UNIVERSITÉ DU QUÉBEC EN ABITIBI-TÉMISCAMINGUE

EFFETS CUMULATIFS DES CHANGEMENTS ENVIRONNEMENTAUX SUR LA VALEUR DES PAYSAGES AUTOCHTONES EN ZONE BORÉALE

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À ma famille, que j'aime

AVANT-PROPOS

Cette thèse présente les travaux de recherche que j'ai réalisés dans le cadre du doctorat en sciences de l'environnement à l'Université du Québec en Abitibi-Témiscamingue (UQAT). Elle a été effectuée en collaboration avec le *Conseil de la Première Nation Abitibiwinni* et *Ouje-Bougoumou Cree Nation*. Il s'agit d'une thèse par articles, qui comprend une introduction générale (Chapitre I), quatre articles scientifiques (Chapitres II à V) et une conclusion générale (Chapitre VI).

L'introduction et la conclusion sont rédigées en français, alors que les articles scientifiques, qui s'adressent à un lectorat international, sont rédigés en anglais. Les articles sont appelés à être publiés dans des revues scientifiques. Le lecteur y trouvera quelques répétitions, particulièrement dans la présentation du contexte de l'étude. Les articles ont été écrits en collaboration avec des co-auteurs de diverses institutions d'enseignement et de recherche et avec des membres des communautés autochtones partenaires. Je suis première auteure de chacun d'eux et j'ai été responsable de chacune des étapes menant à leur réalisation : conception et design de la recherche, développement des outils de collecte de données, collecte et analyse des données, validation et transfert auprès des partenaires, rédaction et publication.

L'introduction générale (Chapitre I) présente le contexte et les objectifs de l'étude, le positionnement conceptuel, les particularités de l'aire d'étude et l'approche méthodologique choisie. Elle présente les lignes directrices du projet de recherche et établit la continuité et la cohérence des articles entre eux.

Le Chapitre II, *From landscape practices to ecosystem services: landscape valuation in Indigenous contexts*[1], a été publié dans la revue *Ecological Economics*. Il a été co-écrit avec Alice Wapachee, partenaire de la Nation Crie d'Oujé-Bougoumou, et Hugo Asselin, professeur à l'UQAT et directeur de recherche.

Le Chapitre III, *Indigenous and scientific perspectives on environmental changes in boreal landscapes: toward knowledge reconciliation*, est en révision pour publication dans la revue *People and Nature*. Il a été réalisé en collaboration avec Sylvie Gauthier, chercheuse scientifique à Ressources naturelles Canada, et Hugo Asselin.

Le Chapitre IV, *A collaborative typology of boreal Indigenous landscapes*[2], a été publié dans la revue *Canadian Journal of Forest Research*. Il a été co-écrit avec Hugo Asselin.

Le Chapitre V, *Indigenous knowledge, forest landscape simulations and the cumulative effects of environmental changes*, n'a pas encore été soumis pour publication. Il a été réalisé en collaboration avec Chrystal Mantyka-Pringle, biologiste à la Wildlife Conservation Society Canada et professeure associée à l'Université de la Saskatchewan, Yan Boulanger, chercheur scientifique à Ressources naturelles Canada, Benoit Croteau, *Directeur territoire et environnement* pour la Première Nation Abitibiwinni, Louis-Joseph Drapeau, étudiant à la maîtrise à l'UQAT, Mélanie Desrochers, professionnelle de recherche au Centre d'étude de la forêt, et Hugo Asselin.

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[1] Bélisle, A. C., A. Wapachee, et H. Asselin. 2021. From landscape practices to ecosystem services: Landscape valuation in Indigenous contexts. Ecological Economics 179:106858.

[2] Bélisle, A. C., et H. Asselin. 2021. A collaborative typology of boreal Indigenous landscapes. Canadian Journal of Forest Research. https://doi.org/10.1139/cjfr-2020-0369.

La conclusion générale (Chapitre VI) fait un retour sur les objectifs, présente les principales contributions de cette recherche et discute des perspectives.

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A	Abitibiwinni
Ab	Abundance (Abondance)
Ac	Access (Accès)
CC	Climate change (Changement climatique)
BN	Bayesian network (Réseau bayésien)
CanESM	Canadian Earth System Model version 2 (Modèle canadien du système terrestre de deuxième génération)
Dim	Dimension
Dist	Disturbance level (Degré de perturbation)
DPSI(R)	Driver Pressure State Impact (Response) (Force motrice, Pression, État, Impact (Réponse))
Ex	Experience (Expérience)
F	Forestry (Foresterie)
Ind	Indigenous (Autochtone)
IPCC (GIEC)	Intergovernmental Panel on Climate Change (Groupe d'experts intergouvernemental sur l'évolution du climat)
maxAGB	Maximum Aboveground Biomass (Biomass aérienne maximale)
maxANPP	Maximum Aboveground Net Primary Productivity (Productivité primaire aérienne nette)
n	Number of (Nombre de)
O	Ouje-Bougoumou (Oujé-Bougoumou)
OCAP	Ownership, Control, Access and Possession (Propriété, Contrôle, Accès et Possession)
PCA	Principal Component Analysis (Analyse en composantes principales)
Qu	Quality (Qualité)

RCP	Representative Concentration Pathway (Profils représentatifs d’évolution de concentration)
Sci	Scientific (Scientifique)
SEP	Species Establishment Probability (Probabilité d’établissement d’espèce)
SQL	Structured Query Language (Langage de requête structurée)
SSI	Simple structure index (Indice simple de structure)
Veg	Hunting ground vegetation type (Type de végétation d’un terrain de trappe)
UQAT	Université du Québec en Abitibi-Témiscamingue

LISTE DES SYMBOLES ET DES UNITÉS

A	Amplitude of change (Amplitude du changement)
A_{max}	Maximum amplitude of change (Amplitude maximale du changement)
h	Hour (Heure)
ha	Hectare
km	Kilometer (Kilomètre)
min	Minute
i	Incidence
Σi_{inf}	Influence
Σi_{sus}	Susceptibility (Susceptibilité)
t	Simulation time (Temps de simulation)
$t_{0.5max}$	Simulation time required to reach half A_{max} (Temps de simulation requis pour atteindre la moitié de A_{max})
ΔP	Probability difference with the reference scenario at time t (Écart de probabilité avec le scenario de référence au temps t)
°C	Celsius degree (Degré Celsius)

RÉSUMÉ

Les paysages boréaux se transforment sous l'effet des changements climatiques et de l'exploitation des ressources naturelles. Les peuples autochtones, qui entretiennent une relation étroite au territoire, sont exposées à ces changements qui affectent plusieurs aspects de leur vie. La mise en commun des savoirs autochtones et scientifiques peut contribuer à mieux comprendre les effets des changements et à en limiter les conséquences. Cette recherche a été réalisée en partenariat avec la communauté anicinape de Pikogan (Première Nation Abitibiwinni) et la communauté crie d'Oujé-Bougoumou (*Ouje-Bougoumou Cree Nation*). Toutes deux ont leur territoire situé en forêt boréale au Québec. L'objectif principal était d'analyser les effets cumulatifs des changements environnementaux sur les paysages boréaux depuis la frontière entre les systèmes de connaissances autochtones et scientifiques. Les objectifs spécifiques étaient de (1) conceptualiser la valeur des paysages autochtones et ses déterminants; (2) concevoir un « objet frontière » qui fait le pont entre les perspectives autochtone et scientifique; (3) faire le portrait de l'état actuel du territoire; (4) mettre en commun les projections d'un modèle de simulation des paysages forestiers et les savoirs d'experts autochtones dans un modèle probabiliste; et (5) projeter les effets cumulatifs des changements environnementaux sur la valeur des paysages autochtones.

La méthodologie est de type séquentiel mixte. D'abord, des données qualitatives ont été recueillies à partir d'entrevues semi-dirigées et d'exercices de cartographie participative avec les experts autochtones de l'utilisation du territoire des deux communautés partenaires. Des analyses thématiques ont fait émerger un cadre d'analyse de la valeur des paysages. Les données terrain ont ensuite été combinées à des données bibliométriques afin de synthétiser les perspectives autochtone et scientifique sous la forme de modèles conceptuels de type *Driver Pressure State Impact* (DPSI). Des indicateurs quantitatifs de l'état du territoire ont été développés et utilisés pour construire une typologie des terrains de trappe familiaux. Enfin les paysages forestiers ont été simulés selon divers scénarios de foresterie et de changements climatiques dans le modèle de simulation des paysages forestiers LANDIS-II. Les projections ont été soumises au jugement des experts autochtones de l'utilisation du territoire lors d'ateliers d'élicitation de probabilités conditionnelles. Les projections du modèle et les jugements d'experts ont été intégrés dans un réseau bayésien.

Les résultats sont présentés dans quatre articles scientifiques (Chapitres II à V). Le cadre d'analyse développé aborde la valeur des paysages en fonction de son potentiel à soutenir les pratiques importantes pour les communautés : la chasse à l'orignal, la chasse à l'outarde, la pêche, la trappe, le ressourcement et l'éducation (Chapitre II). La valeur du paysage y est décrite en quatre dimensions, soit l'abondance des ressources, l'accès au territoire, la qualité des ressources et l'appréciation de l'expérience vécue sur le territoire.

Les convergences et les complémentarités entre les perspectives autochtone et scientifique ont été identifiées en comparant les modèles DPSI (Chapitre III). L'influence de la récolte ligneuse, de la sylviculture et des changements dans la répartition des espèces, ainsi que la structure d'âge de la forêt, la santé de la faune et la qualité de l'eau sont ressortis comme des intérêts convergents. Un intérêt plus grand pour les effets des mines, des lignes à haute-tension et des chemins forestiers est ressorti du modèle autochtone. Un intérêt plus grand pour les changements climatiques, les incendies forestiers, l'état des sols forestiers et la diversité biologique est ressorti du modèle scientifique.

Quatre types de terrains de trappe ont été décrits à partir d'indicateurs quantitatifs (Chapitre IV). Les indicateurs comprennent par exemple la proportion de forêts matures, la densité du réseau routier et la proportion de forêts issues de reboisement. La typologie indique que les stratégies d'aménagement du territoire tendent à creuser les écarts entre l'état des terrains de trappe familiaux au sein d'une même communauté.

Les projections du modèle LANDIS-II indiquent que sous les effets cumulatifs des changements environnementaux, les paysages font face à une transition rapide vers des forêts plus jeunes et plus feuillues (Chapitre V). Les changements sont attribuables à l'action combinée des changements climatiques, de la récolte ligneuse et de l'augmentation de l'activité des incendies forestiers dans certaines régions. L'abondance des animaux à fourrure pour la trappe (particulièrement de la martre), de l'orignal pour la chasse et des lieux de ressourcement seraient parmi les valeurs les plus vulnérables.

Les contributions de cette recherche à l'avancement des connaissances s'inscrivent dans trois domaines des sciences de l'environnement. (1) Le cadre d'analyse de la valeur des paysages développé est à la fois cohérent avec les préoccupations et savoirs des communautés et assez général pour guider d'autres recherches et études d'impacts dans des contextes similaires. (2) Cette recherche contribue au développement de la recherche collaborative en contexte autochtone. L'originalité des travaux réside dans la combinaison des approches et des méthodes, notamment le développement des perspectives et la cocréation des connaissances. (3) La méthode développée pour

évaluer les effets cumulatifs des changements environnementaux en mettant en commun les savoirs autochtones et scientifiques est originale et novatrice. Elle ouvre la voie à une intégration plus riche de diverses formes de connaissances dans les modèles environnementaux.

Les résultats présentés sont utiles aux communautés autochtones pour guider la mise en place de mesures d’atténuation et d’adaptation. Ils mettent en évidence l’importance de considérer l’échelle du terrain de trappe dans l’aménagement du territoire et appuient la nécessité de diminuer l’influence de la foresterie sur les paysages. Ces travaux encouragent l’engagement des institutions autochtones et de recherche dans des partenariats et suggèrent quelques éléments facilitant la collaboration.

Mots clés : Valeur des paysages, recherche collaborative, savoirs autochtones, effets cumulatifs, perturbations, changement climatique, forêt boréale, peuples autochtones

ABSTRACT

Climate change and the exploitation of natural resources transform boreal landscapes. Indigenous peoples have a close relationship with the land and several aspects of their life are affected by environmental changes. Combining Indigenous and scientific knowledge can help better understand the effects of environmental changes and limit their consequences. This research was carried out in partnership with the Anishnaabe community of Pikogan (*Conseil de la Première Nation Abitibiwinni*) and the Cree community of Ouje-Bougoumou (Ouje-Bougoumou Cree Nation). Both have their territory located in boreal Quebec. The general objective was to assess the cumulative effects of environmental changes on boreal landscapes, from the boundary between Indigenous and scientific knowledge systems. The specific objectives were to (1) conceptualize Indigenous landscape value and its determinants; (2) design a "boundary object" that bridges the Indigenous and scientific perspectives; (3) portray the current state of the land; (4) pool the projections of a forest landscape simulation model and the knowledge of indigenous experts into a probabilistic model; and (5) project the cumulative effects of environmental changes on Indigenous landscape value.

The research methodology is mixed and sequential. First, qualitative data were collected using semi-structured interviews and participatory mapping exercises with Indigenous land-use experts from the two partner communities. A framework for analyzing Indigenous landscape value emerged from thematic analysis. Second, field data were combined with bibliometric data to synthesize Indigenous and scientific perspectives of environmental changes using Driver Pressure State Impact (DPSI) conceptual models. Third, quantitative indicators of the state of the land were developed and used to develop a typology of family hunting grounds. Fourth, forest landscapes were simulated under various forestry and climate change scenarios in the forest landscape simulation model LANDIS-II. Conditional probability elicitation workshops were performed with Indigenous land-use experts. Model projections and expert judgments were integrated into a Bayesian network.

The results are presented within four scientific articles (Chapters II to V). The landscape valuation framework is based on the potential to support practices that are important for communities: moose hunting, goose hunting, fishing, trapping, *ressourcement* and education (Chapter II). Landscape value is described along four dimensions: the abundance of resources, access to the land, the quality of resources and the appreciation of the experience on the land.

Convergences and complementarities between the Indigenous and scientific perspectives were identified by comparing the DPSI models (Chapter III). The influence of timber harvesting, silviculture and changes in species distribution, as well as forest age structure, wildlife health, and water quality, were converging interests. Greater interest in the effects of mines, power lines, and roads characterized the Indigenous perspective. Greater interest in the effects of climate change, wildfires, soil condition, and biological diversity characterized the scientific perspective.

Four types of hunting grounds have been described using quantitative indicators (Chapter IV). Indicators included, for example, the proportion of mature forests, the density of the road network, and the proportion of forests resulting from reforestation. The typology indicates that land management strategies tend to widen the gaps between the states of family hunting grounds within a community.

Projections from the LANDIS-II model indicate that under the cumulative effects of environmental changes, landscapes face a rapid transition toward younger and more deciduous forests (Chapter V). The changes are due to the combined action of climate change, timber harvesting, and increased wildfire activity. The abundance of fur-bearers (especially marten), moose, and places of *ressourcement* appear to be the most vulnerable values.

The contributions of this research fall within three areas of environmental sciences. (1) The landscape valuation framework is both consistent with the concerns and knowledge in the Indigenous communities and general enough to guide other research and impact assessments in similar contexts. (2) This research contributes to the development of collaborative research in Indigenous contexts. The originality lies in the combination of approaches and methods, in particular the development of perspectives, the co-creation of knowledge. (3) The method developed to model the cumulative effects of environmental changes by combining Indigenous and scientific knowledge is original and innovative. It paves the way for a richer integration of various forms of knowledge in environmental models.

The results are useful to Indigenous communities, to guide the implementation of mitigation and adaptation measures. They highlight the importance of considering the hunting ground level in land management and the need to reduce the influence of forestry on boreal landscapes. This work encourages the engagement of Indigenous and research institutions in partnerships and provides some guidelines to facilitate collaboration.

Key words : Landscape value, Collaborative research, Indigenous knowledge, Cumulative effects, Disturbances, Climate change, Boreal forest.

CHAPITRE I

INTRODUCTION

1.1 Contexte

Des changements environnementaux sans précédent affectent les écosystèmes de la planète (Lewis et Maslin, 2015). Les changements climatiques, l'exploitation des ressources naturelles et le changement d'utilisation des terres transforment les paysages et ont des effets directs et immédiats sur les populations locales (IPBES, 2019). Leurs interactions créent des dynamiques complexes, non linéaires, dont les effets sont difficiles à anticiper (Chapin *et al.*, 2004; Lenton *et al.*, 2008; Liu *et al.*, 2007). Les peuples autochtones sont souvent les plus exposées aux changements environnementaux, qui affectent directement plusieurs facettes de leur vie (Ford, 2012; Parlee *et al.*, 2012; Turner et Clifton, 2009).

En zone boréale, les changements climatiques transforment les paysages (Gauthier *et al.*, 2015a). Les frontières écologiques se déplacent (Girard *et al.*, 2008; Scheffer *et al.*, 2012), et la fréquence des événements extrêmes augmente (Gaboriau *et al.*, 2020; Wang *et al.*, 2020). Des changements dans les régimes des perturbations, notamment des incendies forestiers, accentuent l'amplitude et la vitesse des changements (Boulanger *et al.*, 2017; Brice *et al.*, 2019; Price *et al.*, 2013). L'aménagement forestier pour la récolte ligneuse a pour effet de rajeunir et d'homogénéiser les paysages (Bergeron *et al.*, 2002; Cyr *et al.*, 2009), de les fragmenter (Kneeshaw *et al.*, 2010) et de réduire la biodiversité associée aux vieilles forêts (Shorohova *et al*., 2011; Tremblay *et al*., 2018). L'industrie minière contribue à l'industrialisation et l'urbanisation du territoire (Frenette, 1985; Mclean, 2016). Les chemins de fer et les routes construits pour transporter le minerai sont des vecteurs de transformation du territoire (Asselin, 2011; Forbes *et al*., 2004). Les parcs à résidus et les sites miniers ont souvent été laissés à l'abandon (Ministère de l'Énergie et des Ressources naturelles du Québec, 2019) et sont une source de pollution de l'eau et des sols (Johnson, 2003; Little *et al*., 2020; Sprague et Vermaire, 2018; Tsuji *et al*., 2007).

Les changements environnementaux qui ont cours en zone boréale affectent la qualité de vie et la santé physique et mentale des peuples autochtones (Downing et Cuerrier, 2011; Fuentes *et al*., 2020; Saint-Arnaud, 2009). Des feux plus fréquents et plus grands menacent la santé et la sécurité des populations (Asfaw *et al*., 2019; Landis *et al*., 2018) et en forcent le déplacement pour accomplir leurs activités culturelles et de subsistance (Morarin, 2020). La hausse des températures retarde la formation de la glace et contraint l'accès au territoire à l'automne et au printemps (Brinkman *et al*., 2016; Royer et Herrmann, 2013). La foresterie influence la répartition d'espèces aux fonctions de subsistance et culturelles, telles que l'orignal (*Alces americanus, MOS, muus*) [3] (Jacqmain *et al*., 2008; Tendeng *et al*., 2016), la martre d'Amérique (*Martes americana, 8APiCECi, Waapishtaan*) (Cheveau, 2010; Suffice *et al*., 2017), le caribou (*Rangifer tarandus caribou, ATiK, atihkw*) (Rudolph *et al*., 2012) et le pin blanc *(Pinus strobus, CiK8ATiK, uschisk*) (Uprety *et al*., 2017). Des préoccupations quant à la salubrité de

[3] Les noms d'espèces sont présentés en français, en latin, en Anicinapemowin et en Cri (Iyniw-ayamiwin). Les traductions proviennent de différentes sources, incluant des notes terrain, un lexique développé dans le cours Introduction aux langues algonquiennes LIN4010 UQAT (hiver 2019) et des ouvrages de référence (Couture 2012, Salt *et al*. 2012)

l'eau et du gibier à proximité des sites miniers sont aussi soulevées par les communautés (Bordeleau *et al*., 2016; Bussières *et al*., 2004; Tsuji *et al*., 2007).

Les communautés autochtones sont appelées à se prononcer sur les activités qui ont cours sur leur territoire. Elles doivent également mettre en place des mesures de mitigation et d'adaptation pour limiter les effets délétères des changements environnementaux. Or, ces décisions sont prises dans un contexte d'incertitude élevée quant aux changements anticipés. En effet, les paysages boréaux sont des systèmes complexes qui comprennent des relations non linéaires, seuils et points de bascule (Filotas *et al*., 2014; Scheffer *et al*., 2012). La réponse de ces systèmes, exposés à des stress multiples et en interaction, est d'autant plus difficile à prévoir (Chapin *et al*., 2004). Il existe un large corpus de savoirs écologiques au sein des communautés autochtones, qui peut être mis à profit dans la prise de décisions. (Berkes, 2012; Miller *et al*., 2010).

Les systèmes de connaissances autochtones contiennent un contingent de savoirs et de stratégies permettant d'appréhender les changements environnementaux et de s'y adapter (Pearce *et al*., 2015; Petzold *et al*., 2020). Les savoirs autochtones, parfois appelés savoirs traditionnels, savoirs écologiques traditionnels ou savoirs locaux, sont développés sur plusieurs générations et mis à jour continuellement grâce à un contact répété avec l'environnement (Asselin, 2015; Berkes, 2012; Mistry et Berardi, 2016). Ils comprennent des observations et inférences, des savoir-faire et des valeurs qui s'inscrivent dans une vision du monde propre (Houde, 2007; Usher, 2000). En zone boréale, des travaux menés notamment avec les Nations Innue (p. ex. Bellefleur, 2019), Crie (p. ex. Feit, 2001; Ohmagari et Berkes, 1997), Anicinape (p. ex. Davidson-Hunt, 2003; Germain, 2012; Saint-Arnaud *et al*., 2009), et Atikamekw (p. ex. Basile *et al*., 2017; Ethier et Poirier, 2018), ont contribué à documenter les perspectives autochtones sur le territoire et ses changements.

Par ailleurs, un effort scientifique important est dédié à développer des outils qui permettent d'appréhender les effets des changements environnementaux à court, moyen et long termes. Les modèles de circulation atmosphérique projettent les changements de température et de précipitations selon différents scénarios d'émissions de gaz à effet de serre (IPCC, 2015; McKenney *et al.*, 2013; van Vuuren *et al.*, 2011b). Les projections climatiques régionales permettent d'anticiper les changements des régimes de perturbations (Boulanger *et al.*, 2013; Flannigan *et al.*, 2009; Pureswaran *et al.*, 2015), et de la répartition des espèces (Boulanger et Puigdevall, 2021). Les modèles qui simulent la croissance des forêts permettent de faire interagir les changements climatiques, la foresterie et autres moteurs de changement afin de mieux comprendre comment la forêt réagit lorsqu'elle est exposée à des stress multiples (Peng, 2000; Scheller *et al.*, 2007).

La mise en commun des savoirs autochtones et de ceux issus de la recherche scientifique permet de faire face aux changements environnementaux de manière plus efficace, pertinente et juste (Barber et Jackson, 2015; Bohensky et Maru, 2011; Tengö *et al.*, 2014). D'abord, les savoirs inscrits dans les systèmes de connaissances autochtones et scientifiques sont complémentaires, tant dans leur portée que dans leurs échelles spatiales et temporelles, menant à une compréhension plus approfondie des phénomènes environnementaux (Lyver *et al.*, 2018; Torrents-Ticó *et al.*, 2021). D'un point de vue plus appliqué, des outils d'analyse et de gestion du territoire à la frontière entre les systèmes de connaissances facilitent la collaboration et donnent de la légitimité aux décisions qui en découlent (Ericksen et Woodley, 2005; Robinson et Wallington, 2012). Finalement, l'accès aux avancées scientifiques en matière de changements climatiques permet d'anticiper les risques et de s'y préparer (Ford *et al.*, 2015).

Les recherches en sciences de l'environnement qui combinent différentes formes et sources de connaissances se font de plus en plus nombreuses (Alexander *et al.*, 2019;

Bélisle *et al.*, 2018). Cependant, les savoirs autochtones se butent à une structure descendante (*top-down*) de la recherche et de l'aménagement du territoire et leur prise en compte demeure souvent superficielle (Castleden *et al.*, 2017a; Wyatt *et al.*, 2019). Le manque de confiance et de compréhension réciproque, héritage d'un processus colonial toujours en cours, fait également obstacle au travail collaboratif (Dam Lam *et al.*, 2019). Aussi, les savoirs autochtones et les savoirs scientifiques s'inscrivent dans des systèmes de connaissances différents, avec chacun leurs ontologies, épistémologies et méthodologies (Rathwell et Armitage, 2015). Leur mise en commun est un exercice délicat qui requiert un travail collaboratif soutenu et des méthodes appropriées.

1.2 Objectifs

L'objectif général de ce projet de recherche est d'analyser les effets cumulatifs des changements environnementaux sur les paysages boréaux depuis la frontière entre les systèmes de connaissances autochtones et scientifiques. La thèse se décline en cinq objectifs spécifiques :

1) Conceptualiser la valeur des paysages autochtones et ses déterminants. Le cadre d'analyse en ayant résulté est présenté au Chapitre II.
2) Concevoir un « objet frontière » qui fait le pont entre les perspectives autochtone et scientifique sur les effets des changements environnementaux et se doter d'une base de travail commune. Les modèles conceptuels développés à cette fin sont présentés au Chapitre III.
3) Faire le portrait de l'état actuel du territoire à l'étude à partir d'indicateurs de l'état des paysages. Le portrait et son analyse sont présentés au Chapitre IV.
4) Mettre en commun les projections d'un modèle de simulation des paysages forestiers et les savoirs d'experts autochtones dans un réseau bayésien (modèle probabiliste). Le réseau bayésien est présenté au Chapitre V.

5) Projeter les effets cumulatifs des changements environnementaux sur la valeur des paysages autochtones selon divers scénarios de changements climatiques et de foresterie. Les projections sont présentées au Chapitre V.

1.3 Positionnement conceptuel

Cette thèse s'inscrit dans trois domaines clés des sciences de l'environnement : le paysage et sa valeur, la recherche en contexte autochtone et les effets cumulatifs des changements environnementaux. Ces domaines ont des racines dans différentes disciplines scientifiques, notamment l'écologie, l'économie et la géographie humaine. Suivant une approche interdisciplinaire, les concepts, méthodes et épistémologies propres à chaque discipline sont intégrés les uns aux autres de manière orientée en fonction des objectifs (Klein, 2017; MacLeod et Nagatsu, 2018; Miller *et al*., 2008).

1.3.1 Valeur des paysages

<u>Le paysage comme objet interdisciplinaire</u>

Le paysage est un objet d'étude en sciences naturelles comme en sciences humaines (Stephenson, 2008; Tress *et al*., 2001). Les conceptions du paysage comportent des différences ontologiques (sur ce qui existe, la nature des choses, ce qui peut être étudié) et épistémologiques (sur le savoir et la manière dont il est créé) qui représentent des défis d'intégration (Moon et Blackman, 2014). La *Convention européenne du paysage* propose une définition interdisciplinaire et englobante du paysage, soit « une partie de territoire telle que perçue par les populations, dont le caractère résulte de l'action de facteurs naturels et/ou humains et de leurs interrelations » (Conseil de l'Europe, 2018, p.44). Elle rejoint les cinq dimensions du paysage énoncées par Tress et Tress, (2001) et utilisées dans cette recherche, soit le paysage comme *entité spatiale*, comme *entité mentale*, comme *entité temporelle*, comme *nexus* et comme *système complexe*.

Le paysage comme *entité spatiale*, en écologie, est défini comme une surface qui est spatialement hétérogène dans au moins un facteur d'intérêt (Turner et Gardner, 2015). Termorshuizen et Opdam (2009) conçoivent pour leur part le paysage comme un système spatial humain-écologie (traduction libre de l'anglais, p. 1041), dont les fonctions sont le résultat des interactions entre les composantes biophysiques et les actions humaines. En zone boréale, l'échelle du paysage est utilisée notamment pour étudier les régimes de feux (Boulanger *et al.*, 2013; Cyr *et al.*, 2016) et pour la planification de l'aménagement forestier (Bergeron *et al.*, 2017). Dans le cadre de cette recherche, les limites du paysage *spatial* ont été définies en fonction des terrains de trappe, répartis entre les familles des communautés.

Le paysage comme *entité mentale* renvoie pour sa part aux perceptions. Lorsqu'une personne ou un groupe de personnes est en contact avec le paysage *spatial*, elle s'en crée une image mentale. Le paysage mental rejoint le concept de paysage culturel, dans lequel un groupe de personnes partage une représentation similaire d'un paysage spatial (Berkes et Davidson-Hunt, 2006; Schaich *et al.*, 2010). La reconnaissance des différentes perspectives sur le paysage est un fondement de la recherche collaborative (Abu *et al.*, 2019; Bartlett *et al.*, 2012; Torrents-Ticó *et al.*, 2021). En contexte autochtone, on appelle *ethical space* l'espace de travail qui se situe entre les systèmes de connaissances, reconnus sans hiérarchie ni préséance de l'un sur l'autre (Ermine, 2007). L'espace éthique dicte les principes d'un travail de recherche respectueux, plus légitime et qui s'inscrit dans un processus de décolonisation (The Indigenous Circle of Experts, 2018). Le Chapitre II met ainsi en contraste des perspectives autochtone et scientifique du paysage.

Le paysage *temporel* se situe dans une trajectoire de changements, ici environnementaux. Les Chapitres II à IV portent sur les paysages récents. Le Chapitre V porte pour sa part sur les paysages projetés (2000-2100), selon différents scénarios de changements environnementaux.

Le paysage comme *nexus* concerne les interactions entre l'humain et la nature (Flint *et al*., 2013). En ce sens, Wu (2013) définit le paysage selon « l'échelle à laquelle les gens et la nature s'entremêlent et interagissent le plus intensément. » (p. 1000). Dans le cadre de cette recherche, le lien au territoire est approché à partir de diverses pratiques comme la chasse, la trappe, la pêche, l'éducation et le ressourcement (Tableau 1.1).

Tableau 1.1 Pratiques de paysage importantes pour la Première Nation Abitibiwinni et la Première Nation d'Oujé-Bougoumou identifiées par l'équipe de recherche.

Pratique	Description
Chasse à l'orignal	L'orignal est une source de nourriture importante pour les deux communautés. Il est chassé toute l'année, et une semaine de vacances y est dédiée chaque automne dans les deux communautés. Des travaux de recherche sur l'habitat de l'orignal ont été réalisés en collaboration avec différentes communautés situées dans le Québec boréal (Jacqmain *et al.*, 2008, 2012; Tendeng *et al.*, 2016).
Chasse à l'outarde	L'outarde (*Branta canadensis, NiKA, nisk*) est chassée deux fois par année au moment de sa migration et est une source de gras importante dans l'alimentation des peuples autochtones (Sayles et Mulrennan, 2010). L'effet des changements environnementaux sur l'abondance et la répartition des populations d'outarde a fait l'objet de recherches en collaboration avec des communautés Cries côtières (Royer et Herrmann, 2013).
Trappe	La trappe, trappage, ou piégeage, fournit nourriture et fourrure en plus d'être une source de revenus. Les animaux à fourrure les plus trappés sont la martre et le castor (*Castor canadensis, AMiK, Amiskw*). Les savoirs des piégeurs ont été mis à contribution dans des travaux de recherche, notamment sur la martre (Cheveau, 2010; Suffice *et al.*, 2017).
Pêche	La pêche au filet (traditionnelle) et la pêche à la ligne sont pratiquées dans les deux communautés. Le doré jaune (*Sander vitreus, OKAS, ukaash*), le grand brochet (*Esox lucius, KiNOCE, chinusheu*) et l'esturgeon jaune (*Acipenser fulvescens, NAME, nameu*) sont parmi les espèces les plus prisées. Des enjeux de bioaccumulation de métaux lourds

Tableau 1.1 Suite

Pratique	Description
	dans les poissons ont fait l'objet de recherches et de guides de santé limitant la consommation des poissons au sommet de la chaîne alimentaire (Liberda *et al.*, 2011; Tsuji *et al.*, 2007; Valera *et al.*, 2011).
Éducation	La transmission des savoirs cris et anicinape a lieu sur le territoire. On y apprend la langue, les connaissances et les savoir-faire nécessaires à la vie en forêt (Ohmagari et Berkes, 1997) et les valeurs et attitudes vis-à-vis du territoire (Davidson-Hunt et Berkes, 2003).
Ressourcement	« Le ressourcement consiste à revenir à ses sources, retrouver ses racines profondes de manière à acquérir un nouvel équilibre. C'est trouver de nouvelles sources (morales, psychologiques, spirituelles, etc.), reprendre des forces physiques, morales, etc. » (Office québécois de la langue française, 1989). Le territoire est un lieu propice au ressourcement et au maintien d'un état de bien-être et d'équilibre appelé *Mino-pimatisiwin* (Landry *et al.*, 2019; Radu *et al.*, 2014).

La dimension relationnelle comprend aussi les relations de pouvoir entre les différents acteurs, parties-prenantes et groupes d'intérêts du paysage (Fortin, 2008).

Le paysage comme *système complexe* est caractérisé par la présence de relations non linéaires, de boucles de rétroaction, de seuils et de points de bascule entre différents états stables (Holling, 1973; Scheffer et al., 2012; Walker et al., 2004). Dans le cadre de cette recherche, la lunette des systèmes complexes est utilisée pour analyser les dynamiques spatiales des changements environnementaux (Chapitre IV). On y décrit les différents états stables alternatifs auxquels peuvent appartenir les paysages ainsi que les facteurs qui entraînent la transition d'un état vers un autre. Les paysages sont abordés en tant que systèmes complexes dans l'approche de modélisation par simulation des paysages forestiers (Chapitre V) par le recours aux simulations des interactions entre les facteurs d'influence.

Services écosystémiques

Les services écosystémiques sont utilisés afin de jauger la valeur des écosystèmes. Parmi les nombreuses définitions existantes (de Groot *et al*., 2010; Wallace, 2007), celle proposée par *l'Évaluation des écosystèmes pour le millénaire* est probablement la plus répandue, soit les « les bénéfices que les personnes obtiennent des écosystèmes » (Millenium Ecosystem Assessment, 2005, p.1, traduit de l'anglais). Les services écosystémiques y sont regroupés en quatre catégories, soit les services d'approvisionnement, culturels, de régulation et de soutien. Les quatre catégories permettent de considérer une diversité de valeurs, de contextes et d'applications (Daily, 1997). D'autres définitions, plus ciblées, intègrent la notion de bien-être. Par exemple, *The Economics of Ecosystems & Biodiversity* définit les services écosystémiques comme « les contributions directes et indirectes des écosystèmes au bien-être humain » (de Groot *et al*., 2010, p.25, traduit de l'anglais). À l'inverse, l'IPBES a adopté un concept plus large et parle plutôt des « contributions de la nature aux humains » (Díaz *et al*., 2018, traduit de l'anglais). Les services écosystémiques sont utilisés à des fins très diverses, notamment pour évaluer les conséquences de l'aménagement du territoire en milieu urbain (Nesbitt *et al*., 2017) et périurbain (Dupras *et al*., 2015), agricole (Raudsepp-Hearne *et al*., 2010) et forestier (Triviño *et al*., 2017).

Dans le contexte de cette recherche, la notion de bien-être a été conservée et abordée selon l'approche des capabilités. Le bien-être y est défini comme la possibilité de mener une vie satisfaisante et remplie de sens, qui repose sur une sphère d'action sur sa propre vie (Nussbaum, 2011; Sen, 1979). Les capabilités incluent par exemple l'aptitude à demeurer en bonne santé, à développer un attachement pour les choses et les personnes et à bénéficier d'un environnement social respectueux (Nussbaum, 2011; Stanton, 2007). L'approche des capabilités contraste avec une approche classique du bien-être basée sur la réponse à une hiérarchie de besoins universels (King *et al*., 2014). Elle se prête bien au contexte de cette recherche parce qu'elle n'impose pas de critères stricts du bien-être, l'ensemble des capabilités pouvant être interprété et modulé selon le contexte (Ballet *et al*., 2018; Polishchuk et Rauschmayer, 2012; Yap et Yu, 2016).

Bien que le cadre des services écosystémiques offre un bon point de départ pour aborder la valeur des paysages boréaux, il fait toutefois face à des limites lorsqu'appliqué en contexte autochtone. D'abord, les services écosystémiques culturels contribuent de manière importante à la valeur des paysages autochtones (Cuerrier *et al*., 2015b; Sangha *et al*., 2015), mais sont difficiles à mesurer et sous-représentés dans les analyses de la valeur des paysages (Hernández-Morcillo *et al*., 2013; Schaich *et al*., 2010a; Winthrop, 2014). Ensuite, le cadre des services écosystémiques est peu outillé lorsque confronté à des valeurs « incommensurables » qui touchent à l'identité et à une vision du monde centrée sur le territoire, qui sont fondamentales en contexte autochtone (Chan *et al*., 2012; Sangha *et al*., 2015).

Deux réponses sont proposées devant la difficulté qu'ont les services écosystémique à rendre compte adéquatement de l'ensemble des dimensions d'utilité, d'existence et relationnelle de la valeur des paysages. D'une part, l'IPBES propose de remplacer le concept de services écosystémiques par « les contributions de la nature aux personnes » (Díaz et *al*., 2018). Les auteurs avancent que cette approche basée sur les contributions plutôt que sur les services se prête mieux à la prise en compte des valeurs culturelles de la nature ainsi qu'aux savoirs locaux et autochtones. D'autres scientifiques ont plutôt misé sur les avantages de travailler avec le concept de services écosystémiques, soit son interdisciplinarité, sa reconnaissance à l'extérieur de la communauté scientifique et l'effort de recherche qui lui a été dédié depuis les vingt dernières années (Kenter, 2018; Braat, 2018). On propose d'insérer les services écosystémiques dans un cadre orienté vers la valeur et le bien-être, davantage que sur les contributions et les bénéfices (Polishchuk and Rauschmayer, 2012). C'est l'approche qui a été retenue dans cette recherche.

Une définition sur mesure de la valeur des paysages

Dans le cadre de cette recherche, la valeur du paysage a été définie comme sa capacité à soutenir les pratiques qui contribuent au bien-être des peuples autochtones. Trois critères ont guidé la formulation de cette définition.

Premièrement, la définition devait faire place aux valeurs instrumentales (ou utilitaires), intrinsèques (ou d'existence) et relationnelles (Pascual *et al.*, 2017) du paysage. La valeur utilitaire renvoie à la conception plus classique des services écosystémiques (de Groot *et al.*, 2010; Wallace, 2007). La valeur intrinsèque émane de l'existence même des organismes et des écosystèmes, sans égard à leur utilité ni à leur utilisation (Flint *et al.*, 2013). La valeur relationnelle est créée par le lien avec les écosystèmes qui est en lui-même source de bien-être (Chan *et al.*, 2018; Klain *et al.*, 2017). Dans la définition de la valeur des paysages adoptée, ce sont les pratiques qui sont source de bien-être, et la valeur du paysage est simplement évaluée en fonction du soutien qu'il offre à la réalisation de ces pratiques (Bieling *et al*. 2014).

Deuxièmement, la définition de la valeur du paysage devait être cohérente avec la manière dont la relation au territoire est vécue, partagée et exprimée au sein des communautés. L'élicitation des valeurs est en effet facilitée lorsqu'elle s'approche de la manière dont les gens ont l'habitude de discuter du territoire (Satterfield, 2001). Les pratiques énoncées dans le Tableau 1.1 font partie de la vie quotidienne dans les communautés partenaires. Des connaissances et savoir-faire y sont associés. Les pratiques font l'objet d'ateliers, de semaines thématiques, et de discussions formelles et informelles (Saint-Arnaud *et al.*, 2009; Femmes autochtones du Québec, 2019; Basile *et al.*, 2017).

Troisièmement, la définition devait pouvoir se prêter à des approches qualitatives et quantitatives dans l'étude de la valeur du paysage. D'une part, les approches qualitatives favorisent la délibération et la discussion sur la valeur du paysage et de ses déterminants (Raymond *et al.*, 2014). Elles sont les plus appropriées pour développer une perspective autochtone des changements environnementaux et de leurs effets sur le territoire (Bartlett *et al.*, 2012; Huntingdon, 2000; Satterfield, 2001). D'autre part, l'évaluation quantitative permet le développement et le suivi d'indicateurs et de faire un pont avec les outils de modélisation développés en sciences naturelles. La capacité du paysage à soutenir une pratique peut ainsi être traitée comme une variable binaire (oui, non), à laquelle une distribution de probabilités est attribuée (O'Leary *et al.*, 2009).

1.3.2 Recherche en contexte autochtone

<u>Savoirs autochtones et scientifiques</u>

Une recherche collaborative menée en contexte autochtone implique des interactions entre les savoirs provenant de systèmes de connaissances différents. La connaissance est définie par Davidson-Hunt et O'Flaherty (2007, p. 293) comme « un processus dynamique, qui dépend de sa formation, de sa validation et de son adaptation à des circonstances changeantes ». En français, il existe une distinction entre les connaissances et les savoirs, tous deux appelés *knowledge* en anglais. Selon Le nouveau Petit Robert (2009), le savoir est un « ensemble de connaissances plus ou moins systématisées, acquises par une activité mentale suivie ». Ainsi, le terme connaissance fera ici référence à une information internalisée par un individu ou un groupe (Reed *et al.*, 2013) alors que le terme savoir fera davantage référence au système dans lequel s'inscrivent les connaissances.

Un système de connaissances est partagé par un groupe dont les membres ont une perception commune, du moins en partie, de la réalité (Ericksen et Woodley, 2005). Un système de connaissances est caractérisé par ses ontologies, épistémologies, méthodologies et axiologies (Bartlett *et al.*, 2012). Un système de connaissances a également une dimension linguistique, particulièrement dans le contexte des langues algonquiennes dont la structure est très descriptive (Éthier, 2014). Les caractéristiques d'un système de connaissances comprennent par exemple la répartition des connaissances au sein du groupe, la manière dont les connaissances individuelles deviennent collectives et la manière dont elles sont transmises d'une génération à l'autre (Davis et Wagner, 2003). La mise en commun des systèmes de connaissances, telle qu'abordée dans l'*Évaluation des écosystèmes pour le millénaire*, repose sur deux prémisses, soit que toute connaissance est située et partielle, et qu'il n'y a pas de hiérarchie de validité entre les systèmes de connaissances (Ericksen et Woodley, 2005).

Les systèmes de connaissances autochtones (traditionnels ou locaux) et les systèmes de connaissances scientifiques sont définis et circonscrits suivant différents courants dans la littérature. La définition des savoirs écologiques traditionnels proposée par Berkes (2012), soit

> Un corpus de connaissances, de pratiques et de croyances qui évoluent par un processus adaptatif, qui traversent les générations par la transmission culturelle et qui concernent la relation des êtres vivants (incluant les humains) entre eux et avec leur environnement. (p. 7, traduit de l'anglais)

est parmi les plus utilisées. Berkes (1993) positionne les savoirs écologiques traditionnels et les savoirs scientifiques aux extrémités d'une série d'axes, par exemple qualitatif et quantitatif, intuitif et rationnel, holistique et réductionniste. Le positionnement dichotomique des savoirs autochtones et scientifiques est toutefois remis en question par Agrawal (1995) qui défend que la diversité interne des deux formes présumées de connaissances soit trop grande pour en justifier l'opposition. Les bases théoriques et empiriques d'un positionnement en dichotomie sont également remises en question (Davis et Ruddle, 2010).

Usher (2000) regroupe pour sa part les savoirs écologiques autochtones en quatre types. Le Type I inclut les connaissances factuelles, soit les observations et les inférences. Par exemple, une montagne est connue pour faire partie de l'habitat de l'orignal parce que des orignaux y sont chassés chaque année (observation) ou parce que la nourriture de l'orignal y est présente (inférence) (p. ex. Jacqmain *et al*., 2008). Le Type II comprend les connaissances liées à l'utilisation du territoire, par exemple les techniques de chasse et de pêche, les connaissances du comportement des espèces chassées ou de leur cycle annuel (p. ex. Davidson-Hunt et Berkes, 2003; Feit, 2001; Ohmagari et Berkes, 1997). Le Type III renvoie aux valeurs, et établit l'état de référence d'un territoire « bon » ou « souhaité ». Il concerne par exemple le sens donné aux changements environnementaux et à leurs effets (Saint-Arnaud, 2009; Turner et Clifton, 2009; Whiteman, 2004). Finalement, le Type IV concerne les visions du monde et le positionnement relatif des humains et de la nature. Il inclut par exemple les histoires de création du monde. Il sous-tend les autres types de connaissances et les perspectives sur les changements environnementaux (Cochran *et al*., 2013; Van Riper et Kyle, 2014).

Dans cette recherche, les savoirs autochtones et les savoirs scientifiques sont distingués en fonction des objectifs de recherche, sans y chercher quelque caractéristique universelle. Ainsi, les savoirs dits autochtones sont détenus par les experts Abitibiwinnik de Pikogan et Cris d'Oujé-Bougoumou, ils concernent l'effet des changements environnementaux sur le territoire et sont rattachés à un lieu (le terrain de trappe familial) (Davidson-Hunt et O'Flaherty, 2007). Pour leur part, les savoirs dits scientifiques sont issus de travaux de recherche dans les disciplines sous le parapluie des sciences de l'environnement, notamment l'écologie et la géographie. Ils sont générés par une méthodologie et un cadre théorique explicites, sont validés par les pairs et le plus souvent publiés dans des revues scientifiques (Ericksen et Woodley, 2005; Reed *et al*., 2013). Les savoirs autochtones comme les savoirs scientifiques s'inscrivent dans des systèmes de connaissances régis par des normes et desquels émanent un sens et une validation interne (Agrawal, 1995; Tengö *et al*., 2017).

Les interactions entre les systèmes de connaissances

Les interactions entre les systèmes de connaissances sont abstraites et des métaphores sont souvent utilisées pour en faciliter la compréhension. Allant de l'image du tissage à celle du poste-frontière, les images permettent de représenter la complexité des relations qui existent entre les systèmes de connaissances (Tableau 1.2). Dans le contexte de cette étude, la métaphore du double regard (traduction libre de *two-eyed seeing*) et celle de la frontière (*boundary work*) illustrent bien la manière dont les interactions ont été abordées. Le double regard a sous-tendu la comparaison des perspectives autochtone et scientifique sur les effets des changements environnementaux (Chapitre III). Le travail à la frontière a conduit au développement d'objets qui font le pont entre les systèmes de connaissances (Robinson et Wallington, 2012) et soutiennent la cocréation des connaissances (Dale et Armitage, 2011; Rathwell et Armitage, 2015; Reed *et al*., 2013). Les objets frontières peuvent prendre différentes formes, comme des cartes (Chapitre II), des modèles (Chapitre III et Chapitre V) et des outils d'aide à la décision (Chapitres IV et V).

Tableau 1.2 Quelques métaphores utilisées pour illustrer les interactions entre les systèmes de connaissances.

Métaphore	Description et exemples d'application
Wampum à deux rangs *Two-Row Wampum*	Le wampum à deux rangs est une ceinture perlée Haudenosaunee (Iroquoise) qui représente les canots mohawks et les bateaux européens qui voguent côte à côte. Le wampum à deux rangs aurait été réalisé au XVII[e] siècle pour officialiser les relations avec les Hollandais dans la région de New York, mais son origine est encore débattue (Otto et Jacobs, 2013). L'image a été reprise pour illustrer deux systèmes de connaissances qui suivent leur cours et qui s'assistent sans interférer (Abu *et al.*, 2019; Doubleday, 1993; Hill et Coleman, 2019; Rathwell et Armitage, 2015).
Tissage *Weaving*	L'image du tissage représente une collaboration qui respecte l'intégrité de chaque système de connaissances (Tengö *et al.*, 2017). Son utilisation est plutôt générale et s'applique à plusieurs domaines, notamment l'écologie, la durabilité et les sciences de l'éducation (e.g. Kimmerer 2002, Johnson *et al*. 2016, Henri *et al*. 2021).
Fertilisation croisée *Cross-fertilization*	L'image de la fertilisation croisée est employée pour décrire l'enrichissement de chacun des systèmes de connaissances par des éléments provenant de l'autre système (Makondo et Thomas, 2018; Tengö *et al.*, 2014). La fertilisation croisée est généralement présentée comme un bénéfice obtenu de la mise en commun des systèmes de connaissances, mais de potentiels effets délétères et des iniquités peuvent également en découler (Löfmarck et Lidskog, 2017, 2019).
Double regard *Two-eyed seeing*	L'expression *two-eyed seeing* a été formulée par l'aîné Mi'kmaq Albert Marshall dans le cadre du développement d'un programme de science intégrative à l'Université du Cap Breton en Nouvelle-Écosse. Il s'agit d'une perspective multiple qui permet de voir d'un œil avec les forces des connaissances et des manières de savoir autochtones, et de l'autre œil avec celles propres à la perspective scientifique. Ces deux regards sont mis en commun au bénéfice de tous (Bartlett *et al.*, 2012). Cette approche, qui met l'accent sur les perspectives, est de plus en plus utilisée, surtout au Canada, pour guider la mise en commun des systèmes de connaissances (Abu *et al.*, 2019; Mantyka-Pringle *et al.*, 2017; Rayne *et al.*, 2020).

Tableau 1.2 Suite

Métaphore	Description et exemples d'application
Frontière *Boundary*	La métaphore de la frontière entre les systèmes de connaissances est utilisée pour illustrer la manière dont les connaissances transitent d'un système à l'autre (Löfmarck et Lidskog, 2017; Robinson et Wallington, 2012). Des « objets frontières » font office de postes-frontières et permettent le passage des connaissances. Les objets frontières ont différentes formes : des institutions (p. ex., Conseil Cri-Québec sur la foresterie), des cartes (Houde, 2007; Robinson *et al.*, 2016; Sandström, 2015), des modèles (Delgado *et al.*, 2009; Mantyka-Pringle *et al.*, 2014). Les personnes qui font la médiation et la traduction des connaissances sont pour leur part présentées comme des agents frontaliers (Reid *et al.*, 2009b; Robinson et Wallington, 2012).

La mise en commun des systèmes de connaissances est un exercice délicat qui, s'il n'est pas réalisé avec une intention et des méthodes appropriées, peut entraîner des conséquences qui ne sont pas souhaitables (Stefanelli *et al.*, 2017). (1) Les démarches qui cherchent à valider une connaissance issue d'un système par les normes et méthodes d'un autre supposent une hiérarchie des systèmes de connaissances et soulèvent des enjeux éthiques (Asselin, 2015; Brook et McLachlan, 2005). (2) Il existe également un risque que les savoirs autochtones soient réduits à de simples données factuelles sur l'environnement, échouant ainsi à reconnaître le contexte épistémologique dans lequel ils ont étés générés et validés, et dans lequel ils trouvent un sens (Alexander *et al*., 2019; Castleden *et al*., 2017b). (3) Ford *et al*. (2016) ont appelé *silencing effect* le phénomène qui se produit lorsque les savoirs autochtones sont présents, parfois même abondants, mais réduits au silence lorsque privés de leur contexte et de leur sens. (4) Un autre enjeu réside dans l'omission du contexte social et politique et genré dans lequel s'inscrivent les interactions entre les systèmes de connaissances. Les relations de pouvoir et l'historique de colonisation sous-tendent les relations entre les peuples autochtones et les institutions occidentales, incluant les universités et centres de recherche, et doivent être reconnues dans la conception des approches pour mettre en commun les systèmes de connaissances (Thompson *et al*., 2020a; Wheeler *et al*., 2020; Wong *et al*., 2020; Basile, 2017; Femmes autochtones du Québec, 2019).

1.3.3 Effets cumulatifs des changements environnementaux

Un changement cumulé est défini comme un « changement dans l'environnement causé par les multiples interactions des activités humaines et des processus naturels qui s'accumulent dans le temps et l'espace. » (adapté de la définition proposée par le CCME, 2014). Les effets cumulatifs sont pour leur part définis par le Nunavut Impact Review Board (2018) :

> Les effets sur les environnements biophysiques et socio-économiques qui sont le résultat des effets incrémentaux d'un développement ajouté aux développements passés, présents et d'un futur raisonnablement prévisible, sans égard à l'agence ou à la personne qui entreprend ce développement. Les effets cumulatifs peuvent être le résultat d'actions mineures, mais collectivement significatives qui se produisent durant une période donnée » (traduction libre de l'anglais).

