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

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, 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.

Expected Outcomes and Impact

This research will produce valuable outcomes for Indigenous communities, land managers, policymakers, and the academic community. The project aims to deliver transparent practical tools and evidence-based insights with a lasting impact.

Primary Deliverables:

This research will produce land cover change layers 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.

The research will generate evidence-based policy recommendations through a comprehensive analysis of forestry land management practices and indigenous land protection policies in both countries. The analysis will produce guidelines for strengthening 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 a visual record of landscape transformations over time. Interactive Sankey diagrams will illustrate land cover transitions, while comparative visualizations demonstrate policy impacts across different territories and periods. Time-series animations will capture patterns of forest cover change, making complex analytical results accessible to diverse audiences.

The research will create an open-source analytical framework for replicating and adapting methodology in different contexts. It will feature Python processing pipelines for large-scale remote sensing data, as well as database schemas and data management protocols, for efficient organization and accessibility. Statistical analysis scripts and detailed documentation will ensure transparency, while quality assurance and validation procedures will deliver reliable results to support land management decisions.

Academic Contributions:

The research will result in three peer-reviewed publications addressing land governance and conservation outcomes, land use change remote sensing methodologies, and comparative policy analysis. A comprehensive PhD thesis will integrate all three comprehensive exam papers with methodological innovations and policy recommendations. Methodological documentation, including technical reports and white papers, will describe analytical approaches and tool development.

Direct engagement with policymakers and communities in Brazil and British Columbia will ensure that research findings and recommendations reach policymakers and community leaders. At the same time, contributions to international forums will contribute to global discussions about Indigenous rights and land management through international conferences and policy networks. Evidence-based resources will support indigenous land rights and self-determination efforts through advocacy channels.

The research may guide training programs for geospatial analysis techniques, land monitoring, and policy assessment. At the same time, partnership development will show ongoing research relationships that facilitate long-term land monitoring and management activities.

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. At the same time, 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 limitations that affect the analysis and results. Misclassifications in source datasets, such as Hansen's Global Forest Change and MapBiomas, require validation and uncertainty assessments. Annual snapshots may overlook seasonal changes, short-term disturbances, or quick recovery

patterns within a year. Additionally, a 30-meter resolution might miss fine-scale degradation, edge effects, or small management interventions. The satellite analysis only covers the period from 1985 to now, missing earlier policy impacts and long-term baselines.

A thorough analysis demands significant computational resources, ideally 32 GB or more RAM, along with specialized technical skills. Land cover class boundaries may change over time, necessitating careful interpretation of transition patterns. Ground-truth data for validation is often limited, especially in remote regions and historical contexts. Additionally, the quality and accessibility of policy documentation can vary widely across different areas and periods.

Establishing causal links between policies and land cover changes requires careful assessment of confounding factors and alternative explanations. Effects can vary by location and may have time delays, necessitating extended periods of observation. Local environmental, economic, and social conditions can also affect policy effectiveness beyond the design itself.

This research employs systematic accuracy assessment and uncertainty quantification, integrating multiple datasets and methodologies to validate its findings. It uses appropriate statistical methods to manage uncertainty and control confounding variables, with thorough documentation of methods, limitations, and assumptions to ensure transparency.

We developed a test computational model and validated its feasibility using MapBiomas Collection 9 data focused on Brazilian Indigenous territories. The framework consists of a 1,205-line Python script, available under the MIT license. Initial processing for 138 territories took 70 minutes on a desktop, demonstrating efficiency. It can handle regions of up to 800x800 km with a 30-meter resolution. Complete technical documentation, including processing architecture, validation procedures, and visualization capabilities, is available on GitHub 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 collectively represent a sophisticated progression from policy analysis theory to technical spatial analysis capabilities and the development of integrated methodologies, which directly inform 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 a particular focus on the evolution of policies from resource extraction to sustainability paradigms. This paper presents a framework for understanding policy boundaries based on geographical scope, stakeholders, and historical context. It highlights how colonial legacies impact modern forest governance, particularly the dispossession of Indigenous peoples and the preference for European legal systems over customary laws.

The study examines the interaction between Indigenous land rights and formal legal systems, using comparative analysis from Australia, Brazil, Canada, and South Africa to explore the opportunities and challenges of legal pluralism. It also considers policy drivers, including ecological issues, economic factors, international agreements, and shifting social values related to climate change.

A multi-stakeholder behavioural analysis identifies forest owners as key providers of ecosystem services, with their reactions to policy changes differing based on whether they are "optimizers" or "traditionalists." The framework encompasses interest groups that influence policy, including governments, local communities, Indigenous populations, the forest industry, financial institutions, and consumer behaviour.

