and Tri-Council guidelines.

Implementation Strategies

Indigenous Data Sovereignty Protocol for Public Data Research

Even when utilizing publicly available datasets such as Hansen's Global Forest Change and MapBiomas, this research implements a comprehensive protocol that recognizes Indigenous rights extend beyond data ownership to encompass governance over knowledge interpretation and territorial representation.

Prior to conducting any territory-specific analysis, the research will notify affected Indigenous Nations of our intent to study their territories, providing clear information about research objectives, methodologies, and potential outcomes. Sample maps and preliminary analyses will be provided for verification of accuracy and cultural appropriateness, ensuring technical interpretations align with Indigenous knowledge. Meaningful collaboration opportunities will be extended including contextualizing forest change causes, identifying traditional management practices, and contributing local knowledge to improve analytical accuracy.

Indigenous Nations maintain complete authority over their territorial representation in research outputs. If communities identify errors in public data interpretation such as misclassified cultural burns as "deforestation" or traditional harvesting areas as "degraded lands," the research will adjust methodology to incorporate Indigenous knowledge and correct misinterpretations. Indigenous perspectives will be cited in methodological limitations and data interpretation sections, with alternative interpretations documented that reflect traditional land management practices. Indigenous Nations retain complete authority to request their territory be excluded from comparative case studies, spatial analysis, maps, visualizations, interactive tools, policy recommendations, and academic publications without requirement for justification.

Indigenous partners will receive comprehensive review opportunities with drafts of all materials referencing their lands provided with 30-day minimum review windows, extended as needed. Communities may contribute contextual information such as "While satellite data shows X, our traditional knowledge indicates Y..." and will be invited to co-author relevant sections or publications where appropriate. Alternative output formats recognize diverse communication preferences including printed atlases, community workshops, oral presentation summaries, territory-specific reports delivered directly to Indigenous governments, and culturally appropriate materials designed with Indigenous communication protocols.

All processed datasets will be deposited with partner Nations' archives upon request, ensuring long-term community access. Technical documentation will accompany materials explaining analytical methods, limitations, and appropriate applications in plain language. Training will be provided for community members to utilize and modify analytical tools independently. Indigenous communities will maintain perpetual rights to ongoing access to updated analyses and technical support, authority to request changes

to analytical parameters or interpretations, and control over how territory-specific data products are shared or distributed.

If meaningful engagement is not achieved despite systematic outreach efforts, research findings will include explicit statements such as "This analysis used publicly available data without Indigenous validation; results should be interpreted cautiously." Methodological limitations will be clearly documented when Indigenous knowledge is unavailable, with conservative interpretation of results affecting Indigenous territories without community input. A formal process will enable communities to submit corrections to published materials with commitment to rapid response, request removal of contested content from publicly accessible platforms, and maintain communication channels for continued feedback and relationship building.

The research framework maintains respect for confidential traditional knowledge while requiring community approval for all territory-specific dissemination activities. Attribution and recognition of indigenous contributions will be prioritized, along with protection of intellectual property rights. Communities can opt out of being named in case studies or request specific territorial boundaries to be excluded from analysis. Where communities decline collaboration, territories will be excluded from analysis or included only with clear disclaimers indicating non-endorsement. Analysis will include Indigenous perspectives on land management practices, avoiding mischaracterization of traditional land use as degradation or abandonment.

Indigenous partners may participate in research design, data interpretation, and output development through co-development approaches where territory-specific tools and resources are developed collaboratively, with communities maintaining control over analytical products. Alternative engagement levels include consultation models where communities review public data analysis and provide feedback on interpretations before publication, notification approaches where communities are informed of research activities and provided with territory-specific results, or territorial exclusion where communities decline engagement and territories are excluded from analysis entirely.

The methodology incorporates Indigenous data sovereignty principles through community-controlled research protocols, with communities determining their level of engagement from full collaboration to territorial exclusion. The research framework ensures that even public data analysis respects Indigenous rights and territorial jurisdiction through flexible engagement that accommodates various levels of community engagement while maintaining ethical standards, community control over territory-specific interpretations and analytical products, and benefit sharing through practical tools, policy advocacy, and capacity building initiatives designed to serve Indigenous communities.

Data and Knowledge Products

Open data repositories will make processed datasets available for ongoing research and management, while documentation standards will establish protocols for ethical data sharing and community benefit. Analytical databases will provide structured information systems supporting ongoing policy analysis, complemented by monitoring protocols that standardize approaches for long-term land cover monitoring.

These outcomes are designed to ensure that research benefits extend beyond academic publication to create lasting value for land managers, policy makers, and indigenous communities. All tools and resources will be developed with accessibility and transferability as core principles, ensuring broad applicability across diverse institutional contexts.

Conclusion

This proposal represents a responsible approach to investigating forest policy and land management through an indigenous-centered lens while ensuring robust academic outcomes and practical impact for diverse stakeholders. The research framework explicitly addresses Indigenous data sovereignty principles, recognizing that even publicly available data requires careful attention to Indigenous rights and territorial jurisdiction.

By integrating insights from three comprehensive exam papers with evidence-based analytical methods and Indigenous data sovereignty principles, this project will generate valuable knowledge and practical tools for land managers, policy makers, and indigenous communities. The ethical framework ensures that research benefits Indigenous communities while avoiding extractive research practices that can harm Indigenous interests.

The 24-month timeline is designed to be feasible while maintaining both analytical rigor and ethical standards, focusing on 4-6 case studies that enable meaningful comparison and transferable insights. The flexible engagement model accommodates various levels of community participation while respecting Indigenous autonomy and territorial rights.

The emphasis on Indigenous-governed tool development, culturally appropriate methodologies, and evidence-based policy recommendations ensures that research outcomes will have lasting positive impacts across multiple user communities while supporting Indigenous self-determination and land stewardship goals. This approach recognizes indigenous communities as essential partners in research rather than subjects of study, creating frameworks for respectful collaboration that can inform future research practices.

The project's success will be measured through academic outputs, practical tool development, contributions to evidence-based policy making, and most importantly, the extent to which research outcomes support Indigenous land rights, self-determination, and traditional governance systems. This balanced approach represents effective, ethical environmental research that serves Indigenous communities while maintaining academic rigor and practical applicability for broader land management applications.

This approach recognizes indigenous communities as important knowledge holders while creating robust analytical frameworks that can inform land management decisions regardless of direct community participation levels. The integration of policy analysis, remote sensing capabilities, and comparative evaluation represents a methodological innovation that can contribute to both academic understanding and practical land management applications.

The project's success will be measured through academic outputs, practical tool development, and contributions to evidence-based policy making. The research design ensures valuable outcomes for indigenous self-determination, conservation efforts, and the strengthening of land management capacity across diverse institutional contexts. This balanced approach represents effective, ethical environmental research that serves multiple communities while maintaining academic rigor and practical applicability.