Les interactions entre les changements peuvent engendrer des effets additifs lorsqu'ils vont dans une même direction et s'ajoutent les uns aux autres, multiplicatifs lorsqu'il y a synergie, et compensatoires lorsqu'il y a antagonisme (Hodgson et Halpern, 2019; Murdoch *et al*., 2020). Les concepts de vulnérabilité, d'exposition, de capacité de s'adapter, de résilience et de points de bascules sont utilisés par le GIEC dans l'analyse des risques associés aux changements climatiques et sont ici définis et appliqués au contexte de l'étude.

La vulnérabilité est définie comme la « propension ou prédisposition à subir des dommages. Cela englobe divers concepts, notamment les notions de sensibilité ou de fragilité et l'incapacité de faire face et de s'adapter. » (GIEC, 2014 p.144). La vulnérabilité dépend non seulement de l'environnement biophysique, mais est aussi tributaire du contexte social et culturel (Adger *et al.*, 2013; Ford *et al.*, 2008b; O'Brien *et al*., 2007). Elle est fonction de l'exposition à des stress environnementaux et sociaux et de la capacité d'adaptation (Adger, 2006).

L'exposition est définie comme :

> La présence de personnes, de moyens de subsistance, d'espèces ou d'écosystèmes, de ressources et de services environnementaux, d'éléments d'infrastructure ou de biens économiques, sociaux ou culturels dans un lieu susceptible de subir des dommages. (GIEC, 2014, p.136)

La capacité de s'adapter peut être définie comme :

> La capacité d'ajustement des systèmes, des institutions, des êtres humains et des autres organismes, leur permettant de se prémunir contre les risques de dégâts, de tirer parti des opportunités ou de réagir aux conséquences (GIEC, 2014, p.133).

L'analyse des effets cumulatifs des changements environnementaux sur les paysages fait appel à des concepts issus de la théorie des systèmes complexes comme la résilience, les points de bascule et les états stables alternatifs (Folke *et al.*, 2010). La résilience est définie comme :

> La capacité des systèmes sociaux, économiques ou environnementaux à faire face à une perturbation, une tendance ou un événement dangereux, leur permettant d'y réagir ou de se réorganiser de façon à conserver leur fonction essentielle, leur identité et leur structure, tout en gardant leurs facultés d'adaptation, d'apprentissage et de transformation. (GIEC, 2014, p.141).

Les effets cumulatifs des changements environnementaux menacent la résilience d'un système lorsqu'ils facilitent le passage d'un point de bascule vers un état stable alternatif (Carpenter *et al.*, 2001). Un point de bascule est défini comme :

> « Le degré de changement touchant les propriétés d'un système au-delà duquel le système en question se réorganise, souvent de façon abrupte, et ne revient pas à son état initial, même si les facteurs du changement sont supprimés » (adapté de la définition du GIEC (2014), p.139).

En zone boréale, le basculement d'un état stable vers un autre est souvent associé à des changements dans les régimes de perturbations (Chapin *et al*., 2004; Scheffer *et al*., 2012). Des transitions d'une forêt fermée vers une forêt ouverte sont attribuées à des perturbations sévères ou en rafale (Asselin et Payette, 2006; Jasinski et Payette, 2005), à un changement dans la régulation des épidémies d'insectes (Pureswaran *et al*., 2015) et à l'absence prolongée de feux lorsque le drainage est déficient et que le terrain est propice à l'accumulation de matière organique (Fenton *et al*., 2005). Des transitions dans la composition de la végétation ont été attribuées à une augmentation de la fréquence des feux (Bergeron *et al*., 2004b; de Lafontaine et Payette, 2012; Le Goff et Sirois, 2004) et de la sévérité des feux (Asselin *et al*., 2006; Greene *et al*., 2004; Johnstone *et al*., 2010) et aux coupes forestières (Dussart et Payette, 2002; Laquerre *et al*., 2011).

1.4 Région à l'étude

1.4.1 Territoires autochtones

La région à l'étude se trouve dans la partie ouest de la forêt boréale au Québec, sur les territoires traditionnels des Abitibiwinnik de Pikogan et des Cris d'Oujé-Bougoumou. Le territoire ancestral du peuple Anicinape est nommé Anicinapek O Takiwa (650 000 km^2) (Conseil de la Première Nation Abitibiwinni, 2020). Il s'étend des abords de la Baie James au nord jusqu'aux rives du Lac Supérieur au sud. Il y a neuf communautés Anicinape au Québec et certaines ont une partie de leur territoire en Ontario. Eeyou Istchee est le nom donné au territoire traditionnel Cri (400 000 km^2). Eeyou Istchee « est situé principalement dans le Grand Nord du Québec et comprend les terres sur la rive orientale de la baie James et au sud-est de la baie d'Hudson, de même que les lacs et les rivières qui s'y déversent » (Grand Council of the Crees (Eeyou Istchee) / Cree Nation Government, 2021). Eeyou Istchee comprend 11 communautés ou Premières Nations, dont neuf sont reconnues par le gouvernement du Québec[4].

Les travaux de recherche ont été réalisés à l'échelle du terrain de trappe familial. Le terrain de trappe est aussi appelé réserve à castor, *trapline* ou *hunting ground* par les communautés autochtones partenaires. Les réserves à castor sont des territoires de trappe à usage autochtone exclusif. Elles ont été mises en place par le Gouvernement du Québec au début du XX^e^ siècle afin d'assurer une continuité et une qualité de l'approvisionnement en fourrures (Frenette 2013). Certaines familles y résident, sur une base saisonnière ou à l'année, d'autres le fréquentent de manière plus occasionnelle. La vie y est organisée autour d'un ou de plusieurs camps. Les terrains de trappe demeurent au sein d'une même famille et sont transmis d'une génération à l'autre. Ce mode de partage du territoire entre les familles date au moins de l'époque de la traite des fourrures, mais il est possible qu'il y soit antérieur (Ethier et Poirier, 2018; Feit, 1985).

Pikogan est le toponyme donné à la communauté de la Première Nation Abitibiwinni (1 080 membres en 2015), qui se situe près de la ville d'Amos en Abitibi-Témiscamingue. La Première Nation Abitibiwinni occupe la région du Lac Abitibi depuis au moins 6 000 ans (Côté, 1995). Le mode de vie traditionnel est nomade, soutenu par la pêche, la chasse, la trappe et la cueillette de petits fruits et de plantes

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[4] La communauté de Washaw Sibi a été été reconnue comme dixième communauté de la Nation crie à l'Assemblée générale annuelle de 2003 du Grand Conseil des Cris (Eeyou Istchee) et du Gouvernement de la Nation Crie. MoCreebec Eeyoud est la onzième Première Nation crie que le Gouvernement de la Nation Crie a reconnue. Les membres de MoCreebec sont des Cris d'Eeyou Istchee qui résident ou ont résidé à Moose Factory ou Moosonee. https://www.cngov.ca/fr/communaute-et-culture/communautes/

(Conseil de la Première Nation Abitibiwinni, 2020). Des changements rapides et majeurs dans le mode de vie comme dans l'environnement des Abitibiwinnik ont cours depuis le début du XX^{e} siècle. Avec l'arrivée de colons en Abitibi pour faire de l'agriculture et l'ouverture d'un pensionnat autochtone à Saint-Marc-de-Figuery, les Abitibiwinnik se sont graduellement installés dans la communauté de Pikogan à partir des années 1950 (Conseil de la Première Nation Abitibiwinni, 2020; Loiselle *et al*., 2011). Malgré les changements, le territoire et les activités qui y sont associées occupent toujours une place importante dans la vie de la communauté et de ses membres.

La communauté d'*Ouje-Bougoumou Cree Nation* (906 membres en 2015) est installée sur les rives du lac Opemiska, à une soixantaine de kilomètres de la ville de Chibougamau (Nord-du-Québec), depuis 1992 (Grand Council of the Crees (Eeyou Istchee) / Cree Nation Government, 2021; Indigenous and Northern Affairs Canada, 2015). La présence des Cris dans la région remonte à au moins 5 000 ans (Wright, 1979) et les familles d'Oujé-Bougoumou sont installées dans la région du lac Chibougamau au moins depuis le début de l'ère du commerce des fourrures au XVI^{e} siècle (Frenette, 1985). Avant l'installation de la communauté à son emplacement actuel, les familles ont subi plusieurs déplacements sous les pressions du développement minier. Certaines s'étaient installées dans la communauté voisine de Mistissini, dans les villes avoisinantes, ou en forêt sur le territoire (Frenette, 1985).

Les activités qui ont cours en Eeyou Istchee sont régulées par une entente négociée entre le Grand Conseil des Cris et le Gouvernement du Québec. *La Paix des Braves*

(2002)[5] impose un régime forestier adapté qui comprend des coupes forestières réparties en mosaïque ainsi qu'une planification forestière multiéchelles avec des contraintes à l'échelle du terrain de trappe. Par exemple, jusqu'à 1 % de la superficie de chaque terrain de trappe peut être établie comme territoire d'intérêt par les Cris et être soustraite à l'aménagement forestier. La mise en œuvre du Chapitre 3 de l'entente (sur la foresterie) ainsi que la consultation avec les Cris sont sous la responsabilité du Conseil Cris-Québec sur la foresterie, un organisme autonome dont les membres sont nommés par chacune des parties signataires. La Première Nation Abitibiwinni évolue pour sa part en territoire non cédé. Cela signifie qu'il n'existe ni traité ni entente avec le gouvernement qui en régule les activités. Le territoire ancestral des Abitibiwinnik est donc administré selon les mêmes règles que l'ensemble des terres publiques au Québec.

Le territoire d'Oujé-Bougoumou compte 14 terrains de trappe. Ils occupent 10 500 km^2 et leur superficie varie entre 329 et 1 652 km^2, avec une moyenne de 747 km^2. La délimitation des terrains de trappe familiaux est officialisée dans *La Paix des Braves*. Un administrateur formel, appelé *tallyman*, est désigné et assure la gestion des activités qui ont cours sur le terrain de trappe, tant par la famille, la communauté que les agents extérieurs comme le gouvernement ou les compagnies forestières. Le territoire de la Première Nation Abitibiwinni compte 34 terrains de trappe. Ils occupent 11 400 km^2 et leur superficie varie entre 112 km^2 et 826 km^2, avec une superficie moyenne de 336 km^2. Les terrains de trappe Abitibiwinnik sont délimités et utilisés pour la gestion des activités sur le territoire, mais de manière moins formelle qu'à Oujé-Bougoumou. Les

[5] *Entente concernant une nouvelle relation entre le Gouvernement du Québec et les Cris du Québec*, 2002

différences de superficie entre les terrains de trappe pour une même communauté s’expliquent en partie par la prise en compte des ressources disponibles sur le territoire. Par exemple, la forêt au nord du territoire de la Première Nation Abitibiwinni est tourbeuse et peu dense comparativement aux forêts fermées et plus diversifiées au sud. Il arrive également qu’un terrain de trappe soit divisé entre les membres d’une même famille.

1.4.2 Caractéristiques écologiques

La plupart des terrains de trappe des deux communautés partenaires se trouvent dans le domaine bioclimatique de la pessière à mousses (sous-domaine de l’ouest). Le climat continental subhumide y est contrasté par des étés chauds et humides et des hivers longs, froids et secs (Robitaille and Saucier 1998, Brandt *et al*. 2013). La forêt est caractérisée par la dominance des conifères comme l’épinette noire (*Picea mariana, SESEKATiK, iiyaahtikw*) et le pin gris (*Pinus banksiana, OKiK, uschisk*) (Robitaille et Saucier, 1998). Des régimes de feux de cime sévères influencent la structure d’âge et la composition des paysages forestiers, dont les parcelles sont caractérisées par le temps qui s’est écoulé depuis la dernière perturbation (Lecomte and Bergeron 2005, Bélisle *et al*. 2011). Le cycle de feu et la distribution de la taille des feux varient d’une région à l’autre en fonction du climat (Boulanger *et al*., 2013), de la topographie (Portier *et al*., 2019) et des propriétés du sol (Mansuy *et al*., 2010). Là où les feux sont fréquents, les jeunes forêts et les espèces adaptées au feu comme le pin gris et l’épinette noire abondent (Le Goff et Sirois, 2004; Lecomte et Bergeron, 2005). Là où les feux sont moins fréquents, les vieilles forêts peuvent représenter plus de 60 % du couvert forestier (Bélisle *et al*., 2011; Bouchard *et al*., 2009) et des espèces tolérantes à l’ombre, notamment le sapin baumier (*Abies balsamea, CiKOPi, iinaasht*) sont plus présentes.

Les paysages boréaux sont aussi influencés par des régimes de perturbations anthropiques. La foresterie y est de type extensif, c’est-à-dire qu’elle se déploie sur un vaste territoire avec peu d'interventions autres que la coupe totale et le reboisement. La région est affectée par les activités minières actuelles et passées. Les activités d'exploration comprennent la coupe de lignes et le prélèvement d'échantillons sur de grandes étendues. Les mines peuvent être souterraines ou à ciel ouvert. Des résidus miniers et des sites miniers abandonnés sont dispersés sur le territoire (Ministère de l'Énergie et des Ressources naturelles du Québec, 2019).

1.5 Approche méthodologique

Ce projet s'inscrit dans une recherche collaborative plus large visant à documenter les effets des changements environnementaux sur les personnes, les communautés et les territoires autochtones. Un appel à participer à un projet de recherche sur les effets cumulatifs des changements environnementaux a été lancé en 2014 aux communautés autochtones dont le territoire est situé dans l'ouest de la zone boréale au Québec. Des présentations ont été faites à diverses instances (Gouvernement de la Nation Crie, Groupe de travail conjoint du Conseil Cris-Québec sur la foresterie) et communautés (*Mistissini Cree Nation*, *Nemaska Cree Nation*, notamment). Le Conseil de la Première Nation Abitibiwinni et *Ouje-Bougoumou Cree Nation* ont répondu positivement à l'appel et une équipe de recherche collaborative a été constituée.

L'équipe de recherche était formée de chercheurs universitaires et gouvernementaux, d'étudiants et de membres des communautés partenaires (Tableau 1.3). Une première rencontre s'est tenue le 26 mai 2016 dans les bureaux de lu Conseil de la Première Nation Abitibiwinni, à Pikogan. Il en est ressorti le souhait de développer des connaissances et des outils pour mieux appréhender les effets cumulatifs des changements environnementaux sur le territoire. Le désir de mobiliser et de mettre en valeur la connaissance du territoire détenue par les aînés est apparu comme une grande motivation à s'impliquer dans le partenariat de recherche. Cette rencontre et les échanges qui ont suivi ont guidé la formulation des objectifs.

Des rencontres entre les membres de l'équipe de recherche ont eu lieu en personne ou en ligne au moins une fois chaque année, souvent plus, tout au long du projet. Ces rencontres ont servi à élaborer et à tester les outils de collecte de données, à interpréter ensemble les données recueillies et à valider les résultats de recherche.

Tableau 10.3 Membres de l'équipe de recherche (en ordre alphabétique). Il est à noter que d'autres personnes ont joué des rôles clés dans la réalisation de chapitres spécifiques.

Nom	Fonction
Hugo Asselin	Professeur à l'Université du Québec en Abitibi-Témiscamingue (UQAT, chercheur principal)
Annie Claude Bélisle	Étudiante au doctorat en sciences de l'environnement à l'UQAT
James Cananasso	Vice-chef, Conseil de la Première Nation Abitibiwinni, anciennement Coordonnateur territoire et environnement
Benoit Croteau	Directeur du service du territoire et de l'environnement, Conseil de la Première Nation Abitibiwinni
Louis-Joseph Drapeau	Assistant de recherche, UQAT
Roxane Germain	Ingénieure forestière, Conseil de la Première Nation Abitibiwininni
Roger Lacroix	Directeur Ressources naturelles, *Ouje-Bougoumou Cree Nation* (jusqu'en 2016)
Alice Wapachee	Professionnelle de recherche, *Ouje-Bougoumou Cree Nation*
Norman Wapachee	Directeur Ressources naturelles, *Ouje-Bougoumou Cree Nation* (depuis 2016)

Le devis de recherche est de type mixte, séquentiel exploratoire (Creswell et Plano Clark, 2011) (Figure 1.1). Un devis mixte fait appel à des méthodes qualitatives et quantitatives. L'approche séquentielle exploratoire signifie que les méthodes qualitatives sont utilisées en début de projet afin de développer un cadre conceptuel à partir des observations et données recueillies sur le terrain. Cette approche, inductive, permet d'ancrer la recherche dans les perspectives et enjeux locaux. Dans un second temps, les méthodes quantitatives sont utilisées afin de développer des indicateurs, de tester des hypothèses et de développer des outils d'aide à la décision. Les devis mixtes séquentiels exploratoires sont souvent utilisés en contexte autochtone parce qu'ils évitent d'imposer un cadre d'analyse préexistant, développé dans un contexte social et culturel différent (Cuerrier *et al*., 2015a; Durkalec *et al*., 2015; Oster *et al*., 2014; Taghipoorreyneh et de Run, 2020). Une méthodologie mixte permet également de faire un pont entre les outils d'analyse qualitatifs souvent propres aux sciences humaines et les outils quantitatifs davantage associés aux sciences naturelles.

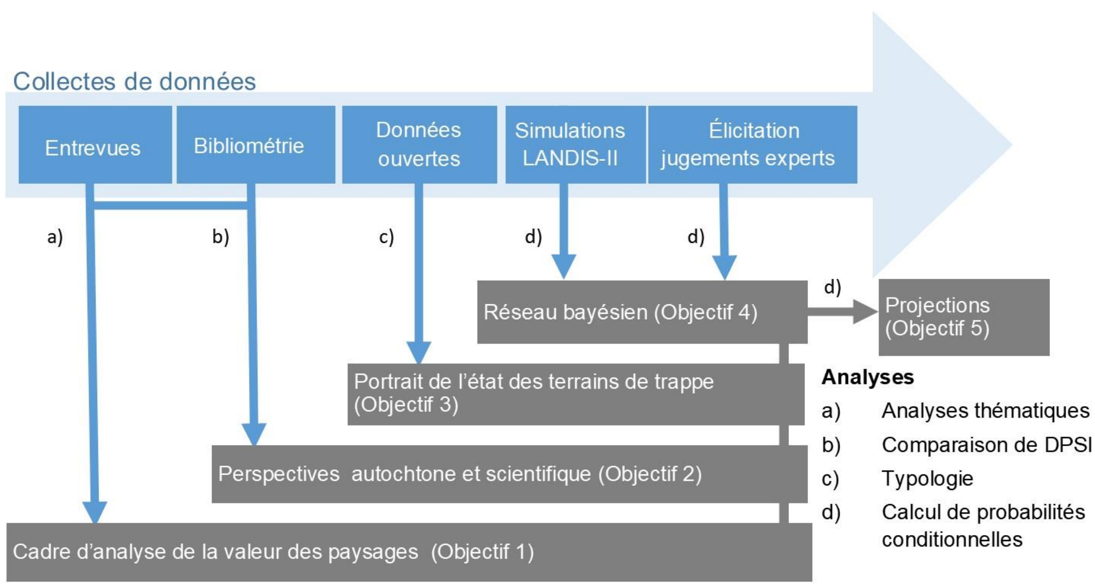

Figure 1.1 Structure méthodologique de la thèse, comprenant la séquence des collectes de données, les principales analyses et leurs contributions à l'atteinte des objectifs de recherche.

Une première collecte de données recueillies auprès des experts locaux du territoire a conduit à l'analyse qualitative de la valeur des paysages et de ses déterminants (Chapitre II). La collecte de données a eu lieu à l'été 2016 et a pris la forme d'exercices de cartographie participative couplés à des entrevues semi-dirigées. La méthode utilisée est inspirée des travaux de Raymond *et al*. (2009), où les participants indiquaient les lieux de valeur positive (en vert) et de valeur négative (ou menaces, en rouge) sur une carte (Annexe A). L'exercice a été adapté au contexte en produisant des cartes plastifiées des terrains de trappe et en demandant aux participants de dessiner en vert et en rouge les valeurs et les menaces associées à chacune des six pratiques (Tableau 1.1). La cartographie participative est utilisée dans la recherche en contexte autochtone pour faciliter les interactions et l'échange de connaissances (Ban *et al*., 2009; Huntingdon, 2000; Robinson *et al*., 2016). L'exercice de cartographie a été couplé à des entrevues semi-dirigées durant lesquelles les participants étaient questionnés sur chacune des zones identifiées. Les données ont été analysées à partir d'un encodage thématique et inductif des verbatims des entrevues afin de faire émerger un cadre d'analyse des valeurs du paysage.

Les perspectives autochtones et scientifiques sur les effets des changements environnementaux ont été comparées à partir de modèles conceptuels de type *Driver-Pressure-State-Impact* (DPSI) (Chapitre III). Les modèles DPSI sont utilisés en écologie pour structurer et analyser des problèmes complexes en soutien à la décision (Borja *et al*., 2006; Lewison *et al*., 2016). La perspective autochtone a été développée à partir des données d'entrevues recueillies pour le Chapitre II et la perspective scientifique à partir d'une analyse scientométrique des articles scientifiques publiés.

Un portrait et une typologie de l'état des terrains de trappe ont été développés à partir d'indicateurs dérivés des entrevues et de données ouvertes comme la proportion de forêts matures, la présence de sites miniers abandonnés et la densité du réseau de chemins forestiers (Chapitre IV). La typologie a été développée à partir d'une analyse de groupement non hiérarchique.

Un réseau bayésien a été utilisé pour projeter et analyser les effets cumulatifs des changements environnementaux sur la valeur des paysages autochtones (Chapitre V). Un réseau bayésien est un modèle probabiliste qui comprend une composante graphique qui définit les associations statistiques entre les variables et une composante statistique qui décrit chaque paramètre par des distributions de probabilités conditionnelles (Marcot *et al*., 2006). L'intérêt du réseau bayésien réside dans sa capacité à accueillir et à mettre en commun des données provenant de différentes sources comme des données expérimentales, des données simulées et des jugements d'experts (Chen et Pollino, 2012; Lynam *et al*., 2007). Ses résultats sont faciles d'interprétation et peuvent servir d'outil d'aide à la décision (Cain, 2001; Ellison, 1996; Martin *et al*., 2015). Les réseaux bayésiens ont d'ailleurs été utilisés en contexte autochtone pour aborder des questions environnementales complexes (Liedloff *et al*., 2013; Mantyka-Pringle *et al*., 2017).

Le réseau bayésien développé au Chapitre V met en commun les projections du modèle de simulations des paysages forestiers LANDIS-II (Scheller *et al*., 2007) et les savoirs d'experts autochtones de l'utilisation du territoire (Mantyka-Pringle *et al*., 2017). Les paysages forestiers ont été simulés sur la période 2000-2100 selon divers scénarios de foresterie et de changements climatiques. Les projections ont été regroupées par terrain de trappe, puis converties en six types de végétation potentielle. Ceux-ci ont été soumis aux experts des communautés selon un protocole d'élicitation de probabilités conditionnelles (Martin *et al*., 2012) (Annexe B).

1.6 Considérations éthiques

Le projet de recherche a été approuvé par le comité d'éthique de la recherche de l'Université du Québec en Abitibi-Témiscamingue (certificat # 2016-04) (Annexe C). Le développement du design de recherche a été guidé par le Protocole de recherche de l'Assemblée des Premières Nations du Québec et du Labrador (AFNQL 2014). Un accord de recherche a été signé entre des représentants de l'université et des communautés partenaires. Tel que prescrit par l'AFNQL (2014), l'accord présente une description détaillée du projet de recherche et en spécifie les objectifs. Il mentionne les principales sources de financement, les avantages et risques attendus ainsi que la méthodologie choisie. Il comprend un engagement de l'équipe de recherche envers les principes PCAP® (propriété, contrôle, accès et possession des données; https://fnigc.ca/ocap) ainsi qu'une description de la manière dont ils seront mis en œuvre. L'accord spécifie le rôle des parties dans l'analyse et l'interprétation des données et dans la validation des résultats préliminaires. Il prévoit la manière dont les résultats de recherche seront présentés aux communautés, le rôle des partenaires dans la révision des articles scientifiques et autres publications issues de la recherche ainsi que les modalités de résolution de conflit.

Les participants ont accepté de prendre part au projet en signant un formulaire de consentement (adapté de Basile *et al.*, 2018), qui explique les engagements de l'équipe de recherche vis-à-vis des données, les droits des participants et les règles de confidentialité (Annexe C). Les membres de l'équipe de recherche ont signé un accord de confidentialité avant de pouvoir accéder aux données.

CHAPITRE II

FROM LANDSCAPE PRACTICES TO ECOSYSTEM SERVICES: LANDSCAPE VALUATION IN INDIGENOUS CONTEXTS

(DES PRATIQUES PAYSAGÈRES AUX SERVICES ÉCOSYSTÉMIQUES : DÉTERMINATION DE LA VALEUR DES PAYSAGES EN CONTEXTES AUTOCHTONES)

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Abstract

The well-being of Indigenous people relies on a deep and complex relationship with the land. The consequences of environmental changes on landscape value need to be addressed from an Indigenous perspective. To this end, the ecosystem services framework is a good starting point as it is comprehensive, bridges a number of disciplines and is acknowledged by decision-makers. However, ecosystem services face contextual limitations when used for landscape valuation in Indigenous contexts. In collaboration with two First Nation communities in boreal Quebec (Canada), we revisited the ecosystem services framework so that it better corresponds to Indigenous values and perspectives. We elicited value related to six landscape practices (moose and goose hunting, trapping, fishing, education and *ressourcement*) using semi-structured interviews and participatory mapping. Participants had to locate on a map and discuss places of high and low value for each landscape practice and for future generations. Four dimensions of landscape value emerged from thematic analysis: abundance, quality, access and experience. Landscapes contribute to the well-being of Indigenous people by sustaining livelihood, culture and identity. We developed a landscape valuation framework that is consistent with Indigenous people's relationship with the land. The framework can guide landscape management towards sustainable Indigenous landscapes.

Key words: Landscape value, Landscape Practices; Ecosystem services; Well-being; Aboriginal people

Résumé

Le bien-être des peuples autochtones repose sur une relation profonde et complexe avec le territoire. Les conséquences des changements environnementaux sur la valeur du paysage doivent être abordées d'un point de vue autochtone. À cette fin, le cadre des services écosystémiques est un bon point de départ car il est assez inclusif pour comprendre un grand nombre de valeurs, et est de plus en plus reconnu chez les décideurs. Cependant, l'application du cadre des services écosystémiques en contextes autochtones requiert des ajustements. En collaboration avec deux communautés autochtones situées dans le Québec boréal (Canada), nous avons revisité le cadre des services écosystémiques afin qu'il corresponde mieux aux valeurs et perspectives autochtones. Nous avons décrit la valeur du territoire liée à six pratiques paysagères (chasse à l'orignal et à l'outarde, trappe, pêche, éducation et ressourcement) à partir d'entretiens semi-dirigés et de cartographie participative. Les participants devaient localiser des lieux de haute et de faible valeur pour chaque pratique et pour les générations futures sur une carte, puis en discuter. Quatre dimensions de la valeur ont émergé d'une analyse thématique : l'abondance, la qualité, l'accès et l'expérience. Les paysages contribuent au bien-être des peuples autochtones en soutenant le mode de vie, la culture et l'identité. Nous avons élaboré un cadre d'évaluation du paysage qui est cohérent avec la relation des peuples autochtones avec le territoire. Le cadre proposé peut assister la gestion durable des paysages autochtones.

Mots-clés : Valeur des paysages; pratiques paysagères; services écosystémiques; bien-être; peuples autochtones

2.1 Introduction

The land is a fundamental contributor to Indigenous people's well-being (Saint-Arnaud *et al* ., 2009; Turner and Clifton, 2009). Not only does the land produce natural resources used for subsistence in remote communities (Furgal and Seguin, 2006; Skinner *et al* ., 2013), but it is a privileged space for learning and sharing cultures and develop place attachment and belonging (Basile *et al* ., 2017; Biddle and Swee, 2012). Everyday life is ruled by activities such as hunting, trapping, fishing, paddling and ceremonies (Davidson-Hunt and Berkes, 2003). Such practices contribute to build and maintain a shared representation of the land between members of a community. The depth of the relationship with the land is testified by an extended body of indigenous ecological knowledge (Agrawal, 1995; Usher, 2000), passed down from generation to generation (Ohmagari and Berkes, 1997; Pearce *et al* ., 2011).

Global change affects Indigenous landscapes (Downing and Cuerrier, 2011; Parlee *et al* ., 2012; Turner and Clifton, 2009). The transformation of traditional food systems causes population health issues (Bussières *et al* ., 2004; Kuhnlein and Chan, 2000). Unpredictability of ice condition (Ford *et al* ., 2008a; Royer *et al* ., 2013), weather, and forest fires (Asfaw *et al* ., 2019) threaten the security of land users. Natural resource exploitation affects Indigenous people's quality of life (Fuentes *et al* ., 2020) and governance processes within communities (Casu, 2018). In addition to the vulnerability caused by environmental change, colonial dynamics have historically excluded Indigenous perspectives from land management (Nadasdy, 2003; United Nations, 2009).

Bridging Indigenous and land managers' perspectives is necessary to sustain landscape value for all stakeholders (Robinson and Wallington, 2012). The ecosystem services framework, developed to acknowledge and value the whole range of contributions of ecosystems to human well-being (Daily, 1997), is a convenient starting point (Pert *et al* ., 2015; Zander and Straton, 2010). Ecosystem services provide common ground for scientists, governments, industries and other stakeholders to address land and resource management (Braat and de Groot, 2012; Bull *et al* ., 2016). The concept is making its way towards international conventions and policies (e.g. *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (IPBES) - Díaz *et al* . 2015), national legislations (e.g. Canada and Chile - Castro *et al* . 2000, Costa-Rica - Pastén *et al* . 2018) and environmental certification (e.g. Forest Stewardship Council, 2015). The ecosystem services framework has been used for landscape valuation in various Indigenous contexts (Pert *et al* ., 2015; Sangha *et al* ., 2018; Uprety *et al* ., 2017; Zander and Straton, 2010).

A number of conceptual and cultural limitations arose from attempts at valuing Indigenous landscape using the ecosystem services framework. (1) The positionality of ecosystem services can be problematic as they place humans as disconnected beneficiaries of the environment (anthropocentric worldview) (Flint *et al* ., 2013; McCauley, 2006). Alternative worldviews (e.g. biocentric, holistic) may be closer to Indigenous cultures and more relevant in local contexts (Asselin, 2015; Getty, 2010; Van Riper and Kyle, 2014). (2) The metrics of ecosystem services are derived from economical sciences and are often formulated in terms of tradeoffs, monetary valuation, willingness to pay and compensation value (de Groot *et al* ., 2012). These metrics do not fully accommodate cultural and non-use values (Hernández-Morcillo *et al* ., 2013; Winthrop, 2014), of particular importance in Indigenous contexts (Pert *et al* ., 2015; Winthrop, 2014). Due to their incommensurate and intangible nature, cultural services are chronically underrepresented in valuation attempts, often being limited to measurable values such as tourism and recreation (Chan *et al* ., 2012; Hernández-Morcillo *et al* ., 2013). Moreover, people are not used to express their relationship with the land in monetary and trade-off terms, making valuation prone to bias and errors (Klain and Chan, 2012; Satterfield, 2001). (3) Most valuation frameworks fail to consider relational value, i.e. the value of the relationship between humans and ecosystems in and of itself (Bieling *et al* ., 2014; Chan *et al* ., 2018). Yet, hunting, fishing, gathering and other landscape practices are at the center of people's livelihood in many Indigenous communities (Cunsolo Willox *et al* ., 2012; Davidson-Hunt and Berkes, 2003; Feit, 2001; Skinner *et al* ., 2013) and are directly affected by environmental change (Brinkman *et al* ., 2016). (4) The concept of well-being is at the heart of the ecosystem services framework (Millenium Ecosystem Assessment, 2005). However, well-being is a subjective and context-dependant concept (King *et al* ., 2014). Among the variety of definitions and indicators of well-being, few were designed for (and in) Indigenous contexts (Parlee and Furgal, 2012; Sangha *et al* ., 2015).

Through a collaborative research project between academic and community researchers from two First Nations located in boreal Quebec (Canada), we aimed at developing a framework for landscape valuation bridging ecosystem services and local values and perspectives. We relied on a people-oriented and inductive design to investigate the influence of landscape state on landscape practices and on well-being.

2.2 Key concepts

2.2.1 Landscape

A landscape is a tangible spatial object of interest to both natural and social scientists (Termorshuizen and Opdam, 2009; Tress *et al* ., 2001). Landscape ecologists study “the interaction between spatial pattern and ecological process—that is, the causes and consequences of spatial heterogeneity across a range of scales” (Turner and Gardner, 2015 p.2). A landscape approach offers a spatially explicit, multi-scalar and systemic framework to analyse complex environmental problems (Opdam *et al* ., 2018). In sustainability science, social and ecological processes are integrated in land-based social-ecological systems (Olsson *et al* ., 2004), social-environmental systems (Turner *et al* ., 2016) or coupled human and natural systems (Liu *et al* ., 2007). Our research focused on the relationship between Indigenous people and the “ecological” landscape. We considered the social and ecological components of the landscape and the relationships between them (Turner *et al* ., 2016).

The theoretical framework we used is anchored into “the five dimensions of the transdisciplinary landscape concept”: spatial, mental, temporal, nexus and complex system (Tress and Tress 2001, p. 147). 1) The *spatial* landscape is a tangible entity that includes the geosphere (non-living), biosphere (living, humans included) and noosphere (artefacts left by human action). The *spatial* landscape is a mosaic of features, sometimes called patches, assets or elements (Wallace, 2007). Landscape features can be ecosystems such as lakes or old-growth forests (Bieling *et al* ., 2014; Stedman, 2003) or human-built such as shelters, roads or graves (Schaich *et al* ., 2010). Structure, patterns and processes and their interactions characterize a *spatial* landscape (Turner, 1989; Turner and Gardner, 2015).

2) The *mental* landscape is an entity created by its observer through reflection, feeling and imagination. Landscape perception changes from one person to another and is partly shared between members of a culture or a social group (Bieling *et al* ., 2014; Liu and Opdam, 2014). In Indigenous contexts, the mental landscape is shaped in accordance with traditional ecological knowledge, including factual knowledge of places and ecosystems, skills, languages and worldviews (Tengö *et al* ., 2017; Usher, 2000).

3) The *temporal* landscape is dynamic. Both spatial and mental landscapes change over time, more rapidly in the context of global change. In landscape ecology, change refers to "the alteration in the structure and function of the ecological mosaic through time" (Turner, 1989, p.173). Ecological modelers aim to project landscape responses to various scenarios of environmental change (Pereira *et al* ., 2010). Research in anthropology and human geography is particularly interested in understanding how landscape perceptions develop and how they are modulated by environmental change (Antrop, 2005; Ingold, 2000).

4) A landscape is a *nexus* between nature and culture. The nexus approach focuses on the links between people and ecosystems (Fürst *et al* ., 2017). Landscape practices such as hunting, fishing and gathering play this connexion role. We define landscape practices as conscious or unconscious interventions generating a bidirectional connection between human and non-human landscape components. Landscape practices shape both spatial and mental landscapes and contribute to place meaning and attachment (Bieling *et al* ., 2014; Stedman, 2003). The *nexus* approach is in line with the concept of relational values, which finds a growing interest in ecological economics (Chan *et al* ., 2018; Díaz *et al* ., 2018).

5) Landscapes are considered *complex systems* as they comprise many components and non-linear interactions, multiple scales and self-organizing proprieties (Berkes *et al* .,

2003; Wu, 2013). Resistance, resilience, adaptability and transformability are proprieties of *complex* landscapes (Liu *et al* ., 2007; Walker *et al* ., 2004).

2.2.2 Landscape valuation and ecosystem services

Landscape valuation is the appreciation of the capacity of a biophysical landscape (*spatial* dimension) to sustain landscape practices (*nexus* dimension) contributing to people's well-being (adapted from Liu and Opdam, 2014). In this research, we were interested in the value that people attribute to landscapes (mental landscape) based on a set of landscape practices.

The ecosystem services framework presented in the Millenium Ecosystem Assessment (2005) is a common ground for landscape valuation. Ecosystem services are divided into four categories: provisioning, cultural, regulation and support. While many definitions of ecosystem services have been suggested (see Braat and de Groot, 2012), we worked with "*the direct and indirect contributions of ecosystems to human well-being*" (de Groot *et al* ., 2010) because it is oriented on well-being instead of benefits.

2.2.3 Well-being

The capability approach defines well-being as the opportunity to live a good, valued and satisfactory life (e.g. Nussbaum, 2000; Sen, 1979; Stanton, 2007). Capabilities are presented as an alternative to the resource accumulation- and utility-based conceptions of well-being (King *et al* , 2014). Ecosystem services are thus considered as contributions to freedom of choice and action (Polishchuk and Rauschmayer, 2012). Well-being is a context-dependant concept (Busch *et al* ., 2011) and indicators need to be adjusted according to local cultures and issues (Busch *et al* ., 2011; King *et al* ., 2014; Liu and Opdam, 2014), especially in Indigenous contexts (Sangha *et al* ., 2015).The capability approach is appropriate for participatory and intercultural research because determinants of well-being are developed with and for the community (Sangha *et al* ., 2015; Yap and Yu, 2016).

2.3 Study area

Two Indigenous communities participated in the project, one Anishnaabe and one Cree, both belonging to the Algonquian cultural and linguistic family. Algonquian Nations are distributed throughout North America, from the Atlantic Ocean to the Rocky Mountains and from the 60th parallel to central USA. The traditional lifestyle is seasonal and ruled by wildlife migration patterns. Prior to their forced settlement in reserves, Anishnaabe and Cree people were living in small movable houses and were travelling the land by canoe. The Indian Act, passed in 1876 and still in force in Canada, forced people to settle in reserves and attempted to eradicate Indigenous cultures through different programs, including residential schools (Truth and Reconciliation Commission of Canada, 2015). Numerous initiatives are taken by Indigenous communities to re-appropriate the land and maintain cultures alive. Cultural weeks spent in the bush, income security programs for those choosing to live in the bush and school curricula including Indigenous knowledge and languages are just a few examples.

We worked in collaboration with the Abitibiwinni First Nation, the northernmost Anishnaabe community in Quebec, Canada (1 080 members) (Indigenous and Northern Affairs Canada 2015). Members of the Abitibiwinni First Nation settled in the Pikogan community near the town of Amos in 1956 (Commission de toponymie du Québec, 2019). Anishnaabe presence in the area dates back at least 6000 years (Côté, 1995).

Ouje-Bougoumou is a Cree community established on a territory they call Eeyou Istchee, in northern Quebec (906 members) (Crown-Indigenous Relations and Northern Affairs Canada, 2017). The village was settled in 1992 and community members live partly there, partly out on the land. They have been living in the Chibougamau lake surroundings at least since the early fur trade era in the 16th century (Frenette, 1985). They were forced to resettle several times in the last century because of active mining in the region (Frenette, 1985). Cree presence in the area dates back at least 5000 years (Wright, 1979).

The study area comprises the hunting grounds of the Ouje-Bougoumou First Nation (10,560 km2, 14 hunting grounds called traplines) and the Abitibiwinni First Nation (11,430 km2, 34 hunting grounds) (Figure 2.1). Hunting grounds, which we considered as individual landscapes in this research, are land units used by a hunting group (generally a family) and passed from one generation to the next (Feit, 1985). Cree hunting grounds are managed by an official administrator called a tallyman (Whiteman, 2004), whereas Abitibiwinni hunting grounds are under the unofficial responsibility of family members. The size of hunting grounds varies between and within communities (Figure 2.1), mostly to take into account the uneven distribution of natural resources and because they are sometimes divided into parts bequeathed to children. For uniformity reasons, we focused on the hunting grounds located in the black spruce (*Picea mariana* Mill. B.S.P.) – feather moss bioclimatic domain (14/14 for the Ouje-Bougoumou First Nation, 24/34 for the Abitibiwinni First Nation). Both territories are mainly located on public lands under the responsibility of the government of Quebec. In addition, activities on the Cree territory are regulated by the *James Bay and Northern Quebec Agreement* (1975) and *La Paix des braves agreement* (2002). No such agreement has yet been signed on the Abitibiwinni territory within the study area).

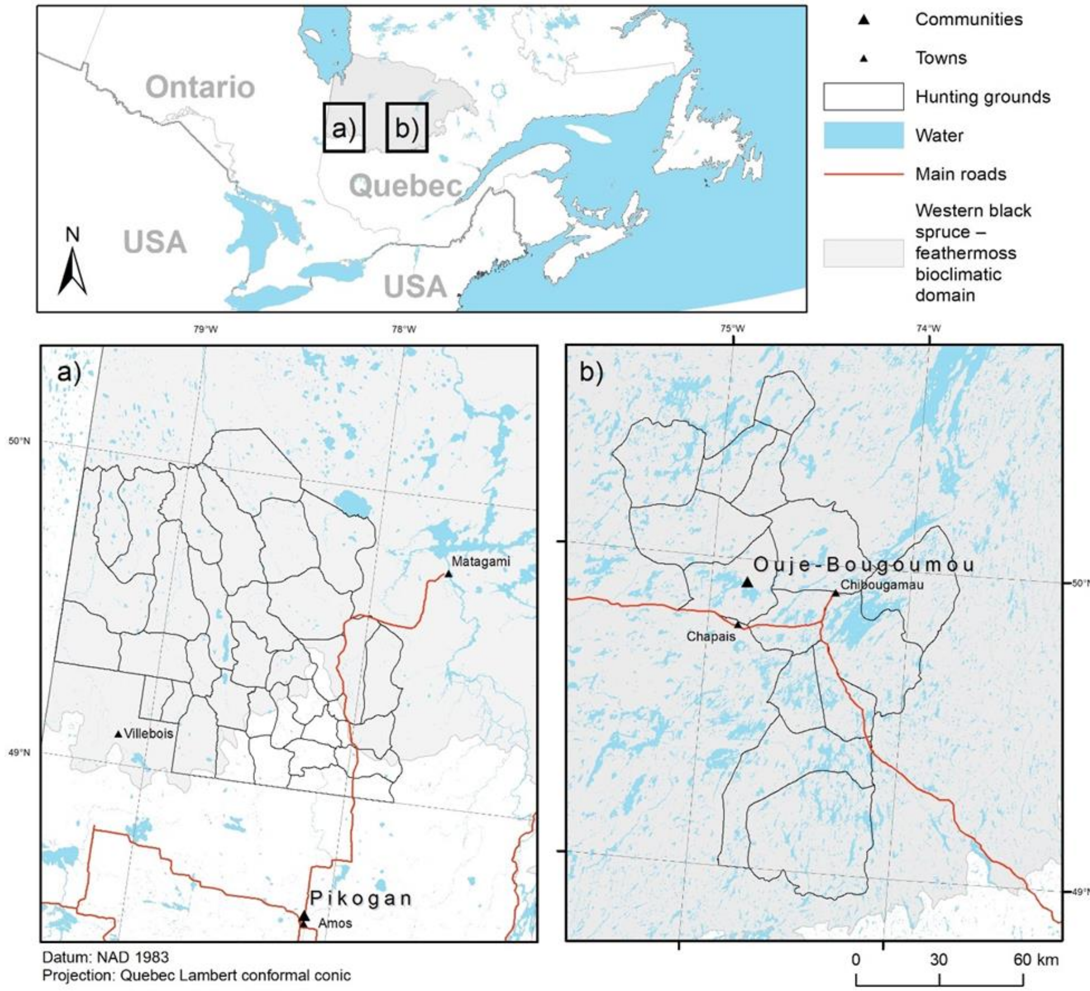

Figure 2.1 Hunting grounds of (a) the Abitibiwinni First Nation and (b) the Ouje-Bougoumou First Nation.

The study area is under a subpolar subhumid continental climate (Robitaille and Saucier, 1998) with mean annual temperature (1981–2010) between 0.0 °C and 0.2 °C and mean annual precipitation between 909 mm and 996 mm, of which 29% to 31% falls as snow (Environment and Climate Change Canada, 2019). The land is mainly covered by coniferous forests and includes a few towns and villages. Relief is generally flat with some rock outcrops on Abitibiwinni hunting grounds and rounded hills on Ouje-Bougoumou hunting grounds. The Harricana river is the main waterbody in the

Abitibiwinni region. It flows from south-east to north-west and connects with a complex network of rivers and streams (Robitaille and Saucier, 1998). The hydrography in the Ouje-Bougoumou region is organized around large lakes covering up to 14% of the area (Robitaille and Saucier 1998).

Forestry (Cyr *et al* ., 2009), wildfires (Boulanger *et al* ., 2013), mining exploration and exploitation (Asselin, 2011) and hydro-electricity transportation (Hydro-Québec, 2015) are the main environmental disturbances in the study area. Industrial development affects Indigenous people's health (Bussières *et al* ., 2004; Tsuji *et al* ., 2007), relationship with the land (Germain, 2012; Kneeshaw *et al* ., 2010; Saint-Arnaud *et al* ., 2009; Whiteman, 2004) and quality of life (Fuentes *et al* ., 2020).

2.4 Methods

We elicited landscape value via landscape practices. Priority landscape practices were chosen by the research team (researchers from academia and communities) (Figure 2.2). We selected landscape practices that were widely spread between members of both participating communities, valued for their contribution to people's well-being and sensitive to landscape state. The relevance of the selected practices was confirmed by dedicated holidays, cultural weeks, learning camps and income programs.

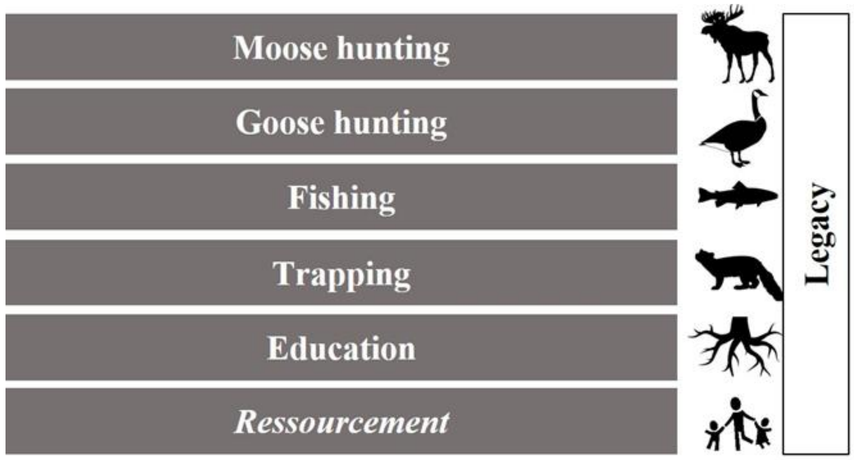

Figure 2.2 Priority landscape practices for the Ouje-Bugoumou and Abitibiwinni First Nations. Moose *(Alces americanus*) hunting delivers many provisioning and cultural ecosystem services such as food, art craft material and traditional knowledge (Jacqmain *et al* ., 2012; Saint-Arnaud *et al* ., 2009). Canada goose (*Branta canadensis*) is hunted during the spring and fall migrations and is an important source of fat in the Cree diet (Delormier and Kuhnlein, 1999). In boreal Quebec, lakes and rivers are abundant and fishing is a regular activity. Wild fish is a staple food in traditional diets and fishing is associated with time spent with family and with traditional skills. Trapping of various wildlife species such as beaver (*Castor canadensis*) and marten (*Martes americana*) provides food (especially beaver), fur and income (especially marten). *Ressourcement* is a French word defined as "*reversion to one's sources, finding one's deep roots in order to reach a new balance. Find sources (moral, psychological, spiritual, etc.) to recover physical and moral forces*" (translated from Office québécois de la langue française, 1989). *Ressourcement* includes notions of healing and health provided by a connexion with the land, and is key to maintaining mino-pimatisiwin, i.e. a state of comprehensive health and well-being (Landry *et al* ., 2019). A cultural week is yearly dedicated to *Ressourcement* in the Abitibiwinni First Nation. Education refers to formal and informal activities involving the transmission of bush skills and knowledge. Legacy to future generations is a general appreciation of the hunting ground value and its contribution to well-being (Clarkson *et al* ., 1992).

2.4.1 Ethics

The project was approved by the Ethics Review Board of Université du Québec en Abitibi-Témiscamingue (certificate # 2016–04). We followed the OCAP® principles (ownership, control, access and possession of data) and we developed the project in accordance with the research protocol of the Assembly of First Nations Quebec-

Labrador (AFNQL 2014). Research agreements were signed between representatives of the university and the two participating communities. The agreements specifically precluded comparative approaches between communities. Participants agreed to take part in the project by signing a consent form (adapted from Basile *et al* . (2018)) with a guarantee that the data would remain confidential and that no map, name or personal information would be released without their consent. Researchers signed a commitment to confidentiality before they could access data.

2.4.2 Value elicitation

We elicited value using a combination of semi-structured interviews with hunting ground managers and participatory mapping (Figure 2.3). We used qualitative methods to elicit landscape value, as they fit well with Indigenous oral traditions (Satterfield, 2001; Schreyer, 2008; Turner and Clifton, 2009). Participatory mapping has also been reported as an appropriate method for value elicitation in various Indigenous contexts (Herlihy, 2003; Klain and Chan, 2012; Robinson *et al* ., 2016; Tendeng *et al* ., 2016; VanSpronsen *et al* ., 2007).

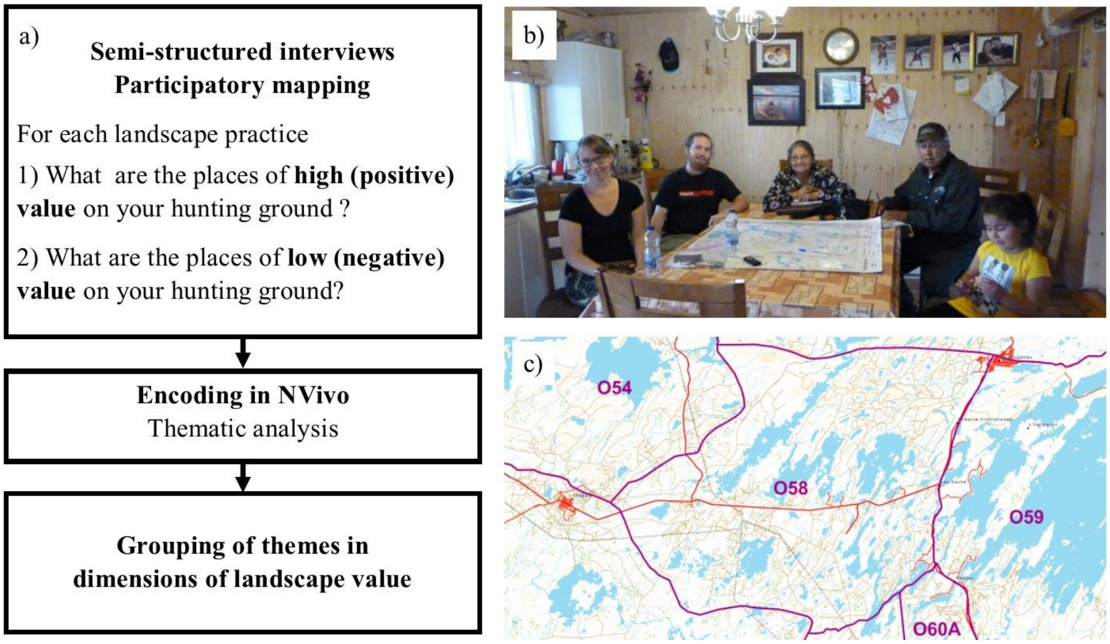

Figure 2.3(a) Interview and coding procedure. (b) Participatory mapping. From left to right: Annie Claude Bélisle, Louis-Joseph Drapeau, Anna Bosum, David Bosum and Faith Lacroix in the Bosum family house (with permission). (c) Example of a map provided to participants.

2.4.2.1 Value elicitation

The recruitment of participants and interviews occurred between July and September 2016. Researchers from the participating communities were responsible for selecting participants according to availability, representativeness of the hunting grounds and expertise. In the Ouje-Bougoumou First Nation, we contacted all 16 tallymen (there are 14 hunting grounds, but some are comanaged) and 11 accepted to participate. Family members were welcome to join the interview, adding gender and age diversity (3 participants were added this way for a total of 14 people met). In the Abitibiwinni First Nation, we contacted managers who had several years of experience in land use and management and extensive knowledge of their hunting ground. We balanced the number of participants from the northern and southern parts of the territory, as they experienced different disturbance levels (wildfires, mines, forest management). We met with 12 of them (out of a possibility of 24) and one family member joined an interview (for a total of 13 people met).