Methodologically, the paper employs historical trajectory analysis to trace the development of policy from European settlement through industrialization to modern environmental awareness. This systematic approach combines document reviews, stakeholder interviews, spatial data analysis, and examination of historical context.

Finally, the paper outlines a framework for evaluating policy objectives, distinguishing between explicit goals, such as economic efficiency, and implicit societal values. It addresses implementation challenges, including bureaucratic inertia and the disconnect between ecological changes and political cycles, emphasizing that successful policy requires effective implementation, public support, enforcement, and ongoing adaptation.

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 a multi-decadal archive, MODIS with 250-1000m resolution and high temporal frequency, as well as SPOT, Sentinel-3, PROBA-V, and AVHRR systems. The technical foundation emphasizes advanced remote sensing preprocessing techniques, including geometric correction, radiometric calibration, atmospheric correction, and temporal normalization, which are crucial for consistent time-series analysis.

The methodological contributions feature sophisticated classification algorithms, such as Random Forest, Classification and Regression Trees, and Neural Networks for supervised learning, along with unsupervised approaches. The paper enhances time-series analysis with temporal segmentation methods, such as LandTrendr, spectral trajectory analysis, and change detection, for capturing disturbances and recovery.

It showcases expertise in integrating diverse data sources, including satellite imagery, ground surveys, aerial photography, and LiDAR, as well as databases on disturbances and socioeconomic factors. Validation methods include ground truthing, accuracy assessment through confusion matrices, and comparisons with reference datasets. The framework addresses data quality issues, such as cloud cover and atmospheric interference, providing robust interpretation techniques for translating imagery into land-use information.

Additionally, the work demonstrates proficiency in cloud computing platforms, such as Google Earth Engine and NASA Earth Exchange, for processing large datasets and automating workflows.

The paper also reviews ready-to-use land change products from sources like Hansen's Global Forest Change, Copernicus Climate Change Service land cover maps, Global Forest Watch, and TerraClass for the Brazilian Amazon. It covers change detection for monitoring deforestation, degradation, and recovery, including the impact of policy interventions. The methodological framework is designed for multiple spatial and temporal scales, addressing applications from local 30m Landsat resolution to regional 300m and global 1km scales, with 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 builds upon the individual contributions of the first two papers to create a comprehensive framework for policy-landscape analysis, bridging theoretical policy analysis with technical spatial data capabilities.

The paper develops systematic approaches for linking policy analysis with spatial data analysis using GIS tools. It presents a framework for analyzing the impacts of various policy interventions on landscape outcomes, utilizing techniques such as spatial correlation, land-use change modelling, and policy boundary mapping. It identifies cause-and-effect relationships, aligning the analysis with the timing of policy implementations to detect their impacts. The approach includes scenario-based evaluations that integrate climate projections and land-use dynamics while addressing potential unintended consequences, such as income support leading to production on sensitive lands.

Three distinct forest governance contexts are examined through comparative case studies: the Brazilian Amazon, with a focus on the PPCDAm and its 66% reduction in deforestation from 2004 to 2015; the Brazilian Atlantic Forest, which faces significant degradation; and British Columbia, highlighting the shift from timber extraction to sustainable management. These case studies illustrate how various policies, historical contexts, socioeconomic factors, and Indigenous rights influence land-use outcomes, employing strategies such as command-and-control regulations and multi-stakeholder engagement.

The paper also emphasizes the importance of incorporating Indigenous land rights and customary laws into forest management policies. It examines how colonial legacies have influenced policy effectiveness and advocates for integrating Indigenous knowledge into policy frameworks to achieve better outcomes.

Additionally, comprehensive tools for analyzing policy coherence and effectiveness are developed. This includes identifying policy gaps, evaluating policy mixes across sectors, and assessing coherence between policies. The framework evaluates the intended and unintended consequences of policies, stakeholder engagement, and long-term landscape impacts while considering international influences from agreements such as the UN SDGs and the Paris Agreement.

Synthesis and Innovation for PhD Research

This research combines policy analysis frameworks with spatial data techniques to assess the effectiveness of policies at local, regional, and global levels. It integrates qualitative stakeholder analysis with quantitative remote sensing to comprehensively assess impacts.

The focus is on co-producing Indigenous-centered knowledge that respects customary law and land rights, moving away from extractive research models toward genuine partnerships that prioritize Indigenous knowledge and governance. The aim is to develop accessible tools for land managers, policymakers, and communities, bridging the gap between complex academic analysis and practical decision-making.

Building on remote sensing expertise, the research will analyze decades of policy implementation to capture both immediate impacts and long-term changes. This approach allows for an understanding of policy lag effects, cumulative impacts, and landscape recovery. Insights will be drawn from both Brazilian and Canadian contexts to offer lessons on policy effectiveness across various political systems and environmental settings.