We verified participant’s expertise using close-ended questions. We asked if they were active land users for each landscape practice. When the answer was no, we excluded this specific practice from the interview. We also asked participants to rank their own expertise for each practice on a scale of 1 to 10 (with graphical support). We further questioned participants who answered below 5. When low expertise was confirmed, we excluded their answers for this specific practice.

2.4.2.2 Semi-structured interviews and participatory mapping

Interviews were held in different locations within and outside the communities according to participant's preferences (Band Council office, personal house our cabin, local restaurant, friendship center). We performed interviews in French, English, Cree and Anishnaabemowin. Interviews conducted in Indigenous languages were directly translated to French or English by a researcher from the community. Most interviews lasted from 45min to 2h, a few extended to 3–4h.

We began the interviews by a short presentation of the project objectives, introduction of the research team members and presentation of the research agreement. We then read and co-signed the consent form. We asked a number of close-ended questions dedicated to sketch the social profile of participants and confirm their expertise before undertaking the semi-structured interview and participatory mapping of landscape value (adapted from Raymond *et al* . (2009)). We provided laminated maps (1:60,000) showing hunting ground delineation, elevation lines, lakes, rivers, wetlands, hydro-power lines, quad paths and roads (Figure 2.3). We asked participants to locate their cabins and campsites and we validated their understanding of the map with simple orientation questions. For each landscape practice, participants were asked to indicate:

1) Places with higher value (positive) using 30 green chips; the more chips, the more value. The contour of each place was drawn with a green marker pen.

2) Places with lower value (negative) using 10 red chips; the more chips, the less value. The contour of each place was drawn with a red marker pen.

The general contribution of landscapes (hunting grounds) to well-being was synthetized as the legacy to future generations with the question "What places make the hunting ground valuable (or not) for future generations?"

Each drawn feature was discussed. Interviews were audio-recorded, and we took a picture of each map before erasing it. Precision and accuracy of mapping were not a matter because the maps and the chips were used to ease discussion rather than to generate weighted spatial data.

2.4.3 Coding and thematic analysis

We followed an inductive protocol to analyze the qualitative data from the interviews. We transcribed all interview recordings and imported the text documents into the NVivo 10 Software (QSR International) for thematic analysis (Guest *et al* ., 2012). One researcher (first author) performed the analysis, assisted by the research team. She grouped information into three hierarchical levels. (1) She created six nodes in NVivo, one per landscape practice. She added a seventh node for legacy. She coded interview excerpts to one or many landscape practice nodes. (2) She analyzed all excerpts thoroughly, one landscape practice at a time. She grouped similar information into thematic nodes of landscape patterns. Landscape patterns include biophysical phenomenon on the hunting ground (e.g. size of a wildlife population, road density, boat access) as well as human interactions with the land (e.g. specific hunting skills, knowledge, healing). (3) She analyzed emerging landscape patterns and grouped them into dimensions of landscape value. The idea was to keep the dimensions general enough so that they would be applicable to other contexts. The analyst validated the classification of each excerpt, one at a time. Participant’'s answers about the value of the hunting ground for future generations were also coded into themes, and themes were grouped into domains of well-being. The research team validated the themes, dimensions of landscape value and classification of ambiguous excerpts and discussed the interpretations.

2.5 Results

2.5.1 Participant characteristics

Most participants were men older than 54 years old. All participants from the Abitibiwinni First Nation lived in the community. In Ouje-Bougoumou, a majority lived in the community, five lived on their hunting ground and one lived in a different community (Table 2.1). Most participants reported going on their hunting ground *most of the days* in the Ouje-Bougoumou First Nation and *one to three times a week* to *one to three times a month* in the Abitibiwinni First Nation. The answer choices were not appropriate for four participants who travelled once or twice a year to their hunting ground, far from the community, staying there for several weeks.

Table 2.1 Characteristics of the participants from the Abitibiwinni First nation (A) and Ouje-Bougoumou First Nation (O), including gender, place of residence, age group, attendance on the hunting ground and landscape practices.

		A	O
Number of participants		13	14
Gender	Man	13	12
	Woman	0	2
Age (years old)	35–44	1	1
	45–54	4	4
	55–64	6	2
	≥65	2	7
Residence	Community	13	8
	Hunting ground	0	5
	Outside	0	1
Attendance on the hunting ground	Most of the days	1	8
	1–3 times / week	3	3
	1–3 times/ month	4	2
	Few times /year	2	0
	Other	3	1
Landscape practices	Moose hunting	13	12
	Goose hunting	10	11
	Fishing	12	13
	Trapping	13	13
	Education	13	14
	Ressourcement	13	14

2.5.2 Four dimensions of landscape value

Four dimensions of landscape value emerged from the themes addressed by the participants. (1) Themes associated with the quantity of landscape features, material or immaterial, were grouped into the *Abundance* dimension. (2) Themes associated with the ease with which a landscape feature can be reached or obtained were grouped into the *Access* dimension. (3) Themes associated with the characteristics of landscape features and their capacity to satisfy a need or to fulfill a function were grouped into the *Quality* dimension. (4) Themes associated with the emotional response, positive or negative, associated to a landscape practice were grouped into the *Experience* dimension.

We grouped the information on legacy and well-being into three components. (1) *Identity* includes information about relationship with the land and place attachment. (2) *Livelihood* is about the potential of the land to sustain the Indigenous way of life. (3) *Culture* concerns the potential of the land to maintain knowledge, languages and traditions.

2.5.2.1 Abundance

Participants described moose abundance with themes associated with habitat, predation and hunting pressure (Table 2.2). Habitat was differentiated according to seasons. Participants from the Abitibiwinni First Nation mainly hunted during the mating season (fall) and while moose travel to winter habitats. The importance of waterbodies during the hunting season was raised by many participants. “They always stay there, moose, in this area. It's because of the lakes. They move around and between lakes.” (A_10)[6] Participants from the Ouje-Bougoumou First Nation mainly hunted during wintertime so “moose yards” (winter habitats) were of particular importance. “There is the best moose yard on my trapline. Every year, every year, you have a moose here, every year. Since I started hunting, […] this is the best moose yard. Right over there, that mountain [hill].” (O_01a) Moose yards were reported to be located on hilltops and in stands of broadleaf trees and shrubs. Participants associated spring habitat with the birth of calves. They also mentioned hunting and predation to influence moose abundance.

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[6] Interviews in Indigenous languages were directly translated to French or English by community researchers. Quotes coded in French were then translated in English for this publication. The letter at the beginning of the code indicates the Nation of the participant (A: Abitibiwinni, O: Ouje-Bougoumou).

Table 2.2 Themes associated with the abundance of landscape features on hunting grounds, addressed in a number (n) of interviews in the Abitibiwinni First Nation (A) and Ouje-Bougoumou First Nation (O).

		n	
Landscape practices	Themes (abundance)	A	O
Moose hunting	General habitat	11	9
	Winter habitat	9	11
	Spring habitat	2	1
	Summer habitat	4	4
	Fall habitat	3	3
	Hunting pressure	7	7
	Predation rate	4	0
Goose hunting	Ice opening (spring)	5	8
	Feeding area	2	2
	Landing area	1	8
	Quietness	4	3
Fishing	Spawning areas	3	7
	Water quality	4	10
	Fishing pressure	3	5
Trapping	Habitat	12	12
	Hunting and trapping (beaver)	3	7
	Natural cycle	0	7
	Population control (beaver)	2	0
	Predation (beaver)	1	2
Education	Attitudes	3	5
	Knowledge	6	8
	Skills	10	10
Ressourcement	Aesthetics	3	8
	Healing	1	3
	Heritage/belonging	5	6
	Spirituality	2	3

Canada goose is hunted during the spring and fall migrations. Hunters from the Abitibiwinni First Nation reported hunting in agricultural fields and other open areas, outside the forest. In the Ouje-Bougoumou First Nation, hunters wait for geese to land on or fly off rest areas, often waterbodies or wetlands. Participants associated goose abundance with the availability of open waters and landing corridors without obstacles.

Fish abundance was reported to be an important component of hunting ground value in both communities. Several species were fished for consumption such as walleye (*Sander vitreus, ukaash, OKAS*), northern pike (*Esox Lucius, chinushesh, KINOCE*) and lake sturgeon (*Acipenser fulvescens,* nameu, NAME). Fish abundance was associated with water quality of lakes and streams. The state of spawning areas was also a concern: "The only place I think is important here is where the fish spawn. Here sturgeon, walleye here, another one here." (O_07) Participants also raised the overfishing issue: "One time I went over here out on the lake. I took my son there and my grandson to go fishing. We counted, there were 27 boats there." (O_08).

Participants trap a diversity of wildlife species. Marten was preferred for the commercial value of its fur and beaver for both fur and meat. Participants associated marten abundance with the availability of closed-canopy coniferous forests. They linked beaver abundance with waterbodies and broadleaf tree species (especially trembling aspen, *Populus tremuloides* Michx.). Beaver abundance was also reported to be influenced by predation (e.g. by eagles) and by trapping and hunting rates. Control of beaver populations (considered a nuisance for road maintenance by government agencies and forestry and mining companies) was also mentioned: "They kill the beavers. They take a shovel, empty the dam and crush the hut. That's what they do. They used to ask us, the family, to go and kill the beavers, and that's what we were doing. But not anymore" (A_01) Participants from Ouje-Bougoumou explained that the abundance of many fur bearing animal species follows natural cycles.

A valuable hunting ground provides a learning environment for the transmission of knowledge about ecology, culture and history:

> When I bring my grandchildren [on the land], I show them. There is not only culture but also history. History of your ancestors, history of the territory, who was there, where you were when you were young. We

> walked, there were no roads and everything. We were there [on the hunting ground] before to be here [in the community]. (A_01)

Participants underlined the importance for children to learn various skills: set fishing nets, install traps, skin animals, hunt moose. They explained the hunting ground needs to provide the learning material to support such technical learning. The educational value of the hunting ground was also mentioned to depend on its potential to transmit culture, develop land attachment and learn how to respect the land:

> It's very important that we, as grand-parents also, teach our grand-children and shall teach also our children by taking them out in the land. You can teach them everything about the native Cree culture and especially our language. (O_09b)

Participants discussed *ressourcement* (see the definition in the caption of Figure 2.2) referring to the positive and reenergizing feelings provided by the land. They reported enjoying the view from a hilltop or a lake shore and good feelings were associated with the aesthetic qualities of the environment. Participants also described the healing potential of the land: "[There is] a healing for every person that goes out on the land. It's something that you can't describe, only you can feel it. You know, when you need help out there." (O_09a) Some participants mentioned a spiritual connexion with the land. *Ressourcement* was also associated with heritage and belonging: "My grand-father, he is there. He passed away, but he is still there. It's the island, we have a cabin there. I go there, I sit down and I think. It's the only place where I feel good." (A_09).

2.5.2.2 Access

Today, access to the hunting ground depends on forestry roads, snowmobile and four-wheeler trails and waterways (Table 2.3). Most participants had one or many cabins on the hunting ground. Those base camps were key access points to the land. For moose hunting, participants said they reach hunting sites by truck or boat during the fall: "That is where we leave in canoe to reach the first camp. We keep going and the portages are over there. We continue to the last camp. This is an area where there are a lot of moose." (A_10) They use snowmobiles in the winter. Goose hunting generally takes place on lakes so access to hunting spots requires a boat or a snowmobile, depending on the season. For participants from Ouje-Bougoumou, goose hunting was reported as a family activity and the proximity of a cabin and the availability of facilities for children added value to the hunting ground: "My favourite spot is way over here. That's where I take the youth because it's by the camp. This one, it's all open and they [geese] land on there." (O_08) Fishing areas were accessed by boat and sometimes directly from the road. Specific places to set a fish net, known from generation to generation, provide additional value to the hunting ground: "These are spots my grandfather taught me. Every year, he caught. Every year I catch." (A_09) Trapping is a winter activity. Participants explained they set traps along a path and visit them daily. Creeks were reported as trapping "hot-spots" where aquatic and terrestrial animals gather.

> "Yeah I trap them [otters], I used to go [with snowshoes] but now we don't [use the snowshoes anymore]. We use the skidoos [snowmobiles]. We used to follow creeks and all that. And also at the same time we go for the mink." (O_05)

For education, many participants reported that the most convenient way to access learning areas is from the cabin: "First of all, I bring them [children] to the cabin. That's the place where education takes place. Education is done around the camp." (O_02b[7]) A road access allows for day trips and makes it easier to fit with school and working schedules. Access to places for *ressourcement* was also reported to be closely tied to the camp for most participants from the Abitibiwinni First Nation and half of those

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[7] Codes a and b distinguish participants from a family who participated in the same interview.

from the Ouje-Bougoumou First Nation. “There at my camp, I kind of forget the bad things, bad experiences. It seems I relax more there.” (A_05).

Table 2.3 Themes associated with access to landscape features on hunting grounds, addressed in a number (n) of interviews in the Abitibiwinni First Nation (A) and in the Ouje-Bougoumou First Nation (O).

		n	
Landscape practices	Themes (access)	A	O
Moose hunting	Boat access	7	0
	Cabin and surroundings	4	1
	Truck/car access	8	2
	Snowmobile trails	1	6
	Walking access	1	4
Goose hunting	Cabin and surroundings	1	7
	Road/vehicle access	2	4
	Shelter/hideout	0	3
Fishing	Boat access	1	4
	Cabin and surroundings	3	1
Trapping	Cabin and surroundings	3	0
	Trails	7	9
	Waterbodies	6	4
Education	Cabin and surroundings	10	6
	Day trips	1	2
	Facilities	1	1
Ressourcement	Cabin/Camp	10	6
	Mountains (hilltops)	0	5
	Routes (canoe, trail)	3	4
	Water bodies	4	1
	Whole hunting ground	6	4

2.5.2.3 Quality

Participants reported that even if desired landscape features are abundant and accessible, their value depends on quality (Table 2.4). Moose quality was associated with meat (food) and hide (art craft material) condition, which changes with seasons (meat was reported to be of better quality in the fall and winter and hide during the spring). Quality of both meat and hide was also related to moose health. Participants were reluctant to eat meat from a skinny or sick moose. No participant reported goose quality to be a concern. Fish quality mainly relied on perceived meat condition: “No, no, I don't cook it. […] I take off all the skin. If it is all red meat, you are going to have stomach-ache because it was not good.” (A_06) Some participants felt that some fish species were more valuable than others, while some did not mention any preference. Hunting ground value for trapping was reported to depend on fur market prices, marten having the highest commercial value.

Table 2.4 Themes associated with the quality of landscape features on hunting grounds, addressed in a number (n) of interviews in the Abitibiwinni First Nation (A) and Ouje-Bougoumou First Nation (O).

		n	
Landscape practices	Themes (quality)	A	O
Moose hunting	Moose health	3	3
	Seasonality	0	2
Goose hunting	-	0	0
Fishing	Preferences (species)	0	4
	Wholesomeness	2	3
Trapping	Market value	7	5
	Meat/fur quality	7	5
Education	Attendance	1	1
	Educator knowledgeability	4	3
	Environment	2	2
	Rules/laws	1	1
Ressourcement	Family	1	4
	Nostalgia	1	3
	Other activities	7	7

Quality of education on the hunting ground was associated to both learning conditions and learning environment. Participants explained that education quality is based primarily on the competence level of the teacher and on attendance on the land. Some reported that legislation was a limitation for the teaching of specific skills. For example, night hunting is forbidden by law but is a valued traditional skill among the Cree and Anishnaabe.

Quality of *ressourcement* was associated with time spent with family. When participants were asked to indicate specific "feel good" places, many answered that the whole hunting ground provides such positive feelings. Participants also indicated places providing negative feelings, associated with the occurrence of other activities, mainly industrial, and with nostalgia in a changing world.

2.5.2.4 Experience

The appreciation of time spent on the hunting ground engaging into landscape practices, summarized as experience, was a critical dimension of landscape value for participants (Table 2.5). A valuable experience was associated with time spent with family, engaging in traditional activities (cultural experience). Some special places were valued because of individual preferences and background: “This is where I killed my first moose. This is a very special place for me.” (O_06) Participants mentioned places they know deeply, where their skills lead to good hunting, fishing and trapping outcomes. To the contrary, a lack of skills was an issue for some participants. Conflicts with other land users negatively affected experience, especially for those who had land management responsibilities: “I think my trap is gone. Somebody took it off. I used to have another one there but it's gone. Sometimes the people take it, sometimes the bear pull it down.” (O_01, during a fieldtrip) Access to technology (satellite internet, television, mobile phone network) was a concern, especially when spending time with children:

> Well when we take them over there [main camp], we don't like them to bring this kind of stuff […] because it's really disturbing for them and they don't have to know what's happening in the world. […] Sometimes, when we're here [in the community], we don't even know at what time the kids go to bed. We don't want that to happen over there [on the land]. We don't even tell them where there is a [mobile phone] signal.” (O_08)

Participants also valued safe learning environments with aesthetic qualities.

Table 2.5 Themes associated with the experience of landscape practices on hunting grounds, addressed in a number (n) of interviews in the Abitibiwinni First Nation (A) and the Ouje-Bougoumou First Nation (O).

		n	
Landscape practices	Themes (experience)	A	O
Moose hunting	Cultural experience	2	3
	Management responsibilities	5	5
	Other activities	8	4
	Preferences	4	4
	Skills	5	0
Goose hunting	Cultural experience	3	2
	Other activities	0	1
	Preferences	6	5
	Skills	3	0
Fishing	Cultural experience	6	3
	Management responsibilities	1	3
	Other activities	1	6
	Preferences	4	4
	Skills	5	0
Trapping	Cultural experience	5	4
	Management	1	1
	Other activities	2	5
	Preferences	6	2
	Skills	5	0
Education	Aesthetics	0	2
	Other activities	3	0
	Safety	7	5
	Technology	3	4
Ressourcement	-	-	-

2.5.2.5 Legacy and well-being

Hunting grounds are handed down from generation to generation within a family and their value is a contribution to the well-being of future generations. When asked about the needs of future generations, a participant answered “When you think about the land and land users, your mind is clear. You don't have anything to worry about. You will always go hunting wherever you can.” (O_09b) Three domains of well-being emerged from participant's sayings about the value of the hunting grounds for future generations (Table 2.6). (1) Identity was associated with continuity of the relationship with the land. Older participants were concerned about the loss of youth interest in the land:

> “I used to take them in the bush when they were small, four or five years old, sometimes three. My grandsons and my granddaughters, they liked that. After, when they got older, I asked my youngest one two years ago : ‘Hey, how come you never come with me in the bush?’ He said: ‘Grandpa, it's boring in the bush.’.” (O_02)

Participants reported that it is hard to get children and teenagers engaged with the land, and that school and working schedules are not always compatible with life in the bush. (2) Legacy was also associated with the potential of the land to sustain the livelihood of future generations. When asked to describe a valuable forest for future generations, a man from the Abitibiwinni First Nation answered “A nice forest where you can do your activities, where you can teach many things, hunting, trapping, survival, everything you need to survive in the forest.” (A_02b) Continuity and integrity of the land were also a mater. To the question “What is important for future generations?”, a participant answered “All the forest, the whole territory. Even when they make plantations, animals don’t taste the same.” (A_07) (3) The capacity of the land to sustain Indigenous cultures, including knowledge, skills and languages was a concern:

> You know these young hunters today, some of them were not trained to hunt. They go hunting alone and they don't know what they are doing out there. They don't know how to hunt the moose, mostly the moose. They don't even know what date to go there (O_01b).

Table 2.6 Themes associated with legacy addressed in a number (n) of interviews in the Abitibiwinni First Nation (A) and the Ouje-Bougoumou First Nation (O). Themes are grouped in domains of well-being.

Domains of well-being	Themes	n A	n O
Identity	Interest	1	6
	Schedule	1	4
	Management	0	2
	Identity	2	0
Livelihood	Resources	6	5
	Continuity/integrity	8	8
Culture	Knowledge	5	4

2.6 Discussion

Through this collaborative research project, we built upon a transdisciplinary conception of landscapes to revisit the ecosystem services framework and address landscape valuation in Indigenous contexts. Following an inductive design, we collected empirical qualitative data on Indigenous landscape value and developed a conceptual framework for landscape valuation. Landscape valuation is represented as a process initiated by landscape practices generating ecosystem services from landscape features (Figure 2.4). Abundance, access, quality and experience influence how ecosystem services contribute to the well-being of Indigenous land users, notably by supporting livelihood, culture and identity. In the following sections, we discuss the components of the valuation framework and its implications for future research and sustainable land management.

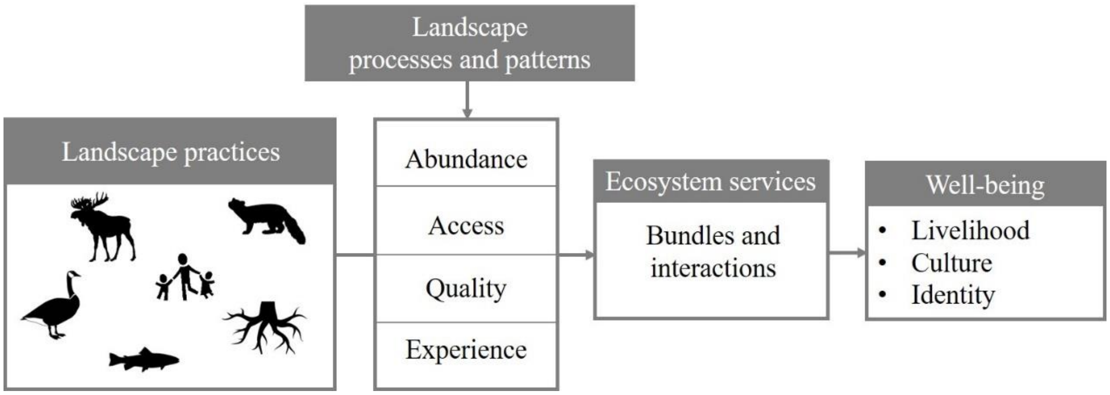

Figure 2.4 Indigenous landscape valuation framework, represented as the process beginning with landscape practices and leading to well-being. Landscape practices generate ecosystem services which value is influenced by landscape patterns and processes via abundance, access, quality and experience. Bundles of ecosystem services, and the interactions between them, contribute to three domains of well-being: livelihood, culture and identity.

2.6.1 Landscape valuation through landscape practices

We developed a valuation framework based on landscape practices at the suggestion of the research partners from the Abitibiwinni and Ouje-Bougoumou First Nations. At the first project meeting, when discussing the research objectives, they were very clear that "everything is about hunting, fishing and trapping". We then identified together a larger set of valued landscape practices. Landscape valuation based on practices is consistent with previous research based on the experience of land users and having used a bottom-up design (Klain *et al* ., 2017; Ramirez-Gomez *et al* ., 2016). As Bieling *et al* . (2014, p.19) reported, "practices and experiences play an important role in the creation and acknowledgement of such [landscape] values". Relational values have garnered increasing scientific attention since their inclusion in the IPBES framework alongside instrumental and intrinsic values (Chan *et al* ., 2018; Díaz *et al* ., 2015).

Landscape practices revealed to be a convenient valuation method, appropriate to Indigenous contexts. Indigenous people's relationship with the land is complex and involves a multitude of provisioning, cultural and regulation ecosystem services (Klain and Chan, 2012; Ramirez-Gomez *et al* ., 2015; Saint-Arnaud *et al* ., 2009; Tengö *et al* ., 2017). Ecosystem services are bundled and their value is influenced by their interaction with one another (Klain *et al* ., 2014; Raudsepp-Hearne *et al* ., 2010). For example, moose hunting does not only provide food and leather, but is also an opportunity to acquire bush skills and ecological knowledge, to strengthen family bonds, and to stay physically and mentally healthy. Attempting to value all individual ecosystem services and their interactions appears an infinitely complex, if not impossible task. Alternatively, addressing the ability of ecosystems to sustain landscape practices generating ecosystem services is a more comprehensive and feasible approach. Moreover, in line with Satterfield (2001), we observed that values are more easily elicited in a format that approximates the way people are used to discuss and express themselves. Participants enjoyed talking about the land, their hunting and fishing experiences, their family, their worries, just as they do regularly with friends and family.

2.6.2 The four dimensions of landscape value

In their effort to bridge ecosystem services and the capability approach of well-being, Polishchuk and Rauschmayer (2012 p.107) insisted on "the specific conditions in which the person makes use of the available goods and services". They introduced "conversion factors" in the valuation process, i.e. factors that influence how and to what extent landscape features are converted into capabilities and well-being. In the landscape valuation framework, *abundance*, *access*, *quality* and *experience* act as conversion factors. They are under the influence of landscape processes including timber harvesting (Cyr *et al* ., 2009), wildfires (Boulanger *et al* ., 2013) and road network expansion (Kneeshaw *et al* ., 2010), among others.

Abundance is the quantity of landscape features necessary for satisfactory achievement of a landscape practice. Abundance of landscape features depends on ecosystem composition and structure (Wallace, 2007) and is thus the product of landscape processes (Turner and Gardner, 2015). Abundance of features from the *spatial* landscape, such as fish stocks, timber volumes or freshwater can be assimilated to provision services. Landscape features, when provided with meanings, are also cultural and belong to the *mental* landscape, like graves and healing places. Landscape valuation based on ecosystem services is typically based on stock and flow models and focus on abundance metrics (Díaz *et al* ., 2018). Those useful metrics should however be designed in collaboration with local populations to acknowledge culturally specific perceptions of the environment and account for both *spatial* and *mental* landscapes.

Access is “the ability to benefit from things—including material objects, persons, institutions, and symbols” (Ribot and Peluso 2009, p.153). Access is required to make landscape features available and depends on physical, contextual and cultural factors. Physical distance between ecosystem services production and consumption is a critical matter for landscape valuation (Cimon-Morin *et al* ., 2014; Locatelli *et al* ., 2011) and depends on the ecosystem mosaic. Brinkman *et al* . (2016) reported that physical access was the main constraint to resource availability for hunters of Indigenous communities in Alaska. In the study area, physical access constraints were less critical because of the extended network of forestry roads. However, contextual factors associated with land use and tenure emerged. Land appropriation by recreational hunters and outfitters, traffic increase and multiplication of hunting cabins were limitations reported by participants and by previous studies in the boreal area (Basile, 2017; Kneeshaw *et al* ., 2010). Access constraints also revealed to be cultural. Some landscape practices required up-to-date skills and knowledge of the environment to be fruitful and satisfactory. In the context of global change, disturbance regimes, such as wildfire or timber harvesting affect landscape patterns and make ecosystems prone to rapid and unexpected transitions (Chapin *et al* ., 2004; Girard *et al* ., 2008). Wildlife species distribution and behavior are also prone to shifts, forcing rapid adaptation of ecological knowledge to maintain an access (Berkes *et al* ., 2000; Pearce *et al* ., 2015; Suffice *et al* ., 2020).

Quality is “a characteristic of a product or a service that bears on its ability to satisfy stated or implied needs” (Narasimhan 2007, p.1). The condition of landscape features determines the value of ecosystem services. Quality as a dimension of landscape value is in line with previous studies that focused on food attributes and food security in Indigenous contexts (Downing and Cuerrier, 2011; Lambden *et al* ., 2007). Concerns about chemical contamination of meat and fish raised by the participants are consistent with previous research conducted within the same communities (Bordeleau *et al* ., 2016; Bussières *et al* ., 2004; Tam *et al* ., 2011; Tsuji *et al* ., 2007; VanSpronsen *et al* ., 2007) and throughout the northern hemisphere (Kuhnlein and Chan, 2000; Lambden *et al* ., 2007). Quality standards may differ whether quality is evaluated according to a procedure based on scientific or traditional knowledge. To assess food palatability for instance, scientists measure the concentration of heavy metals and other contaminants in fish and game flesh (Bordeleau *et al* ., 2016). However, participants in this study, like Parlee *et al* . (2014) before, reported that land users look at flesh and hide condition, color, texture and fat thickness. Quality criteria for education and *ressourcement* were less tangible but still consistent with previous studies: teacher’s personal knowledge (Reyes-García *et al* ., 2009), attitudes towards the land (Ohmagari and Berkes, 1997) as well as place attachment (Brown and Raymond, 2007), sense of place (Cunsolo Willox *et al* ., 2012) and wilderness (Williams, 2002) all provide additional value to landscape features.

Experience is the most subjective dimension of landscape value. It relates to concepts from human geography like place attachment, sense of place and special places (Brown and Raymond, 2007; Eisenhauer *et al* ., 2000). Anchored in the *mental* landscape, experience changes from one social group to another and from one individual to another, depending on culture, values and personal history (Eisenhauer *et al* ., 2000;

Fagerholm *et al* ., 2020). Experience is affected by aesthetical (Gobster *et al* ., 2007), scenic (Daniel 2001) and acoustic (Brown, 2012) properties of the environment. Negative experiences arise when Indigenous people feel a gap between the biophysical landscape they observe and the desired landscape, according to their values and knowledge system (Albrecht *et al* ., 2007; Usher, 2000).The negative impacts of conflicts with land users from within and outside the community is consistent with previous research conducted in similar contexts (Webb *et al* ., 2008; Whiteman, 2004). Exclusion from land management institutions and feelings of land dispossession due to natural resources extraction add a layer of dissatisfaction (Banerjee, 2000).

2.6.3 Domains of well-being

Three domains of well-being revealed to be of importance to the two Indigenous communities we worked with: livelihood, culture and identity. We discuss them with regard to the capability approach of well-being. (1) *Life on the land*, or livelihood, is a fundamental component of well-being in the Cree and Anishnaabe peoples (Adelson, 2000; Landry *et al* ., 2019; Saint-Arnaud and al., 2009) as well as in other Indigenous contexts (e.g. Kant *et al* ., 2013; Parlee and Furgal, 2012; Sangha *et al* ., 2011). The land sustains livelihood by providing food, medicine, drinking water, clothing, art craft material, spiritual and patrimonial places, among others (Cuerrier *et al* ., 2012; Saint-Arnaud *et al* ., 2009; Uprety *et al* ., 2012). In terms of capabilities, livelihood is the possibility of adopting and maintaining a lifestyle out on the land that fulfills primary needs and fits one's preferences and values. (2) The *cultural* domain of well-being refers to the capacity to connect with and actualize Indigenous languages, rituals, traditional ecological knowledge and other key elements of local culture (Biddle and Swee, 2012; Wexler, 2009). Traditional ecological knowledge includes knowledge of wildlife behavior, hunting skills and stories. Knowledge is acquired through landscape practices, and is necessary to their efficiently to convert landscape features into capabilities (Polishchuk et Rauschmayer, 2012). (3) The *identity* dimension of well-being can be defined in Indigenous contexts as the capacity and freedom to develop and maintain a sense of belonging to the land (United Nations, 2009) and play a role as part of the land (Feit, 2001; Kimmerer and Lake, 2001; Sangha *et al* ., 2015). Identity is sometimes merged with culture in capability sets (Ballet *et al* ., 2018), but the particularities of Indigenous contexts justify the consideration of identity as a singular dimension of well-being.

2.6.4 Implications, limits and conclusion

The landscape valuation framework we developed in collaboration with two Indigenous communities has implications for future research and for sustainable land management. The framework emerged from a descriptive and qualitative analysis but can be used as a conceptual basis for further deductive research, hypothesis testing and ecological modeling (Bélisle *et al* ., 2018; Turner *et al* ., 2016). The development of quantitative indicators of landscape value based on abundance, access, quality and experience could be the basis for landscape monitoring, analysis of management scenarios, and impact assessment. According to the sustainability perspective of Raworth (2017), land management (and other economic activities) should aim at maintaining humanity inside a desired doughnut-shaped space. The inner boundary is determined by fundamental capabilities necessary to human well-being (e.g. Indigenous livelihood, culture and identity) and the outer boundary is set by environmental limits (e.g. the ecosystem conditions conducive to landscape practices) (adapted from Rockström *et al* ., 2009). In a context of global change, future research is needed to better define environmental thresholds from an Indigenous perspective.

The research design could be improved by aiming at more diversity when selecting participants. Youth and women were under represented and could have brought different perspectives (Basile *et al* ., 2017; Desbiens, 2010; Robson *et al* ., 2019). Valuation based on landscape practices may under-estimate non-use values, of importance to Indigenous people (Chan *et al* ., 2012). Further research is thus needed to better understand landscape valuation from the perspective of those who are not active land users, who live in urban areas, or with a different lifestyle within the community.

In conclusion, by working as a collaborative research team at a scale relevant to land users and through the prism of landscape practices, we provided an environment where participants were comfortable expressing their values and concerns. The resulting landscape valuation framework acknowledges and respects the complex and unique relationship of Indigenous people with the land. The approach could easily be applied to other contexts where landscape practices are key elements of the relationship with the land.

Acknowledgements

We acknowledge the central contribution of local land experts from the Ouje-Bougoumou and Abitibiwinni First Nations who shared their time, values and knowledge. We also thank Louis-Joseph Drapeau for help during data collection and Roxane Germain, Benoît Croteau, Roger Lacroix, James Cananasso and Norman Wapachee for their contribution to the project design. We also thank the anonymous reviewers and the Editor-in-Chief whose comments contributed to improve the article. This work was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), the Social Sciences and Humanities Research Council of Canada (SSHRC), the Fonds de Recherche du Québec - Nature et Technologies (FRQNT), the Ouranos Consortium on Regional Climatology and Adaptation to Climate Change, and the Northern Scientific Training Program (NSTP).

Authors' Contribution

ACB, AW and HA conceived the ideas and designed the methodology; ACB and AW collected the data. ACB analyzed the data and HA and AW validated the interpretations; ACB led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

CHAPITRE III

INDIGENOUS AND SCIENTIFIC PERSPECTIVES ON ENVIRONMENTAL CHANGES IN BOREAL LANDSCAPES : TOWARD KNOWLEDGE RECONCILIATION

(PERSPECTIVES AUTOCHTONES ET SCIENTIFIQUES DES CHANGEMENTS ENVIRONNEMENTAUX EN ZONE BORÉALE : VERS UNE RÉCONCILIATION DES SAVOIRS)

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Abstract

1. Major environmental changes are occurring in boreal landscapes, thereby affecting ecosystem health and their capacity to sustain Indigenous people's well-being. Collaboration between Indigenous communities and researchers could help assess and mitigate the impacts of environmental changes.

2. We developed and compared an Indigenous and a scientific perspective on environmental changes using Driver Pressure State Impact (DPSI) conceptual models.

3. The Indigenous model emerged from interviews with local land-use experts from two communities located in boreal Quebec, Canada. The scientific model was informed by a bibliometric analysis of the research effort dedicated to each component of the Indigenous model.

4. We compared the Indigenous and the scientific models, and exposed convergences and divergences between perspectives. Forestry was a major driver of change in both models. Most issues related to mining, hydro-power and forest road development were specific to the Indigenous model. Climate change and wildfires were of greater interest in the scientific model.

5. Convergences between the Indigenous and the scientific perspectives are conducive to collaborative research. Divergences could be addressed through reciprocal knowledge transfer activities, and lead to research that better aligns with community concerns and needs.

Key words: Boreal landscapes, Environmental changes, DPSI, Traditional ecological knowledge, Collaborative research.

Résumé

1. Des changements environnementaux majeurs se produisent dans les paysages boréaux, affectant la santé des écosystèmes et leur capacité à soutenir le bien-être des peuples autochtones. La collaboration entre les communautés autochtones et les chercheurs pourrait aider à évaluer et à atténuer les effets des changements environnementaux.

2. Nous avons développé et comparé une perspective autochtone et une perspective scientifique sur les changements environnementaux à l'aide de modèles conceptuels de type Driver Pressure State Impact (DPSI).

3. Le modèle autochtone a émergé d'entrevues avec des experts locaux de l'utilisation du territoire provenant de deux communautés autochtones situées dans la région boréale du Québec, Canada. Le modèle scientifique est issu d'une analyse bibliométrique de l'effort de recherche consacré à chaque composante du modèle autochtone.

4. Nous avons comparé les modèles autochtone et scientifique et exposé les convergences et les divergences entre les perspectives. La foresterie a été l'un des principaux moteurs de changement dans les deux modèles. La plupart des enjeux liés à l'exploitation minière, à l'hydroélectricité et à l'aménagement de routes forestières étaient spécifiques au modèle autochtone. Les changements climatiques et les feux de forêt ont suscité un plus grand intérêt dans le modèle scientifique.

5. Les convergences entre les perspectives autochtone et scientifique sont propices à la recherche collaborative. Les divergences pourraient être comblées par des activités de transfert de connaissances réciproques et mener à des recherches qui correspondent mieux aux préoccupations et aux besoins des communautés.

Mots-clés : Paysages boréaux, changements environnementaux, DPSI, savoir écologique traditionnel, recherche collaborative, peuples autochtones

3.1 Introduction

The world's landscapes are facing unprecedented transformations under the pressures of climate change, natural resource exploitation and land use change (IPBES, 2018; Lewis and Maslin, 2015). Environmental changes affect human well-being, especially in Indigenous contexts (Chapin *et al.*, 2004; Fuentes *et al.*, 2020). Indigenous people have a close and multifaced relationship with the land, as it provides goods and services, in addition to supporting livelihood, culture and identity (Bélisle *et al.*, 2021; Davidson-Hunt and Berkes, 2003; Saint-Arnaud *et al.*, 2009). The impacts of environmental changes are observed first-hand by Indigenous people and interpreted through Indigenous ecological knowledge (IEK), anchored in place, time and culture (Asselin, 2015; Davidson-Hunt and O'Flaherty, 2007).

The necessity of combining scientific and Indigenous knowledge to face the challenges raised by environmental changes has been increasingly acknowledged (Ericksen and Woodley, 2005; Ford *et al.*, 2016; Tengö *et al.*, 2017). Collaboration between Indigenous communities and researchers contributes to better address complex environmental problems (Blackstock *et al.*, 2007; Parsons *et al.*, 2016). Indigenous and scientific knowledge are complementary (Fagerholm *et al.*, 2012; Lyver *et al.*, 2018), and when combined, they can increase the legitimacy of the resulting land management decisions to local populations (Cash and Belloy, 2020; Ericksen and Woodley, 2005; Tengö *et al.*, 2014). Collaboration also contributes to local development and empowerment by generating knowledge and expertise that are directly relevant to the communities (Ban *et al.*, 2018; Brook and McLachlan, 2005). However, Indigenous and scientific knowledge belong to different knowledge systems and their weaving is a delicate exercise (Davis and Ruddle, 2010; Stefanelli *et al.*, 2017; Tengö *et al.*, 2014).

Reconciliation of Indigenous and scientific knowledge is based on the premises that any knowledge is partial and situated, and that there is no hierarchy between knowledge systems (Ericksen and Woodley, 2005; McGregor, 2018). Knowledge systems encompass ontology (nature of things), epistemology (nature of knowledge), methodology (how knowledge is acquired) and axiology (underlying values) (Bartlett *et al.*, 2012; Wilson, 2001). Attempts to bridge knowledge systems thus require to consider an information in the light of the context in which it was generated, validated, and in which it makes sense (Alexander *et al.*, 2019; Davis and Ruddle, 2010). The *two-eyed seeing* approach provides guidance for considering multiple perspectives in environmental assessments (Abu *et al.*, 2019; Rayne *et al.*, 2020; Reid *et al.*, 2021).

> "Two-Eyed Seeing is the gift of multiple perspectives treasured by many aboriginal peoples […] it refers to learning to see from one eye with the

> strengths of Indigenous knowledges and ways of knowing, and from the other eye with the strengths of Western knowledges and ways of knowing, and to using both these eyes together, for the benefit of all" (Bartlett *et al*., 2012 p. 335).

North American boreal landscapes provide fertile ground to bring together Indigenous and scientific perspectives on environmental changes. First, boreal landscapes are undergoing major transformations, under the pressures of climate change and natural resource exploitation (Gauthier *et al*., 2015). Climate change is more acute at higher latitudes and induces increased wildfire activity (Boulanger *et al.*, 2013; Flannigan *et al.*, 2009). Forestry simplifies and uniformizes forest landscapes (Cyr *et al.*, 2009), mining converts forested lands into industrial areas, and hydroelectricity production floods large areas to create reservoirs affecting downstream floodplain ecosystems (Rood *et al.*, 2005). Second, the density of the Indigenous population is higher in the boreal zone, and is increasing (Nitoslawski *et al.*, 2019). Indigenous knowledge is sustained, constantly updated by an active relationship with the land. Third, an extended scientific effort has been dedicated to better understand the impacts of forestry and climate change on landscape sustainability since the 1990s (Gauthier *et al.*, 2009).

There are still few empirical studies that bridge Indigenous and scientific perspectives on environmental changes in the boreal (Abu *et al.*, 2019). In this research, we assessed and compared an Indigenous and a scientific perspective on the impacts of environmental changes in boreal Quebec, Canada. To achieve this, (1) we synthetized the Indigenous perspective using a Driver Pressure State Impact (DPSI) conceptual model based on the knowledge of land-use experts from two Indigenous communities; (2) we conducted a bibliometric analysis of the research effort dedicated to each component of the Indigenous model and developed a scientific DPSI; and (3) we compared the models, assessed convergences and divergences between the Indigenous and the scientific perspectives, and discussed collaboration opportunities.

3.2 Study area

The study area is located in boreal Quebec, Canada (Figure 3.1) and it is influenced by a subpolar subhumid continental climate. The study area is mainly forested, with a high density of lakes and rivers. The relief is low and is characterized by plains and rounded hills (Jobidon *et al.*, 2015). Forests are mainly coniferous, with black spruce (*Picea mariana*), jack pine (*Pinus banksiana*) and balsam fir (*Abies balsamea*) as the most common tree species. Broadleaved species, mainly trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*) are also present. Wildlife species include moose (*Alces americanus*), woodland caribou (*Rangifer tarandus caribou*), American marten (*Martes americana*), North American beaver (*Castor canadensis*) and black bear (*Ursus americanus*), among others. Common fish species include Northern pike (*Esox lucius*), walleye (*Sander vitreus*) and lake sturgeon (*Acipenser fulvescens*).

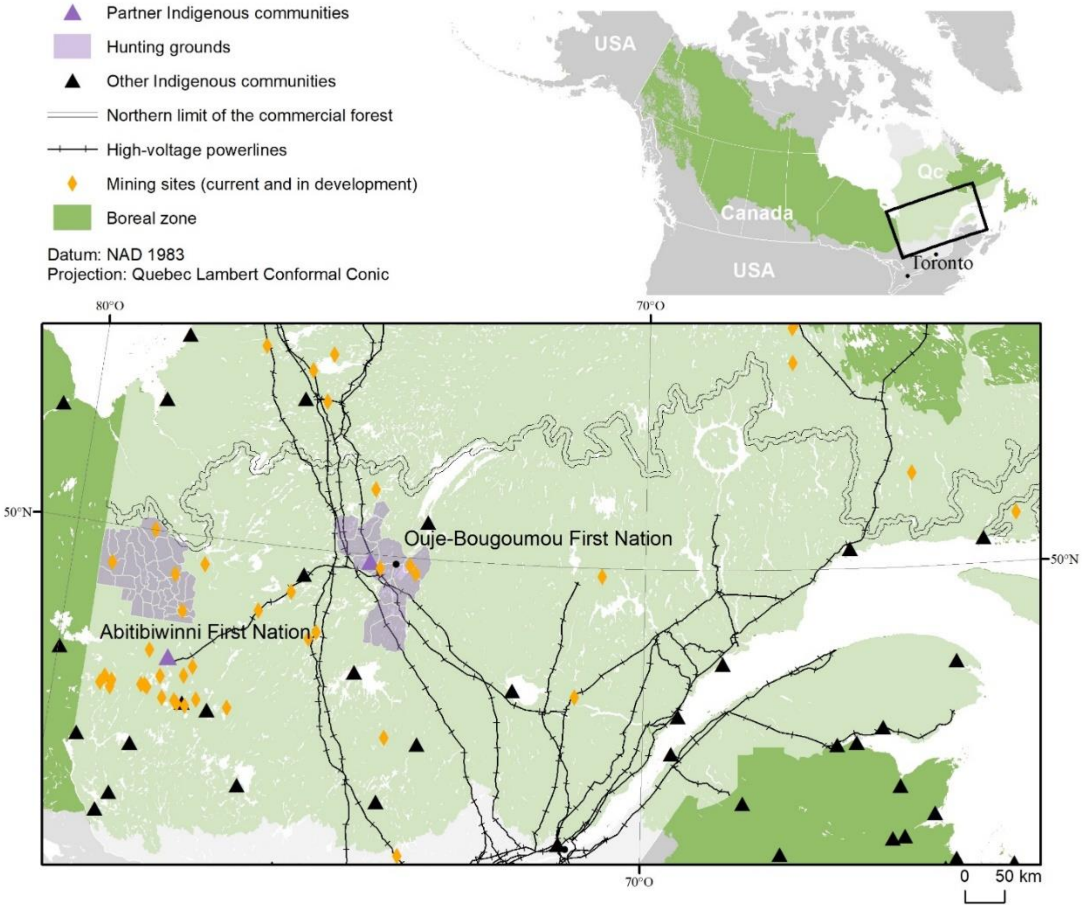

Figure 3.1 The boreal zone in Canada (Brandt, 2009) and Quebec (light green) and the hunting grounds of the Abitibiwinni and Ouje-Bougoumou First Nations (purple). Boreal landscapes are affected by forestry south of the northern limit of commercial forests (Ministère des Forêts de la Faune et des Parcs du Québec, 2018), mining (Ministère de l'Énergie et des Ressources naturelles du Québec, 2018), hydro-electric development (Hydro-Québec, 2015) and climate change (Ouranos, 2015).

Boreal landscapes are under the influence of natural and industrial disturbances (Brandt *et al.*, 2013, Figure 3.2). Large and severe wildfires are recurrent in the study area (Boulanger *et al*., 2013). Increased wildfire activity is projected due to climate change (Boulanger *et al.*, 2013; Ouranos, 2015). Most areas located south of the northern limit of the commercial forest are dedicated to extensive forestry, mainly through clear-cut harvest (Ministère des Ressources naturelles du Québec, 2013). Active, abandoned and projected mines are numerous (Ministère de l'Énergie et des Ressources naturelles du Québec, 2016). Hydro-electricity dams were developed in the northern part of the study area in the 1970s and high-voltage powerlines (735 kV) carry electricity from north to south (Hydro-Québec, 2015).

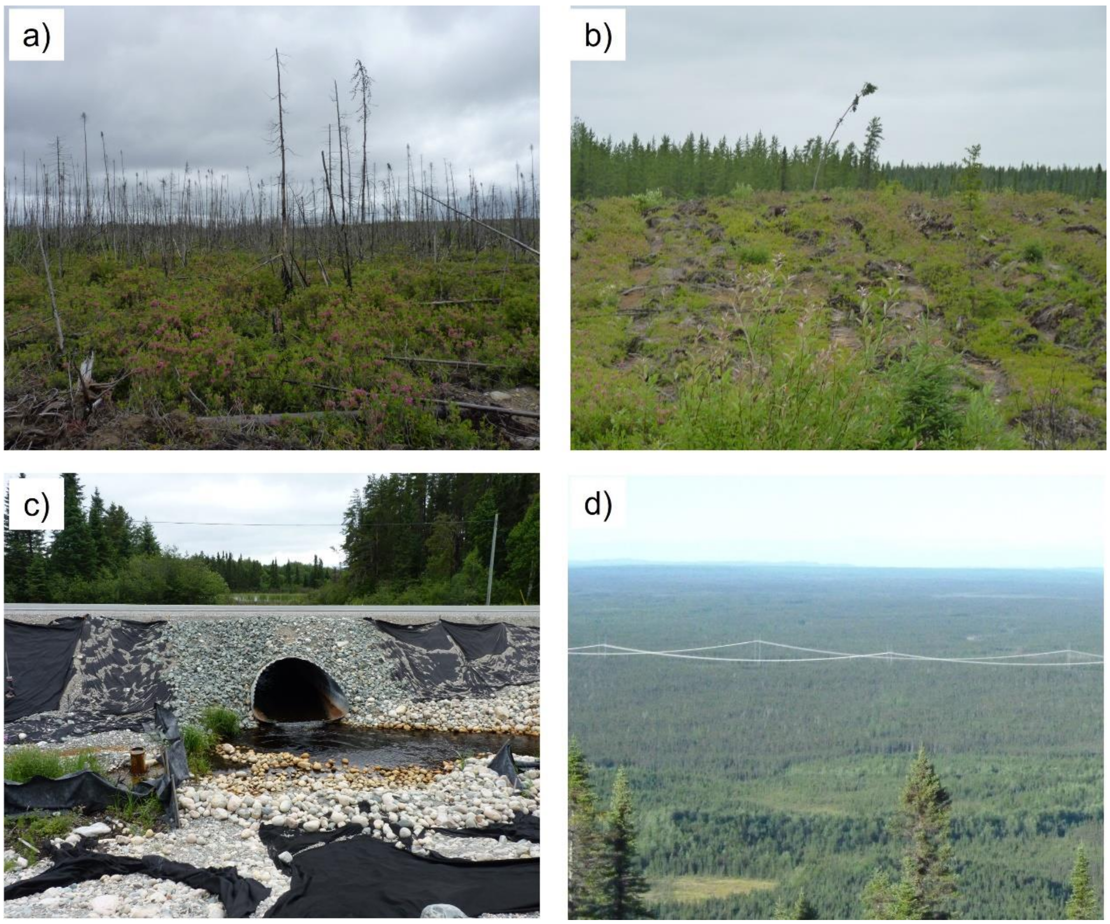

Figure 3.2 Pictures from the study area taken during field work in 2016: a) A burned forest, b) a harvested forest, c) a transportation road, d) a high-voltage powerline.

Communities from eight Indigenous peoples have their territory in the boreal forest of Quebec. Their traditional nomadic lifestyle is coordinated with seasonal changes and wildlife migrations and makes them part of the *Woodland First Nations* (Aboriginal Affairs and Northern Development Canada, 2013). We partnered with the Abitibiwinni

First Nation (Anishnaabeg) (population of ca. 1 080) and the Ouje-Bougoumou First Nation (Cree) (population of ca. 906) (Indigenous and Northern Affairs Canada, 2015). The Ouje-Bougoumou territory and most of the Abitibiwinni territory are located in the black spruce – feathermoss bioclimatic domain, characterized by the dominance of coniferous tree species and recurrent stand-replacing wildfires.

In both communities, landscape practices include hunting, fishing, and trapping, as well as a variety of cultural and recreational activities. Life on the land takes place on family hunting grounds which are transferred from one generation to the next (Feit, 1985). There are 34 hunting grounds (11,430 km^2 in total) on the Abitibiwinni territory and 14 (10,560 km^2 in total) on the Ouje-Bougoumou territory, which sizes range between 112 km^2 and 1,652 km^2. Activities on the hunting grounds are under the responsibility of official tallymen in the Ouje-Bougoumou First Nation and unofficial managers in the Abitibiwinni First Nation.

The hunting grounds are located on public lands under provincial government regulation. Activities on Eeyou Istchee, the Cree territory, are subject to the *James Bay and Northern Quebec Agreement* (1975) – a modern treaty – and *La Paix des Braves Agreement* (2002). These agreements impose guidelines for the economic development of the territory and ensure that the Cree Nation is involved in decision-making and derives benefits from it. No treaty is yet in force on the Abitibiwinni territory, and thus industrial projects and their benefits and consequences for the community are negotiated on a case by case basis.

3.3 Methodology

Our research team included academic researchers and co-researchers from the Indigenous communities (three from the Abitibiwinni First Nation and two from the Ouje-Bougoumou First Nation). Co-researchers were working for the departments of natural resources and environment in each community. The whole research team met once at the beginning of the project (2016) to set the objectives and in smaller groups afterward at each step of the research (data collection, analysis, validation and transfer).

3.3.1 Analytical approach

We compared the Indigenous and scientific perspectives on the impacts of environmental changes by developing DPSI conceptual models, which address complex environmental problems through a hierarchical causality network (Borja *et al.*, 2006; Gregory *et al.*, 2013; Lewison *et al.*, 2016). DPSI models are used to assist communication between stakeholders and to support decision-making (Degnbol, 2005; Rehr *et al.*, 2012; Tscherning *et al.*, 2012), notably by exposing the interactions between ecological and social processes (Atkins *et al.*, 2011; Leenhardt *et al.*, 2017; Mangi *et al.*, 2007; Pirrone *et al.*, 2005). Processes and pathways leading to environmental changes are exposed and addressed explicitly through the four levels: drivers, pressures, sates and impacts (Mach *et al.*, 2015). Drivers are forces operating on the system, such as climate change, demand for natural resources, or political orientations. Drivers influence Pressures, i.e. ecological processes (e.g. wildfires, timber harvesting). Pressures influence States, i.e. landscape patterns in a given time and place (e.g. diversity, water quality, habitat abundance). States lead to impacts on landscape values. For the purpose of this research, we focused on ecology-related variables and did not consider the economical, political or social factors that can also be included in DPSI models. The use of DPSI models is appropriate in Indigenous contexts because it accommodates different forms and sources of information and because the impacts to be included can be based on local values (Dam Lam *et al.*, 2019; Singh *et al.*, 2017).

We considered landscape values with a relational approach. “Relational values are not present in things but derivative of relationships and responsibilities to them” (Chan *et* *al*., 2016 p.1462). The relational approach is increasingly acknowledged for landscape valuation and impact assessment (Klain *et al*., 2017; Pascual *et al*., 2017), especially in Indigenous contexts (Grubert, 2018; Sheremata, 2018). We articulated and elicited landscape value through a set of landscape practices that embodied the relationship with the land. With the research team, we identified six landscape practices that have provisioning and cultural functions in both communities and that are affected by environmental changes: moose hunting, trapping, fishing, goose (*Branta canadensis*) hunting, education and *ressourcement*[8] (see Bélisle *et al*., 2021).

We first developed an Indigenous DPSI model based on the knowledge of land-use experts (Figure 3.3 a-d). We then developed the scientific model by estimating the number of active researchers for each association between variables specified in the Indigenous DPSI model (Figure 3.3 e-f). We compared the Indigenous and scientific perspectives by ranking the attention given to each Driver, Pressure and State variable. We identified convergences and divergences between the Indigenous and scientific perspectives on environmental changes (Figure 3.3 g).

[8] Ressourcement is a French word defined as "reversion to one's sources, finding one's deep roots to reach a new balance, also to find sources (moral, psychological, spiritual, etc.) to recover physical and moral forces" (translated from Office québécois de la langue française, 1989)

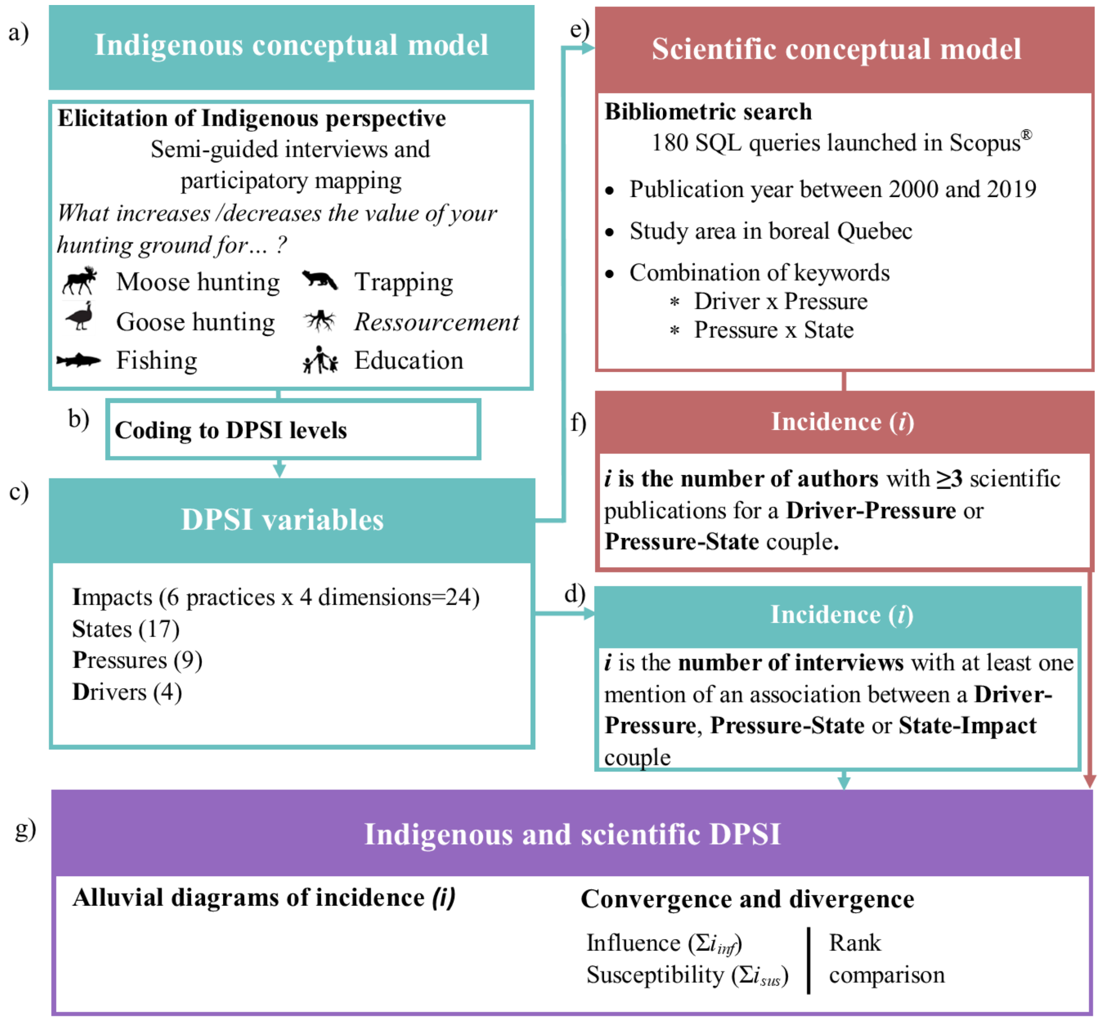

Figure 3.3 Method used to develop the scientific and the Indigenous conceptual models (DPSI) and to compare perspectives on environmental changes.

3.3.2 Indigenous DPSI model

We elicited the impacts of environmental changes and underlying pathways with land-use experts from the communities using participatory mapping of places of high and low value (Klain and Chan, 2012; Raymond et al., 2009) and semi-structured interviews.

3.3.2.1 Selection and recruitment of land-use experts

Co-researchers in the communities were responsible for recruiting land-use experts based on experience (number of years of landscape practices), responsibility in land-use management and peer recognition of expertise. As part of their job within the communities, the co-researchers work in close collaboration and on a regular basis with land-use experts on matters related to land management, consultation, and knowledge sharing. In the Ouje-Bougoumou First Nation, all tallymen met the expertise criteria as per the requirements of their function: they were long-term active land users, were responsible for coordinating family activities on the hunting ground, and were mandated to participate in consultations with extractive industries. Each tallyman was invited to participate by a personal letter and by at least one in-person visit or phone call. The territory of the Abitibiwinni First Nation has more hunting grounds than that of the Ouje-Bougoumou First Nation. The co-researchers listed the people responsible for consultation and management in each hunting ground and identified those who met the expertise criteria. They were invited to participate by phone or in person. We balanced the representation of hunting ground types based on disturbance level in the previous 15 years (mining, wildfire, timber harvesting). We stopped recruiting when we reached a balanced number of experts from the two communities (13 in the Abitibiwinni First Nation and 14 in the Ouje-Bougoumou First Nation). Family members were invited to join the experts during the interviews, adding age and gender diversity.

3.3.2.2 Interviews and participatory mapping

We conducted 12 semi-structured interviews and participatory mapping exercises with Abitibiwinni experts and 11 with Ouje-Bougoumou experts (some interviews involved more than one expert). Interviews and participatory mapping took place in the communities or nearby (band office, restaurant, Chibougamau Eenou Friendship Center, participant’s residence) between June and September 2016. All interviews were conducted by the first author, sometimes accompanied by co-researchers and research assistants. Ten interviews were conducted in French, 7 in English, 5 in Cree and 1 in Anishnaabemowin. A member of the research team from the community live-translated the interviews when needed. Interviews were audio-recorded and lasted between 45 minutes and 2 hours.

Interviews started with close-ended questions dedicated to sketch the social profile of participants (gender, age, attendance on the land). We verified the participants' expertise by asking if they were active in each of the six landscape practices (yes/no). As the interview progressed, we asked participants to self-assess their expertise level on a visual scale (0-10) for each landscape practice. We further questioned participants who answered "no" or who rated their expertise below 5/10. If low expertise was confirmed, the specific landscape practice was not investigated in the interview.

Participatory mapping was supported by laminated maps (1:60 000) showing hunting ground delineation, elevation lines, lakes, rivers, wetlands, powerlines, quad paths and roads. Landmarks were chosen as neutral as possible to avoid introducing bias. We asked participants to locate their cabins and campsites and we validated their understanding of the map with simple orientation questions. For each landscape practice, participants had to indicate places of high value with green chips and places of low value with red chips (Raymond et al., 2009). Participants drew the boundaries of places of high value with a green pen and the boundaries of places of low value with a red pen. Each feature was discussed.

3.3.2.3 DPSI

We used the NVivo 11 software (QSR International, Melbourne) to perform a thematic analysis of the interview transcripts and develop the DPSI structure (Figure 3.3b). We followed an inductive and bottom-up procedure. In a first step, we analyzed all excerpts with mentions of impacts. Four dimensions of landscape value emerged: abundance, access, quality and experience (the full procedure is presented in Bélisle *et al*., 2021). We created 24 Impact themes (6 landscape practices x 4 dimensions, e.g. fishing-abundance, fishing-access, fishing-quality, fishing-experience) (Figure 3.3c). We coded interview excerpts to the corresponding Impact theme(s). We then coded the excerpts contained in Impact themes to one or many State themes, when appropriate (example in Figure 3.4). We created the State themes as they were mentioned for the first time. We coded excerpts contained in State themes to Pressure themes and Driver themes following the same procedure. We extracted the excerpts coded to each possible Driver-Pressure, Pressure-State, or State-Impact combination using NVivo queries (Figure 3.3d).

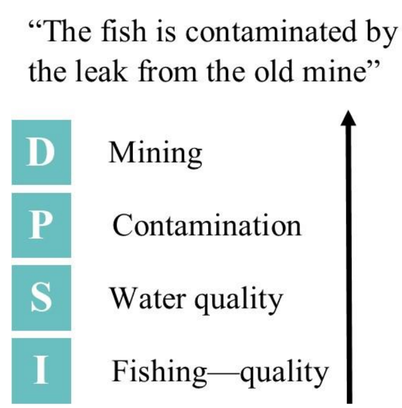

Figure 3.4 Example of the coding procedure of an interview excerpt into Impact (I), State (S), Pressure (P) and Driver (D) levels. The arrow presents the bottom-up coding sequence.

3.3.2.4 Validation

The DPSI conceptual model was validated with the community co-researchers. We discussed ambiguous statements and checked coding accuracy. We paid attention to topics mentioned by only a few experts to distinguish rare but important phenomenon from anecdotal events.

3.3.3 Scientific DPS(I) model

We synthetized the scientific perspective on environmental changes under a DPS(I) format using the number of active researchers as an indicator of the attention paid by the scientific community to a given topic. An active researcher was defined as an author or co-author of at least three scientific articles published in peer-reviewed journals between 2000 and 2019, on a given topic. We considered the number of active researchers to be a more robust and direct measure of scientific activity than the number of published papers or influence of papers, which are influenced by disciplinary cultures and changes over time (Mabe and Amin 2004; Bornmann and Mutz 2015). We first tested for thresholds between one and four articles, and we found that the three-article threshold worked best to associate researchers with their research topics while excluding punctual collaborations.

3.3.3.1 Bibliometric search

We developed a set of keywords for each variable in the Indigenous conceptual model (Supplementary Material S3.1). We searched the Scopus® database to list the scientific articles published on each possible Driver-Pressure and Pressure-State association (Figure 3.3e). We searched article titles, abstracts and keywords with SQL queries that specified keyword combinations, publication year and geographical area.

We developed the queries as follows: (1) we included geographic location keywords to restrict the search to the study area; (2) we included publication year boundaries to search articles published between 2000 and 2019 for consistency with Indigenous expert's experience on the land. Although the interviews were conducted in 2016, we extended the search period to 2019 to consider the time lag between data collection and publication; (3) we included the keywords associated with the query variables (a driver and a pressure or a pressure and a state), separated by the Boolean operator "AND". We did not investigate the links between States and Impacts because too few articles were published on landscape practices. We compiled the list of authors and the associated number of publications for each query with the R 3.4.4 software.

3.3.3.2 Validation

The validation exercise aimed to check if the queries were able to generate an accurate list of active researchers for each topic. We validated the queries using specificity and sensitivity analyses. The specificity analysis aimed to ensure that no article outside the intended scope of a query was selected. We inspected the list of researchers for each query to spot "intruders" and unknown authors. We investigated suspicious cases and clarified the queries when necessary. The sensitivity analysis aimed to identify queries that failed to fetch all the authors active in a given topic. To do so, we listed the queries having generated little or no results. Each query was inspected for grammatical or keyword errors. We also investigated whether some authors were not associated with their known research topics. In these cases, we searched articles that should have qualified, inspected the keywords and adjusted the queries when necessary (Supplementary Material S3.2). We uniformized the names of authors with spelling differences (e.g. with or without middle name initial) in the Scopus® generic reports and kept in check the authors sharing the same initials.

3.3.4 Indigenous and scientific DPS(I)

We represented the Indigenous and the scientific DPS(I) models with alluvial diagrams using the web open-source platform RAWGraphs® (https://rawgraphs.io/) (Figure 3.3 g). A variable is represented by a node, and nodes are grouped into blocks (Drivers, Pressures, States, Impacts). Flows connect nodes from adjacent blocks. Flow width is proportional to flow incidence (*i*). For the Indigenous DPSI model, *i* is the number of interviews with at least one mention of the association between nodes. For the scientific DPS model, *i* is the number of authors who published at least three peer-reviewed articles on the association between nodes during the studied period (2000-2019). A node's length is proportional to its influence (Σi_{inf}) or susceptibility (Σi_{sus}), depending on its hierarchical position in the network. A node's influence (Σi_{inf}) is the sum of the incidences (*i*) going toward the right. A node's susceptibility is the sum of the incidences (*i*) coming from the left. We ranked the variables according to Σi_{inf} and Σi_{sus} to compare the Indigenous and scientific DPS. When $\Sigma i_{\text{inf}} = 0$ or $\Sigma i_{\text{sus}} = 0$, we attributed the last possible rank.

We identified convergence and divergence between the Indigenous and the scientific perspectives visually on scatter plots. Each variable was attributed an *x*- (Indigenous rank) and a *y*- (Scientific rank) coordinate on a scatter plot. The diagonal and its surroundings (similar Indigenous and scientific ranks) corresponded to the convergence zone. The variables located over the diagonal belonged to the scientific perspective and those under the diagonal belonged to the Indigenous perspective. Variables with no active researcher associated were considered exclusive to the Indigenous perspectives and were shown below the x-axis.

3.3.5 Methodological limitations

Our assessment of the Indigenous and scientific perspectives on the impacts of environmental changes was based on the number of persons (either land-use expert or researcher) who reported an impact. This metric was accurate to assess and compare the perspectives but should not be interpreted as a proxy for the ecological importance or influence of ecological phenomena. For instance, a localized but high-impact disturbance such as a mine or a spill may have tremendous local impacts but would be reported by only a few land-use experts whose hunting grounds would have been affected. Similarly, the scientific research orientations depend on many factors other than ecological importance (e.g., funding priorities, commercial interest, scientific trends) so the scientific perspective needs to be interpreted as the interest of researchers for an environmental phenomenon rather than its ecological importance.

3.3.6 Ethical considerations

The project was approved by the Ethics Review Board of Université du Québec en Abitibi-Témiscamingue (certificate # 2016-04). We followed the OCAP® principles (ownership, control, access and possession of research data) and we developed the project following the research protocol of the Assembly of First Nations of Quebec and Labrador (AFNQL 2014). Research agreements were signed between representatives of the university and the two participating communities. Those agreements stipulate the roles and responsibilities of the researchers and of the communities, how data can be used, the publication process, and the procedure to resolve conflicts. Participants agreed to take part in the project by signing a consent form (adapted from Basile *et al*. (2018)) with the assurance that the data would remain confidential. Members of the research team had to sign a commitment to confidentiality before they could access the data.

Datasets (agglomerated for confidentiality), Scopus® outputs and R codes can be consulted in an open-access repository (https://github.com/acbelisle/Perspectives-of-environemental-change).

3.4 Results

3.4.1 Indigenous conceptual model

We conducted 23 interviews and met with 27 Indigenous experts (some interviews included two members of the same family). Twenty-five experts were men and two were women. Most experts (17) were older than 54 years old. All experts were active land-users with confirmed expertise in most of the six landscape practices. Twenty-one experts reported going on their hunting ground one to three times a month and 15 of them at least one to three times a week. Additional information on the social profile of participants is available online (Table 2.1).

3.4.1.1 Drivers

Four drivers emerged from the interviews with Indigenous experts: forestry, mining, climate change and hydro-electric development (Table 3.1). In the Indigenous conceptual model, forestry (Σi_{inf}=59) drives five landscape pressures (Figure 3.5 a): timber harvesting (*i*=22), silvicultural treatments (*i*=12), forest road network development and maintenance (*i*=12), contamination of terrestrial and aquatic ecosystems (*i*=9) and species distribution ranges (*i*=4). Mining (Σi_{inf}=19) drives contaminant release (*i*=9), mineral extraction (*i*=6) and road network development and maintenance (*i*=4). Climate change (Σi_{inf}=16) drives species distribution ranges (*i*=9) and weather events and season changes (*i*=7). Hydro-electric development (Σi_{inf}=12), drives electricity transmission by high-voltage power lines (*i*=12).

Table 3.1 Driver-Pressure-State-Impact variables that emerged from the interviews with Indigenous experts. Definitions are based on Indigenous experts' explanations and scientific literature when available.

DPSI level	Variable	Definitions
Drivers	Climate change	IPCC (2015, Annex II) defines climate change as "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer."
	Forestry	Forestry includes landscape planning, timber harvesting methods, silvicultural practices and forest road development and maintenance (Doucet and Côté, 2009). Forest management practices are regulated by the Quebec Law on sustainable forest management (A-18.1), by wood markets and by certification agencies (e.g. Forest Stewardship Council).

Table 3.1 Suite

DPSI level	Variable	Definitions
	Hydro-power development	The energy sector, in the study area, includes hydroelectricity production, transportation and distribution.
	Mining	Mining includes mineral prospection, extraction, transformation and transportation, waste disposal, and restoration of closed mining sites.
Pressures	Contaminant release	Substance or agent released in the soil or water as a result of human activities (e.g. oil spill, phosphorous loading) (adapted from IPBES 2018).
	Distribution changes	Shifts in species distributions (including range displacement, local extinction, or local apparition).
	Electricity transmission	Transmission of electricity from the place of production to the place of distribution by aerial or underground lines at a voltage between 44 and 765 kilovolts (adapted from Hydro-Québec, 2015)
	Mineral extraction	IPBES (2018, Annex I) defines mineral extraction as “the removal of a mineral resource in or on the Earth’s crust, which has appropriate form, quality and quantity to allow economic extraction”.
	Road network development	Changes in the extent and distribution of areas accessible by the road network (including forestry roads).
	Silviculture	Intervention to direct the development of a forest stand, including its renewal, or to increase its yield, on a given area and time. Silvicultural treatments include regeneration intervention, site preparation, plantation, thinning and other treatments (adapted from Boulet and Huot 2013).
	Timber harvesting	Tree removal for industrial purposes, including partial and total harvests (Doucet and Côté, 2009).

Table 3.1 Suite

DPSI level	Variable	Definitions
	Weather and season changes	Anomalies in the timing of seasons and weather (temperature, precipitation, wind, extreme events).
	Wildfire	Wildfires are described by their size, duration, intensity and severity. Fire activity depends on the fire regime parameters such as burn rate (or fire cycle), seasonality, size distribution and periodicity (Vaillancourt *et al.*, 2009).
States	Age structure (forest)	Age structure of the forest stand. The age can represent the time elapsed since the last stand-replacing disturbance or a successional stage.
	Cultural places	"Particular places, for any cultural group, that are critically important to people's lifeways and identity" (Cuerrier, Turner, Gomes, Garibaldi, & Downing, 2015, p.428) such as graves, ancient trails and birthplaces.
	Goose landing areas	Suitable landing and resting areas for geese during migrations.
	Ground condition	Microtopography of the soil surface (e.g. bumpiness, muddiness) and soil proprieties.
	Ice conditions	State of the ice on rivers and lakes (thickness, dates of formation and break-up).
	Mine tailings	Solid wastes left after mineral processing.
	Naturalness	Areas undisturbed by industrial activities.
	Predators	Wildlife species feeding on species of interest for the community (e.g. beaver, moose).
	Road network	Density of roads providing access by car or truck to the different parts of the hunting ground.
	Spawning areas	State of fish spawning areas for species valued by the community.

Table 3.1 Suite

DPSI level	Variable	Definitions
	Technology (communication)	Availability of a cellphone, internet, or television signal.
	Traffic	Presence of land users on the hunting ground.
	Transportation	Passage of truckloads of minerals, timber, or other material.
	Tree species composition	Species assemblage of a forest stand.
	Water quality	Chemical, physical and biological properties of water.
	Water temperature	Surface water temperature.
	Wildlife diversity	Abundance and richness of wildlife species valued by the community.
	Wildlife health	General health of wildlife (diseases, fat reserves, parasites).
Impacts on landscape practices: - Moose hunting - Goose hunting - Trapping - Fishing - *Ressourcement* - Education	Abundance	Quantity of landscape features, material or immaterial, necessary for a satisfactory achievement of a landscape practice.
	Access	Ease with which a landscape feature can be reached or obtained in the course of a landscape practice.
	Quality	Characteristics of a landscape feature and its capacity to satisfy a need or to fulfill a function of a landscape practice.
	Experience	Emotional response, positive or negative, associated with a landscape practice.

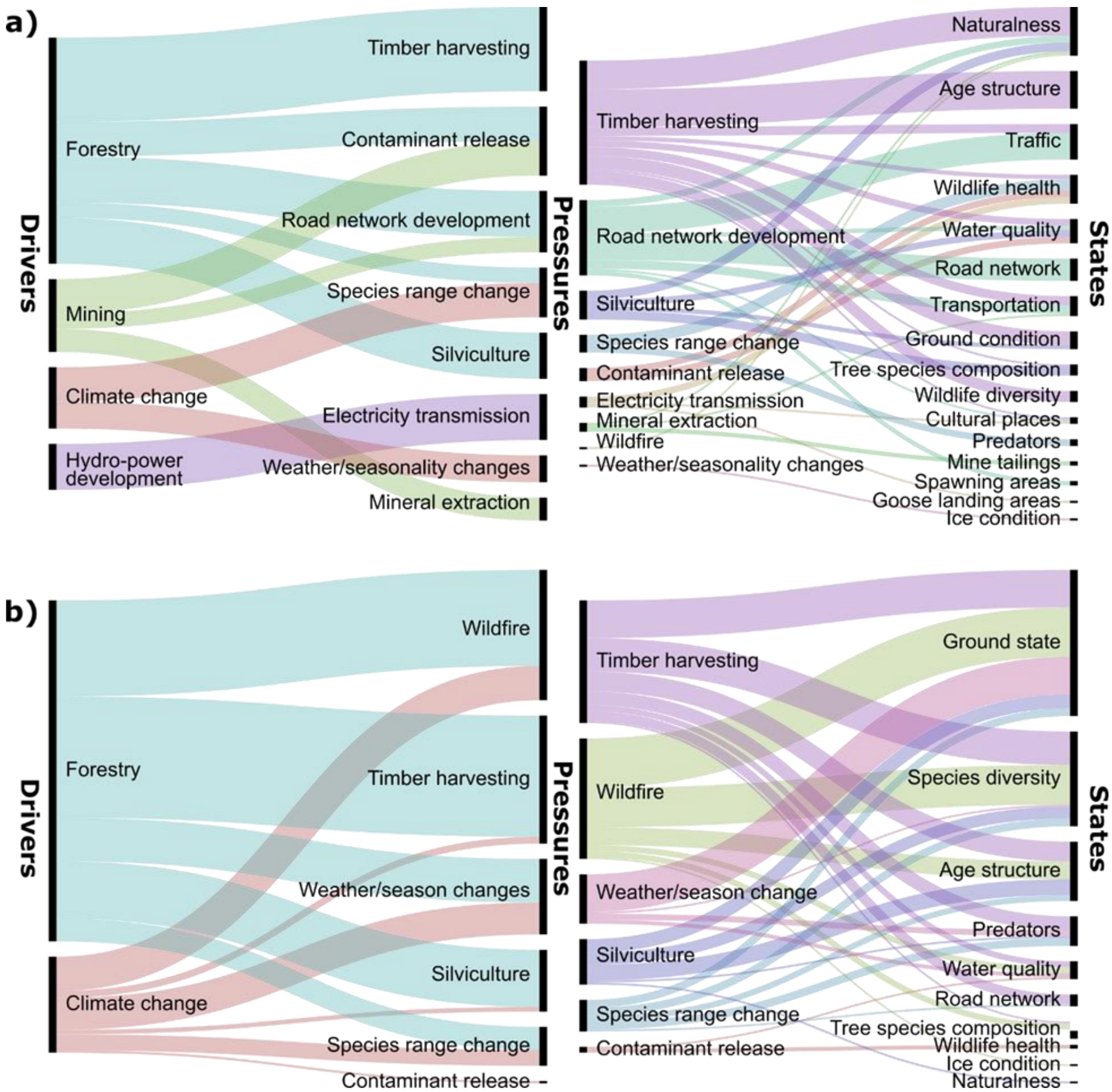

Figure 3.5 DPS conceptual models (Impacts are shown in Figure 3.6) based on (a) the Indigenous perspective and (b) the scientific perspective. Flow thickness is proportional to incidence (*i*). Node thickness (black lines) is proportional to influence (Σi_{inf}) when on the left side of the flows and to susceptibility (Σi_{sus}) when on the right side.

3.4.1.2 Pressures

Ten pressures emerged from the interviews with Indigenous experts (Table 3.1). Timber harvesting (Σi_{sus}=22, Σi_{inf}=56) was the most susceptible and influential pressure

(Figure 3.5 a), influencing all 10 states, with greatest incidence on age structure (i=17) and naturalness (i=13). Road network development and maintenance (Σi_{sus}=16, Σi_{inf}=34) influenced six states, mainly traffic (i=12), road network density (i=10) and transportation (i=4). Silvicultural treatments (Σi_{sus}=12, Σi_{inf}=21,) influenced wildlife health (i=5), naturalness (i=4), tree species composition (i=4), water quality (i=3) and ground condition (i=2). Contaminant release (Σi_{sus}=18, Σi_{inf}=6), either from abandoned mining sites or during harvesting operations, influenced wildlife health (i=3) and water quality (i=3). Mineral extraction (Σi_{sus}=6, Σi_{inf}=4) influenced mine tailings (i=2), naturalness (i=1) and mineral transportation by truck (i=1). Wildfires (Σi_{sus}=0, Σi_{inf}=1) can increase naturalness, as long as they are not followed by salvage logging (i=1). Changes in species distribution ranges (Σi_{sus}=13, Σi_{inf}=8) influenced wildlife health because of parasites and diseases dispersion, (i=5) and predator abundance (i=3). Weather events and season changes (Σi_{sus}=7, Σi_{inf}=1) influenced ice condition (i=1). Electricity transport (Σi_{sus}=12, Σi_{inf}=5) influenced the health of wildlife that lived and fed under powerlines (i=3), cultural places (i=1) and were an obstacle in goose landing areas (i=1).

3.4.1.3 States

Eighteen states emerged from the interviews with Indigenous experts (Table 3.1). Participants reported an influence of traffic (Σi_{sus}=20, Σi_{inf}=35) on all six landscape practices, especially on moose hunting (i=7 for abundance, i=6 for experience) (Figure 3.6). Age structure (Σi_{sus}=17, Σi_{inf}=31) was associated with the abundance of moose (for moose hunting) (i=16) and furbearers (for trapping) (i=11). Land-use experts specified that moose avoided very young forests and that marten needed mature trees. Participants reported an influence of naturalness (Σi_{sus}=22, Σi_{inf}=24) on moose hunting (i=5 for abundance and i=4 for experience) and *ressourcement* (i=8 for abundance). Naturalness referred to the level of influence of industrial activities on the land rather than to the absence of human activities. For example, some participants reported a lack of naturalness in tree plantations after harvesting due to tree species and design of the plantation. Road network density (Σi_{sus}=10, Σi_{inf}=21) influenced access to moose hunting (i=3), trapping (i=4) and education (i=6) sites. The influence was perceived as positive when facilitating access to the land for short trips, but as a limitation when non-Indigenous recreational hunters used the roads to appropriate parts of the land. Wildlife health (Σi_{sus}=13, Σi_{inf}=13) influenced fish abundance (i=3) and quality (i=3) (for fishing), moose abundance (i=3) and quality (i=4) (for moose hunting) and beaver quality (i=3) (for trapping). Wildlife diseases included excessive thinness, parasites (especially ticks), and flesh alteration (color, texture). Water quality (Σi_{sus}=11, Σi_{inf}=1) was associated with fish abundance (i=3) and quality (i=3) and with educational activities because family trips on hunting grounds were reported to be easier if no drinking water needed to be carried (i=2 for experience).

3.4.1.4 Impacts

Ground condition (Σi_{sus}=8, Σi_{inf}=11) influenced land walkability and the ability to travel with a snowmobile when the snow layer is not yet thick enough for trapping (i=3) and moose hunting (i=2) (Figure 3.6). Tree composition (Σi_{sus}=5, Σi_{inf}=7) influenced the quality of trapped wildlife (i=5). Transportation of wood and minerals by truck (Σi_{sus}=9, Σi_{inf}=7) was reported as a noisy and dangerous disturbance affecting the quality of *ressourcement* (i=3). Wildlife diversity (Σi_{sus}=5, Σi_{inf}=5) was considered important for educational purposes (i=5). The abundance of cultural places (Σi_{sus}=3, Σi_{inf}=4) such as old portages and graves influenced education (i=3). Predators (Σi_{sus}=3, Σi_{inf}=3) were considered competitors for beaver trapping (i=3), whereas spawning areas (Σi_{sus}=2, Σi_{inf}=2) were considered necessary for maintaining fish populations, especially lake sturgeon and walleye (i=2). Increased water temperature (Σi_{sus}=2, Σi_{inf}=2) caused by windthrow on the shorelines was associated with lower fish abundance (i=2). Ice conditions (Σi_{sus}=1, Σi_{inf}=1) and mine tailings (Σi_{sus}=2, Σi_{inf}=1) influenced goose hunting, the first affecting the access to hunting sites (i=1) and the second providing hunting sites (i=1). Additional explanations and interview excerpts are provided in Supplementary Material S3.3.

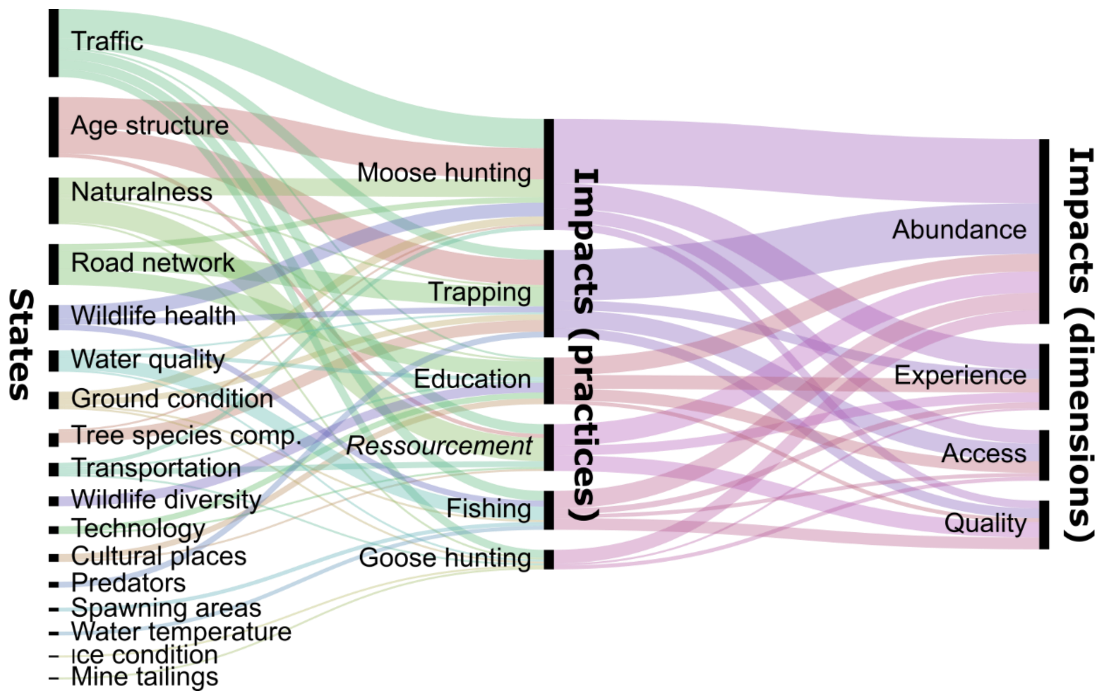

Figure 3.6 State-Impact model from the Indigenous perspective. Impacts are reported for six landscape practices and four dimensions of landscape value (abundance, experience, access, quality). Flow thickness is proportional to incidence (i). Node thickness (black lines) is proportional to influence (Σi_{inf}) when on the left side of the flow and to susceptibility (Σi_{sus}) when on the right side.

3.4.2 Scientific research conceptual model

The bibliometric search led to the identification of 91 active authors in at least one driver-pressure association and 81 in at least one pressure-state association.

3.4.2.1 Drivers

We found active researchers for two Drivers: forestry and climate change (Figure 3.5 b). Researchers associated forestry (Σi_{inf}=149) with timber harvesting (*i*=53), wildfire (*i*=42), silvicultural treatments (*i*=25), weather changes (*i*=19) and species range changes (*i*=10). Researchers associated climate change (Σi_{inf}=42) with wildfire (*i*=15), weather and season changes (*i*=14), species range changes (*i*=7), timber harvesting (*i*=3), silvicultural treatments (*i*=2) and contaminant release (*i*=1).

3.4.2.2 Pressures

We found active researchers for six pressures (Figure 3.5 b). Timber harvesting (Σi_{sus}=56, Σi_{inf}=62) had the greatest influence and was associated with seven States: ground condition (*i*=19), species diversity (*i*=17), age structure (*i*=10), predators (*i*=7), road density (*i*=5), water quality (*i*=3) and tree species composition (*i*=1). Wildfires (Σi_{sus}=57, Σi_{inf}=62) were associated with ground condition (*i*=25), species diversity (*i*=20), age structure (*i*=9), species composition (*i*=3), water quality (*i*=3), and ice conditions (*i*=1). Weather and season changes (Σi_{sus}=33, Σi_{inf}=25) were associated with ground condition (*i*=19), predators (*i*=7), water quality (*i*=2) and species diversity (*i*=1). Silvicultural treatments (Σi_{sus}=27, Σi_{inf}=23) were associated with age structure (*i*=8), ground condition (*i*=7), species diversity (*i*=6), naturalness (*i*=1) and predators (*i*=1). Species range change (Σi_{sus}=17, $\Sigma \mathrm{i}_{inf}$=16) was associated with ground condition (*i*=4), predators (*i*=4), species diversity (*i*=4), age structure (*i*=3) and road density (*i*=1). Contaminant release (Σi_{sus}=1, Σi_{inf}=16) was associated with wildlife health (*i*=2) and water quality (*i*=1).

3.4.2.3 States

We found active researchers for ten States (Figure 3.5 b). Ground condition (Σi_{sus}=74) had the greatest susceptibility, associated with wildfire, timber harvesting, weather and season changes, silvicultural treatments and species range changes. Age structure

(Σi_{sus}=74) was associated with timber harvesting, wildfire, silvicultural treatments and species range changes. Composition (Σi_{sus}=4) was associated with timber harvesting and wildfires. Ice condition (Σi_{sus}=1) was associated with wildfires. Naturalness (Σi_{sus}=1) was associated with silviculture. Predators (Σi_{sus}=15) were associated with timber harvesting, weather and season changes, silviculture and species range changes. Road density (Σi_{sus}=6) was associated with timber harvesting and species range changes. Species diversity (Σi_{sus}=48) was associated with all Pressures except contaminant release. Water quality (Σi_{sus}=9) was associated with timber harvesting, wildfire, weather and season changes and contaminant release. Wildlife health (Σi_{sus}=2) was associated with contaminant release.

3.4.3 Convergence and divergence between the Indigenous and the scientific perspectives

We compared the influence and susceptibility ranks for each Driver, Pressure and State, and we identified convergence and divergence between the Indigenous and scientific perspectives (Figure 3.7). References to the scientific literature, uncommon in a *Results* section, are direct outputs from the bibliometric search.

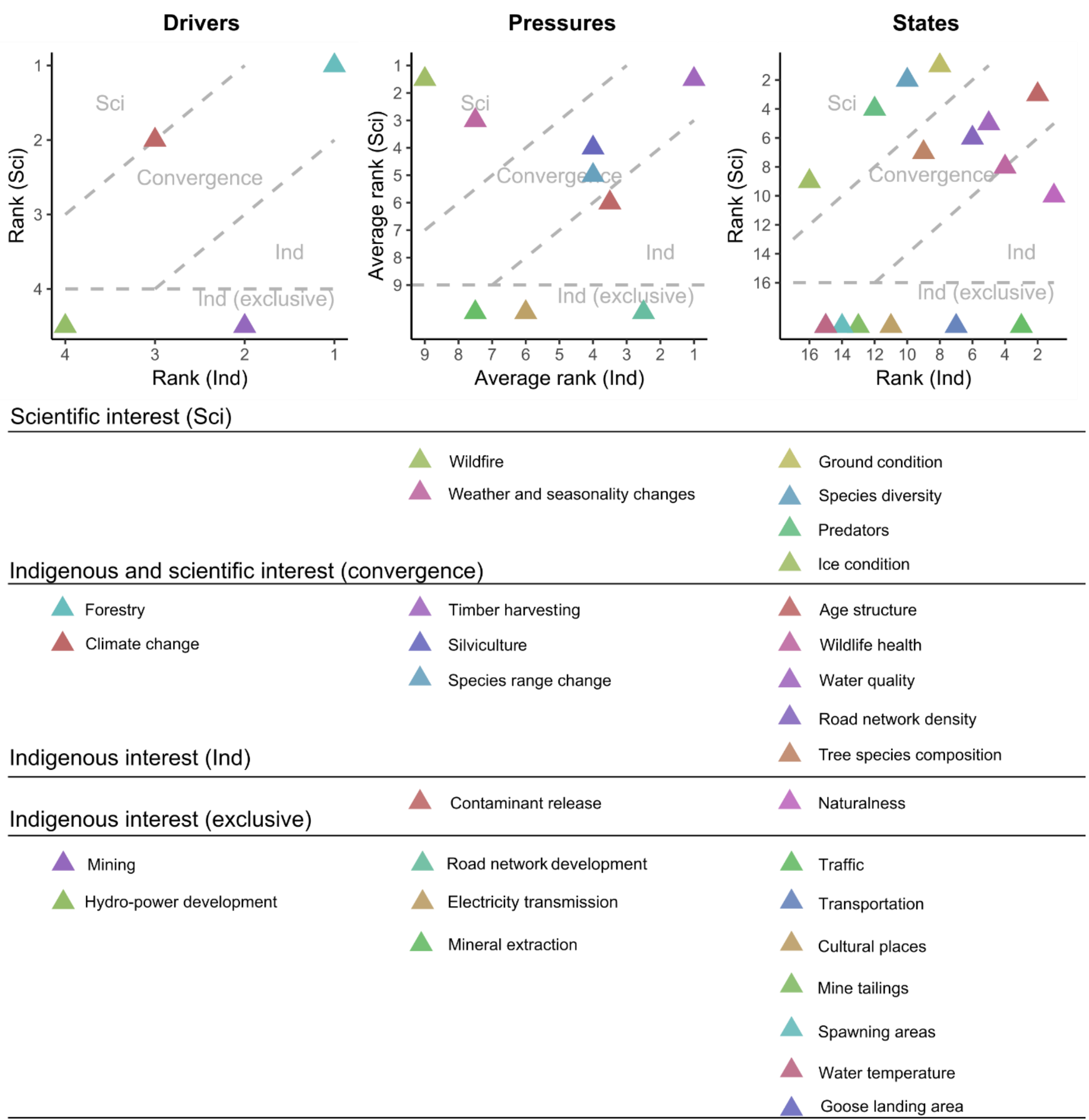

Figure 3.7 Convergence and divergence between the Indigenous (Ind) and the scientific (Sci) perspectives. Drivers are compared based on Σi_{inf} rank. Pressures are compared based on the average of Σi_{sus} rank and Σi_{inf} rank. States are compared based on Σi_{inf} rank. The closer the points are to the diagonal, the more convergence there is. Points above the diagonal indicate greater interest from the scientific perspective, while points below the diagonal indicate greater interest from the Indigenous perspective. Variables that are absent from the scientific model are shown in the "Ind exclusive" area at the bottom of the plots.

3.4.3.1 Convergence

The primary influence of forestry as a Driver of boreal landscapes is common to the Indigenous and the scientific perspectives. The influence of climate change on boreal landscapes is present in both the Indigenous and the scientific models. From the Indigenous perspective, climate change influenced wildlife distribution and weather. From the scientific perspective, researchers were interested in the impacts of climate change on wildfire activity (e.g. Flannigan *et al*. 2009; Terrier *et al*. 2013), weather and forest productivity (Grant *et al.*, 2009; Rossi *et al.*, 2014), and tree species distributions (e.g. Graignic *et al*. 2014; Housset *et al*. 2016).

Three Pressures had similar ranks in the Indigenous and scientific models. Timber harvesting ranked first in both the Indigenous and the scientific (equally with wildfire) models. In the Indigenous model, timber harvesting influences landscape practices through terrestrial and aquatic ecosystem alteration, increased traffic and timber transportation by trucks and loss of naturalness. From the scientific perspective, timber harvesting affects forest soils (e.g. Simard *et al*. 2001; Brais *et al*. 2013), species diversity of a variety of taxa (e.g. Nappi *et al*. 2004; Paradis and Work 2011), and forest age structure (e.g. Cyr *et al*. 2009; Bélisle *et al*. 2011) and composition (e.g. Dupuis *et al*. 2011; Boucher *et al*. 2014).

Indigenous experts reported negative impacts of silviculture. They shared concerns about ground bumpiness and the development of contaminated ponds after soil preparation for tree planting. They reported a loss of naturalness in plantations and observed water contamination downstream. In contrast, scientists were interested in using silviculture to increase stand productivity (e.g. Bilodeau-Gauthier *et al*. 2011; Thiffault *et al*. 2013), enhance forest resilience and carbon sequestration (e.g. Tremblay *et al*. 2013; Van Bogaert *et al*. 2015) and restore old-growth attributes to recover diversity in managed landscapes (e.g. Fenton *et al*. 2009; Hodson *et al*. 2012).

Wildlife species range changes found interest in both the Indigenous and the scientific models. Indigenous experts reported fine-scale observations of mammals, fishes and birds they encountered in unusual places. Some reported increased sightings of bald eagles (*Haliaeetus leucocephalus*). Others worried about the northward expansion of white-tailed deer (*Odocoileus virginianus*), threatening moose populations with diseases. One participant shared concerns about the loss of mice and other small wildlife habitats in harvested forests. From the scientific perspective, researchers were interested in the availability of deadwood habitat in managed forests (e.g. Aakala *et al*. 2008; Déchêne and Buddle 2010) and in the sensitivity of tree species to climate change and wildfire (e.g. Bergeron *et al*. 2004; Pilon and Payette 2015).

Five States had similar ranks in the Indigenous and scientific models. Age structure ranked high in both models. Participants reported an excess of regenerating forests due to harvesting with impacts on hunting and trapping, as well as on the general experience out on the land. Researchers also considered the depletion of old-growth forests in managed landscapes as a threat to boreal diversity and resilience (e.g. Kuuluvainen and Gauthier 2018; Tremblay *et al*. 2018). Indigenous experts reported changes in tree species before and after harvesting and tree planting. They also reported a takeover of forest road borders by broadleaved species (trembling aspen). From the scientific perspective, composition transition from coniferous to broad-leaved forests in managed forests was a concern as well (e.g. Laquerre *et al*. 2011; Danneyrolles *et al*. 2016).

Road network density ranked high in both perspectives, but for different reasons. Some Indigenous participants mentioned that road density threatened beaver populations and interrupted the connexion with the land because of noise and traffic. They mentioned the necessary balance to be found between facilitating access while keeping in check the negative impacts of increasing road density. From the scientific perspective, most research on the impacts of forest roads was dedicated to studying landscape fragmentation (Croke and Hairsine, 2006), and woodland caribou and wolf (*Canis* *lupus*) dynamics (e.g. St-Laurent *et al*. 2009; Lesmerises *et al*. 2012). A few publications addressed the social impacts of forest roads (Asselin, 2011; Kneeshaw *et al.*, 2010).

Water quality was a concern according to both the Indigenous and the scientific models. Some participants lived in areas contaminated by abandoned mines (Ministère de de l'Environnement, du Développement durable et des Parcs du Québec, 2008). They had to buy drinking water and they could not eat fish from contaminated areas. Lake eutrophication was also reported and attributed to road building and salvage logging upstream. Some participants mentioned oil leaks and stream contamination after forest harvesting. Scientific research was interested in the impacts of forest harvesting on hydrology (e.g. Tremblay *et al*. 2009) and lake ecology (e.g. Pinel-Alloul *et al*. 2002). Researchers also studied water and wildlife contamination by heavy metals (e.g. Montgomery *et al*. 2000; Tsuji *et al*. 2007; Liberda *et al*. 2011; Valera *et al*. 2011). Wildlife health was a particular case of convergence because most of the scientific articles that came out from the bibliometric search resulted from collaborative research with Indigenous communities.

3.4.3.2 Divergence – Indigenous perspective

Mining and hydroelectric development were two drivers exclusive to the Indigenous perspective. Although mining impacts on the environment are widely acknowledged (Bridge, 2004; Dudka and Adriano, 1997) and conflicts between mining companies and Indigenous Nations are numerous (Hilson, 2002), no researcher came out as a specialist of the influence of mines on landscape processes of importance from an Indigenous perspective. The influence of hydro-electric development was also specific to the Indigenous perspective and to a few hunting grounds crossed by high-voltage powerlines.

Road development, mineral extraction and electricity transmission were pressures exclusive to the Indigenous perspective. Indigenous experts mentioned conflicts associated with increased traffic, impairment of naturalness and threats to water quality caused by erosion, bridges and culverts. Some authors described the cascading impacts of road development on boreal landscapes in scientific articles (e.g. Kneeshaw *et al*. 2010; Walker *et al*. 2011) but did not cumulate enough publications to be considered in the model. Mineral extraction was associated with mine tailings and with a loss of naturalness. Electricity transmission caused suspicions regarding the palatability of food growing underneath, even if the usage of chemicals for vegetation control is forbidden in the region. One expert reported having a cabin so close to the powerline that she could feel the "glaze" (electric or magnetic field). Goose landing areas and cultural sites were also affected by powerlines. Contaminant release ranked high from the Indigenous perspective but low from the scientific perspective. Leaks from ancient mines and forest machinery were mentioned as sources of contamination. Most scientific research that came out from the bibliometric search was performed in Indigenous contexts, in collaboration with the communities (e.g. Tsuji *et al*. 2007; Valera *et al*. 2011).

Eight states found greater interest in the Indigenous perspective, among which seven were absent from the scientific model. Traffic and transportation were shared concerns among Indigenous experts. Traffic limited the access and experience associated with landscape practices. Safety and noise problems were associated with wood transportation by trucks. Cultural places such as old portages and graves were reported to be altered or destroyed by industrial development, especially forest harvests and transmission lines. The increase in water temperature caused by windthrow in riparian areas and the state of goose landing areas were also specific to the Indigenous perspective.

3.4.3.3 Divergence – scientific perspective

Wildfires are more prominent in the scientific model. Fire regimes are studied to set benchmarks for ecosystem-based management aiming to maintain forest ecosystems within their natural range of variability (Bergeron *et al.*, 2006; Vaillancourt *et al.*, 2009). Increased fire activity is expected due to climate change (Boulanger *et al.*, 2013), and research efforts are dedicated to better understand fire hazards and ecology (e.g. Portier *et al.*, 2016; Terrier *et al.*, 2013). Conversely, few Indigenous experts reported the impacts of wildfires. Some conceived them as forest rejuvenating processes rather than threats to landscape value. Weather and season changes also received greater attention in the scientific model. Researchers were interested in the influence of soil temperature and moisture on tree growth (e.g. Lupi *et al*. 2012; Gewehr *et al*. 2014) and in carbon sequestration (e.g. Miquelajauregui *et al*. 2019). Some researchers studied the impacts of weather and season changes on wildlife habitats (e.g. Beauchesne *et al*. 2014; Lafontaine *et al*. 2017), hydrology (e.g. Proulx-McInnis *et al*., 2013) and lake ecology (e.g. Fauteux *et al*., 2015).

Ground condition ranked first among all States in the scientific model. Ground and soil studies are at the intersection of a variety of research fields. Foresters (e.g. Laamrani *et al*. 2014; Trottier-Picard *et al*. 2016), plant physiologists (e.g. Deslauriers and Morin 2005; Dao *et al*. 2015), fire scientists (e.g. Schaffhauser *et al*. 2017; Portier *et al*. 2019) and pedologists (e.g. Bélanger *et al*. 2003; Paré *et al*. 2011) all take forest soils into account in their research. Species diversity is studied by community and conservation ecologists (e.g. Work *et al*. 2013; Cadieux and Drapeau 2017; Boudreault *et al*. 2018). Research on predators especially focused on the conservation of woodland caribou, a vulnerable species (e.g. Boisjoly *et al.*, 2010; Lesmerises *et al.*, 2012).

3.5 Discussion

Indigenous land-use experts and researchers look at the same biophysical landscape but through different lenses. In this section, we discuss the drivers of environmental changes in boreal landscapes according to both perspectives, we explore opportunities for collaborative research based on perspective convergence and divergence and we formulate recommendations for future research.

3.5.1 Drivers of environmental changes

While forestry and climate change were drivers of environmental change in both the Indigenous and the scientific DPSI models, mining and hydro-electric development were exclusive to the Indigenous model. Forestry has the most influence according to both models. The Indigenous model is consistent with previous research in boreal North America (Adam *et al.*, 2012; Saint-Arnaud *et al.*, 2009) and Fennoscandia (Sandström *et al.*, 2016). The scientific model reflects the research efforts dedicated to assessing the impacts of forestry on ecosystems in the 1990s-2000s, along with the development of sustainable management practices (Angelstam and Kuuluvainen, 2004; Gauthier *et al.*, 2009; Klenk and Hickey, 2009). The influence of climate change in the Indigenous model was lower than expected based on previous research (e.g. Cuerrier *et al*., 2015a; David-Chavez and Gavin, 2018; Turner and Clifton, 2009). This can be explained by the lower latitude of our study area compared with that of other studies that were performed in arctic and subarctic environments where climate change is more acute (e.g. Furgal and Seguin 2006; Ford *et al*. 2008; Royer and Herrmann 2013). Moreover, as the Ouje-Bougoumou and Abitibiwinni hunting grounds are located inland and have a dense network of forest roads, access to the land is less vulnerable to climate change than in coastal or remote communities that rely on ice for transportation (Tremblay *et al.*, 2006).

The absence of mining from the scientific model could be explained by the fact that studies on acid drainage (Bussière, 2010; Reid *et al.*, 2009), forest and lake recovery near mining sites (Alpay *et al.*, 2006; Hamilton *et al.*, 2015; Larchevêque *et al.*, 2014) and the impacts of mining on quality of life (Fuentes *et al*. 2020) did not consider the effects on landscape processes and states. The influence of hydro-electric development was also absent from the scientific model. This is because most of the research effort was done in the 1970s and 1980s when dams and reservoirs were developed in James Bay (Quebec), affecting Cree populations (e.g. Feit 1979, 1985; Niezen 1993). Few research projects on the impact of hydropower facilities were done since 2000 (Rood *et al*., 2005; Desbiens, 2013).