Overall, this PhD research synthesizes findings from comprehensive papers to create new knowledge at the intersection of Indigenous governance, evidence-based forestry policy, and landscape science. It aims to develop methodologies that are accessible to communities and organizations with varying technical capabilities, promoting more effective and sustainable forest governance that benefits both Indigenous communities and society as a whole.

Ethical Considerations and Indigenous Data Sovereignty

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 impact Indigenous communities, regardless of the data source.

CARE Principles

The research framework prioritizes **Collective Benefit** by designing research that benefits Indigenous communities and ensures research outcomes support Indigenous self-determination and land stewardship goals. **Authority to Control** is respected by ensuring that 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 that affect 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. At the same time, **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 labelling 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 acknowledges that Hansen's Global Forest Change data and MapBiomas datasets, although publicly available, still depict Indigenous territories as subject to inherent rights and jurisdiction under the

UNDRIP and national frameworks. Interpretations and policy recommendations derived from these datasets can significantly impact Indigenous communities, creating ethical obligations regardless of the data source.

Legal and Ethical Precedents

Canada's DRIPA (Declaration on the Rights of Indigenous Peoples Act) and Brazil's ongoing debates over the Marco Temporal 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.

Sovereignty Implementation Strategies

"Indigenous and First Nations data sovereignty: is the concept of First Nations authority, right, power to govern as sovereign Nations and make decisions or laws on the ownership, control, collection, access, analysis, application, possession and use of their own data". Indigenous data sovereignty "is linked with Indigenous peoples' right to maintain, control, protect and develop their cultural heritage, Traditional Knowledge and traditional cultural expressions, as well as their right to maintain, control, protect and develop their intellectual property over these." (The First Nations Data Governance Strategy, 2020)

The Indigenous Data Sovereignty ensures that Indigenous rights encompass governance over knowledge interpretation and territorial representation, even when utilizing publicly available datasets, such as Hansen's Global Forest Change and MapBiomas. Before analyzing specific territories, we will inform affected Indigenous Nations about our research intentions, objectives, methodologies, and potential outcomes. We will provide sample maps and preliminary analyses for accuracy verification and cultural appropriateness.

Indigenous Nations control their territorial representation in research outputs. If they identify errors, such as misclassifying cultural burns as deforestation, we will adjust our methodology to incorporate their knowledge. Indigenous perspectives will be incorporated into our methodology and data interpretation sections if offered by representatives. Communities can opt to exclude their territories from analysis, maps, and publications without justification.

Indigenous partners may review drafts referencing their lands with a 30-day minimum window for feedback. They can contribute contextual information and co-author relevant sections as needed. We will offer a diverse range of output formats, including printed atlases and territory-specific reports. Processed datasets will be archived for community access, accompanied by technical documentation in plain language. We may provide training to enable community members to use and modify analytical tools, ensuring they have ongoing access to updated analyses and support.

If meaningful engagement fails despite outreach efforts, we will clearly state that results used publicly available data without Indigenous validation. We will document methodological limitations when Indigenous knowledge is absent, and a formal process will be in place to allow communities to submit corrections and request the removal of contested content. We will protect traditional, confidential knowledge and require community approval for the dissemination of territory-specific information. Attribution of Indigenous contributions is a priority, and communities may opt out of being named in case studies. When collaboration is declined, we will exclude those territories or include disclaimers indicating non-endorsement, ensuring that Indigenous land management practices are accurately represented. Communities will have the opportunity to participate in research design, data interpretation, and output development through collaborative approaches, maintaining control over the analytical products.

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 shall ensure that research benefits extend beyond academic publication, creating lasting value for land managers, policymakers, 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 outlines a responsible approach to forest policy and land management through a geospatial information lens, ensuring robust academic and practical outcomes for diverse stakeholders. It prioritizes Indigenous data sovereignty, open-source tools, and open data.

By integrating insights from forestry policies and land-use analysis and employing evidence-based methods, this project aims to produce valuable knowledge and practical tools for land managers, policymakers, and Indigenous communities. The ethical framework ensures that research benefits forestry-related communities.

The 24-month timeline targets 4-6 case studies for meaningful comparison and transferable insights while allowing flexibility in community participation and respecting Indigenous autonomy. We focus on the development of fair tools, culturally appropriate methodologies, and evidence-based recommendations to promote lasting, positive impacts.

Success will be measured through academic outputs, practical tool development, contributions to evidence-based policymaking, and support for sustainable forestry management and Indigenous rights and self-determination. This approach fosters respectful collaboration and creates frameworks that enhance land stewardship and collaborative knowledge while maintaining academic rigour and practical relevance.