3.5.2 Collaboration opportunities

Our results showed that environmental changes are a major concern from both the Indigenous and the scientific perspectives. Mitigation and adaptation strategies are needed to maintain the capacity of boreal landscapes to sustain Indigenous and other land uses. To this end, strategies issuing from collaborative research would benefit from knowledge complementarity and find higher legitimacy within communities (Wong *et al.*, 2020).

Convergences between the Indigenous and scientific perspectives can be good starting points for new collaborations (Robinson and Wallington, 2012). Issues related to wildlife have been especially conducive to collaborative research in the sturdy area. Studies with Cree and Anishnaabe communities improved the understanding of moose habitat quality (Jacqmain *et al.*, 2008; Tendeng *et al.*, 2016). The knowledge of local trappers (Indigenous and non-Indigenous) led to the formulation of research hypotheses about marten and fisher (*Pekania pennanti*) habitat use (Suffice *et al.*, 2017) that were tested in a research project based on animal ecology methods (Suffice *et al.*, 2020). Wildlife monitoring by local populations has been reported as an important source of information to address the impacts of environmental change (Ban *et al.*, 2018), as exampled by caribou monitoring by Cree and Naskapi communities (Herrmann *et al*., 2014). The impacts of environmental contamination on wildlife and human health were also the object of many collaborative research projects (Bordeleau *et al.*, 2016; Larose *et al.*, 2008; VanSpronsen *et al.*, 2007). Other converging interests could be further explored by collaborative research, including the impacts of the forest road network (Kneeshaw *et al.*, 2010), timber harvesting and silviculture on boreal landscapes.

Divergences between the Indigenous and scientific perspectives shed light on knowledge complementarity. Our results revealed that on the one hand, Indigenous experts possess a deep ecological knowledge of topics that have not yet received much attention from the scientific community. They knew precisely where and when fish species spawn and were able to locate seasonal moose habitat according to vegetation and topography (as reported by Jacqmain *et al*., 2008). They described with precision the spatial progression of a moose parasite in the region (*Dermacentor albipictus*) and located ancient trails and portages with patrimonial and historical value. On the other hand, researchers have used remote sensing and modeling to study large scale phenomena. They have shown a process leading to younger forest landscapes throughout the managed boreal zone in Quebec (Cyr *et al.*, 2009), an ecotone shift between closed boreal forest and open woodlands (Girard *et al.*, 2008) and a risk of biome transitions due to environmental changes (Johnstone *et al*. 2010; Gauthier *et al*. 2015). The complementarity of Indigenous and scientific knowledge needs to be explored further, as shown in other regions of Canada (Abu *et al.*, 2019; Mantyka-Pringle *et al.*, 2017), New-Zealand (Lyver *et al.*, 2018) and Australia (Liedloff *et al.*, 2013).

3.5.3 Implications and recommendations

We present four recommendations to foster knowledge reconciliation based on the lessons learned in this research. First, our research design faced limitations that will need to be addressed in future research. (1) Women were underrepresented among the Indigenous experts that took part in our study. This is a chronic problem in studies in environmental sciences that aim to bridge Indigenous and scientific knowledge systems (Alexander *et al.*, 2019b). We enhanced women participation by inviting family members to join the interviews, but this was not enough to reach parity. Designs dedicated to elicit women perspectives on environmental changes will be necessary to access the "whole story" (Basile *et al.*, 2017; Kim *et al.*, 2013). (2) Our method for quantifying causal associations in the DPSI was based on the number of experts (or researchers) who mentioned (or published on) them. While this provided a valid overview of the incidence of environmental changes, it did not address their strength. Further research is needed to differentiate infrequent but acute changes from common but lighter changes.

Second, community co-researchers' involvement in the research design as well as in the elicitation and interpretation of local experts' knowledge was essential for the success of our collaborative research. Community-based research institutions and dedicated human resources in the long term are key to maintaining fruitful research partnerships (Bohensky and Maru, 2011; Robinson and Wallington, 2012; Reid *et al*., 2016). The *Chisasibi Eeyou Resource and Research Institute* (Cree Nation) (www.cerri.ca/), the *Bureau Ndakina* (www.gcnwa.com/bureau-du-ndakina-2/) (Wabanaki Nation) and *l'Institut de développement durable des Premières Nations du Québec* et *du Labrador* (https://iddpnql.ca/) are eloquent examples of dynamic Indigenous research agencies. Funding programs committed to increase research capacity within Indigenous communities would help multiply such initiatives.

Third, researchers need to avoid "disciplinary silos" by addressing simultaneously the ecological, geological, social and cultural aspects of environmental changes at the landscape scale (Castleden *et al.*, 2017; Termorshuizen and Opdam, 2009; Tress et Tress, 2001). The *Delta Dialog Network* is an example of a transdisciplinary partnership that addressed environmental issues for three river deltas in Canada (www.usask.ca/research-groups/ddn/). The collaboration revealed fruitful in knowledge sharing and co-creation (e.g. Bradford and Bharadwaj, 2015; Mantyka-Pringle *et al*., 2017; Abu *et al*., 2019).

Fourth, addressing the underrepresentation of Indigenous researchers in universities and scientific institutions is a critical step toward knowledge reconciliation (Castleden *et al.*, 2017; Littlechild *et al.*, 2021; McGregor, 2018). Among all the researchers that came out of our bibliometric search, none was Indigenous to our knowledge. Efforts are needed to make university curricula more culturally relevant and to enhance the representation of Indigenous students in scientific training programs (Bartlett *et al.*, 2012).

3.6 Conclusion

Although approaches such as two-eyed seeing are increasingly valued to bridge Indigenous and scientific knowledge systems (Bartlett *et al.*, 2012; Rayne *et al.*, 2020; Tengö *et al.*, 2017), applied examples remain few and methods need to be developed (Abu *et al.*, 2019). In this research, we developed an empirical assessment of Indigenous and scientific perspectives on environmental changes using DPSI models. The boreal context was well-suited for this assessment because on the one hand, Indigenous communities are numerous and very active on the land and on the other hand, boreal landscapes has received great attention from the scientific community. The method could be applied for impact assessments and collaborative research in other environmental contexts where multiple and potentially conflicting perspectives on the land are at stake.

Indigenous people have a unique perspective on their land and its transformations. The differences we observed between the Indigenous and scientific perspectives underline the crucial role of Indigenous communities in seeking the balance between the benefits of economic development of the land and the consequences on people's life. The complementarity between knowledge systems is an opportunity to develop a wider and better-informed view of the effects of environmental changes on boreal landscapes.

Acknowledgments

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Authors' Contribution

ACB, SG and HA conceived the ideas and designed the methodology; ACB collected the data; ACB, SG and HA validated the bibliometric data; ACB, SG and HA analyzed the data; ACB led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

Supplementary Material S3

S3.1 SQL queries for the bibliometric search in Scopus

Location criteria

Geographic zone	Keywords
Boreal Quebec	(Boreal OR {James Bay} OR James-Bay OR {Clay Belt} OR {Canadian shield}) AND Quebec

Content criteria (Title, abstract, keywords)

Level	Variable	SQL Query
Drivers	Climate change	{Climate change} OR {Climatic change} OR {Global warming}
	Forest management	Forestry OR {Forest management} OR {Forest practices}
	Mining industry	Mine OR Mining
	Electricity production	Electricity OR Hydropower OR Hydro-power OR Hydroelectricity OR Hydro-electricity
Pressures	Contaminant release	Contamination OR Contaminant OR Pollut* OR {Acid rain} OR {Nitrogen deposition}
	Distribution changes	Species AND (Distribution OR Extinct* OR Invasi* OR Transition OR Exotic)
	Electricity transmission	{Power line} OR (Electricity AND

		(Distribution OR Transmission))
	Forest fires	(Forest AND Fire) OR Wildfire OR {Crown fire}OR {Wildland fire}
	Ore extraction	Mining AND (Metal OR Mineral OR Ore)
	Road network maintenance and expansion	Road AND (Construction OR Closure)
	Season/ weather changes	Weather OR Season* OR Meteo*
	Silvicultural treatment	Silvicultur* OR Intensive OR {Site preparation} OR Plantation OR {Tree planting}
	Timber harvesting	Harvest* OR Logging OR Cut OR Clear-cut OR Clearcut OR {Clear cut}
States	Age structure (forest)	{Age structure} OR Old-growth
	Composition (forest)	{Tree composition} OR {Tree species composition} OR {Stand composition} OR {Tree assemblage} OR {Tree species assemblage}
	Cultural places	((Cultural AND Keystone) OR Spiritual OR Sacred OR Special) AND (Site OR Place)
	Geese areas	Geese OR Goose
	Ground condition	Soil OR Ground OR {Woody debris} OR Microtopography OR

		Micro-topography NOT {Sediment core} NOT {Breeding ground} NOT {Spawning ground}
	Ice conditions	Ice OR Thaw* NOT {Little Ice age}
	Mine tailings	(Mine OR Mining) AND (Tailing OR Slam OR Waste OR Residu*)
	Naturalness	Naturalness OR Wilderness OR Primeval OR Preindustrial OR Pre-industrial OR {Intact forest}
	Predators	Predat*
	Road network	Road AND (Density OR Network)
	Spawning areas	{Fish habitat} OR (Spawning AND (Ground OR Area))
	Traffic	Traffic OR Crowd* OR {Human presence} OR Cabin OR “Land users” OR “Recreational”
	Transportation	Truck OR Train OR (Noise AND Disturbance)
	Water quality	Water AND (Quality OR Lake OR River OR Stream)

	Water temperature	{Water temperature} OR {Lake temperature} OR {River temperature} OR {Stream temperature}
	Wildlife diversity	(Species AND Diversity) OR Biodiversity
	Wildlife health	(Wildlife OR Fish OR Moose OR Beaver OR Caribou OR Goose OR Geese) AND (Health OR Disease OR Contamination OR {Heavy metal} OR Parasite OR stress OR {Heavy metal} OR Mercury OR {Persistent organic pollutant} OR Toxic* OR Arsenic OR Lead OR Cadmium)

S3.2 Qualitative description of impacts reported by Indigenous experts

Impacts

Moose local abundance depends both on habitat suitability and on hunting pressure. Habitat requirements change with seasons, and so change impacts. Winter habitat (called moose yards in Ouje-Bougoumou) were reported as especially sensitive to recent forest harvests (composition and age structure): “Moose comes out the forest during wintertime. He stays in the thick bush but he comes out to eat” (P_01)[9] . Hunting pressure from recreational, Indigenous or non-Indigenous, hunters is also important. The more extensive the road network, the more traffic there is, the more hunters there are. Access to hunting sites is mainly influenced by density of the forest road network. On the one hand, participants, especially in Pikogan, reported that roads are often necessary to access hunting sites. On the other hand, roads can become a limitation because of the associated traffic: “There are people forbidding us to pass and we don’t like that.” (P_05). The bumpy surface left after timber harvesting and scarification for tree planting (was reported as another access limitation:

> “When they do that (scarification), it’s very hard to walk. You have holes there maybe three feet deep. […] We have a lot of ski-doo [snowmobile] trails and very old trails that are all over this trapline […]. We can’t use the trails. Not before the snow is higher than two feet because of the holes.” (O_01B).

Moose quality depends directly on animal health, which is affected by parasites (ticks) and by contaminants:

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[9] Excerpts in French were translated in English for the purpose of this article

> "All they leave in the bush [after timber harvesting], is big mud. It makes water [holes] in there and the water turns all green. The animal is going to drink that [and get] sick. Sometimes, the animal is really skinny." (P_06)

Experience is affected by disturbances on the hunting ground, such as traffic noise (transportation, mostly from trucks) or by crowding by recreational hunters (traffic), and more generally by a lack of naturalness.

Geese are migratory birds hunted during short periods in Spring and Fall. Geese abundance is not affected by forest state variables but is sensitive to ice and water (water quality, windthrow) conditions. Landscape value is maintained as long as geese can land on a quiet waterbody free from obstacle.

Trapping involves a diversity of wildlife species and is affected by numerous state variables. Marten (*Martes americana*) abundance is mainly threatened by a lack of mature coniferous forests (composition and age structure). Beaver needs water and broadleaf trees (composition) and is threatened by population control (road network), by abundance of bald eagle (predation) and by the amount of trappers in the area (traffic). Intact cricks are hotspots for trapping (wildlife diversity), and they are especially sensitive to disturbances. Access to trapping sites is eased by an extended road network. Trapping sites are often located along waterbodies and boat access can be limited by fallen trees in the waterway (windthrow). Fur commercial value is higher for marten than for beaver, so trapline quality for trapping is primarily influenced by marten habitat. Participants reported worries regarding contamination of animals caught close to industrial areas (water quality). Trapper's experience is affected by conflicts with other land users (traffic) and industrial activities and by a lack of naturalness due to industrial activities.

Fish abundance is affected by overfishing, especially for traplines located close to town and accessible via the road network (traffic). Fish habitat and spawning areas are affected by sedimentation, nutrient load and increased stream water temperature due to forest road maintenance and salvage logging. Boat access to fishing spots is not a problem for most participants. Fish quality was an important concern, especially in areas exposed to mining activities. Participants worried about flesh alteration and contamination with heavy metals downstream of mine tailings, abandoned mine sites and active mines (water quality). Fishing experience is affected by traffic on the trapline:

> What hunters don't like, one of the biggest things, is forestry cuts. Everybody has access to it. […] You know that opening roads [allows] somebody else to go hunting and fishing. […] It's open access. (O_01B).

Education to Cree and Anishnaabe life in the bush requires a suitable learning environment. Abundance of educational material primarily depends on wildlife diversity, including richness and abundance. Integrity of cultural and patrimonial places such as graves, old portages and canoe routes also contributes to enroot education into the land. Participants, especially in Pikogan, highlighted the importance of road access (road network), facilitating weekend trips and making life in the bush compatible with school and working schedules: "I go with him [grandson] and we install traps. I make him install them. […] We are close from Amos [township]. It takes us 45 minutes to get there" (P_01). Education quality was not reported to depend on trapline state more than on teacher's knowledgeability. Water contamination and high level of transportation are issues for educational experience.

Participant's wellbeing on the hunting ground mainly goes along with naturalness. As a mountain view of a meaningful intact landscape provides good feelings, a landscape affected by industrial activities provides bad feelings. Participants reported a gap between the desired state of their hunting ground, and it's actual state, creating sadness and pain:

> When you see something that is not good, you don't feel good. Once they destroyed it, when they cut the trees. Like this […] this nice mountain here, it has all been cleaned. You sit on the top of the mountain and you cry. (O_07)

Participants also reported a feeling of dispossession from their ancestral territory, converted for industrial purposes.

> There are so many damages to the land that it's not the same that I grew-up in. […] There is a lot that they don't see. There are big changes in there. I can't come there to actually [recharge my batteries]. There are limitations. My wellbeing is incomplete for that reason. Everywhere I go, there was something that was done on the land. There is so much that I see that is not for that purpose anymore. (O_10)

Most participants indicated their cabin is the place they go to recharge their batteries and the surrounding is especially sensitive to disturbances.

> When I went to my camp, it was a devastated time. I noticed the trees were cut again. My heart was torn. It was like they give no care to the land. And I was going there to hunt for the bears that were fooling around the area. It was so destructed, so much pain […]. (O_01A).

The quality of time spent at the cabin was associated with quietness and was thus affected by traffic noise (transportation) and by crowding by other land users (traffic). "Cars pass around, big trucks pass around. When you drive around, you meet them. The whole house shakes when they are charged (with wood)" (P_07). Some participants said the lack of a phone signal at the cabin was a source of worries but others were satisfied with the absence of a connexion, claiming their commitment to the land was more complete without a phone access.

CHAPITRE IV

A COLLABORATIVE TYPOLOGY OF BOREAL INDIGENOUS LANDSCAPES

(UNE TYPOLOGIE COLLABORATIVE DES PAYSAGES BORÉAUX AUTOCHTONES)

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Abstract

Climate change and natural resource extraction are transforming boreal forest landscapes, with effects on Indigenous people's relationship with the land. Collaborative management could enhance the consideration of Indigenous perspectives and limit negative outcomes of environmental change, but it remains the exception rather than the norm. We addressed barriers to involvement of Indigenous people in land management by developing a method to enhance communication and trust, while favouring bottom-up decision-making. We partnered with the Abitibiwinni and Ouje-Bougoumou First Nations (boreal Quebec, Canada) (1) to develop indicators of Indigenous landscape state, (2) to create a typology of Indigenous hunting grounds, and 3) to suggest guidelines for sustainable land management in Indigenous contexts. Through participatory mapping and semi-directed interviews with 23 local experts, we identified factors influencing Indigenous landscape value. Using open-access data, we developed indicators to measure landscape state according to those values. We identified four types of hunting grounds with *k*-means clustering, based upon biophysical factors and disturbance history. Our results suggest that land management should aim to reduce differences between hunting ground states and consider the risk of rapid shifts from one state to another.

Key words: Environmental change, Indigenous people, Forest management, Boreal forest, cumulative impacts, collaborative research.

Résumé

Les changements climatiques et le prélèvement des ressources naturelles transforment les paysages de la forêt boréale, ce qui a des effets sur la relation des peuples autochtones avec le territoire. La gestion collaborative pourrait améliorer la reconnaissance des perspectives autochtones et limiter les impacts négatifs des changements environnementaux, mais cela demeure l'exception plutôt que la règle. Nous abordons les obstacles qui nuisent à l'implication des peuples autochtones dans la gestion du territoire en élaborant une méthode pour améliorer la communication et la confiance tout en favorisant la prise de décision ascendante. Nous nous sommes associés aux Premières Nations Abitibiwinni et Oujé-Bougoumou (Québec boréal, Canada) pour (i) élaborer des indicateurs de l'état du paysage autochtone; (ii) créer une typologie des terrains de trappe autochtones; et (iii) suggérer des lignes directrices pour une gestion durable en contextes autochtones. Grâce à la cartographie participative et à des entrevues semi-dirigées avec 23 experts locaux, nous avons identifié les facteurs qui influencent la valeur du paysage autochtone. En utilisant des données en libre accès nous avons développé des indicateurs pour mesurer l'état du paysage selon ces valeurs. Nous avons identifié quatre types de terrains de trappe avec l'analyse de partitionnement par la méthode des k centroïdes, sur la base des facteurs biophysiques et de l'historique des perturbations. Nos résultats indiquent que la gestion du territoire devrait viser à réduire les différences entre l'état des terrains de trappe et tenir compte des risques de changements rapides d'un état à un autre.

Mots-clés : Changement environnemental, Peuples autochtones, aménagement forestier, forêt boréale, effets cumulatifs, recherche collaborative.

4.1 Introduction

About 30% of the world's forests are part of the boreal biome. Boreal landscapes are characterized by a cold climate, dominance of coniferous tree species, and abundance of lakes and rivers (Brandt, 2009). Boreal landscapes are important providers of natural resources, such as timber, hydroelectricity, and minerals (Gauthier *et al*., 2015a). Population density is low (except in parts of Fennoscandia) and includes a high proportion of Indigenous people (Burton *et al*., 2010).

The well-being of Indigenous people living in boreal environments relies upon a variety of provisioning and cultural practices that take place on the land (Davidson-Hunt and Berkes 2003; Bélisle *et al*. 2021). Hunting, fishing, trapping, teaching, and resting, for example, contribute to developing and maintaining a highly valued relationship with the land (Chan *et al*., 2018). Landscape value can be defined as the capacity of a biophysical landscape to sustain landscape practices contributing to people's well-being (Bélisle *et al*., 2021). Landscape value depends upon the abundance of landscape features, such as habitats for wildlife and medicinal plants (Jacqmain *et al*., 2012; Saint-Arnaud *et al*., 2009; Uprety *et al*., 2012). Access to landscape features by forestry roads, snowmobile trails or the hydrographic system, is also necessary (Brinkman *et al*., 2016; Kneeshaw *et al*., 2010). The quality of landscape features (e.g., wildlife health, landscape aesthetics, water quality) influences landscape value, as well as the experience and satisfaction of land users while engaging in landscape practices (Bélisle *et al*., 2021; Fagerholm *et al*., 2012; Lambden *et al*., 2007) .

Disturbances resulting from forestry (Cyr *et al*., 2009), mineral exploration and exploitation (Bridge, 2004), and energy production (Pickell *et al*., 2014) transform boreal landscapes. Climate change, which is more pronounced at higher latitudes, adds yet another layer of disturbance (IPCC, 2015). Although the proportion of the boreal biome that is affected by industrial activities is low overall, development tends to concentrate regionally. Disturbances interact with one another and local people are exposed to the cumulative impacts of environmental changes (Forbes *et al*., 2004; Fuentes *et al*., 2020). Beyond a certain disturbance threshold, the landscape might abruptly change and land-users will need to rapidly adapt their landscape practices (Parlee *et al*., 2012; Walker *et al*., 2011). The growing demand for natural resources and the uncertainty that is associated with climate change raise concerns regarding the limits of Indigenous people's adaptive capacity (Parlee *et al*., 2012; Turner et Clifton, 2009).

Active involvement of Indigenous communities and organizations in land management can limit the negative outcomes of environmental change (Casu, 2018; Parsons et Prest, 2003; Sarr et Puettmann, 2008). Collaboration provides land management with substance and legitimacy, and contributes to empowering local populations. However, modifying management structures is challenging and successful collaborations among Indigenous people, industries, and governments remain rare. Dam Lam *et al*. (2019) described three sets of barriers to the consideration of Indigenous values in land management. First, technical barriers include the remoteness of some communities, together with communication issues due to language and cultural differences. Second, structural barriers emerge from the top-down organization of land management. In Canada, consultation with Indigenous people is mandatory throughout the landscape planning process (Wyatt *et al*., 2010). However, landscape development is informed by timber volume, forest productivity or mineral potential indicators emerging from an industrial perspective of the land. Conversely, the consideration of Indigenous values requires the development of bottom-up indicators, which emerge from local perspectives (Fraser *et al*., 2006; Saint-Arnaud *et al*., 2009). Third, perceptual barriers refer to the lack of mutual trust between Indigenous people and other stakeholders.

Collaborative research can lead to the development of management tools at the boundary between different perspectives of the land (Robinson and Wallington, 2012). Our objective was thus to develop a landscape assessment method that would be consistent with local values and informative to land managers. Specifically, our objectives were (1) to develop indicators of Indigenous landscape state based on local values, and (2) to create a typology of Indigenous hunting grounds, in order (3) to suggest guidelines for sustainable land management. We adopted a collaborative, bottom-up, and open-source approach so that our results could find direct applications in a wide range of Indigenous contexts.

4.2 Study area

We conducted the study in boreal Quebec, Canada (Figure 4.1), in collaboration with the Abitibiwinni (Anishnaabe) First Nation (1080 members) and the Ouje-Bougoumou (Cree) First Nation (906 members) (Indigenous and Northern Affairs Canada, 2015). Both Nations are part of the Algonquian cultural family that is spread throughout Canada and the United States. They are considered Woodland First Nations in Canada (Aboriginal Affairs and Northern Development Canada, 2013) according to their geographic location and traditional nomadic lifestyle, which is coordinated with wildlife migrations.

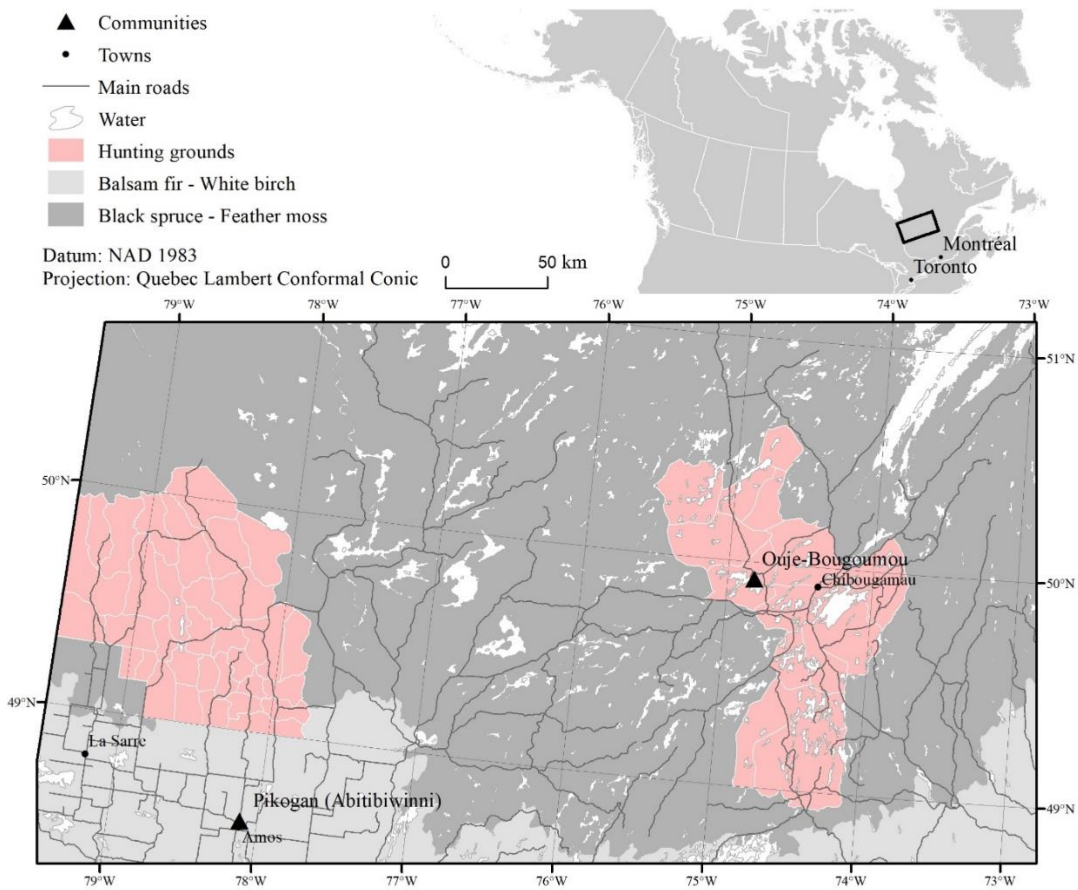

Figure 4.1 Hunting grounds of the Abitibiwinni First Nation (on the left, Pikogan is the toponym for the community) and Ouje-Bougoumou First Nation (on the right). The map was produced in ArcMap 10.6 (ESRI). Data are provided by Natural Resources Canada (towns, communities and water), Adresses Québec (roads) and the Ministère de l'Énergie et des Ressources Naturelles du Québec (bioclimatic domains).

We worked at the scale of the family hunting ground, the basic spatial unit of land use (Saint-Arnaud *et al*. 2009). Hunting grounds are used and managed by Indigenous families. Landscape practices such as hunting, trapping, teaching traditional knowledge, holding ceremonies, having family gatherings, and other provisioning and cultural activities take place on the hunting ground. Given that they are passed down from generation to generation, hunting grounds are places where in-depth ecological knowledge is developed over time (Ethier and Poirier, 2018; Sayles and Mulrennan, 2010).

The 34 Abitibiwinni hunting grounds cover 11430 km^2, whereas the 14 Ouje-Bougoumou hunting grounds cover 10560 km^2. Hunting ground size ranges between 112 km^2 and 1652 km^2 (mean = 456 km^2; standard deviation = 310 km^2). Size differences are due to the uneven distribution of resources and to subdivisions when the land is bequeathed to children. Land management on Eeyou Istchee (Cree territory) is regulated by the *James Bay and Northern Quebec Agreement* (1975)[10] and *La Paix des Braves Agreement* (2002)[11]. Implementation of the forestry chapter is under the supervision of the Cree-Quebec Forestry Board, an independent organization originating from the agreement and including members from both parties. No such agreement has yet been ratified by the Abitibiwinni First Nation and, thus, the Abitibiwinni territory is under the rules of public forest land in Quebec.

The region has a subhumid continental climate, with average annual temperatures (1981-2010) ranging between 0.0 °and 0.2 °C, and average annual precipitation between 909 and 996 mm, 30% of which falls as snow (Environment and Climate Change Canada, 2019). All Ouje-Bougoumou hunting grounds and those in the northern part of the Abitibiwinni territory are located in the black spruce (*Picea mariana* [Miller]

[10] Available from https://www.rcaanc-cirnac.gc.ca/eng/1100100030604/1542740089024

[11] Available from https://cdn-contenu.quebec.ca/cdn-contenu/adm/min/conseil-executif/publications-adm/saa/administratives/ententes/Cris/2002-02-07_cris-entente.pdf?1607004430

BSP)−feather moss bioclimatic domain. Hunting grounds in the southern part of the Abitibiwinni territory are located in the balsam fir (*Abies balsamea* [L.] Miller)−white birch (*Betula papyrifera* Marshall) bioclimatic domain. For the sake of uniformity, we have included only the Abitibiwinni hunting grounds that are located in the black spruce−feather moss bioclimatic domain (23/34 hunting grounds, covering 9 460 km^2). Large and severe wildfires, forestry (harvesting, road building, and silviculture), mining (exploration, exploitation, and abandoned mines), and electrical transmission corridors are the main disturbances in the study area.

4.3 Material and Methods

4.4 Ethical considerations

The project was approved by the Ethics Review Board of the Université du Québec en Abitibi-Témiscamingue (certificate # 2016-04). We followed the OCAP® principles (ownership, control, access and possession of data; https://fnigc.ca/ocap) and developed the project in accordance with the research protocol of the Assembly of First Nations of Quebec and Labrador (AFNQL 2014). Representatives of the university and the two participating communities signed a research agreement. Participants agreed to take part in the project by signing a consent form (adapted from Basile *et al*. 2018) with assurance that the data would remain confidential. Members of the research team signed a confidentiality agreement before they could access data.

4.5 Indicators of hunting ground state

In collaboration with the project partners in the communities, we selected six important landscape practices taking place on the hunting grounds. (1) Moose (*Alces americanus* Clinton) hunting provides food, leather, and art craft material (Jacqmain *et al*., 2012;

Saint-Arnaud *et al*., 2009). (2) Canada goose (*Branta canadensis* L.) hunting occurs during migrations and is associated with holidays that are spent on the land with family. Goose is an important source of fat in the Cree diet (Delormier et Kuhnlein, 1999). (3) Fishing is a staple and readily accessible source of protein. (4) Trapping is a source of revenue, food, and fur. (5) The hunting ground is a privileged place for education, including skill, language, and knowledge transmission (Basile *et al*., 2017; Ohmagari and Berkes, 1997). (6) *Ressourcement* is a French word defined as "reversion to one's sources, finding one's deep roots to reach a new balance, also to find sources (moral, psychological, spiritual, etc.) to recover physical and moral forces" (translated from Office québécois de la langue française 1989). The contribution of these six practices to Indigenous landscape value and well-being is detailed in Bélisle *et al*. (2021) (Chapter II).

We elicited the factors influencing landscape value at the hunting ground scale using semi-directed interviews and participatory mapping with Indigenous land users. Participatory mapping is an efficient collaborative method for co-production of knowledge (Sandström, 2015). The research partners selected participants in both communities according to the criteria of experience, land management responsibilities, and peer recognition of expertise. We met with 27 land users from different hunting grounds, namely, 13 from the Abitibiwinni First Nation and 14 from the Ouje-Bougoumou First Nation. The fieldwork took place between June and September 2016. The interviews typically lasted 1–2 h and took place in different locations in the communities (meeting room, local restaurant), on the land (houses and cabins), and in town (Chibougamau Eenou Friendship Centre). For each landscape practice, we asked participants to locate places of high and low value on a map of their hunting ground, respectively using green and red pens. We questioned the participants about the factors influencing landscape value using the map to generate discussion. Further details on data collection (expert identification, the social profile of participants, validation of expertise, interview process) are presented in Bélisle *et al*. (2021).

We transcribed the interviews and imported the text files into the NVivo 10 software (QSR International, Melbourne, Australia) for thematic analysis. We first classified interview excerpts according to the landscape practice(s) to which they referred. For each landscape practice, we then grouped excerpts according to the factor(s) affecting landscape value. New factors were added as they were mentioned for the first time. Interviews, transcriptions, encoding, and theme groupings were all performed by the first author to ensure consistency.

We developed indicators using open-access data that were available to the communities. To be considered, the data needed to be spatially explicit and available at the proper scale and spatial extent. We selected databases that are maintained and updated regularly to facilitate long-term monitoring. Data sources included forest inventories that are published by the Ministry of Forests Wildlife and Parks (Quebec), road maps that are produced by the Ministry of Transportation (Quebec), and mining and power line maps that were obtained from the Ministry of Energy and Natural Resources (Quebec) and Hydro-Québec. We used ESRI ArcGIS (version 10.6) to compile information for each hunting ground. Data sources and geo-treatment queries are available in the electronic Supplementary Material S4.1.

4.6 Typology

We developed a typology of hunting grounds based on landscape state indicators using k-means non-hierarchical clustering (R software version 3.4.4, package *stats*, *Hartigan and Wong* algorithm, maximum of 100 iterations, 5 starts). *k*-means clustering is a multivariate statistical analysis that assigns objects to a given number of groups (here, hunting ground types) based upon their similarity. Variables, objects and groups can be visualized on ordination biplots that are generated from principal component analysis (PCA).

A multivariate approach was appropriate for comparing hunting grounds because state indicators were numerous and highly correlated with one another (Legendre and Legendre, 2012). We centred and scaled the indicators prior to analyses (function *scale*, *base* package). We used the *Calinski-Harabasz* and the *simple structure* indices to determine the optimal number of clusters (function *cascadeKM*, package *vegan*, 2–8 groups). We analyzed the correlation patterns among clusters, hunting grounds, and indicators with PCA (function *prcom*, package *stats*). We compared cumulative impacts between clusters using the average level of naturalness (undisturbed area). We used a one-way analysis of variance (function *aov*, package *stats*), followed by post-hoc Tukey tests (function *TukeyHSD*, package *stats*).

Our methodology could be applied to other contexts/communities using similar data sources and other indictors. All material that we developed, including datasets and R codes, is open-source and available online (*https://github.com/acbelisle/Hunting-ground-indicators-and-typology*).

4.7 Results

4.8 Indicators of hunting ground state

Nineteen factors affecting landscape value emerged from the interviews with local experts (Table 4.1). Given data availability, we were able to develop indicators for 10 factors. Indicators were direct, indirect, or synthetic (see Supplementary Material S4.1 for metadata and distribution of indicators). Direct indicators describe forest composition and age structure, power lines, road density, and ground state (microtopography). We developed indirect indicators when no direct data were available. Indirect indicators are proxies based upon the information that was obtained from the interviews. Traffic is approximated by the density of leases for hunting cabins and outfitters, and distance to the nearest town. Transportation of material is approximated by the density of main roads. Water quality is approximated by the density of abandoned mine sites, while water temperature is approximated by the density of windthrow on shorelines, causing an increase of solar radiation. Synthetic indicators summarize many indicators with a single metric. Naturalness is a synthetic indicator of the proportion of a hunting ground that has not been affected by industrial activities or infrastructures. We could not develop indicators for cultural places, goose landing areas, ice condition, mine tailings, access to technology (cellphone signal), spawning area integrity, wildlife diversity, and wildlife health due to the lack of data.

Table 4.1 Factors affecting landscape value, indicators of hunting ground state, and definitions. The codes are used in figures and throughout the text. Data sources, distributions and SQL queries are available as electronic supplementary material (Supplementary Material S4.1)

Factor	Indicator	Definition	Code
Age structure	Mature forests	Proportion of hunting ground (terrestrial area) covered by forests ≥ 80 years-old.	Age_mat
	Regenerating forests	Proportion of hunting ground (terrestrial area) covered by forests ≤ 14 years-old.	Age_reg
Composition	Broad-leaved forests	Proportion of hunting ground (terrestrial area) covered by forest stands with broad-leaf species dominance.	Com_brd
	Coniferous forests	Proportion of hunting ground (terrestrial area) covered by forest stands with coniferous species dominance.	Com_con
	Mixedwood forests	Proportion of hunting ground (terrestrial area) covered by forest stands co-dominated by coniferous and broad-leaf species.	Com_mix
Cultural places	No data		
Geese areas	No data		
Ground state (microtopography)	Plantations	Proportion of hunting ground (terrestrial area) covered by forest stands originating from plantations.	Grn_pla
	Windthrow	Proportion of hunting ground (terrestrial area) affected by windthrow.	Grn_win
Ice condition	No data		
Mine tailings	No data		

Table 4.1 Suite

Factor	Indicator	Definition	Code
Naturalness	Naturalness	Proportion of hunting ground (total area) free from industrial disturbance (mines, forestry, roads, towns)	Nat_nat
Power lines	High voltage power lines	Density of power lines on the hunting ground (total area) ($km \cdot km^{-2}$)	Pow_lin
Predators	No data		
Road network	Road density	Density of roads on the hunting ground (terrestrial area) ($km \cdot km^{-2}$)	Roa_roa
Spawning area integrity	No data		
Technology	No data	Access to a phone – TV signal	
Transportation	Main road density	Density of main roads on the hunting ground (terrestrial area) ($km \cdot km^{-2}$)	Trs_road
Traffic	Distance to town	Distance between hunting ground centroid and nearest town (km), as the crow flies	Trf_twn
	Lease density	Density of hunting cabin leases on the hunting ground (terrestrial area) ($cabin \cdot km^{-2}$)	Trf_lea
Water quality	Abandoned mining sites	Number of abandoned mining sites	Waq_min
Water temperature	Windthrow in shorelines	Proportion of shoreline affected by windthrow	Wat_win
Wildlife diversity	No data		
Wildlife health	No data		

4.9 Typology of hunting grounds

Hunting grounds were grouped into four types based upon state indicators (Figure 4.2). Both the Calinski – Harabasz and simple structure indices suggested a four-type solution (Table S4.2). Type A includes 14 hunting grounds that are located in the northern part of the Abitibiwinni area; Type B includes eight hunting grounds, all of which are located in the Ouje-Bougoumou area; Type C includes 12 hunting grounds that are located in the southern part of the Abitibiwinni and Ouje-Bougoumou areas; and type D includes five hunting grounds that are located in the Ouje-Bougoumou central area.

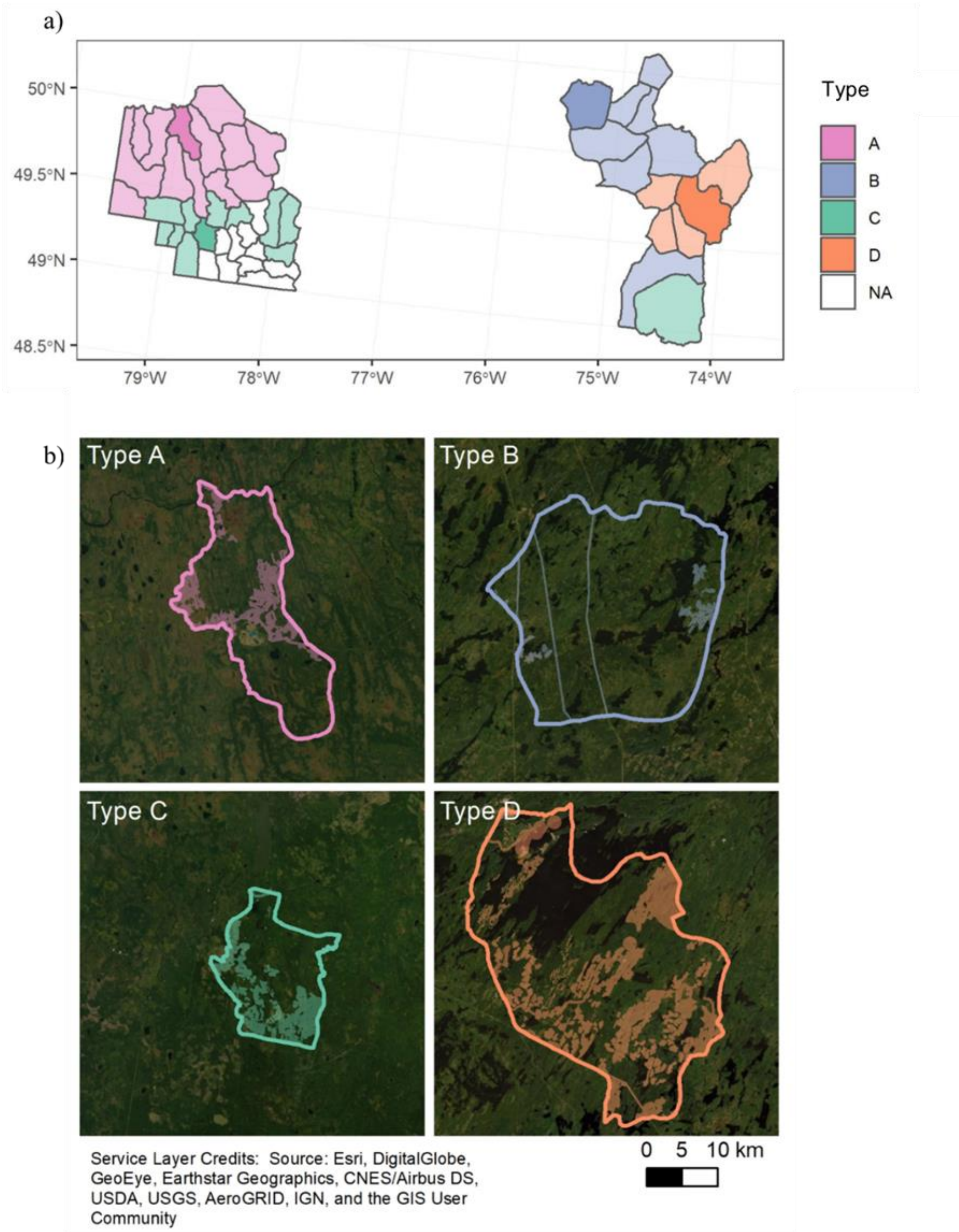

Figure 4.2 Hunting ground typology, with a) spatial distribution of hunting ground types and b) examples of how disturbed areas (shaded) and natural areas (unshaded) are distributed in each hunting ground type. The maps were produced in a) R version 3.4.4 (libraries sf and ggplot2) and b) ArcMap 10.6 (ESRI).

Patterns of correlations among hunting grounds, hunting ground types, and indicators appear as arrows in the biplots that are associated with the PCAs (Figure 4.3). Points that are close together on the ordinations indicate more similar hunting grounds. The first three dimensions explained 67% of the variance in hunting ground state. Density of mixedwood forests (Com_mix), roads (Roa_roa), and cabin leases (Trf_lea) load negatively onto the first dimension, which accounts for 30.9% of the variance. Dimension 1 separates hunting ground Types C and D from hunting ground Type A, with Type B in between. Density of broad-leaved forests (Com_brd), windthrow on shorelines (Wat_win), and distance to the nearest town (Trf_dis) load positively onto the second dimension, which accounts for 21.6% of the variance. Density of coniferous forests (Com_con), high voltage power lines (Pow_lin), and naturalness (Nat_nat) load negatively on dimension 2, which separates Types A and C from Types B and D. Density of regenerating forests (Age_reg) load negatively, whereas density of roads (Roa_roa) and windthrow (Grn_win) load positively onto dimension 3, which accounts for 14.4% of the variance and separates Type B from Type D

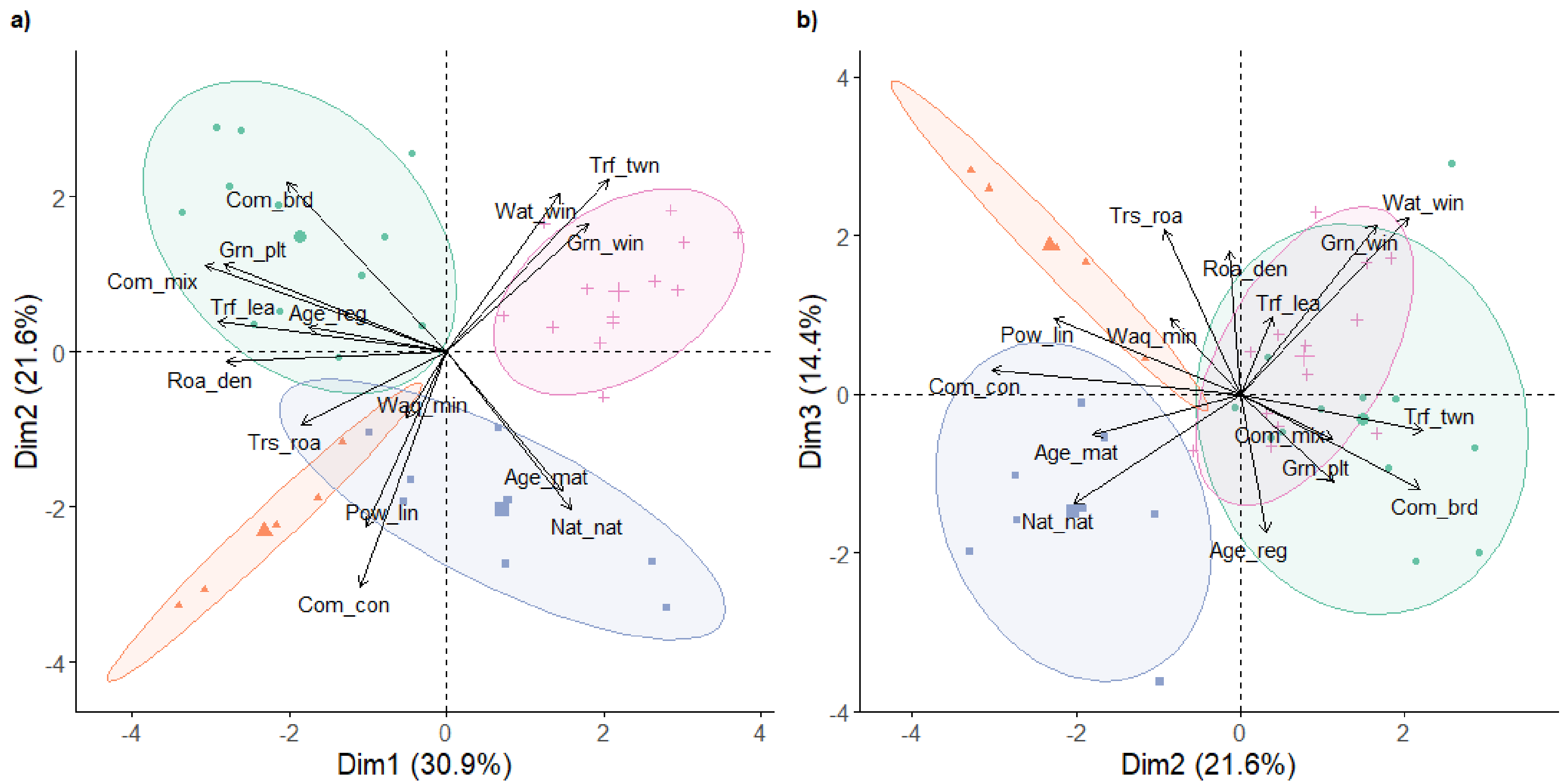

Figure 4.3 Principal component analysis (PCA) biplots showing hunting grounds (dots), hunting ground types (ellipses including at least 80% of cluster members), and indicators of hunting ground state (arrows). Separate biplots are presented for (a)dimensions 1 and 2 and (b) dimensions 2 and 3 of the PCA. Age structure: Mature forests (Age_mat), Regenerating forests (Age_reg). Composition: Broad-leaved forests (Com_brd), Mixedwood forests (Com_mix), Coniferous forests (Com_con). Ground condition: Plantations (Grn_pla), Windthrow (Grn_win). Naturalness: Naturalness proportion (Nat_nat). Power lines: High voltage power line density (Pow_lin). Road network: Road density (Roa_roa). Transportation: Density of main roads (Trs_road), Traffic: Distance to nearest town (Trf_twn), Cabin lease density (Trf_lea). Water quality: Abandoned mining sites (Waq_min), Water temperature: Windthrow on shorelines (Wat_win)

The hunting ground types have different levels of cumulative disturbances, as shown by the naturalness index. Average disturbance levels among types can be ordered as follows: 30%, Type C (naturalness = 70%); 22%, type D; 19%, Type A; and 8%, Type B. All differences are statistically significant ($\alpha = 0.05$) except between pairs A-D and C-D. An example of the spatial distribution of natural and disturbed areas for each type is presented in Figure 4.2b. Land managers can use the data visualization tool that we developed to obtain information on the state of a given hunting ground (Figure 4.2; Supplementary Material S4.3). For example, hunting ground O48B (Ouje-Bougoumou, Type B) has the highest proportion of mature forests and the highest level of naturalness among hunting grounds of both communities (Figure 4.4). Compared with other hunting grounds belonging to Type B, O48B also has a higher proportion of old-growth forests, a lower proportion of mixedwood forests, fewer plantations, and a lower road density (both forestry and main).

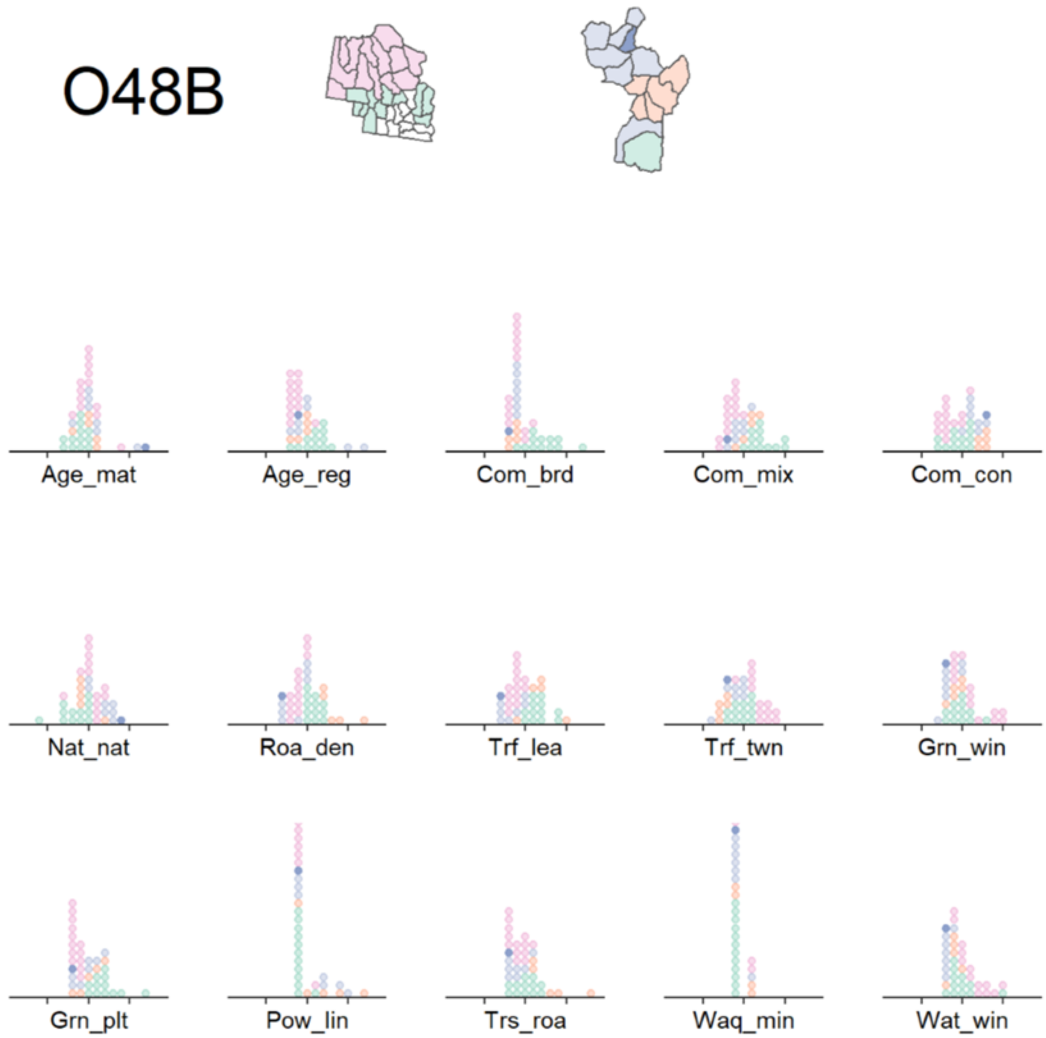

Figure 4.3 Example of output from the hunting ground visualization tool. A report is generated for each hunting ground, including hunting ground ID (048B in the example), a map of the study area with hunting ground contours and a dot plot for each indicator. The dot plots present the frequency of hunting grounds (dots) among scaled indicator values (x-axis, range = 0 to 1). The target hunting ground (full colour dot) can be compared to other hunting grounds from the same cluster (same colour transparent dots) and from the study area (transparent dots of all colours).

4.10 Discussion

With this research, we aimed to facilitate consideration of Indigenous values in land management by developing a method for collaborative landscape assessment. We worked at the scale most relevant to land users to develop indicators of hunting ground state that were consistent with local ecology, culture, and livelihood. Our results show a diversity of hunting ground types resulting from the interaction between biophysical factors and development history. In the following section, we discuss the validity and limits of the indicators that we developed, analyze hunting ground types, and suggest land management guidelines.

4.11 Indicators of hunting ground state

We elicited the factors affecting landscape value through interviews with local experts. Our approach, which was based on landscape practices such as hunting, fishing and education, was consistent with each participant's relationship with the land and favoured in-depth discussions (Satterfield, 2001). Our use of participatory mapping also proved effective in overcoming communication barriers and in sparking discussions regarding both tangible and intangible values (Klain and Chan, 2012).

Open data from monitoring programs were crucial to the development of quantitative indicators of hunting ground state. We used government datasets so that the method could be easily transferred to other communities and contexts. Similar datasets are indeed available for other jurisdictions (e.g. British Columbia Forest Inventory Program, Ontario Forest Resources Inventory, USDA Forest Inventory and Analysis Program). We were able to develop indicators that were directly associated with industrial activities. For instance, data on forest composition and age structure were directly provided by forest inventories that were produced by *La direction de la* *recherche forestière du Québec* (Ministère des Forêts de la Faune et des Parcs du Québec, 2019) and data on active and abandoned mines were available from SIGÉOM, which is a spatial reference geo-mining information system that was developed by the Ministry of Energy and Natural Resources. For factors that could not be directly associated with industrial activities, we were able to derive proxies from data that had been collected for different purposes. For instance, data on hunting cabin leases is routinely used for management and consultation purposes, but we used it alongside road density to estimate traffic on the hunting grounds. Similarly, we combined data on windthrow that was included in forest inventories with hydrographic data to calculate windthrow density in riparian zones, which we used as a proxy of water temperature increase.

The lack of data for eight factors that are of importance to Indigenous experts (e.g., wildlife health, water quality, or cultural sites) is a limitation of this research. Nevertheless, the direct and indirect indicators that we developed likely include "umbrella indicators" which are correlated with other indicators that we could not include due to a paucity of data (Kienast *et al*., 2015). Further research is needed to assess the correlation between indicators and identify those requiring a dedicated monitoring effort. Indigenous communities themselves gather data that could be used to develop additional indicators (e.g. Cucciurean *et al*., 2011). We did not use these data sets because they contained highly sensitive and confidential information. Moreover, spatial extent of this data was limited to traditional territories and not all were monitored regularly. Yet, communities could include these data in their own analyses, using the open-source material that we developed, thereby updating the typology.

4.12 Typology of hunting ground states

Biophysical conditions and the history of natural resource exploitation and land management explain differences among the four types of hunting ground states. Type A hunting grounds have low disturbance levels. They are located on clay soils that are unfavourable to the growth of tree species other than black spruce and tamarack or eastern larch (*Larix laricina* [Du Roi] Koch) (Fenton *et al*., 2005). Forests in these areas are of little industrial interest. Consequently, other human activities are limited by the low density of forest roads.

In type B hunting grounds, a protected area (Assinica Park; not yet officialized but nevertheless forbidden to industrial development), partly explains the low level of disturbances from forestry and mining, while Indigenous people still exercise their hunting rights. Additionally, the forest-harvesting front proceeds from south to north and was located close to the boundary between types B and D at the time of data collection. The high proportion of regenerating forests in some of the hunting grounds that were grouped in type B is due to wildfires, which are more frequent in this part of the study area (Boulanger *et al*., 2013). The dominance of coniferous forests is also consistent with higher fire frequencies, favouring the regeneration and growth of black spruce and jack pine (*Pinus banksiana* Lambert) (Bergeron *et al*., 2004b).

The state of Type C hunting grounds is driven by forestry activities. Simplification of the forest mosaic and depletion of old-growth forest stands are consequences of timber harvesting (Bélisle *et al*., 2011; Cyr *et al*., 2009). Forest logging induces a compositional transition from coniferous to broad-leaved stands (Laquerre *et al*., 2011). Forestry roads cause canopy opening, habitat fragmentation, water contamination, and conflicts between land users (Kneeshaw *et al*., 2010). Silvicultural treatments such as scarification and tree planting reduce walkability and naturalness of the terrain (Saint-Arnaud *et al*. 2009).

Human activities in the vicinity of the town of Chibougamau (7553 inhabitants in 2018) drive the state of Type D hunting grounds. Chibougamau developed in the 1950s around mineral extraction, including copper (Frenette, 1985). The negative effects of mining on water quality (Bussières *et al*., 2004), wildlife (Weir *et al*., 2007), and Indigenous livelihoods (Herrmann *et al*., 2014; Horowitz *et al*., 2018) are still being experienced. The development of access vectors − first railways, then roads − and the influx of mining workers who settled in the area likely prompted the development of other sectors of the economy such as forestry, tourism, and electricity transmission (Forbes *et al*., 2004; Walker *et al*., 2011). Hence, the impacts of economic development are concentrated in the hunting grounds of a few families.

4.13 Implications for management

We suggest two guidelines to better consider the effects of management decisions for Indigenous land-users.

1) Reduce differences between hunting ground states

As reported by Forbes *et al*. (2004), we observed that disturbances tend to concentrate in some areas, while other areas remain relatively untouched. The concentration of disturbances in a few hunting grounds can lead to inequities among Indigenous families in terms of access to land and resources, which in turn creates governance issues within communities (Asselin *et al*., 2015; Casu, 2018). Land management strategies, such as functional zoning in forestry, can exacerbate disparities by intensifying industrial activities in disturbed and accessible areas, while concentrating conservation efforts in less affected areas (Bottrill *et al*., 2008; Hartmann *et al*., 2010). Alternatively, in Eeyou

Istchee (Cree territory), the *Paix des Braves Agreement* restricts the proportion of regenerating forests and imposes a percentage of protected area in each hunting ground. Similar ways of linking land development regulation to land use by local people could be implemented in other Indigenous contexts to ensure a more equitable distribution of benefits and drawbacks from resource extraction activities.

2) Consider the risk of rapid shift in hunting ground state

Boreal landscapes are complex adaptative systems (Filotas *et al*., 2014). They follow non-linear dynamics, including disturbance thresholds beyond which they can switch between alternative stable states (Walker *et al*., 2004). In the study area, remote and relatively undisturbed hunting grounds (Types A and B) could shift to a disturbed state (such as the case in hunting ground Types C and D), for example after construction of a road for forestry, mining, recreational hunting and other activities (Walker *et al*., 2011). While road decommissioning could induce a transition from a disturbed (Type C or D) to an undisturbed state (Type A or B), such a transition could be much more gradual or, under some circumstances, might simply not be possible, given that some changes are irreversible (Chapin *et al*., 2004).

The risk of abrupt transitions from one state to another can be assessed using the proximity of a given hunting ground to those belonging to other clusters (Figure 4.3). Using the methodology that we developed in this study, land managers can individually assess every indicator of hunting ground state for any given hunting ground to early detect deviations from desired conditions and rapidly implement corrective measures (Figure 4.4; Supplementary Material S4.3). Careful planning and management are required to keep non-linearities in check and to avoid exceeding thresholds that could cause sudden shifts in landscape state (Chapin *et al*., 2004).

4.14 Conclusion

We conducted this research to facilitate the consideration of Indigenous values and perspectives in land management. We faced, and partly overcame, the barriers that are commonly encountered in collaboration attempts (Dam Lam *et al*., 2019). Cultural and language differences (technical barriers) were challenging because some participants, especially the elders, were neither comfortable speaking French nor English and were sometimes reluctant to work with the elicitation tools that we designed. Co-researchers who worked for the communities played a key role, especially during knowledge elicitation (Reid *et al*., 2016; Robinson and Wallington, 2012). They presented the project to participants and translated and explained their responses to the research team. They adapted the data collection material to the participants. Their involvement in the early steps of the project was crucial in aligning the research objectives with local perspectives.

We encountered structural barriers to collaboration through limits to data availability. We developed indicators using datasets from the forestry, mining, energy, recreation and tourism sectors. These data are highly valuable because they are spatially explicit, systematic and regularly updated, thereby providing valid and relevant indicators. However, factors such as water quality, wildlife health, environmental contamination and traffic on forest roads remain undocumented. Monitoring programs are primarily designed to inform industrial landscape values. With this research, we diverted data from their primary purposes to inform Indigenous landscape value. Widening the objectives of monitoring programs to include Indigenous values contributes to aligning landscape assessments with these local perspectives (Hedblom *et al*., 2020; Kienast *et al*., 2015; Lyver *et al*., 2018).

Our results, however, need to be used with caution, bearing in mind that they were informed by incomplete data. The absence of indicators for some key factors of landscape value should not justify their exclusion from decision-making processes. Other sources of information, including consultations with land users and data collection by communities, could complement the landscape portrait that we developed and should be investigated in future collaborative research projects.

Collaborative research contributes to enhance mutual trust among Indigenous communities, scientists and land managers (reducing perceptual barriers). Our inductive method to elicit local values, combined with qualitative and quantitative data analysis, generated a typology of hunting grounds that was consistent with local perspectives. The involvement of co-researchers from the communities throughout the project also enhanced its legitimacy and local relevance (Ericksen and Woodley, 2005). In the last few decades, research efforts have been dedicated to a better understanding of the functioning of ecosystems, while setting sustainable management guidelines accordingly (Christensen *et al*., 1996; Landres *et al*., 1999). However, sustainability needs to consider the values and knowledge of local and Indigenous peoples. Collaborative research plays a key role in this regard.

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Climatology and Adaptation to Climate Change, and the Northern Scientific Training Program (NSTP).

Authors' Contribution

ACB conceived the ideas and designed the methodology and collected and analyzed the data; ACB and HA interpreted the results. ACB led the writing of the manuscript in collaboration with HA.

Supplementary Material S4

S4.1 Indicators of hunting ground state (metadata)

Available online :

https://cdnsciencepub.com/doi/suppl/10.1139/cjfr-2020-0369/suppl_file/cjfr-2020-0369suppla.pdf

S4.2 Summed squared error (SSE), Calinski index and SSI index for the solutions (two to eight groups) of the *k*-means clustering. Optimal solutions are shown in bold.

n groups	2	3	4	5	6	7	8
SSE	415.27	343.61	277.42	245.53	213.99	184.34	162.64
Calinski	**12.11**	10.77	**11.34**	10.40	10.20	10.39	10.34
SSI	0.838	1.107	**1.118**	0.683	0.600	0.581	0.988

S4.3 Abitibiwinni and Ouje-Bougoumou Nations hunting ground state assessment

Available online:

https://cdnsciencepub.com/doi/suppl/10.1139/cjfr-2020-0369/suppl_file/cjfr-2020-0369supplc.pdf

CHAPITRE V

INDIGENOUS KNOWLEDGE, FOREST LANDSCAPE SIMULATIONS AND THE CUMULATIVE EFFECTS OF ENVIRONMENTAL CHANGES

(SAVOIRS AUTOCHTONES, SIMULATIONS DES PAYSAGES FORESTIERS ET EFFETS CUMULATIFS DES CHANGEMENTS ENVIRONNEMENTAUX)

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Abstract

Boreal landscapes are exposed to climate change, forestry and other industrial stressors, with consequences for Indigenous people whose wellbeing is tied to the land. We worked in collaboration with two Indigenous communities located in Eastern boreal Canada to (1) develop a landscape value model combining Indigenous knowledge and forest landscape simulations; (2) evaluate vulnerability to cumulative environmental changes for a set of 12 landscape value variables (e.g., moose abundance, fish quality, summer and winter access); and (3) assess the relative importance of climate change and forestry as drivers of environmental changes. We performed forest landscape simulations (2000-2100) using combinations of climate change and forestry gradients using the model LANDIS-II. We presented the simulation outputs to 17 Indigenous land-use experts and elicited the probability of fulfilling their needs relative to landscape values. We combined Indigenous knowledge and forest landscape simulations within a Bayesian network. Our results indicate that rapid and acute changes in forest structure and composition are to be expected. The most vulnerable landscape values are those associated with mature and undisturbed forests. The harvesting rate influences the timing and amplitude of change. The influence of climate change varied from one region to another and was mostly associated with wildfire frequency. Adaptation strategies to preserve Indigenous landscape value could include reducing harvesting rates, implementing wildfire-prevention measures, and valuing alternative forest uses.

Key words: Indigenous knowledge; Bayesian network; Cumulative impacts; Forest landscape simulations; Landscape values

Résumé

Les paysages boréaux sont exposés aux changements climatiques, à la foresterie et à d’autres facteurs de stress industriels, avec des conséquences pour les peuples autochtones, dont le bien-être est lié au territoire. Nous avons travaillé en collaboration avec deux communautés autochtones situées dans l’est du Canada boréal pour (1) développer un modèle de valeur du paysage combinant les connaissances autochtones et les simulations de paysages forestiers; (2) évaluer la vulnérabilité aux changements environnementaux cumulatifs pour un ensemble de 12 facteurs de valeur du paysage (p. ex. abondance de l’orignal, qualité du poisson, accès estival et hivernal); et (3) évaluer l’importance relative des changements climatiques et de la foresterie en tant que moteurs des changements environnementaux. Nous avons effectué des simulations de paysages forestiers (2000-2100) en combinant des gradients de changements climatiques et de foresterie à l’aide du modèle LANDIS-II. Nous avons synthétisé les résultats des simulations et les avons présentés à 17 experts autochtones de l’utilisation du territoire afin de déterminer la probabilité de répondre à leurs besoins en lien avec les facteurs de la valeur du paysage. Nous avons combiné les connaissances autochtones et des simulations de paysages forestiers au sein d’un réseau bayésien. Nos résultats indiquent qu’il faut s’attendre à des changements rapides et marqués dans la structure et la composition des forêts. Les valeurs paysagères les plus vulnérables sont celles associées aux forêts matures et non perturbées. Le taux de récolte influence le moment et l’amplitude des changements. L’influence du changement climatique variait d’une région à l'autre et était principalement associée à la fréquence des feux de forêt. Les stratégies d’adaptation pour préserver la valeur des paysages autochtones pourraient inclure la réduction des taux de coupe, la mise en œuvre de mesures de prévention des incendies de forêt et la valorisation des utilisations alternatives de la forêt.

Mots clés: Savoirs autochtones; Réseau bayésien; Effets cumulatifs; Simulation des paysages forestiers, Valeur des paysages

5.1 Introduction

The identity, culture and livelihood of Indigenous peoples living in boreal regions are rooted in the relationship with the land (Berkes and Davidson-Hunt, 2006; Burton *et al*., 2006; Jaakkola *et al*., 2018; Nitoslawski *et al*., 2019). Practices such as hunting, fishing, gathering, story-telling and teaching contribute to develop and maintain this relationship in everyday life (Bélisle *et al*., 2021; Davidson-Hunt and Berkes, 2003; Ohmagari and Berkes, 1997). In boreal regions, environmental changes threaten Indigenous wellbeing by limiting the capacity of the land to support these landscape practices and associated values (Chapter III). Climate change, more acute at higher latitudes, generates offsets between species distribution and their optimal climatic conditions, in addition to intensifying wildfire activity (Bergeron *et al*., 2004a; Boulanger *et al*., 2017; Burton *et al*., 2010; Price *et al*., 2013). Forestry homogenizes forest landscapes and decreases old-growth areas (Cyr *et al*., 2009; Kuuluvainen and Gauthier, 2018). The expansion of the forestry road network fragments ecosystems and concentrates anthropogenic disturbances in the accessible sectors (Forbes *et al*., 2004; Kneeshaw *et al*., 2010; Walker *et al*., 2011). While Indigenous people have continuously had to adapt to landscape changes, cumulative effects of environmental changes could exceed social and ecological thresholds (Parlee *et al*., 2012).

Vulnerability is the propensity or predisposition to be adversely affected by environmental changes (IPCC, 2014) and can be assessed using landscape values (Ramm *et al*., 2017; Raymond *et al*., 2011). Indigenous landscape value can be defined by its capacity to support practices that are important to a community and can be assessed using four dimensions: abundance, access, quality and experience (Bélisle *et *al* 2021). Environmental changes affect the abundance of wildlife populations (Herrmann *et al*., 2014; Jacqmain *et al*., 2008; Suffice *et al*., 2017), cultural keystone species (Uprety *et al*., 2013) and old-growth forests and associated biodiversity (Bélisle *et al*., 2011; Tremblay *et al*., 2018), among other things. Environmental changes hinder access to the land, for example by reducing ice thickness on water bodies or by leaving the ground cluttered and bumpy after timber harvesting (Brinkman *et al*., 2016; Golden *et al*., 2015). Environmental changes affect quality through water quality, wildlife health and healthiness of traditional food (Bordeleau *et al*., 2016; Liberda *et al*., 2011). Environmental changes also affect the experience, or satisfaction out on the land, which depends on one's preferences and expectations (Saint-Arnaud *et al*., 2009; Whiteman, 2004).

Indigenous landscapes are exposed to multiple and concurrent stressors whose effects on landscape value are not only individual but cumulative (Burton *et al*., 2010; Creed *et al*., 2019). The interactions between stressors can lead to additive, multiplicative or compensatory effects, depending on synergies and antagonisms (Hodgson and Halpern, 2019). Responses are often non-linear, include thresholds and tipping points, and are hard to predict (Beauchesne *et al*., 2014; Murdoch *et al*., 2020; Scheffer *et al*., 2012). Adaptation strategies are needed to adjust to current and projected environmental changes, to moderate harm to landscape value and to benefit from emerging opportunities (Adger *et al*., 2013; IPCC, 2014). However, the inherent uncertainty in the interplays between environmental stressors is a barrier to adaptation and impedes robust adaptive strategies (Keith *et al*., 2011; Regan *et al*., 2005). Moreover, the lack of Indigenous and scientific knowledge integration regarding expected ecological changes and their impacts on Indigenous landscapes is an important limitation to adaptation (Adger *et al*., 2013; Ford *et al*., 2008b, 2016).

Indigenous knowledge and scientific knowledge on environmental changes are complementary (Chapter III, Lyver *et al*. 2018, Torrents-Ticó *et al*. 2021). On the one hand, Indigenous people are first-hand witnesses of environmental changes and have intricate ecological knowledge that is rich from long-term interaction with traditional lands (Asselin, 2015; Inglis, 1993; Usher, 2000). Indigenous land-use experts are best able to evaluate the consequences of land transformations on the well-being of their community (Davis and Wagner, 2003). On the other hand, major research efforts has been dedicated to forecasting the consequences of environmental changes on forest landscape sustainability (Boulanger *et al*., 2017; Boulanger and Puigdevall, 2021; Gauthier *et al*., 2014; Murdoch *et al*., 2020). Climate models provide more and more precise projections of climatic trends and greenhouse gas emission (IPCC, 2015; van Vuuren *et al*., 2011b). Climate change and forest management are implemented in forest landscape simulation models to project their long-term interplays and cumulative effects (Peng, 2000; Scheller and Mladenoff, 2007). Simulation models have focused on a variety of landscape values including timber supply (Boucher *et al*., 2018), biodiversity (Tremblay *et al*., 2018; Whitman *et al*., 2017), habitats (Asselin *et al*., 2015), and provision of ecosystem services (Triviño *et al*., 2017; Uprety *et al*., 2017).

There has been a proliferation of interest for bridging Indigenous and scientific knowledge systems (Alexander *et al*., 2019; Bartlett *et al*., 2012; Tengö *et al*., 2014). Despite that integrative modeling strategies are increasingly developing (Bélisle *et al*., 2018), to our knowledge, there has not been any research that combined Indigenous knowledge and forest simulation models to address the effects of environmental changes. In this research, we worked in collaboration with two Indigenous communities in boreal Quebec (Canada) to assess the cumulative effects of environmental changes on Indigenous landscape values. This area is exposed to multiple environmental stressors including extensive and continuous forestry, mining prospection and exploitation and severe wildfires, which frequency is expected to increase under climate change (Bélisle and Asselin, 2021; Boulanger *et al*., 2014). Our objectives were (1) to develop a landscape value model combining Indigenous knowledge and forest landscape simulations; (2) to evaluate vulnerabilities to cumulative environmental changes and (3) to assess the relative importance of climate change and forestry as drivers of environmental changes. Based on model projections, we discuss adaptation needs and opportunities.

5.2 Study area

We worked in collaboration with the Abitibiwini First Nation (population of 1080 people) and the Ouje-Bougoumou First Nation (population of 906 people) (Indigenous and Northern Affairs Canada, 2015). Both Nations belong to the Algonquian linguistic and cultural family. The Abitibiwinni First Nation is Anishnaabe (Algonquin). The Anishnaabe ancestral land is called *Anicinapek O Takiwa* and ranges from the Great Lakes to James Bay. The presence of Abitibiwinni people in the region surrounding lake Abitibi dates back at least 6000 years (Côté, 1995). Previously semi-nomad, Abitibiwinni people were settled in the 1950s in a village called Pikogan located near the town of Amos (Québec, Canada). Ouje-Bougoumou is a Cree Nation and its ancestral land is called *Eeyou Istchee*. Ouje-Bougoumou families have been present in the Chibougamau lake area since at least the fur trade era (16th century) (Frenette, 1985). Previously semi-nomad, Ouje-Bougoumou people settled on the shore of Opemiska lake (Quebec, Canada) in 1992.

The study area includes the hunting grounds of the Abitibiwinni and Ouje-Bougoumou First Nations (Figure 5.1). Hunting grounds are land units that are used and managed by Indigenous families (Feit, 2004). Several practices take place on the hunting grounds, including moose hunting, fishing, trapping, berry picking, education and *ressourcement*[12] (Bélisle *et al*., 2021). Given that practices are passed down from generation to generation, hunting grounds are places where acute ecological and land-use expertise is developed over time (Ethier and Poirier, 2018; Sayles and Mulrennan, 2010).

[12] *Ressourcement* is a French word defined as "reversion to one's sources, finding one's deep roots to reach a new balance, also to find sources (moral, psychological, spiritual, etc.) to recover physical and moral forces" (translated from Office québécois de la langue française 1989).

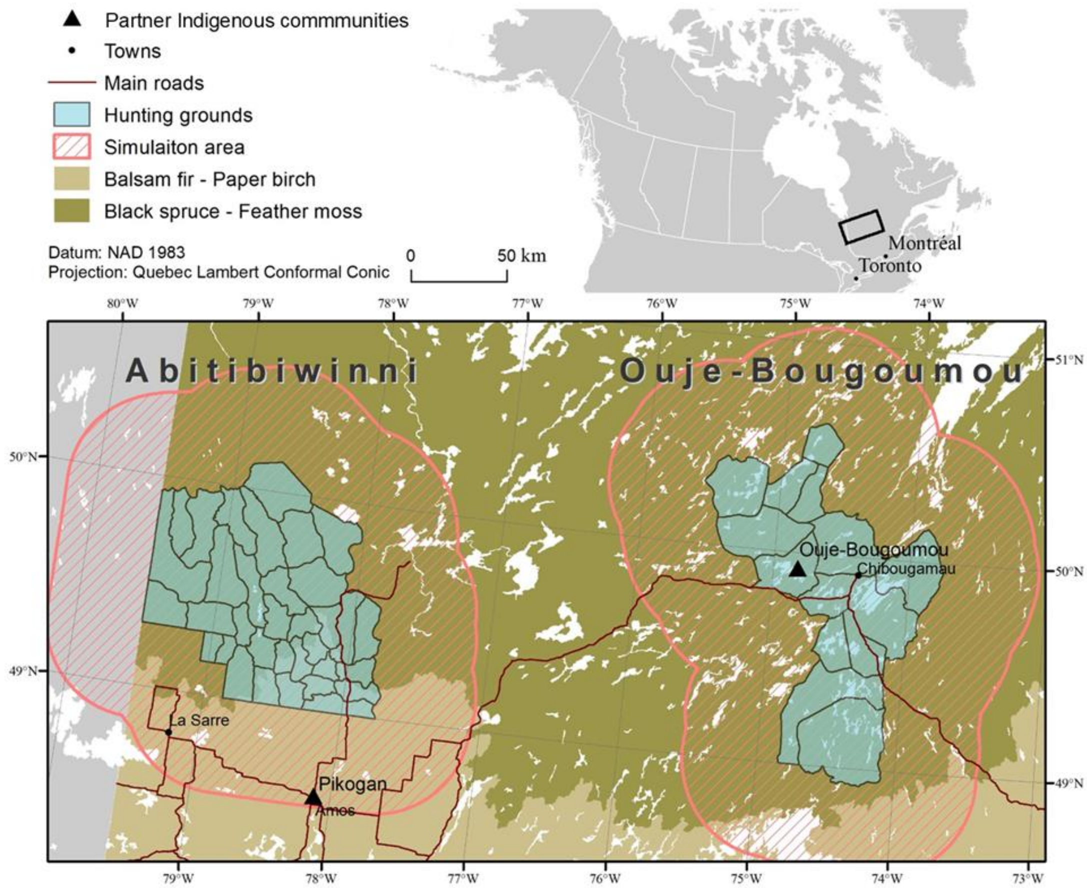

Figure 5.1 Study area, showing the hunting grounds of the Abitibiwinni and Ouje-Bougoumou First Nations and a 50 km buffer considered in the forest model simulations.

The 34 Abitibiwinni hunting grounds cover 11 430 km^2 and the 14 Ouje-Bougoumou hunting grounds cover 10 560 km^2. Hunting ground size ranges between 112 km2 and 1 652 km^2 (mean: 456 km^2; standard deviation: 310 km^2). Land management on Eeyou Istchee is regulated by the *James Bay and Northern Quebec Agreement* (1975)[13] and

[13] Available from https://www.rcaanc-cirnac.gc.ca/eng/1100100030604/1542740089024

La Paix des Braves Agreement (2002)[14]. These agreements include specifications on the spatial distribution of forest harvesting zones, impose logging limits within hunting grounds and officialize the responsibilities of hunting ground managers (called tallymen). No such agreement has yet been ratified by the Abitibiwinni First Nation, whose traditional territory is under the same rules as the public forest lands in Quebec (even-aged management, ecosystem management, harvested timber volumes planned at the management unit level).

The region has a subhumid continental climate, with average annual temperatures (1981-2010) ranging between 0.0 °C and 0.2 °C, and annual precipitation averaging between 909 mm and 996 mm, 30% of which falling as snow (Environment and Climate Change Canada, 2019). All Ouje-Bougoumou hunting grounds and those in the northern part of the Abitibiwinni territory are located within the black spruce (*Picea mariana* Mill.) – feather moss bioclimatic domain, characterized by the dominance of coniferous tree species and recurrent crown fires. Vegetation composition and structure are influenced by soil type and drainage and by the time elapsed since the last fire (Grondin *et al*., 2007; Lecomte and Bergeron, 2005). Young forests are even-aged and mainly composed of jack pine (*Pinus banksiana* Lamb.), black spruce and trembling aspen (*Populus tremuloides* Michx.). Mature forests have a more complex structure (Kneeshaw and Gauthier, 2003) and are mainly composed of black spruce and balsam fir (*Abies balsamea* Mill.). Hunting grounds in the southern part of the Abitibiwinni territory are located in the balsam fir–white birch (*Beltula papyrifera* Marsh.) bioclimatic domain, where wildfires also influence landscape dynamics but are less frequent (Bergeron *et al*., 2004b). The composition of young forest stands is dominated

[14] Available from https://cdn-contenu.quebec.ca/cdn-contenu/adm/min/conseil-executif/publications-adm/saa/administratives/ententes/Cris/2002-02-07_cris-entente.pdf?1607004430

by paper birch and trembling aspen, and the composition of mature forests is dominated by balsam fir, white spruce (*Picea glauca* Moench) and black spruce (Bergeron, 2000).

Forestry and climate change are the main drivers of environmental changes in the study area (Chapter III). Forestry decreases the proportion of old-growth forests, uniformizes the forest mosaic (Bélisle *et al*., 2011; Cyr *et al*., 2009) and triggers composition changes from coniferous to broadleaf forests (Laquerre *et al*., 2011). Forestry also increases road density, wood transportation, hunting cabin density, environmental contamination and traffic on the hunting grounds (Chapter III, Kneeshaw *et al*. 2010, Bélisle and Asselin 2021). The recent annual burn rate (1940 – ~2000) in the study area was estimated at 0.239 % (Bergeron *et al*., 2006) and is expected to increase significantly with climate change (Boulanger *et al*., 2013). Warmer temperatures and CO_2 fertilization could enhance tree growth and productivity (Price *et al*., 2013) but may not compensate for growth decline and mortality associated with more frequent drought episodes (D'Orangeville *et al*., 2018).

5.3 Methods

5.4 Analytical approach

We assessed the cumulative effects of forestry and climate change on Abitibiwinni and Ouje-Bougoumou hunting grounds using a Bayesian (probabilistic) network (BN). The model structure is derived from the Indigenous and scientific perspectives on environmental changes developed in Chapter III. We used a set of 20 scenarios that combined a gradient of harvesting rate (forestry) with a gradient of radiative forcing (climate change). We implemented the scenarios in the forest simulation model LANDIS-II and projected the composition and structure of the vegetation in the simulation area for the period 2000-2100. The model parametrization followed the one from Tremblay *et al*. (2018), developed in a similar environment. We grouped the model projections into seven hunting ground types that we presented to Indigenous land-use experts. The experts estimated the probability of fulfilling a family's needs for each vegetation type, relative to landscape value variables taken from Bélisle *et al* (2021). The elicitation methods were developed from Mantyka-Pringle *et al*. (2017) and Martin *et al*. (2012). We compared the probabilities of fulfilling a family needs along the forestry gradient, the climate change gradient, and under the cumulated pressures of forestry and climate change. The methods were developed by the collaborative research team that included researchers and professionals from universities, government agencies, and the Abitibiwinni and Ouje-Bougoumou First Nations.

5.5 Bayesian network

BN are probabilistic models that are used to bring together information from various sources (Liedloff *et al*., 2013; Lynam *et al*., 2007; Mantyka-Pringle *et al*., 2017). Information is used to estimate parameters under the format of probability distributions. A BN is structured as an acyclic graph made of nodes (variables) and arcs (dependencies) (Aguilera *et al*., 2011; Denis and Scutari, 2014). The BN structure is hierarchical: parent nodes are connected to child nodes, which are informed by conditional probability tables (when discrete). Conditional probability tables contain the probability distribution among the levels (possible values) of a child node conditional to each possible combination of its parent's levels. Distributions can be derived from various sources of knowledge including experimental data (e.g. Renken and Mumby 2009, Mcdonald *et al*. 2016), simulated data (Couture *et al*., 2018) and expert knowledge (Kuhnert *et al*., 2010; Mantyka-Pringle *et al*., 2014; Martin *et al*., 2015). BN can be used to bridge Indigenous and scientific knowledge in both the model structure and the conditional probability distributions (Liedloff *et al*., 2013; Mantyka-Pringle *et al*., 2017).

The process by which expert knowledge is collected and translated into probability distributions is called elicitation (O'Hagan *et al*., 2006). The elicitation design specifies the expertise criteria, the way probabilities are estimated and formulated, the consideration of uncertainties, how biases are handled and controlled and the methods used for pooling and validating expert judgment (Ayyub, 2001; Kuhnert *et al*., 2010; Martin *et al*., 2012; O'Leary *et al*., 2009). For Indigenous knowledge to be meaningfully considered, elicitation designs need to reflect the local knowledge system, including how knowledge is acquired, distributed and shared (Davis and Wagner, 2003; Mantyka-Pringle *et al*., 2017).

Our directional acyclic graph (Figure 5.2) had a Driver Pressure State Impact (DPSI) structure. DPSI models are useful to address complex environmental problems through a hierarchical causality network (Borja *et al*., 2006; Gregory *et al*., 2013; Lewison *et al*., 2016). Drivers influence landscape processes (pressures), which influence landscape condition (states), which in turn have impacts on landscape values. The variables included (Table 5.1) and their dependencies were developed from a previous assessment of Indigenous and scientific perspectives on environmental changes conducted within the same First Nations (Chapter III). We populated the conditional probability tables using data from forest modeling outputs, expert knowledge and government open datasets. Data for the two First Nations were processed separately. All variables were discrete, so the probabilities for each node were distributed among all possible levels to sum 1 (Denis and Scutari, 2014).

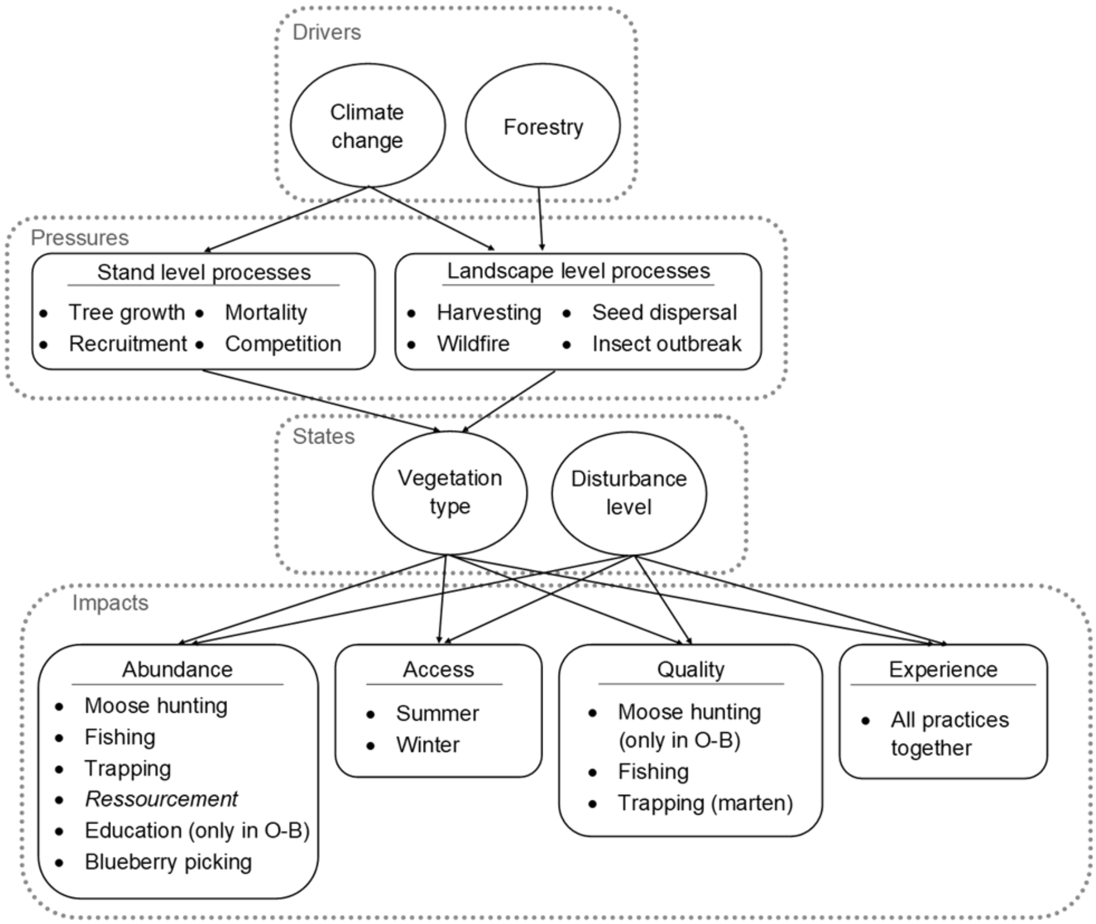

Figure 5.2 DPSI structure of the Bayesian network. Drivers included climate change and forestry scenarios. Pressures were implemented in LANDIS-II rather than as levels in the BN. States included hunting ground vegetation types and disturbance levels. Impacts included landscape value variables grouped among the four dimensions of landscape values described in Bélisle *et al* (2021), i.e. abundance, access, quality and experience. The influence of vegetation type on education (abundance) and moose hunting (quality) were considered negligible by the Abitibiwinni land-use experts so the conditional probabilities for these landscape value variables were not elicited with this First Nation.

Table 5.1 Structure of the conditional probability tables for the BN nodes, with variable levels, description and data source.

DPSI	Node	Levels	Description	Source
Drivers	Climate change	Baseline RCP2.6 RCP4.5 RCP8.5	Representative Concentration Pathways of radiatively important greenhouse gases (van Vuuren *et al.*, 2011b).	climate models and scenarios
	Forestry	F0x F0.5x F1x F1.5x F2x	Harvesting rates relative to current rates, at the management unit level.	Forest management planning
States	Vegetation type	Veg[A/O]1 Veg[A/O]2 Veg[A/O]3 Veg[A/O]4 Veg[A/O]5 Veg[A/O]6	Vegetation types in the hunting grounds of the Abitibiwinni First Nation (A) and the Ouje-Bougoumou First Nation (O).	LANDIS-II simulations
	Disturbance level	High[A/O] Low[A/O]	Level of anthropogenic disturbance (other than harvesting) in the hunting grounds of the Abitibiwinni First Nation (A) and the Ouje-Bougoumou First Nation (O). Hunting grounds were classified in one or the other group (*k*-means).	Open spatial data
Impacts	Abundance	Yes Adaptation No	Answer to the question: "*Would I get enough of […] to fulfill my needs and those of my family on this hunting ground?* "	Indigenous land-use experts
	Access	Yes Adaptation No	Answer to the question: "*Would I be able to access this trapline as much as I need in [winter time\summer time] to fulfill my needs and those of my family on this trapline?*"	

Table 5.1 Suite

DPSI	Node	Levels	Description	Source
	Quality	Yes Adaptation No	Answer to the question: "*Would the […] be of a quality good enough for its purpose [example] on this trapline?*"[1]	
	Experience	Yes Adaptation No	Answer to the question: "*Would I be able to get a positive experience overall while doing my activities on this trapline?*"	

[1] The quality for trapping was assessed using marten abundance because marten has a greater commercial value than other species.

Drivers – Climate change and forestry

The climate change gradient included four scenarios that were based on Representative Concentration Pathways (RCPs) of radiatively important greenhouse gases: baseline, RCP2.6, RCP4.5 and RCP8.5 (IPCC, 2015; van Vuuren *et al*., 2011b). The baseline scenario (no climate change), based on the 1981-2010 climate conditions, was included as a reference and scenario RCP8.5 was included to set the upper boundary of plausible futures (Hausfather and Peters, 2020). Between these two extreme scenarios, scenario RCP2.6 is optimistic and involves active climate change mitigation (Sanderson *et al*., 2016; van Vuuren *et al*., 2011a), while scenario RCP4.5 is intermediate. The historical climate (1981-2010) was retrieved by interpolating data from climate station records following McKenney *et al*. (2013). Future temperature and precipitation (2000-2100) for the study area were based on the projections from the Canadian Earth System Model version 2 (CanESM) (Environment and Climate Change Canada, 2018). Those were further downscaled at a 10 km resolution using the ANUSPLIN method (McKenney *et al*., 2013) to cover the entire simulation area (see Tremblay *et al*. 2018 for details).

The forestry gradient included five scenarios centered on the current harvesting rate (2018-2023) for each management unit in the study area (Bureau du forestier en chef, 2021). Forestry scenarios were defined by a multiplicative factor of the current harvesting rate: 0x, 0.5x, 1x, 1.5x and 2x. Scenario F0x (no forestry) was included as a reference and scenario F2x was included to set the upper boundary of the gradient. Intermediate scenarios represented different forest management policies, i.e. reducing harvesting rates (F0.5x), keeping harvesting rate unchanged (F1x) and increasing harvesting rate (F1.5x).

Scenario names were developed as follows: the letter F (forestry) is followed by the multiplicative factor of current harvesting rate and the letters CC (climate change) are followed by bsl for the baseline scenario and by a number that refers to the RCP scenario (Table S5.1.1). We used the "reference" scenario *(F0CCbsl*) i.e., no forestry and baseline climate, as the benchmark against which the effects of scenarios were assessed. The reference thus changes with time rather than being a snapshot at a fixed and subjective reference time and is taking into account model idiosyncrasies (Boulanger and Puigdevall, 2021). We assessed the individual effects of climate change using the scenarios that combined no forestry and a gradient of climate change (*F0CC2.6*, *F0CC4.5*, *F0CC8.5*). We assessed the individual impacts of forestry using the scenarios that combined the baseline climate and a gradient of harvesting rates (*F0.5CCbsl*, *F1CCbsl*, *F1.5CCbsl*, *F2CCbsl*). We assessed the cumulative effects of climate change and forestry using scenarios that included both climate change (CC > *bsl*) and forestry (F > 0).

Pressures –LANDIS-II simulations

We implemented the influence of forestry and climate change on ecological processes (or pressures) and on vegetation using LANDIS-II. LANDIS-II is a the spatially explicit and dynamic forest landscape model which simulates long-term changes in forest landscapes according to stand and landscape processes (Scheller *et al*. 2007, Creutzburg *et al*. 2017). Stand-level processes include tree growth, recruitment, mortality and competition whereas landscape-level processes include timber harvesting, wildfire, seed dispersal and insect outbreaks. In LANDIS-II, a forest landscape is represented as a grid of homogenous forest cells (6.25 ha in this case). Cells include tree cohorts defined by a tree species and an age class (10-years in this study). Each cell belongs to a region with homogeneous climate and soil conditions called landtype (Mansuy *et al*., 2014). Tree growth and regeneration parameters are set at the landtype level for each species under each climate scenario. Forest succession in LANDIS-II is simulated using the Biomass Succession v3.2 extension (Scheller and Mladenoff, 2004), which simulates changes in species-specific aboveground biomass through time according to species autecology (Table S5.1.2) as well as stand- and landscape-level processes. Succession is an emergent property from the model's parameters and was validated under baseline climate using various sources (see Boulanger *et al*. 2016).

Implementing biomass succession required the parameterization of species- climate- and soil-specific dynamic growth and regeneration parameters. These parameters include species establishment probability (SEP), maximum aboveground net primary productivity (maxANPP) and maximum aboveground biomass (maxAGB) (Table S5.1.3). Each parameter was estimated using PICUS V1.5 simulations (Lexer and Hönninger, 2001). PICUS is a tree-based spatially explicit forest gap model that simulates germination, establishment, growth and mortality under different climate and soil conditions (Lexer & Hönninger, 2001). Simulations were performed for monospecific stands for each species-landtype combination, on a 300-year time scale, for the four climate change scenarios. Parameters were averaged and extracted for the periods 2000-2010, 2011-2040, 2041-2070 and 2071-2100. We implemented forestry scenarios with the LANDIS-II Biomass Harvest extension v3.0 (Gustafson *et al*., 2000). Clear-cut was the only harvesting treatment implemented as it is nearly exclusive in the study area. Harvesting patch size distribution was derived from past forestry inventories (1980-2000) (see Tremblay *et al*. (2018) for details). Harvesting rates remained constant during the simulations unless not enough stands qualified for harvest. In the latter case, harvest proceeded until no more stands were available. We implemented wildfire with the LANDIS-II Base Fire Extension (Scheller & Domingo, 2005). Fire regime parameters included ignition probability, minimum, mean and maximum fire size, and spread probability (Creutzburg *et al*., 2017). Parameters were estimated for fire regions and climate scenarios (2000-2100) according to the models developed by Boulanger *et al*. (2014) and further updated for RCP scenarios by Gauthier *et al*. (2015b). We implemented spruce budworm (*Choristoneura fumiferana* Clem.) outbreaks with the LANDIS-II Budworm Biological Disturbance Agent extension (v1.0) (Sturtevant *et al*., 2004). The extension simulated stochastic outbreaks and tree mortality according to the regional outbreak cycles (Boulanger *et al*., 2012), the composition of site and surroundings, and tree species susceptibility (Hennigar *et al*., 2008). See Tremblay *et al*. (2018) for additional details regarding how each disturbance was parameterized and calibrated.

We initiated LANDIS-II initial biomass from the early 2000s using MODIS-based remote sensing data (Canadian National Forest Inventory[15]; Beaudoin *et al*., 2014). The initial cohort structure was obtained from a nearest neighbor spectral analysis linking each raster cell to a field sample plot (from government forest inventories). A spin-up phase was necessary to populate the cohort rasters with aboveground biomass estimations. The resulting biomass values were compared to MODIS data and were

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[15] https://nfi.nfis.org

corrected by adding a global multiplicative scaler when needed (see Tremblay *et al*., 2018 for details).

We included a 50-km simulation buffer to avoid a concentration of wildfires in the boundaries of the simulation area. Sites with < 50% forest cover were considered unforested (e.g. peatlands, urban areas, waterbodies) and were not included in the forest simulations. Simulations were replicated five times for each scenario for the period 2000-2100, with a 10-year time step, for each First Nation (200 simulations). Species-specific aboveground biomass was extracted at each time step and for each cell and used to assign a composition type (coniferous, mixed, broadleaf) and age-class: regenerating (< 10 years old), young (10-59 years old), or mature (⩾ 60 years old) to each cell. Regenerating cells were classified according to stand origin (i.e. from harvesting or wildfire).

States – Vegetation type and disturbance level

We developed six hunting ground vegetation types. We used R 4.0.3 with the packages *raster* and *sp* for the spatial analysis of LANDIS-II outputs. Vegetation variables (% coniferous, % mixed, % young, % mature, % harvested, % burned) were collated for each hunting ground, scenario, simulation time, and replicate. We classified hunting grounds into vegetation types using *k*-means non-hierarchical clustering (R 4.0.3, package *stats*, function *kmeans*), with a maximum of 1000 iterations, 10 starts and using the *MacQueen* algorithm on scaled vegetation variables (*function scale*) (Jain, 2010). We developed vegetation types specific to each First Nation to account for regional differences in forest dynamics (Boulanger and Puigdevall, 2021). We set the number of groups at six, which was the maximum complexity we could handle for the following elicitation of conditional probabilities with Indigenous land-use experts. The accuracy of the six-group solution was verified using the Calinski-Harabasz index and the simple structure index (SSI) (Oksanen *et al*., 2020) (Table S5.2.1). We used principal component analysis (PCA) (package *stats*, function *prcomp*) to describe and compare vegetation types (package *factoextra*, function *fviz_pca_biplot* for visualisation).

We classified hunting grounds between two anthropogenic disturbance levels, high or low, using the same *k*-means procedure as for vegetation types. The two-level solution was consistent with the propensity of anthropogenic disturbances to concentrate spatially in the study area (Bélisle and Asselin 2021) as in boreal landscapes (Walker *et al*., 2011). The disturbance factors were previously identified by Indigenous land-use experts and indicators were developed using open spatial data, including road density, hunting cabin density and powerline density (Table S5.2.2, adapted from Bélisle and Asselin 2021).

Impacts – Landscape value variables

We developed the set of landscape value variables combining six landscape practices (blueberry picking, education, moose hunting, fishing, trapping, and *ressourcement*) and four dimensions of landscape value (abundance, access, experience and quality) (Bélisle *et al*., 2021). After consultation with community partners, we selected twelve variables that would be presented to Indigenous land-use experts for elicitation: abundance for all six practices, winter and summer access, quality for moose hunting, trapping, and fishing and experience (for all practices together). Trapping – abundance was for all furbearers and trapping – quality referred specifically to marten (Martes americana), because marten has a higher commercial value. Landscape value variables had three levels based on the capacity of fulfilling a family's needs: Yes – Needs are fulfilled without any constraint, Adaptation – Needs are fulfilled conditional to adaptation, and No – Needs are not fulfilled.

5.6 Elicitation of conditional probabilities

We elicited conditional probabilities for landscape value variables from Indigenous land-use experts. We developed the elicitation design from existing methods developed in Indigenous (Mantyka-Pringle *et al*., 2017) and non-Indigenous (Low Choy *et al*., 2009; Martin *et al*., 2012; O'Hagan *et al*., 2006) contexts. We represented the vegetation types on simplified maps of a fictive hunting ground. We used a fictive hunting ground instead of direct outputs from LANDIS-II to uniformize the material between experts and to reduce noise and bias introduced by references to real-life events on specific hunting grounds (Mantyka-Pringle *et al*., 2017). Fictive hunting grounds were represented as 10 ×10 grids (1:200,000) where each cell corresponded to a surface type, i.e. water, bog, or forest (Figure 5.3 and Figure S5.3.1). The median proportion of surface types was calculated for high and low disturbance levels. Forest cells were randomly assigned a composition and an age class which proportions were set according to the vegetation type. We used the cluster centers to approximate the composition and age structure of each vegetation type. Coniferous, mixedwood and broadleaf forests were differentiated by a color scale, and young and mature forests by a saturation scale. Regenerating forests originating from harvesting (diagonal red lines) and wildfire (fire icons) were also differentiated. Following a suggestion from community researchers, we added a seventh vegetation type: regenerating forests originating from salvage logging after a wildfire.

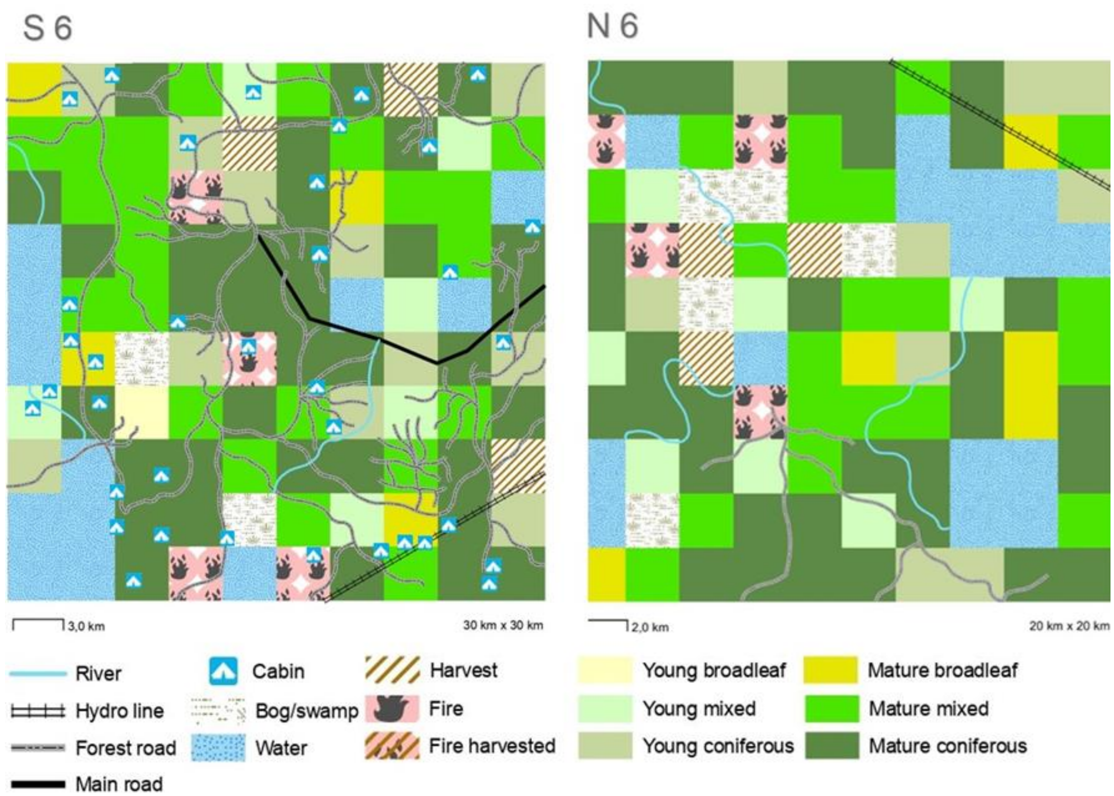

Figure 5.3 Examples of fictive hunting ground maps (Ouje-Bougoumou, vegetation type 6, disturbance levels high (S) and low (N)). Maps can be consulted in the Supplementary Material (Figure S5.3.1).

We developed two sets of vegetation maps for each First Nation, for high and low disturbance levels. Forest roads, main roads, hunting cabins and powerlines were overlayed to the vegetation maps. Distance to town and scale were indicated on the maps. Indicator values for high and low disturbance levels were set on the cluster centers (Table S5.2.3).

The elicitation forms included boxes representing the variable levels (yes, adaptation, no), and dots representing probabilities, each worth 10% (Figure 5.4). For a hunting ground map, experts had to distribute ten dots among boxes to represent aleatory uncertainty. Aleatory uncertainty is due to the stochasticity of environmental phenomena. In addition, epistemic uncertainty arises from limited or incomplete knowledge and was self-assed by experts on a graphical scale (O'Hagan *et al*., 2006). The elicitation material was tested, improved and validated with the community partners.

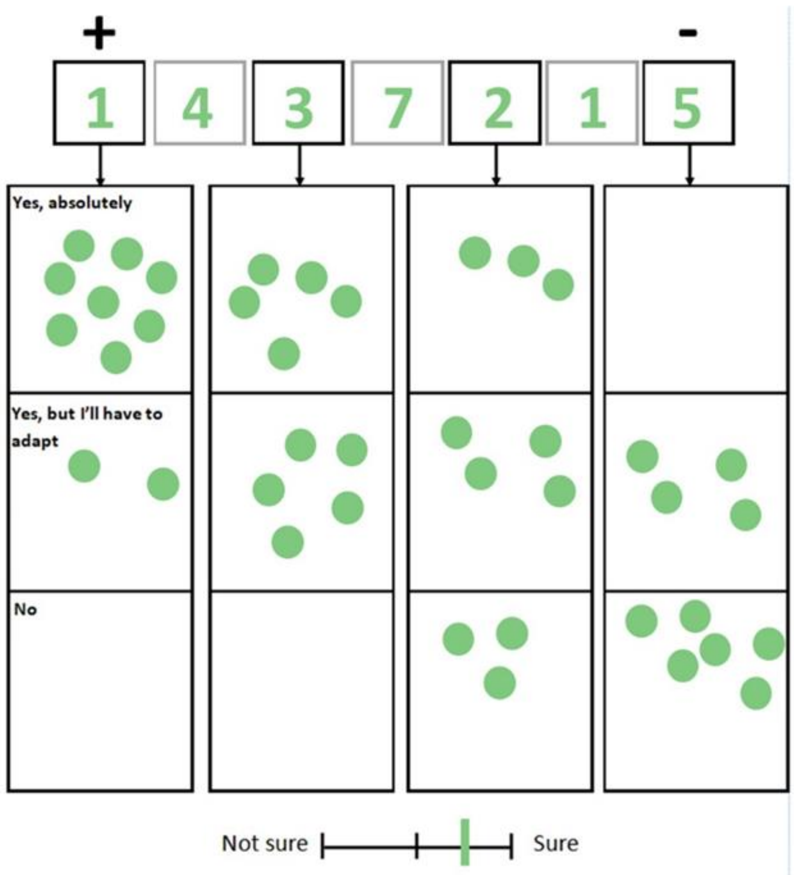

Figure 5.4 Example of an elicitation record for a landscape value variable. Scenarios were ranked from the most valuable to the less valuable. For scenarios at ranks 1, 3, 5 and 7, ten dots representing probabilities of fulfilling a family's needs were distributed among three boxes i.e., yes, with adaptation and no. Epistemic uncertainty was estimated on a *Not sure* – *Sure* scale.

Elicitation workshops took place in the communities during spring and summer of 2019 (Figure 5.5). In the Abitibiwinni First Nation, elicitation was performed in a one-day workshop (10 Indigenous land use experts, 25 April 2019). The elicitation team included a "problem owner" responsible for the achievement of the workshop objectives, an "analyst" who processed and analyzed elicited probabilities in real-time and three "facilitators" who assisted the experts in the elicitation task (Martin *et al* 2012). The elicitation team was trained during a trial workshop where team members played the role of experts and got familiar with the elicitation material (details in Supplementary material S5.3). In the Ouje-Bougoumou First Nation, elicitation took place in smaller groups (June 2019, seven land use experts, 2-3 persons at a time) and with a smaller elicitation team (one problem owner and two facilitators).

Figure 5.5 An Abitibiwinni land-use expert ranking vegetation scenarios during the elicitation workshop, Pikogan, 25 April 2019. Picture by Julia Morarin (facilitator).

Indigenous land-use experts were identified and recruited by Indigenous researchers from the community. Expertise criteria included (1) experience on the land, (2) peer recognition, and (3) management responsibilities in the hunting ground. We paid special attention to gender and age diversity among the expert panel because women and youth were typically underrepresented in previous research in similar contexts

(Castleden *et al.*, 2017a; Alexander *et al*. 2019). Participants answered a short questionnaire to establish their social profile and expertise. Fourteen were men and three were women, most lived in the community or on the land and their time spent on the land was distributed between “most of the days” to “a few times a year”. The age of participants was distributed among all age classes in the Abitibiwinni First Nation and age classes 35-44 and over in the Ouje-Bougoumou First Nation. All experts claimed to be moose hunters and most claimed to be trappers and fishers.

Participants had a booklet containing elicitation forms and a set of vegetation maps. Half of the booklets included maps for the high disturbance level and the other half for the low disturbance level. They were distributed accordingly to the expert’s hunting ground disturbance level. Conditional probabilities were elicited for all landscape value variables following four steps: (1) ranking of the hunting ground maps from the best to the worse; (2) distribution of dots for the best and the worst maps (ranks 1 and 7); (3) distribution of dots for intermediate maps (ranks 3 and 5); (4) validation with a group or an individual discussion and adjustments if desired. Probability distributions for the remaining maps (ranks 2, 4 and 6) were averaged afterward. In Ouje-Bougoumou, the small group formula made it possible for Elders to be paired with a facilitator from the community so they could discuss the research project and the task in their own language and be assisted with the elicitation material.

We tried avoiding biases in expert judgment with a proper design, training of the elicitation team and feedback to experts (O’Hagan *et al*., 2006). Motivational bias arises from the context, personal beliefs, or personal stake one might have in a decision (Martin *et al*., 2012). We thus avoided any reference to an existing hunting ground or to real-life events. Anchoring bias occurs when an expert links an estimate to a benchmark value and cannot distance his or her judgment from it. Probabilities for the best and worst scenarios were thus elicited first to set the boundaries of the distribution. Accessibility bias occurs when the ease with which information comes to mind is disproportionate to its importance and overconfidence bias occurs when experts underestimate their uncertainty (Martin *et al*., 2012). Accessibility and overconfidence biases were avoided through group discussion and feedback from the research team. Any suspicion of a bias during elicitation was noted by the facilitators and investigated during data validation.

The elicitation team paid attention to possible misunderstandings and inconsistencies in the probabilities elicited. Facilitators provided feedback and noted possible errors (e.g. when less or more than ten dots were used and when the dot distributions were not consistent with the rank or did not match the expert's verbal explanations). We plotted P(Yes) and P(No) versus rank for each expert and landscape value variable to spot possible errors. P(Yes) was expected to decrease with rank or to remain constant and P(No) was expected to increase with rank or to remain constant. For cases that did not respect these assumptions, we carefully analyzed the notes taken by the elicitation team and the epistemic uncertainty self-assessment (Table S5.4.1). When the reasons were sufficient to believe a mistake was made during elicitation, probabilities were removed from the dataset.

5.7 BN computation and projection of landscape value

We implemented the Abitibiwinni and the Ouje-Bougoumou BN in R 4.0.3, using the packages *bnlearn* (Scutari, 2010) and *gRain* (De Leeuw, 2009), following the procedure for discrete BN presented in Denis & Scutari (2014).

The BN formula was :

$$[Scenario][Time][Dist][Veg|Scenario:Time]\left[Ab_{MooseHunting}\middle|Veg:Dist\right]\left[Ab_{Fishing}\middle|Veg:Dist\right]\left[Ab_{trapping}\middle|Veg:Dist\right][Ab_{Ressourcement}|Veg:Dist]\left[Ab_{Blueberry}\middle|Veg:Dist\right][Ab_{Education}|Veg:Dist]\left[Qu_{Fishing}\middle|Veg:Dist\right]\left[Qu_{MooseHunting}\middle|Veg:Dist\right]\left[Qu_{trapping}\middle|Veg:Dist\right][Ac_{Winter}|Veg:Dist][Ac_{Summer}|Veg:Dist]\left[Ex_{Experience}\middle|Veg:Dist\right]$$

where child variables are represented on the left-hand side of a parenthesis ([]), and parent variables on the right-hand side. Vertical bars (|) separate child and parent variables and colons (:) separate parent variables. Dist: Anthropogenic disturbance level, Veg: Vegetation type, Ab: Abundance, Qu: Quality, Ac: Access, Ex: Experience.

Vegetation conditional probability tables contained the likelihood for a hunting ground to belong to a vegetation type conditional to climate change, forestry and simulation time, averaged for the five replicates. For the salvage logging vegetation type (VegA7 or VegO7), we attributed a proportion of the probability of the vegetation type the most affected by wildfire, following the forestry scenario (Table S5.2.4). Anthropogenic disturbance conditional probability tables contained the likelihood of high and low disturbance levels, calculated from the actual hunting ground distribution. Landscape value conditional probability tables contained the average probability (between experts from a First Nation) of fulfilling a family's needs.

We combined the directional acyclic graph and the conditional probability tables and generated the BN (function *custom.fit)*. The maximum likelihood method (*mle*) was chosen so conditional probabilities were implemented directly. We addressed queries (functions *SetEvidence* and *querygrain*) to a junction tree (functions *as.grain* and *compile*) and extracted the probability tables for each landscape value variable, scenario and time step. The probability of the vegetation types and 90% confidence intervals on landscape value variables were calculated by resampling the LANDIS-II five replicates (bootstrap procedure) and running the BN iteratively (1000 sampling of 5 replicates with replacement). We extracted the 5th, 50th and 95th percentiles of the probability distributions.

5.8 Relative influence of climate change and forestry

For each scenario, landscape value variable and simulation time, we calculated the probability of fulfilling family needs without adaptation P(Yes) and with adaptation P(Yes) + P(Adaptation). We assessed the effect of each scenario using P(Yes) difference with the reference scenario (*For0CCbsl*) at the same simulation time (ΔP(Yes)). We analyzed trends in ΔP(Yes) at mid-simulation time (2050). Although major changes are expected after 2050, we extracted the projections early in simulations for two reasons. First, 2050 projections reveal ongoing trends that require rapid adaptation and is a time scale that makes sense at a human life level. Second, pre-analysis showed that the amount of change tends to increase until reaching a tipping point and then to collapse. Extracting the projections at simulation 2050 allowed us to capture the peak that was hidden in longer simulations (2100).

We compared scenarios based on the amplitude (A) and timing of changes. A at a given simulation time cumulates change for all landscape value variables (absolute values). A is the average |ΔP(Yes)| of all landscape value variables at simulation time t. A_{max} is the maximum amplitude reached during simulations. We assessed the timing of change using the simulation time required to reach half A_{max}. ($t_{0.5max}$). We used half A_{max} to avoid a plateau effect before A_{max} is reached.

5.9 Ethical considerations

The project was approved by the Ethics Review Board of the Université du Québec en Abitibi-Témiscamingue (certificate # 2016-04). We followed the OCAP® principles (ownership, control, access and possession of data; https://fnigc.ca/ocap) and developed the project following the research protocol of the Assembly of First Nations of Quebec and Labrador (AFNQL 2014). Representatives of the university and the two participating communities signed a research agreement. Participants agreed to take part in the project by signing a consent form (adapted from Basile *et al*. 2018) with the assurance that the data would remain confidential. Members of the research team signed a confidentiality agreement before they could access data.

5.10 Results

5.10.1 Bayesian network

Vegetation types

Vegetation types are presented on PCA biplots (Figure 5.6), For the Abitibiwinni First Nation, the first and second dimensions of the PCA (Dim1 and Dim2) explain 36.1 % and 22.5% of the variance respectively. Dim1 has a negative correlation with mature age structure (-0.52) and coniferous composition (-0.43) and a positive correlation with young age structure (0.52) and broadleaf composition (0.39). Dim1 discriminates between vegetation types VegA1 and VegA6 on the negative side and vegetation types VegA3, VegA4 and VegA5 on the positive side. Dim2 has a negative correlation with mixedwood composition (-0.63) and a positive correlation with wildfire (0.32). Dim2 discriminates between vegetation types VegA1 and VegA4 on the negative side and VegA2 on the positive side.

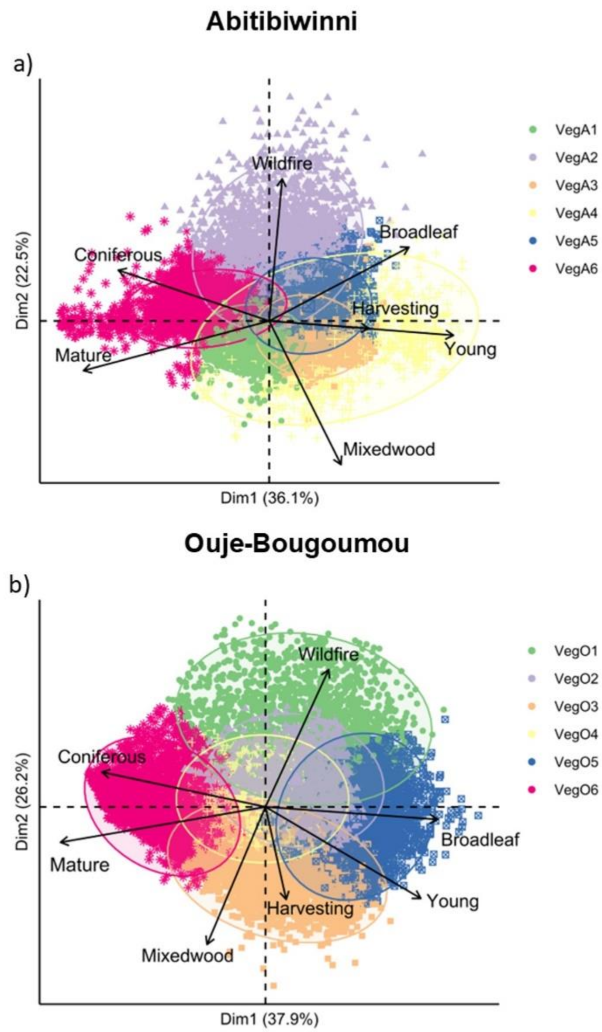

Figure 5.6 Vegetation types for (a) the Abitibiwinni First Nation and (b) the Ouje-Bougoumou First Nation. Principal component analysis (PCA) biplots (dim 1 and 2) show hunting grounds (dots), vegetation types (colors and ellipses including 80% of cluster members) and vegetation variables (arrows). Each dot represents a hunting ground at a given simulation time (2010-2100), for a given scenario and replicate.

For the Ouje-Bougoumou First Nation, Dim1 and Dim2 explain 37.9 % and 26.2% of the variance respectively. Dim1 has a negative correlation with coniferous composition (-0.45) and mature age structure (-0.75) and a positive correlation with broadleaf composition (0.48) and young age structure (0.43). Dim1 discriminates between vegetation types VegO6 on the negative side and VegO5 on the positive side. Dim2 has a negative correlation with mixedwood composition (-0.57), harvesting (-0.39) and young age structure (-0.38) and has a positive correlation with wildfire (0.57). Dim2 discriminates between vegetation types VegO3 on the negative side and VegO1 VegO2 on the positive side. VegO4 is a “middle” vegetation type, not correlated with Dim1 nor Dim2.

We calculated the likelihood for a hunting ground to belong to a vegetation type for each scenario and simulation time (Figure 5.7). For the Abitibiwinni First Nation, climate change alone (F0x) led to an increase in the likelihoods of VegA2 (wildfire) and VegA4 (young harvested) at the expense of VegA6 (mature coniferous). The transition was marked for RCP4.5 and RCP8.5 and started between 2040 and 2060. Forestry alone (CC baseline), led to a gradual replacement of VegA6 (mature coniferous) by VegA1 (mixedwood mature) for a low harvesting rate (F0.5x). Higher harvesting rates (F1x, F1.5x and F2x) were associated with a replacement of VegA6 (mature coniferous) by VegA3 (young mixedwood) and VegA4 (young harvested) between 2020 and 2050. The cumulative effects of climate change and forestry increased the probability of VegA4 (young harvested), especially for RCP8.5, where VegA4 became dominant by 2100 for all forestry scenarios except F0.

Figure 5.7 Likelihood of a hunting ground from (a) the Abitibiwinni First Nation and (b) the Ouje-Bougoumou First Nation to belong to a vegetation type versus simulation time (2010-2000), for combinations of forestry (F0x, F0.5x, F1x, F1.5x, F2x) and climate change scenario (Baseline, RCP2.6, RCP4.5, RCP8.5) scenarios.

Ouje-Bougoumou

Figure 5.7 Suite

For the Ouje-Bougoumou First Nation, climate change alone (F0x) led to the replacement of VegO6 (mature coniferous) by VegO1 (wildfire) and VegO4 (balanced) for all RCPs. An increase in VegO5 (young broadleaf) was associated with RCP8.5, starting in 2080. Forestry alone (CC baseline), led to a decline of VegO6 (mature coniferous), gradual for low harvesting rates (F0.5x) and more rapid as the harvesting rate increased. For higher harvesting rates (F1.5x and F2x), VegO5 (young broadleaf) started increasing near 2040 and VegO6 (mature coniferous) came back near 2070. The cumulative effects of climate change and forestry were an increase of VegO5 (young broadleaf), which became dominant between 2040 and 2100, depending on scenarios.

Disturbance levels

Hunting grounds from the Abitibiwinni and the Ouje-Bougoumou First Nations were distributed among high and low disturbance levels (static in the model) (Figure S5.2.2)..

Eighteen hunting grounds from the Abitibiwinni First Nation belonged to the high-level disturbance cluster (P(high) = 0.53) and 16 belonged to the low disturbance level (P(low) = 0.47). Nine hunting grounds of the Ouje-Bougoumou First Nation belonged to the high disturbance level (P(high) = 0.64) and five to the low disturbance level (P(low) = 0.36).

Landscape value variables

We elicited P(Yes), P(Adaptation) and P(No) for landscape value variables conditional to vegetation type. The validation process led to the removal of four variables from two experts (see Supplementary Material S5.4 for the entire validation process). Probabilities conditional to vegetation type are presented in Supplementary Material S5.5 (Figure S5.5.1). Initial P(Yes) ranged between 0.15 (blueberry picking – abundance) and 0.98 (*ressourcement* – abundance) in the Abitibiwinni First Nation and between 0.47 (blueberry picking – abundance) and 0.93 (Winter – access) in the Ouje-Bougoumou First Nation (Figure 5.8). When adaptation was considered (P(Yes + Adaptation)), the initial probability ranged between 0.51 (blueberry picking – abundance) and 1 (*ressourcement* – abundance) in the Abitibiwinni First Nation, and between 0.81 (fishing – quality) and 1 (winter access) in the Ouje-Bougoumou First Nation.

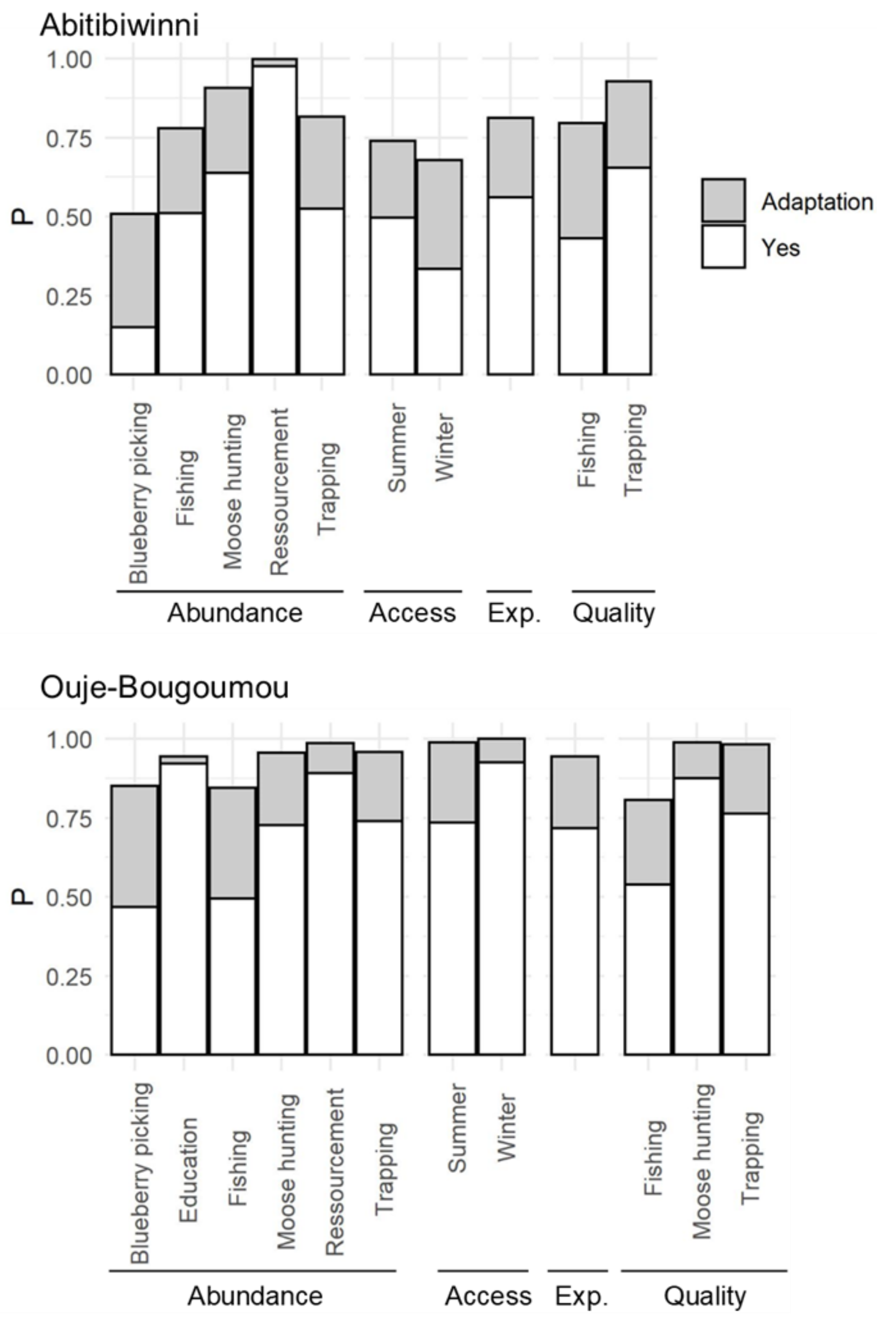

Figure 5.8 Initial likelihood (averaged between land use experts) for a hunting ground from the Abitibiwinni First Nation and the Ouje-Bougoumou First Nation to fulfill needs of a family relative to a landscape practice without any constraints P(yes) and with adaptation P(Adaptation). P(No) corresponds to the empty space between the bars and P=1. Exp: Experience.

5.10.2 Landscape value vulnerabilities

We evaluated landscape value vulnerabilities associated with individual and cumulative effects of forestry and climate change based on projections of ΔP(Yes) at simulation time 2050 (Figure 5.9). Results for the full simulation time are available in Supplementary Material S5.6 (FigureS5.6.1). For individual effects of forestry, ΔP(Yes) ranged from -0.33 to 0.35. In the Abitibiwinni First Nation, positive ΔP(Yes) was projected for blueberry picking (abundance) (0.35), winter access (0.23) and summer access (0.12), reaching their maximum at 1.5x harvesting rate). Negative ΔP(Yes) were projected for all other variables, with the lowest values for trapping (quality) (-0.33), experience (-0.29) and trapping (abundance) (-0.26), reaching their minimum at 1.5x harvesting rate. In the Ouje-Bougoumou First Nation, individual effects of forestry were negative for all landscape value variables except for blueberry picking at scenario F2 (0.11). The most negative ΔP(Yes) were projected for *ressourcement* (-0.29) and trapping (quality) (-0.27) at the current harvesting rate (1x) and for trapping (abundance) (-0.27) at 1.5x harvesting rate.

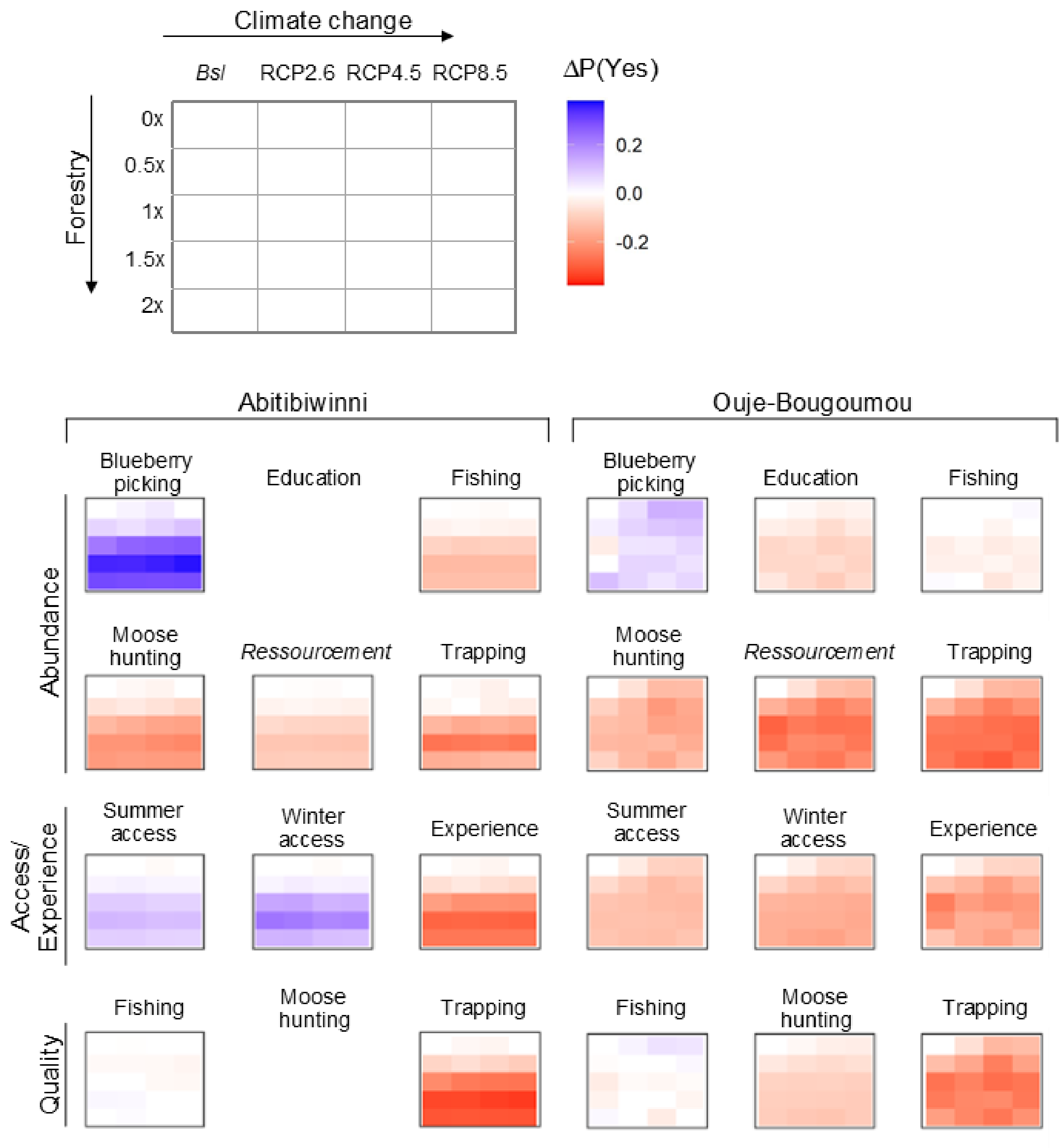

Figure 5.9 ΔP(Yes) (color scale) for landscape value variables at a mid-simulation time (2050). The climate change gradient goes from left to right and the forestry gradient from top to bottom. ΔP(Yes) was reported to 0 when the 90% confidence interval included 0 (See Figure S5.6.1 for detailed projections including full simulation time, confidence intervals and P(Adaptation)).

The individual effects of climate change at simulation time 2050 were different between Abitibiwinni and Ouje-Bougoumou First Nations (Figure 5.9). In the

Abitibiwinni First Nation, ΔP(Yes) was close to 0 for all landscape value variables, with a range between -0.03 and 0.04. In the Ouje-Bougoumou First Nation, ΔP(Yes) ranged from -0.15 (trapping abundance, RCP8.5) to 0.13 (blueberry picking abundance, RCP4.5). Negative ΔP(Yes) were also projected for trapping (quality) (-0.14) and moose hunting (abundance) (-0.13) at RCP4.5 and for *ressourcement* (-0.14) and trapping (quality) (-0.14) at RCP8.5.

Additive effects of forestry and climate change were considered when the maximum |ΔP(Yes)| among scenarios that cumulated climate change and forestry exceeded the maximum |ΔP(Yes)| for individual climate change or forestry scenarios.). In the Abitibiwinni First Nation, small additive effects were observed for blueberry picking (abundance) (+0.02, *F1.5CC8.5*), fishing (quality) (+0.02) trapping (quality) (+0.02, *F1.5CC8.5*), moose hunting (abundance) (+0.02, *F1.5CC8.5*) and *ressourcement* (+0.01). In the Ouje-Bougoumou First Nation, small additive effects were observed for trapping (abundance) (+0.03, *F2CC4.5*), moose hunting (abundance) (+0.06, *F0.5CC4.5*), winter access (+0.02, *F2CC4.5*), summer access (+0.02, *F0.5CC4.5*), moose hunting (quality) (+0.02, *F2CC4.5*) and education (abundance) (+0.02, *F2CC4.5*).

Compensatory effects of forestry and climate change were considered when the maximum |ΔP(Yes)| among scenarios that cumulated climate change and forestry was inferior to the maximum |ΔP(Yes)| for individual climate change or forestry scenarios. In the Abitibiwinni First Nation, compensatory effects were not observed. In the Ouje-Bougoumou First Nation, compensatory effects were observed for *ressourcement* (-0.02, *F1CC4.5*) (abundance) and for experience (-0.04, *F1CC4.5*).

5.10.3 Relative influence of climate change and forestry

The individual effects of forestry were observed on the amplitude and timing of change in the Abitibiwinni and Ouje-Bougoumou First Nations (Figure 5.10a). In the Abitibiwinni First Nation, A_{max} (for P(Yes)) increased along the forestry gradient, ranging from 0.12 for scenario *F0.5bsl* to 0.20 for scenarios *F1.5CCbsl* and *F2CCbsl.* The trends were similar for the Ouje-Bougoumou First Nation, but with faster changes. For scenario F0.5x, A_{max} was 0.08 and $A_{0.5max}$ was reached at simulation time 2040. For higher harvesting rates (*F1CCbsl*, *F1.5CCbsl* and *F2CCbsl)*, A_{max} was similar (between 0.14 and 0.15) and $A_{0.5max}$ was reached at simulation time 2020 (*F1CCbsl*) and 2010 (*F1.5CCbsl* and *F2CCbsl*).

The individual effects of climate change on the amplitude and timing of change in the Abitibiwinni First Nation were observed only for scenarios *F0CC4.5* (A_{max} = 0.05, $t_{0.5max}$ = 2060) and *F0RCP8.5* (A_{max} = 0.10, , $t_{0.5max}$ = 2080) (Figure 5.10a), and started in the second half of simulations (Figure S5.6.2). In the Ouje-Bougoumou First Nation, the effects of climate change on the amplitude and timing of change were observed for all RCP scenarios and happened earlier in the simulations. For scenario *F0RCP2.6* (A_{max} = 0.10, $t_{0.5max}$ = 2060), *A* reached a plateau at simulation time 2070 (Figure S5.6.2). The amplitude and timing of change were similar for *F0RCP4.5* (A_{max} = 0.12, $t_{0.5max}$=2050), and *F0RCP8.5* (A_{max} = 0.13, $t_{0.5max}$=2050).

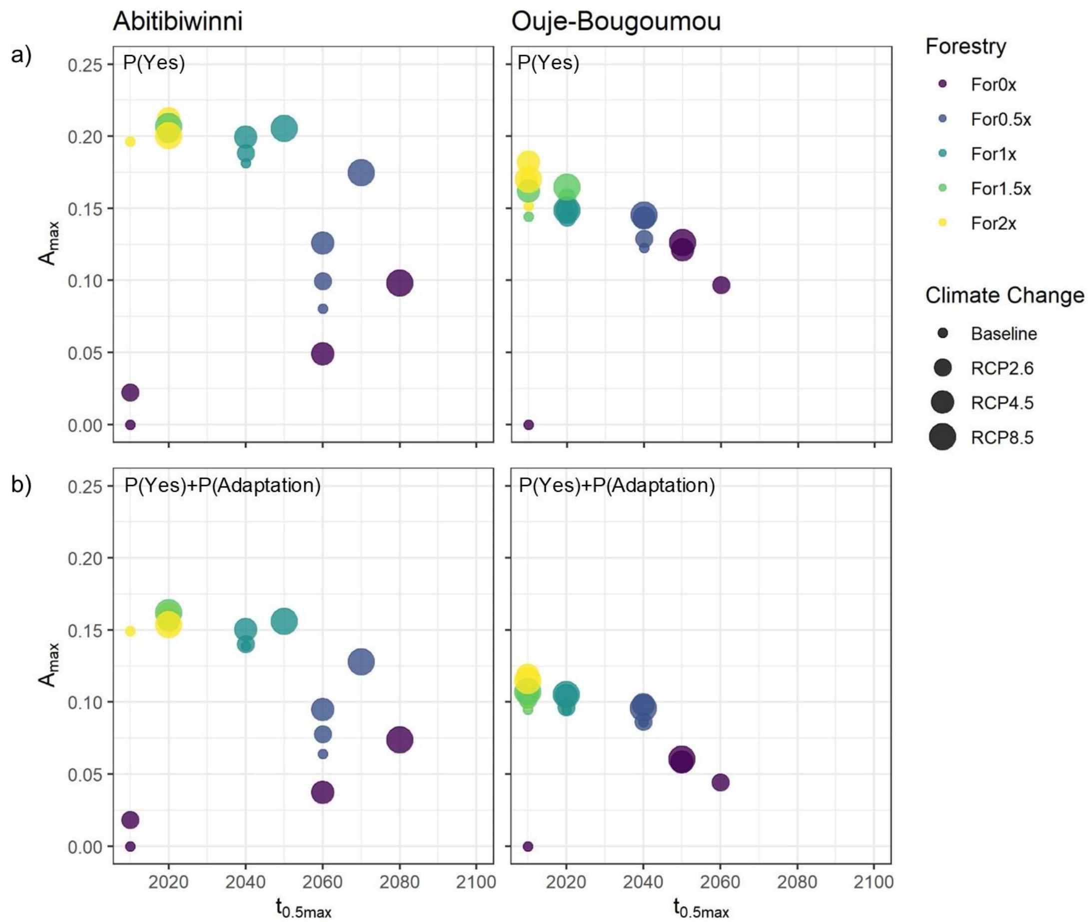

Figure 5.10 Maximum amplitude of change (A_{max}) and time required to reach half A_{max} ($t_{0.5max}$) for all forestry and climate change scenarios in the Abitibiwinni and the Ouje-Bougoumou First Nations, for a) the probability of fulfilling needs without any constraints P(Yes) and the probability of fulfilling the needs with adaptation (P(yes) + P(Adaptation)).

The cumulative effects of climate change and forestry was the most perceptible at a low harvesting rate (F0.5x) for the Abitibiwinni First Nation (Figure 5.10a). *A* increased with the climate change gradient, from scenario *F0.5CC2.6* (A_{max} = 0.10) to scenario *F0.5CC8.5* (A_{max} = 0.17). The timing of change was similar for scenario *F0.5*RCP2.6 and scenario *F0.5*RCP4.5 ($t_{0.5max}$ = 2060) and extended in scenario *F0.5CC8.5* ($t_{0.5max}$ = 2070). At higher harvesting rates, *A* peaked early in the simulations, before the effects of climate change were observable (Figure S5.6.2). For the Ouje-Bougoumou First Nation, the cumulative effects of forestry and climate change on amplitude and timing of change were less perceptible. At a low harvesting rate (F0.5x), *A* increased along the climate change gradient (A_{max} = 0.13 for *F0.5CC2.6* to A_{max} = 0.15 for *F0.5CC8.5*) and the timing remained similar ($t_{0.5max}$ = 2040). For higher harvesting rates (F1x, F1.5x, F2x), *A* peaked early in the simulations ($t_{0.5max}$ = 2010 or 2020) and there was no major increase in *A* along the climate change gradient (A_{max} ranged from 0.15 for *F1CC4.5* and *F1CC8.5* to 0.18 for *F2CC4.5*).

When the probability of adaptation was considered (Figure 5.10b), A_{max} was reduced by between 18% and 27% in the Abitibiwinni First Nation and by between 29% and 54% in the Ouje-Bougoumou First Nation, depending on the scenario. The timing of change remained similar.

5.11 Discussion

In this research, we combined Indigenous and scientific knowledge to assess the cumulative effects of environmental changes on Indigenous landscape value. In the following section, we discuss our findings relative to the three main objectives, i.e. (1) to develop a landscape value model combining Indigenous knowledge and forest landscape simulations; (2) to evaluate landscape value vulnerabilities to cumulative environmental changes and (3) to assess the relative importance of climate change and forestry as drivers of environmental changes. Based on model projections, we discuss adaptation needs and opportunities. We then (4) present the limitations of the research and (5) discuss implications for land management.

5.11.1 Bayesian network

In ecology and environmental sciences, BN are used to fill gaps in available field data with expert knowledge and to include professional input in the modeling process (Fidler *et al*., 2012; Lynam *et al*., 2010; Mantyka-Pringle *et al*., 2016; Martin *et al*., 2015). We improved existing methods for participatory model building (Voinov and Bousquet, 2010) and expert knowledge elicitation (Kuhnert *et al*., 2010; Martin *et al*., 2012) to make them appropriate and meaningful for Indigenous land-use experts. We drew on previous efforts to bring together Indigenous and scientific knowledge in a BN (Girondot and Rizzo, 2015; Liedloff *et al*., 2013; Lynam *et al*., 2007; Mantyka-Pringle *et al*., 2017) and developed a method for comparing environmental change scenarios using forest simulations and Indigenous land-use expert knowledge.

We based the DPSI model structure on a previous qualitative and inductive assessment of the Indigenous perspective on environmental changes (Chapter III). The DPSI format made it possible to portray Indigenous and scientific perspectives side by side and to find bridging points and complementarities, including the driving effects of climate change and forestry and the influence of vegetation composition and structure on hunting ground value (Chapter III). DPSI usually has a Response level (DPSIR), but we could not include the response in the BN because it would have involved feed-back loops and required an acyclic structure, which is not handled in BN. The results thus need to be interpreted considering that the system does not respond to environmental change by changing forest management regulation or adapting landscape practices.

The maps of fictive hunting grounds played a mediation role between the forest landscape simulation outputs and Indigenous land use experts (Robinson and Wallington, 2012). The maps were easy to handle and could be placed, ordered and moved on the table. The facilitators could use maps to start discussions with experts and to provide visual feedback. In future research, the correspondence between the symbology and real forest types could be developed further. Field trips with the experts could be used to align the forest representations with real-world examples. The recent development of virtual immersive environments could also contribute to mediate forest landscape model outputs for Indigenous experts (Huang *et al*., 2021).

The elicitation design (the dots representing probabilities to be distributed among boxes) was generally appropriate for the context. The principal challenge that we faced was to develop a common understanding of uncertainty with the experts and to translate it into dot distributions. The training exercise at the beginning of the workshops (Supplementary Material S5.3) played a key role to make experts conformable with the task and should not be neglected in future research using this method. We experimented knowledge elicitation with large groups in the Abitibiwinni First Nation and with small groups in the Ouje-Bougoumou First Nation. In the large group formula, participants had the opportunity to change their answers after group discussion, providing uniformity and clarity to the results (Gordon, 1994; Wheeler *et al*., 2020). The large group formula was more conducive to informal discussions, storytelling and knowledge sharing between youth and Elders. However, we noticed some Elders appeared intimidated by the “school-like” material and would have benefited from a closer accompaniment. We addressed the issue using smaller groups and one-by-one accompaniment in the Ouje-Bougoumou First Nation. Elders were paired with a researcher from the community who explained the task and the expert’s role in Indigenous language (Cree), which was more appropriate and led to fewer errors than in the large group.

The elicitation of conditional probabilities with Indigenous experts could be applied to a variety of ecological models using Bayesian statistics. In our BN, we only used *likelihoods* to estimate parameters, but the method we developed could be applied to consider Indigenous knowledge as *priors* in a variety of ecological models, alongside experimental data. *Priors* are informed by previous knowledge (e.g. expert knowledge) and are "updated" with *likelihood*s (e.g. experimental data) to estimate a *posterior* distribution, accordingly with the Bayes theorem (Hobbs, 2015).

5.11.2 Vulnerabilities

A transition from mature and coniferous to younger and broadleaf landscapes is projected along the forestry gradient for both communities. Changes in age structure can be explained by the even-aged forest management in the study area that regulates landscape age structure and reduces the proportion of mature forests, compared with the natural range of variability (Bélisle *et al*., 2011; Cyr *et al*., 2009). Climate change also contributes to increase the proportion of regenerating and young forests through higher burn rates, especially in the Ouje-Bougoumou area where a dramatic increase in wildfire activity is expected (Bergeron *et al*., 2017; Boulanger *et al*., 2013; Flannigan *et al*., 2009). The Abitibiwinni territory may be partly protected by its clay soils and poor drainage conditions, restraining fire frequency and severity (Mansuy *et al*., 2014; Terrier *et al*., 2015). Forestry drives composition changes by creating openings favorable to the establishment of shade-intolerant species, mainly trembling aspen (Boucher *et al*., 2009; Boulanger and Puigdevall, 2021; Laquerre *et al*., 2011).

We identified vulnerabilities in the abundance of features, especially for practices associated with mature forests and naturalness. For moose abundance, a decline was associated with forestry in the Abitibiwinni First Nation, and with both forestry and climate change in the Ouje-Bougoumou First Nation. On the one hand, the results are consistent with studies showing that sites recently disturbed by wildfire and timber harvesting are avoided by moose and that timber harvesting is associated with lower carrying capacity; on the other hand, broadleaf and mixedwood covers, increased by timber harvesting, are expected to increase moose habitat suitability (Jacqmain *et al*. 2008, Joly *et al*. 2012, Street *et al*. 2015a, 2015b). According to the Indigenous experts, the balance is found with lesser disturbance levels in that some anthropogenic disturbances associated with forestry, including road development can increase hunting opportunities (Asselin *et al*., 2015; Kneeshaw *et al*., 2010; Chapter III). For trapping, the abundance of fur-bearers was negatively associated with forestry, as reported by trappers elsewhere in boreal North America (Bridger *et al*., 2016; Suffice *et al*., 2017; Webb *et al*., 2008). *Ressourcement* was negatively affected by forestry in both First Nations, consistent with previous research that showed that environmental changes have negative consequences on sense of place and mental health (Cunsolo Willox *et al*., 2012; Fuentes *et al*., 2020).

The model predicts access to be facilitated by forestry in the Abitibiwinni First Nation but hampered by forestry and climate change in the Ouje-Bougoumou First Nation. Hydrography differences between the two regions may explain the opposite trends, as Abitibiwinnik land users may rely more on forestry roads to access the land while Ouje-Bougoumou land users may use waterbodies. The hydrography of the Abitibiwinni sector consists of a network of streams and rivers and of small and isolated lakes, so land users rely on forestry roads to access the land (Germain, 2012). In the Ouje-Bougoumou sector, a network of large lakes connects the hunting grounds together so the land can be traveled by motorboat during summer and by snowmobile during winter. The negative effects of forestry on access can be associated with the bumpy ground left after soil preparation for planting and the debris left over. The negative influence of climate change can be attributed to forest fires that also leave material on the ground, especially when cumulated with salvage logging. Moreover, income security programs (embedded in *La Convention de la Baie James et du Nord québécois*), available to the Crees (Ouje-Bougoumou) but not to the Abitibiwinnik, are dedicated to supporting the time spent on the hunting grounds and lower access constraints.

Experience was negatively affected by forestry in both First Nations and to a lesser extent by climate change in the Ouje-Bougoumou First Nation. Experience is less tangible than abundance and access, but affects all practices as it is directly associated with landscape relational values (Arias-Arévalo *et al*., 2017; Chan *et al*., 2018). Indigenous people have long spoken about the impacts of industrial activities and environmental changes on their culture and a general feeling of loss when out on the land in comparison to their past and previous generations (e.g. Whiteman 2004, Booth and Skelton 2011). Land users associated industrial interventions on the land with feelings of dispossession and inadequacy with the way the land is meant to be (Bélisle *et al*., 2021). The consequences of environmental changes on mental health and quality of life are increasingly studied and acknowledged(Higginbotham *et al*. 2006, Albrecht *et al*. 2007, Cunsolo Willox *et al*. 2012, Fuentes *et al*. 2020).

The effects of forestry and climate change on quality were the strongest for trapping, which is consistent with the acknowledged association between marten and mature forests (Suffice *et al*., 2017; Webb *et al*., 2008). The effects of climate change and forestry on moose and fish quality did not reveal as strong as expected according to previous qualitative assessments (Chapter II and III). For moose hunting, diseases and parasites have been associated with forestry by land users but the effects did not come out in this research. The low influence of environmental changes on fish quality can be explained by the research design that only included changes in vegetation patterns. Effects on fish quality could however be expected from increasing temperature, drought or precipitation (Murdoch *et al*., 2020).

The cumulative effects of wildfire and timber harvesting were sometimes additive, sometimes compensatory, depending on landscape values. Landscape values associated with mature coniferous forests, mainly trapping (abundance and quality), were susceptible to additive effects. Both timber harvesting and climate change (wildfire) are contributing to lower the proportion of mature forests and enhance the establishment of early succession broadleaf species (Brice *et al*., 2019; Cadieux *et al*., 2020; Tremblay *et al*., 2018). On the opposite, compensatory effects were associated with the landscape value variables that were more severely affected by timber harvesting than by wildfire, like blueberry (abundance), *ressourcement* (abundance) and experience. In the simulations, high burn rates due to climate change contributed to reduce timber harvesting because of to the lack of mature stands, thus enhancing landscape value for these specific variables. Multiplicative effects were not predicted by the model but could arise when wildfire and salvage logging overlay. Harvesting may also accelerate the vegetation type transitions caused by climate change (Brice *et al*., 2019).

5.11.3 Relative influence of forestry and climate change

Forestry was a major driver of long-term changes (2000-2100) in landscape value for both First Nations. Our results indicate that under current forest management policies, very little margin of maneuver is available to cope with unexpected events such as large wildfires or insect outbreaks (Brecka *et al*., 2020; Leduc *et al*., 2015). For forestry scenarios F1x (in Ouje-Bougoumou only), F1.5x and F2x, we observed a sustained increase in the amplitude of change with simulation time, as long as timber resources were available, followed by a relatively rapid drop when no more forest stand qualified for harvesting (Figure S5.6.2). This pattern indicates that current harvesting rates are close to (Abitibiwinni) or trespass (Ouje-Bougoumou) an overexploitation threshold of timber resources. On the opposite, changes are slower and more constant with reduced harvesting rates (F0.5x).

We see two main consequences of timber overexploitation for Indigenous land users. First, rapid and sustained adaptation is required to cope with an uncertain and changing environment, both during the exploitation and recovery phases. Although our results indicate that adaptation can contribute significantly to maintain landscape value under a changing environment, continuous and persistent change may overcome adaptation capacity (Parlee *et al*., 2012; Sayles and Mulrennan, 2010). Second, when timber volumes are limited, unexpected events such as wildfires or insect outbreaks put pressure on the industry to develop emergency plans and avoid a shortfall in timber supply. Emergency salvage logging is deployed with major consequences for both forest and aquatic ecosystems, as reported both by Indigenous land users and research in ecology (Bélisle *et al*., 2021; Boucher *et al*., 2014; Lindenmayer *et al*., 2008).

Landscape value in the Ouje-Bougoumou First Nation was more sensitive to climate change than in the Abitibiwinni First Nation. This can be explained by the regional heterogeneity of the fire regime, as the two territories belong to different fire regions with different occurrence and size parameters implemented in LANDIS-II (Boulanger *et al*., 2014). Fire activity is projected to increase in the Ouje-Bougoumou region under all climate change scenarios (Bergeron *et al*., 2006; Gauthier *et al*., 2015b). In the Abitibiwinni region, the edaphic conditions associated with low relief and clay soils are less conducive to wildfire are projected to constrain the increase of fire activity (Terrier *et al*., 2015).

5.12 Limitations, biases and uncertainties

Our results need to be interpreted considering the model's limitations, bias and uncertainties. The projections of hunting ground vegetation depend on which and how ecological processes are implemented in LANDIS-II. First, burn rates were not sensitive to fuel characteristics in the model. Compositional changes could however increase the proportion of less flammable tree species and generate negative feedback on fire activity (Stralberg *et al*., 2018; Terrier *et al*., 2013). Second, forest stands are susceptible to transitions from closed canopy to open woodland following successive disturbances (Asselin *et al*., 2006; Jasinski and Payette, 2005). Such transitions between alternative stable states were only partially implemented in the model through seed availability and dispersal, but could significantly lower forest density (Girard *et* *al*., 2008; Payette and Delwaide, 2003; Splawinski *et al*., 2019). Third, paludification (i.e. the transformation of soil organic matter into peat) affects the Abitibiwinni area because of clay surface deposits and deficient drainage conditions in the region (Fenton *et al*., 2009). The organic soil layer gradually thickens, preventing seeds to reach the mineral soil and leading to the formation of sphagnum bogs. The organic layer thickness remained static during simulations so an additional loss of forest density can be expected in this area in the long term.

Additional risk due to extreme events should also be considered because we used the cluster centers to define the vegetation types. Extreme hunting ground conditions were not considered in the vegetation types but are increasingly likely to occur. Climate change increases the length of the fire season and the occurrence of extremely large fires (Gaboriau *et al*., 2020; Wang *et al*., 2020), with consequences for health, safety and landscape value (Gauthier *et al*. 2014, Landis *et al*. 2018, Asfaw *et al*. 2019, Morarin 2020). Regarding forestry, harvesting blocks aggregate near access roads and tend to concentrate on specific hunting grounds (Bélisle and Asselin, 2021). Moreover, the effects of climate change and forestry were only considered through vegetation changes but direct impacts on lakes and rivers should also be expected, especially on fish communities (Murdoch *et al*., 2020), ice thickness (Golden *et al*., 2015) and water quality (Coogan *et al*., 2019).

Limitations in the elicitation design and data processing also need to be considered. We decided to aggregate raw expert judgments using averages with equal weights among experts. Methods exist to calibrate expert’s judgements based on their propensity to over or underestimate probabilities using calibration questions and to weight expert’s answers based on their expertise level (O’Hagan *et al*., 2006). However, we considered such exercise would be highly subjective and that judging and comparing expertise levels would be unethical in the specific context of this research. The consequence of using “raw” averages is that phenomena associated with rare expertise or with a lesser agreement between experts, may have been silenced. An example is the effect of harvesting on moose quality in Ouje-Bougoumou. Experts did not associate harvesting with lower moose quality except for one who did it clearly (Figure S5.5.1). This specific concern was previously raised and explained in the prior qualitative research on landscape valuation (Bélisle *et al*., 2021). Further discussions with Indigenous experts, especially for landscape values for which experts disagreed, will be necessary to specify and validate our interpretations.

5.13 Implications for land management

Our results indicate that Indigenous people are currently adapting to environmental changes and that supporting adaptive capacity will be necessary to maintain landscape value. We discuss four land management strategies to reduce the negative effects of upcoming environmental changes.

(1) Setting lower timber harvesting rate limits at the hunting ground level would reduce the vulnerability of landscape values and extend the time available for adaptation, regardless of the climate scenario. Lowering harvesting rate would also bring landscapes closer to their natural range of variability and increase their resilience (Bergeron *et al*., 2017; Kuuluvainen and Gauthier, 2018; Landres *et al*., 1999). The forest industry could also benefit from this strategy. Timber volumes that are left untouched play the role of an "insurance policy" against wildfire and unexpected disturbances, especially under high climate forcing (Brecka *et al*., 2020; Raulier *et al*., 2014). Reducing harvesting rates could hence be a win-win strategy that enhances forest sustainability under uncertain future conditions.

(2) Fire management can reduce the threats to landscape values through prevention, mitigation and preparation (Coogan *et al*., 2019). Fire-smart management

includes fuel removal and reduction and the plantation of less flammable tree species in strategic locations to prevent damages to infrastructures (FireSmart Canada, 2021). Fire management could be targeted to protect key wildlife areas such as calving grounds or wintering habitat for moose, and connectivity corridors. It should however be noted that no fire management strategy can fire-proof the forest and there is a primary need for adaptation to a new reality that involves more wildfire.

(3) Our results raise a red flag on using salvage logging to cope with more frequent wildfire. The community researchers considered that there were so many differences between a hunting ground after wildfire and after salvage logging that a vegetation type needed to be added. Consistently, the salvage logging vegetation type scored the lowest for most landscape value variables. Salvage logging should thus be planned in close collaboration with the Indigenous communities and implemented with great caution.

(4) Indigenous peoples could play a key role in the valorization of the novel forest landscapes that will be increasingly present. New forest landscapes will likely be younger, less dense, include more broadleaf and burned forests and might be of lesser interest to the forest industry. A decrease in the industrial value of forest landscapes (Brecka *et al*., 2020) could be an opportunity for forest management to be guided by alternative landscape values. Further research could be dedicated to assessing the values and knowledge specific to the vegetation types that will be increasing in the future. Programs to enhance and share Indigenous knowledge, skills and economical opportunities associated with future landscapes would contribute to building adaptative capacity.

5.14 Conclusion

In this research, we initiated interactions between Indigenous land use experts and a forest landscape simulation model to better understand the cumulative effects of environmental changes on boreal landscapes. Scientific and Indigenous knowledge showed complementary differences and together can improve conservation and resource management policies (Ban *et al*., 2018). Ecological models are increasingly used to bridge knowledge systems, but proper methods are required to preserve their integrity in the process (Bélisle *et al*., 2018; Mantyka-Pringle *et al*., 2017). The method we developed for knowledge elicitation and modeling could be mainstreamed into cumulative effect models as well as resource management policies. Vulnerabilities of boreal landscape values and the interplays between climate change and forestry call for an immediate implementation of adaptation strategies for Indigenous landscape value to be maintained in the future.

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Authors' Contribution

ACB, CMP, YB and HA conceived the ideas and designed the research; ACB and YB designed the simulation method and ACB, CMP, LJD and BC designed the elicitation method. ACB, BC, LJD and HA collected the data (elicitation workshops). ACB and YB processed the simulation data ACB did the statistical analysis. ACB led the writing of the manuscript. All authors contributed critically to the drafts.

Supplementary Material S5.1
Scenarios and parameters used in LANDIS-II and PICUS simulations

Table S5.1 1 Forestry and climate change scenarios.

	Climate change			
Forestry	Baseline	RCP2.6	RCP4.5	RCP8.5
No harvesting	*F0CCbsl*	*F0CC2.6*	*F0CC4.5*	*F0CC8.5*
Low harvesting (0.5x current rate)	*F0.5CCbsl*	*F0.5CC2.6*	*F0.5CC4.5*	*F0.5CC8.5*
Current harvesting rate	*F1CCbsl*	*F1CC2.6*	*F1CC4.5*	*F1CC8.5*
Moderate-high harvesting (1.5x current rate)	*F1.5CCbsl*	*F1.5CC2.6*	*F1.5CC4.5*	*F1.5CC8.5*
High harvesting (2x current rate)	*F2CCbsl*	*F2CC2.6*	*F2CC4.5*	*F2CC8.5*

Table S5.1.2 LANDIS-II input data for tree species simulated within the study area.

Species	Longevity	Age at maturity	Shade	Effective seed dispersal (m)‡	Maximum seed dispersal (m)	Vegetative regeneration	Post-fire regeneration	Growth curve shape parameter	Mortality curve shape parameter
Abies balsamea	150	30	5	25	160	No	Seeding	0	25
Acer rubrum	150	10	3	100	200	Yes	Resprout	0	25
Acer saccharum	300	40	5	100	200	Yes	Resprout	1	15
Betula alleghaniensis	300	40	3	100	400	Yes	Resprout	1	15
Betula papyrifera	150	20	2	200	5000	Yes	Resprout	0	25
Fagus grandifolia	250	40	5	30	3000	Yes	Seeding	1	15
Larix laricina	150	40	1	50	200	No	Seeding	0	25
Picea glauca	200	30	3	100	303	No	Seeding	1	15
Picea mariana	200	30	4	80	200	No	Serotiny	1	15
Picea rubens	300	30	4	100	303	No	Seeding	1	15
Pinus banksiana	150	20	1	30	100	No	Serotiny	0	25
Pinus resinosa	200	40	2	12	275	No	Seeding	1	15
Pinus strobus	300	20	3	100	250	No	Seeding	1	15
Populus tremuloides	150	20	1	1000	5000	Yes	Resprout	0	25
Quercus rubra	250	30	3	30	3000	Yes	Resprout	1	15
Thuja occidentalis	300	30	5	45	60	No	Seeding	1	15
Tsuga canadensis	300	60	5	30	100	No	Seeding	1	15

† Index of the ability of a species to establish under varying light levels where 1 is the least shade tolerant and 5 is the most shade tolerant. ‡Distance within which 95 % of the seeds disperse

Table S5.1.3 Input parameters specific to PICUS for species simulated within the study area.

Species	Soil nitrogen*	Minimum soil pH†	Maximum soil pH†	Minimum GDD (Base temp 5°C) ‡	Maximum GDD (Base temp 5°C) ‡	Maximum SMI§	Optimum SMI§
Abies balsamea	2	2	9	150	2723	0.3	0
Acer rubrum	2	2	9.5	500	6608	0.5	0.05
Acer saccharum	2	1.7	9.9	450	5093	0.3	0
Betula alleghaniensis	2	2	10	500	4517	0.5	0.05
Betula papyrifera	2	2.2	9.4	150	3081	0.5	0.05
Fagus grandifolia	2	2.1	9	500	5602	0.7	0.1
Larix laricina	1	3	9.6	150	2548	0.3	0
Picea glauca	3	2	10.2	150	2495	0.5	0.05
Picea mariana	2	2	8.5	150	2495	0.3	0
Picea rubens	2	2	7.8	450	3239	0.3	0
Pinus banksiana	1	2.5	10.2	300	3188	0.7	0.1
Pinus resinosa	1	2.5	8	500	3300	0.7	0.1
Pinus strobus	2	2	9.3	500	4261	0.7	0.1
Populus tremuloides	1	2.3	9.3	500	5171	0.3	0
Quercus rubra	2	2.3	11	150	3024	0.5	0.05
Thuja occidentalis	2	3	10	500	3383	0.7	0.1
Tsuga canadensis	2	2.2	9	500	4660	0.5	0.05

* Nitrogen response curves: Three classes (1-3) with 1 being very tolerant

† USDA plant fact sheets (USDA, 2016) and the Ontario Silvics Manual (OMNR, 2000) were used to derive the widest optimum pH range possible.

‡ Growing Degree Days (GDD). We used McKenney *et al*. (2011) growing season model, specifically the minimum GDD for the 0°C and growing season window with degree days over 5°C. For the maximum GDD, we used GDD Maximum from McKenney's previous growing season model (McKenney *et al*. 2007).

§ Soil Moisture Index (SMI). Determines each species tolerance to drought (see Lexer and Honninger pg. 52). HighTolerance (0.1 to 0.7), MedTolerance (0.05 to 0.5), LowTolerance (0 to 0.3).

Supplementary material S5.2
Bayesian Network parameters

TableS5.2.1 Simple structure index (SSI) and Calinski index for vegetation k-means clustering (2 to 6 groups). The best partition is indicated by the highest values.

a) Abitibiwinni First Nation

	2 groups	3 groups	4 groups	5 groups	6 groups
SSI	1.67e+04	2.27e+04	2.56e+04	2.68e+04	**2.81e+04**
Calinski	1.50e+04	1.99e+04	2.55e+04	2.98e+04	**3.52e+04**

b) Ouje-Bougoumou First Nation

	2 groups	3 groups	4 groups	5 groups	6 groups
SSI	6.97+03	9.31e+03	1.03e+04	1.10e+04	**1.14e+04**
Calinski	1.51e+04	20432.6	2.52e+04	3.07e+04	**3.53e+04**

TableS5.2.2 Disturbance factors, indicators and data sources used to classify hunting grounds among high and low disturbance types (adapted from Bélisle and Asselin, (2020))

Disturbance factor	Indicator	Data source
Hunting cabins	Density of hunting cabin leases on the hunting ground (terrestrial area) (cabin·km^{-2})	(Ministère de l'Énergie et des Ressources naturelles du Québec, 2019)
Forest roads	Density of roads on the hunting ground (terrestrial area) (km·km^{-2})	(Ministère de l'Énergie et des Ressources naturelles du Québec, 2019)
Transportation	Density of main roads on the hunting ground (terrestrial area) (km·km^{-2})	Ministère de l'Énergie et des Ressources naturelles du Québec, (2019)
Distance to town	Distance between hunting ground centroid and nearest town (km), as the crow flies	Ministère des Ressources naturelles du Québec, 2019
Plantations	Proportion of hunting ground (terrestrial area) covered by forest stands originating from plantations.	Berger *et al.*, 2015
Naturalness	Proportion of hunting ground (total area) free from industrial disturbance (mines, forestry, roads, towns)	Bélisle & Asselin (2020)
Powerlines[1]	Density of power lines on the hunting ground (total area) (km·km^{-2})	Ministère des Ressources naturelles du Québec (2019)

[1] Not considered for the Abitbiwinni First Nation because no impact was reported by local experts

Hunting grounds from the Abitibiwinni and the Ouje-Bougoumou First Nations were distributed among high and low disturbance levels (Figure S5.2.1). Eighteen hunting grounds from the Abitibiwinni First Nation belonged to the high-level disturbance cluster (P = 0.53) and 16 belonged to the low disturbance level (P = 0.47). Nine hunting grounds of the Ouje-Bougoumou First Nation belonged to the high disturbance level (P = 0.64) and five to the low disturbance level (P = 0.36). We developed the maps based on the median values for disturbance indicators for high and low disturbance levels (Table S5.2.3).

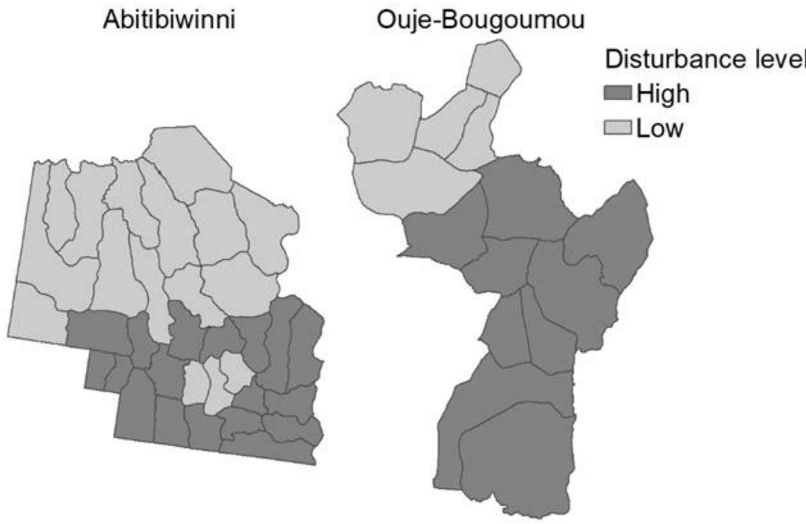


Figure S5.2.1 Distribution of high and low disturbance levels among the hunting grounds of the Abitibiwinni and the Ouje-Bougoumou First Nations.

TableS5.2 3 Median value of disturbance variables (presented on elicitation maps) for high and low disturbance levels in the Abitibiwinni and the Ouje-Bougoumou huntiong grounds.

	Abitibiwinni		Ouje-Bougoumou	
Disturbance level	Low	Low	High	High
Forest roads (km·km^{-2})	0.77	0.18	1.62	1.34
Transportation (km·km^{-2})	0.01	0.0	0.07	0.05
Distance to town (km)	102	59	36	65
Powerlines (km·km^{-2})	0	0.03	0.03	0
Hunting cabins (cabin·km^{-2})	0.03	0	0.05	0.09

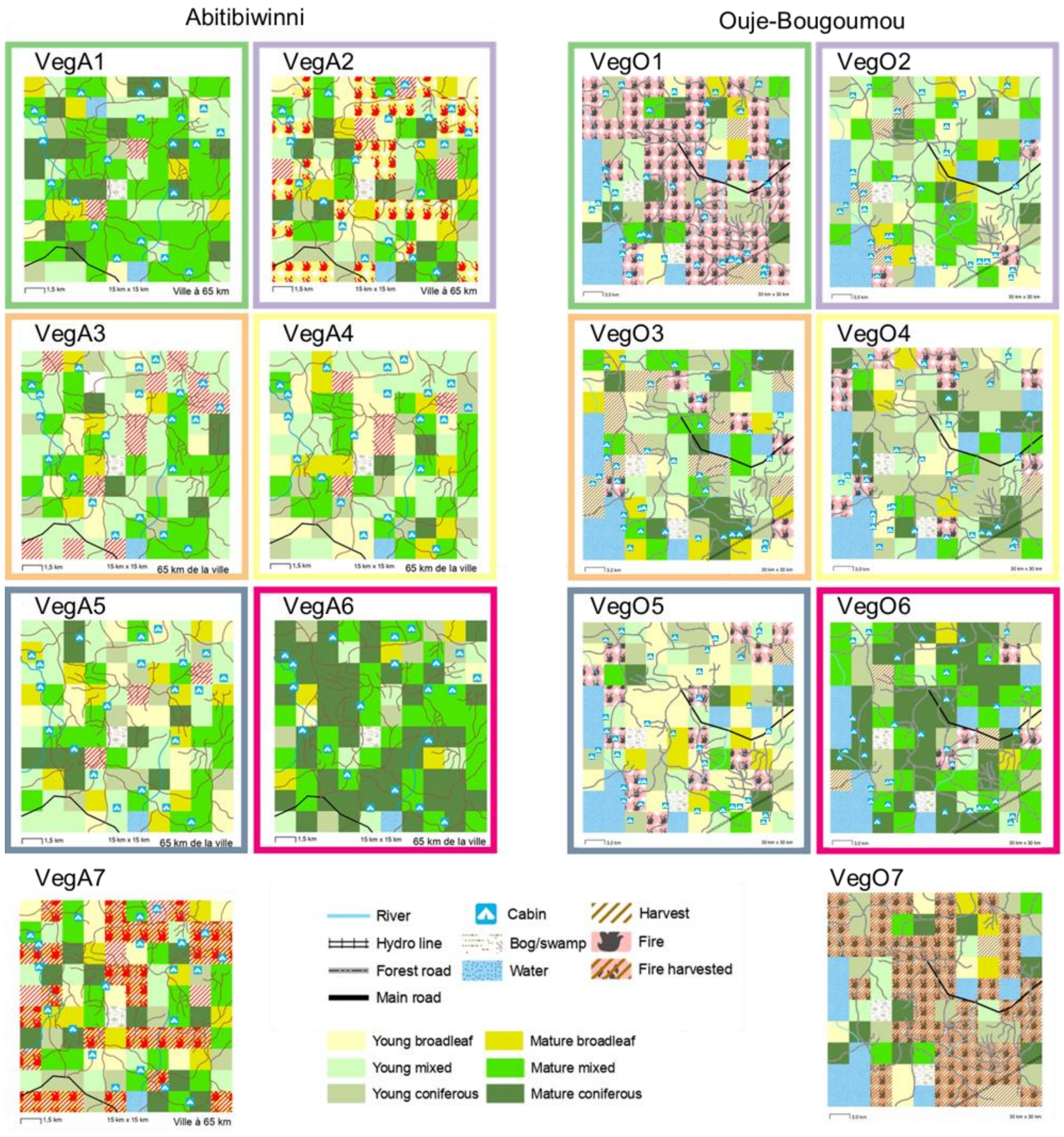
TableS5.2.4 Probability of the salvage logging vegetation type P(Veg7) conditional to forestry scenario P(Veg7|For), relative to the probability of the vegetation type being the most affected by wildfire.

Foresrty scenario	P(Veg7)
For0x	0
For0.5x	0.25
For1x	0.5
For1.5x	0.75
For2x	1

Supplementary material S5.3
Elicitation procedure and material

The elicitation process included an introductory presentation of the research project to the group, time for familiarization with the elicitation material, an expert training exercise, and the actual elicitation of conditional probabilities. The presentation introduced experts to the research team, the objectives of the workshop, their rights as experts, consent to information, and overall planning for the day. The expert training exercise was designed to get experts familiar with the elicitation process, including the material, what probabilities are, and uncertainties. Experts had to make a judgement on the question "*What are the chances of rain tomorrow*"? by distributing ten dots among two boxes: "*rain*" or "*no rain*". They were guided with the example of a 50% probability of rain that would be represented with five dots in each box. Once they made their judgment, experts were asked on what information they based their judgment on (season, a weather bulletin, etc.) and were asked to assess their epistemic uncertainty on an uncertainty-certainty graphical scale. We avoided statistical jargon, using, for example, the word "chance" instead of "probability" and "*I am unsure*" instead of "*I am uncertain*".

The maps were presented using visual support (projected and printed) and included pictures for all features and associated symbology. Maps were analyzed and interpreted (in a group or individually) (Figure S5.3.1). The full elicitation process took six hours in the Abitibiwinni First Nation workshop and between two and three hours in the Ouje-Bougoumou small groups



FigureS5.3.1 Fictive hunting ground maps for the Abitibiwinni and Ouje-Bougoumou First Nations (high disturbance level)

Supplementary material S5.4
Validation of expert judgement

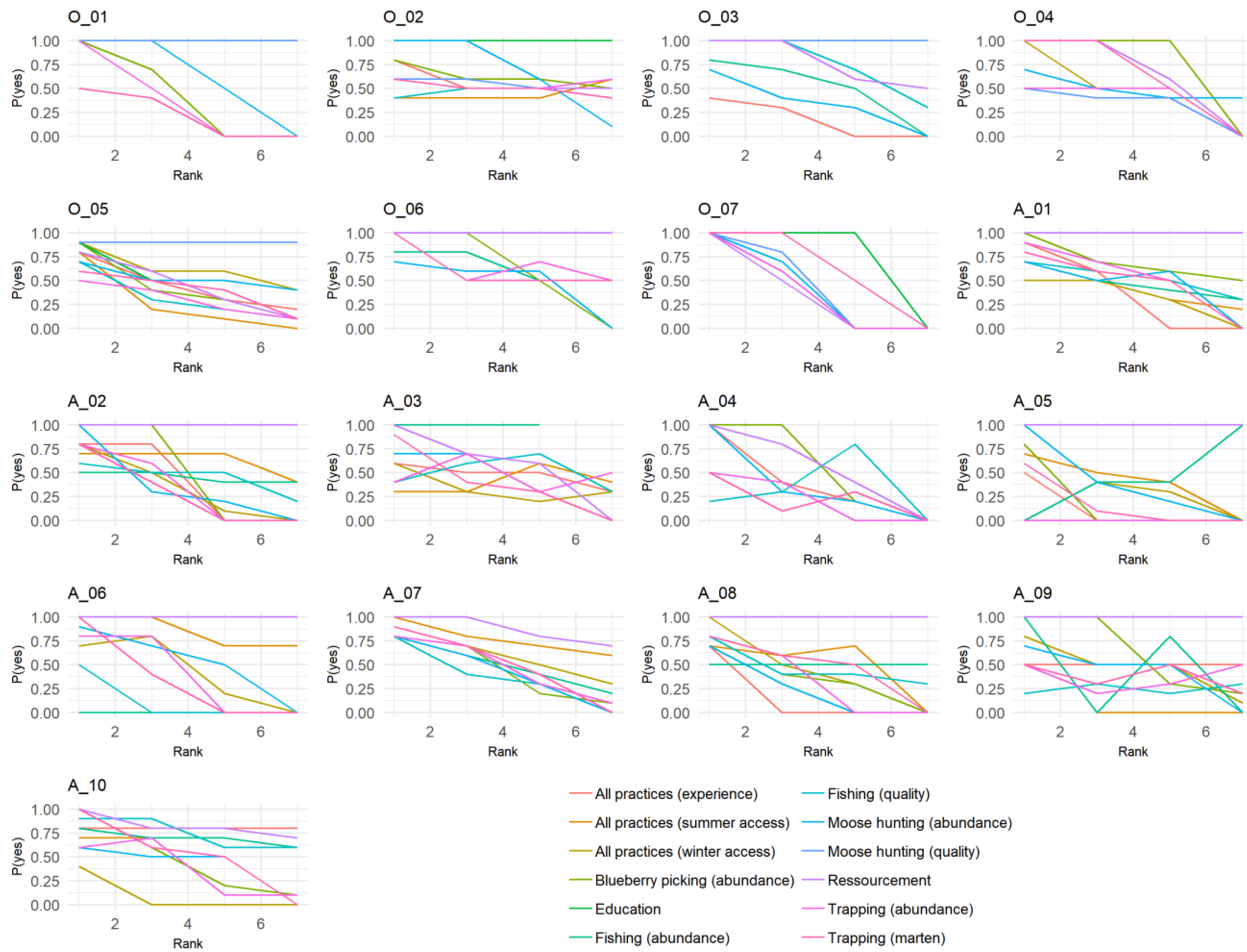


Figure S5.4.1 Distribution of the probability assigned to the answer “ yes” (P(yes)) given by the experts according to the rank of vegetation assemblages specific to the landscape practices (and dimensions) (colors).

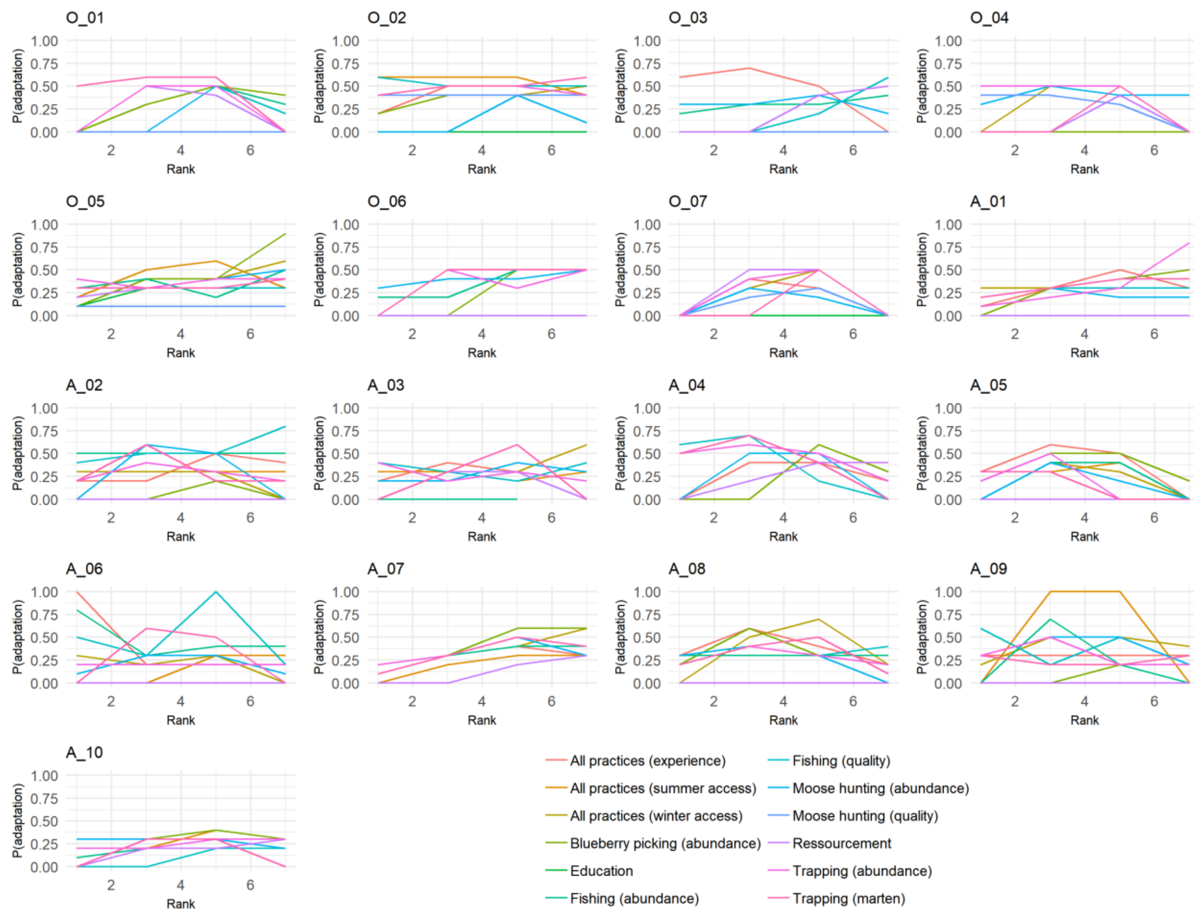


Figure S5.4.2 Distribution of the probability assigned to the answer "Yes, but I will have to adapt" (P(adaptation)) by the experts according to the rank of vegetation assemblages specific to the landscape practices (and dimensions) (colors).

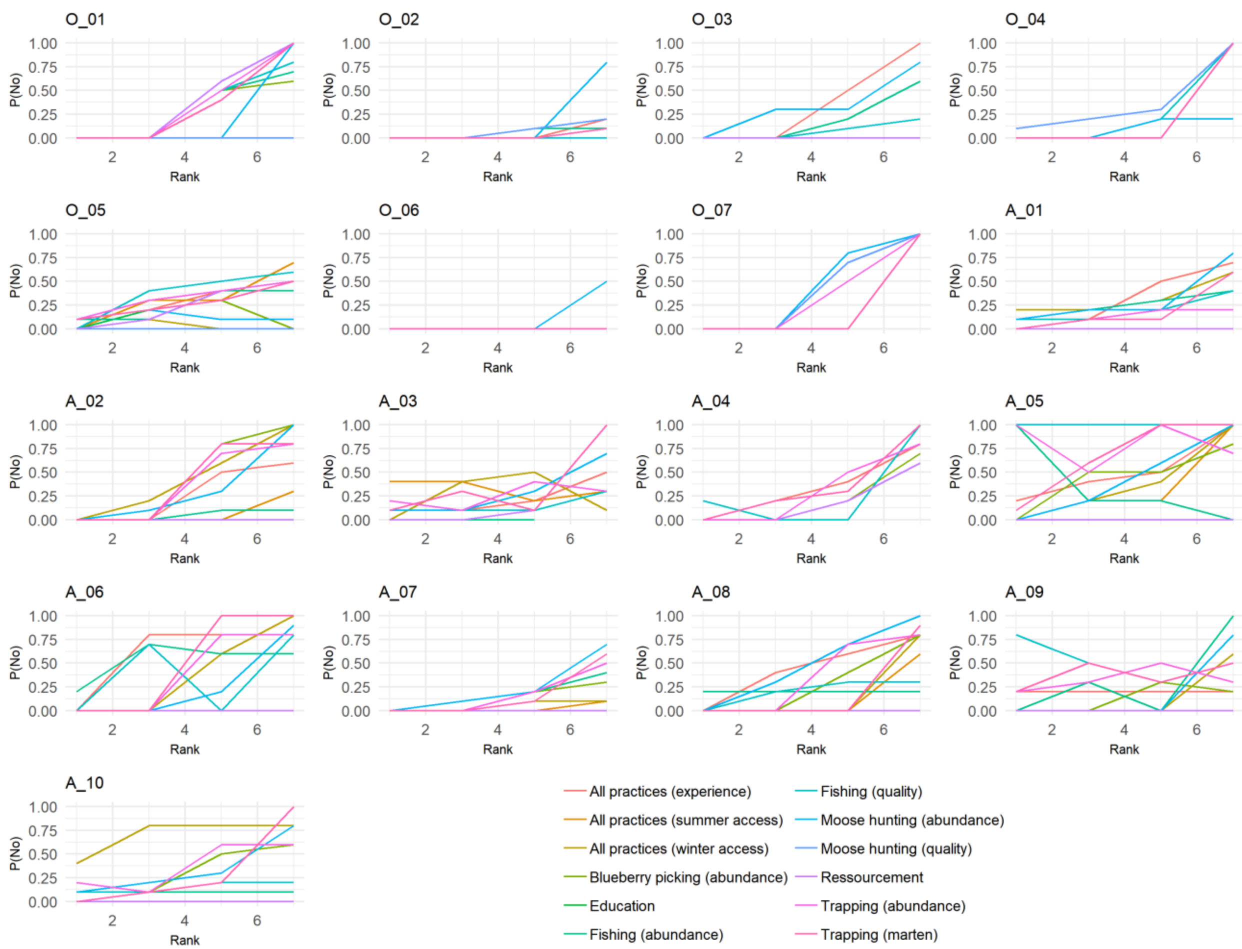


Figure S5.4.3 Distribution of the probability assigned to the answer " No") by the experts according to the rank of vegetation assemblages specific to the landscape practices and dimensions (colors).

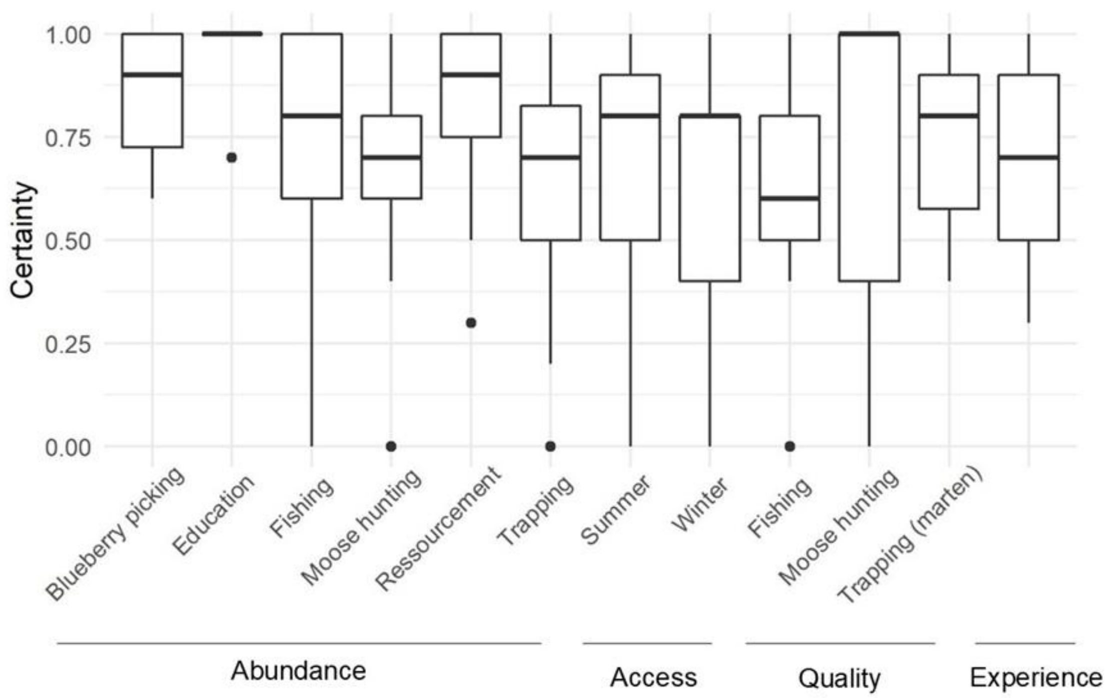


Figure S5.4.4 Epistemic (un)certainty distribution for landscape value variables. We pooled uncertainty from the two First Nations to avoid unethical comparisons. Education (abundance) and moose hunting (quality) were elicited only in the Ouje-Bougoumou First Nation.

Table S5.4.1 Ambiguous expert answers for specific questions and decisions of keeping or excluding the answers by question. Problems are identified by inconsistencies in figures S5.4.1, S5.4.2, S5.4.3, by self-estimated level of certainty ≤ 0.5 and by the notes taken by the elicitation team during the workshops.

Expert	Question	Problem	Decision
A_02	All practices (winter access)	Low certainty (0.1)	Keep in check
A_02	Trapping (marten)	Low certainty (0.4)	Keep in check
A_03	**Blueberry (abundance)**	**Misunderstanding noted by the elicitation team**	**Exclude the answers from A_03 for blueberry (abundance)**
A_03	**Fishing (abundance)**	- **Misunderstanding noted by the elicitation team** - **No P(yes) for ranks >4**	**Exclude the answers from A_03 for fishing (abundance)**
A_03	**Fishing (quality)**	**Inconsistencies between Ranks, P(yes) and P(no)**	**Exclude the answers from A_03 for fishing (quality)**
A_03	**Trapping (abundance)**	**P(yes)|Rank 3 > P(yes) | Rank 1** **Low certainty (0.2)**	**Exclude the answers from A_03 for trapping (abundance)**
A_03	*Ressourcement*	Low certainty (0.3)	Keep in check
A_03	All practices (experience)	Low certainty (0.3)	Keep in check
A_03	All practices (summer access)	Low certainty (0.3)	Keep in check
A_03	All practices (winter access)	Low certainty (0.2)	Keep in check
A_04	Fishing (quality)	P(yes) (figure S5.4.1) increases with the rank instead of decreasing.	Keep the answers as they are because the mistake has no influence on the analysis. Only the probabilities are considered, and not the rank.
A_05	Fishing (abundance)	The vegetation assemblages have reverse rank according to scores (also noted	Keep the answers as they are because the mistake has no influence on the

Table S5.4.1 Suite

Expert	Question	Problem	Decision
		by the elicitation team).	analysis. Only the probabilities are considered, and not the rank.
A_06	Fishing (abundance)	Rank 3 has a higher P(no) than Rank 5	Keep the answers as they are because the mistake has no influence on the analysis. Only the probabilities are considered, and not the rank.
A_06	Fishing (quality), Trapping (abundance), Moose hunting (abundance), all practices (winter and access), fishing (abundance)	Low certainty	Keep in check
A_08	Fishning (abundance)	Low certainty (0.2)	Keep in check
A_09	**Fishing (abundance)**	**P(yes)|Rank 5 > P(yes)|Rank 3. The difference is large P(yes)|Rank 5=0.8, P(yes)|Rank 3=0.**	**Exclude the answers from A_09 for fishing (abundance).**
A_09	**Fishing (quality)**	**Inconsistencies between rank and, P(yes) and P(no)**	**Exclude the answers from A_09 for fishing (quality).**
0_04	All practices (winter access), moose hunting (quality), fishing (quality), fishing (quality)	Low certainty (0). O_04 circled the ticks on the scale (0, 0.5 or 1). There is maybe a confusion between stochastic and epistemic uncertainty	Keep the data.
O_05	Blueberries (abundance)	P(no)|Rank 7>P(no)|Rank 5	Leave the answers as they are.

Table S5.4.1 Suite

Expert	Question	Problem	Decision
		A good understanding of the task was noted by the elicitation team and the P(adaptation) the balance.	
O_06	Moose hunting (quality)	Low certainty (0)	Keep in check

Supplementary material S5.5
P(Yes|Veg), P(Adaptation|Veg) and P(No|Veg) elicited from experts of the Abitibiwinni First Nation of Ouje-Bougoumou First Nation

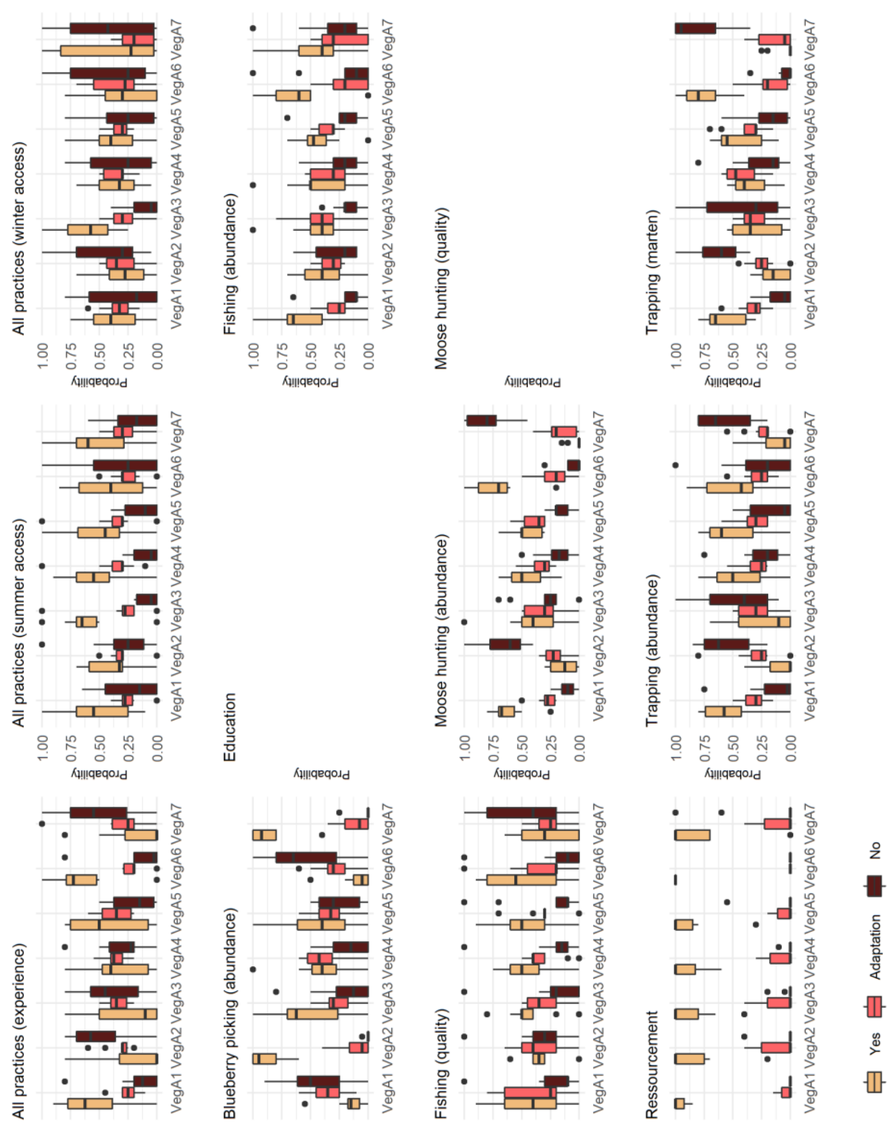


Figure S5.5.1 Probability of fulfilling family' s needs (yes, adaptation, no) for landscape value variables conditional to vegetation type, estimated by experts from the Abitibiwinni First Nation and the Ouje-Bougoumou First Nation (disturbance levels were pooled). In the Abitibinni First Nation, education and moose hunting (quality) were not elicited after the group stated there was no influence of the vegetation type on the probability to fulfill needs for these landscape value variables.

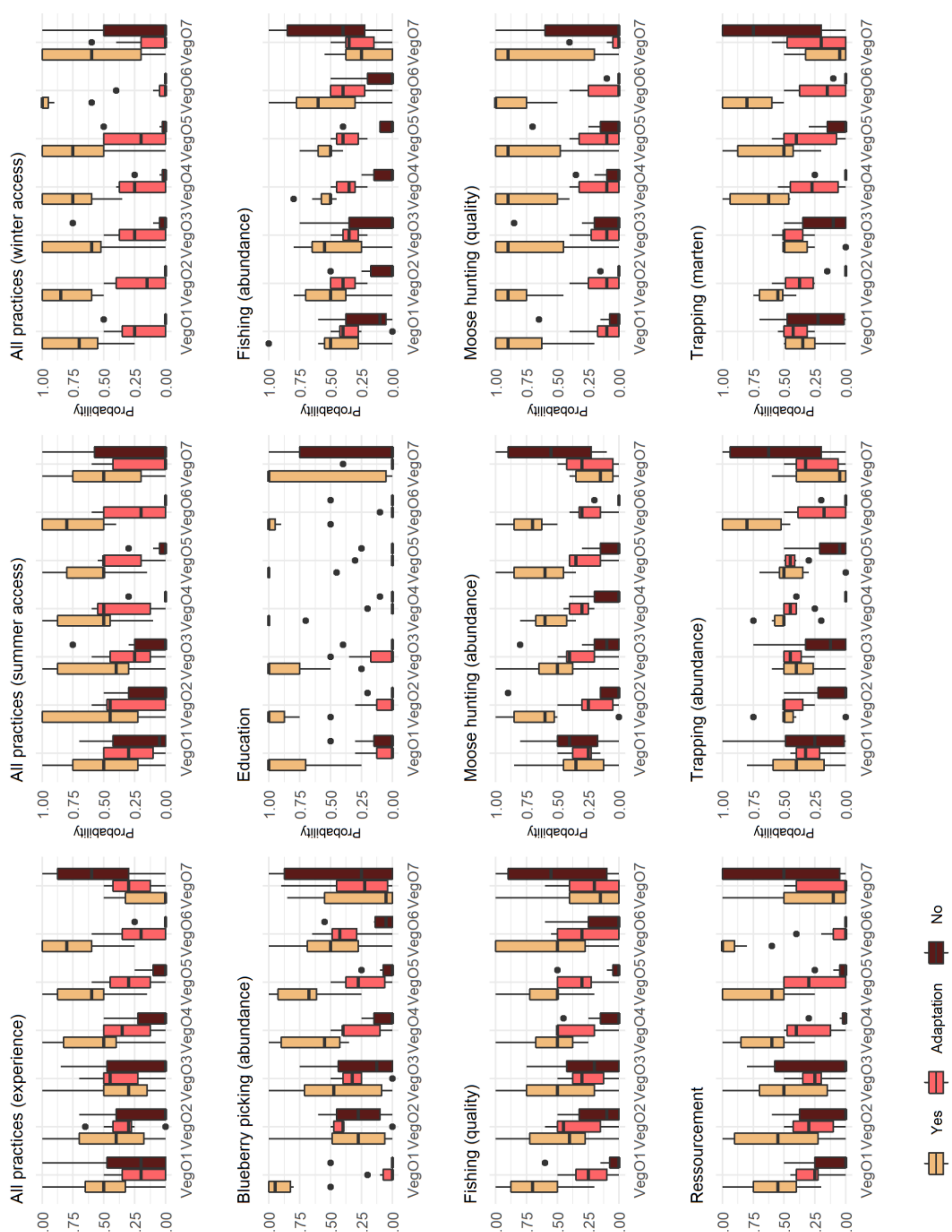


Figure S3.5.1 Suite

Supplementary material S5.6
Projections for landscape value variables

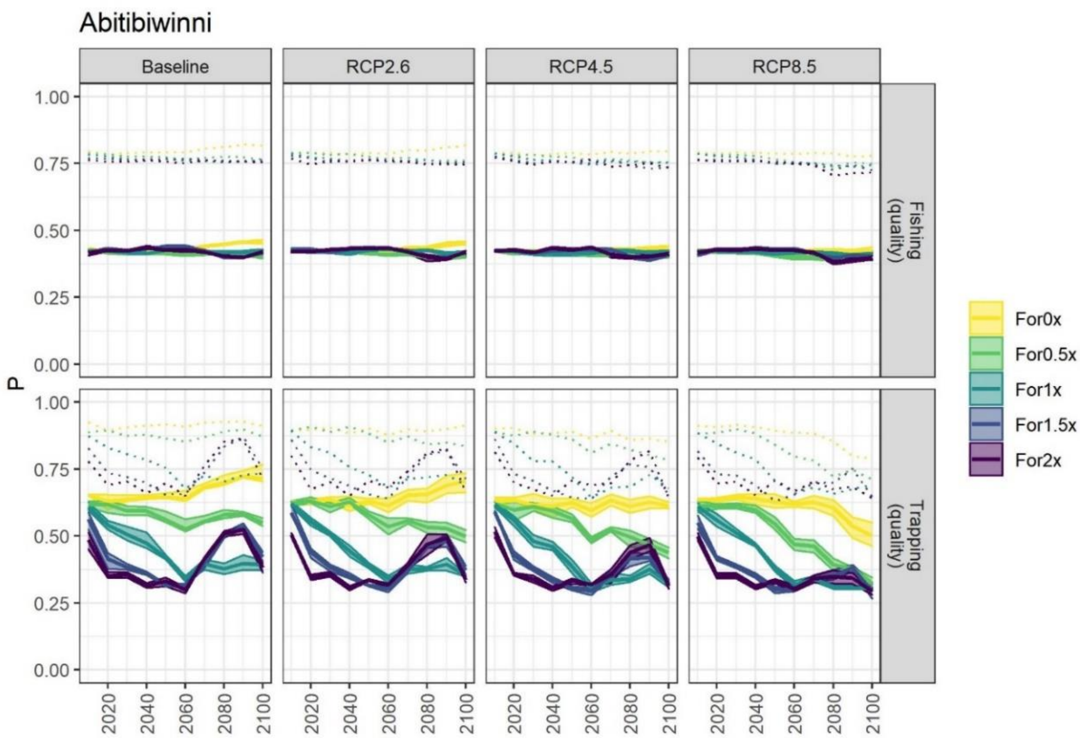


Figure S5.6.1 Projections (2010-2100) of P(Yes) (full lines) and 95% confidence intervals (shaded area) and P(Yes)+P(Adaptation) (dotted lines) for landscape value variables for the Abitibiwinni and Ouje-Boumou First Nations

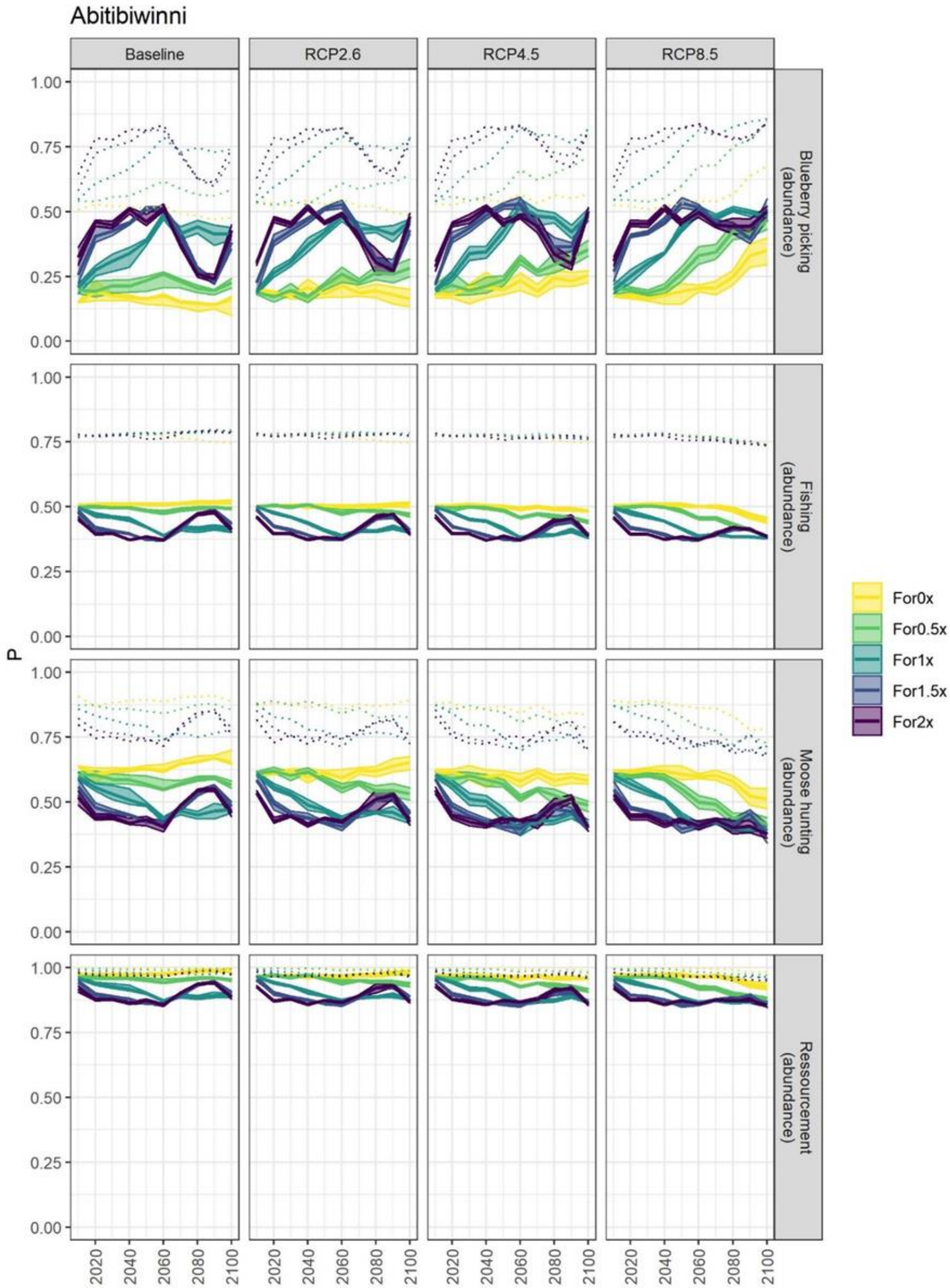


Figure S5.6.1 Suite

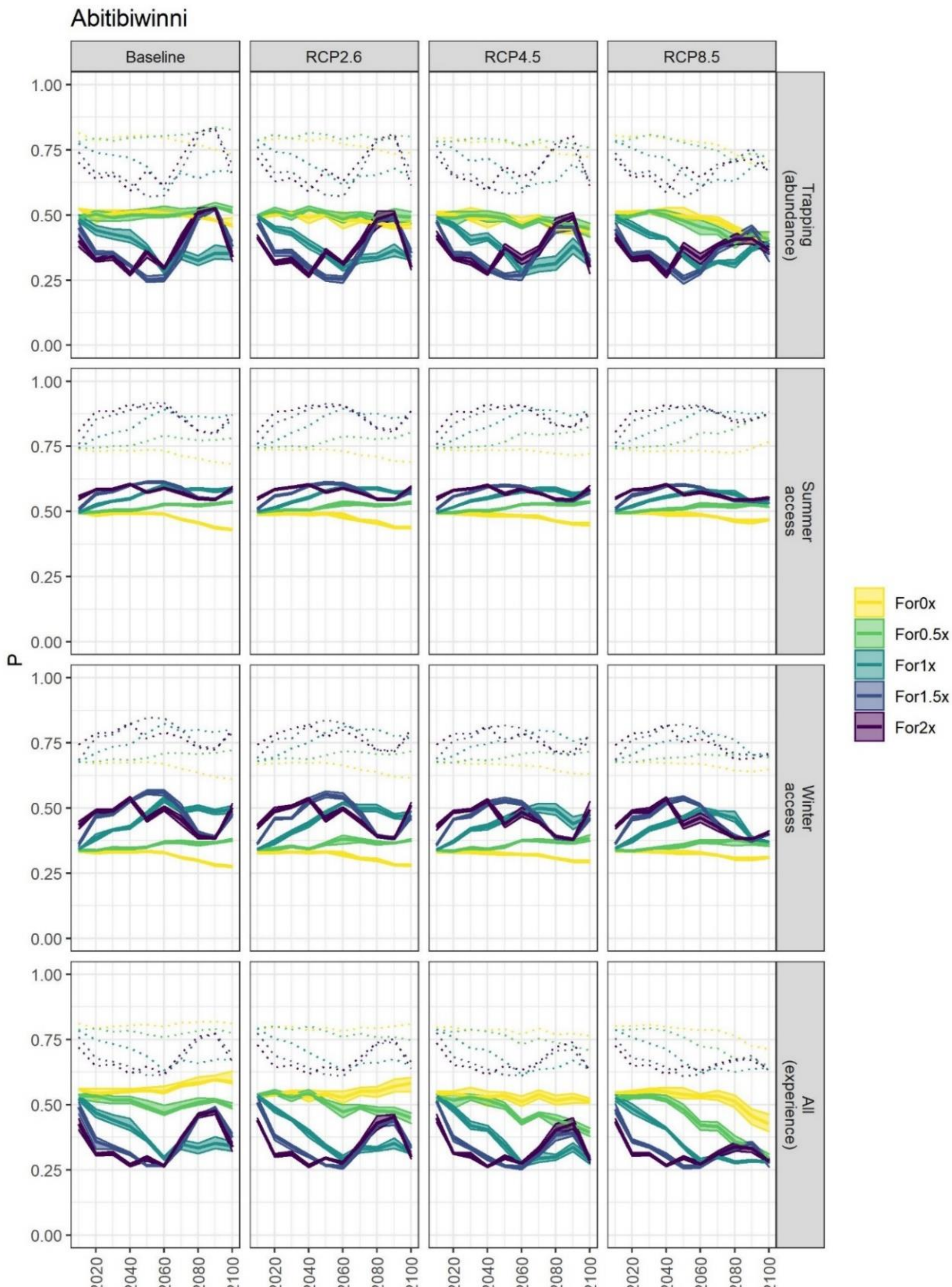


Figure S5.6.1 Suite

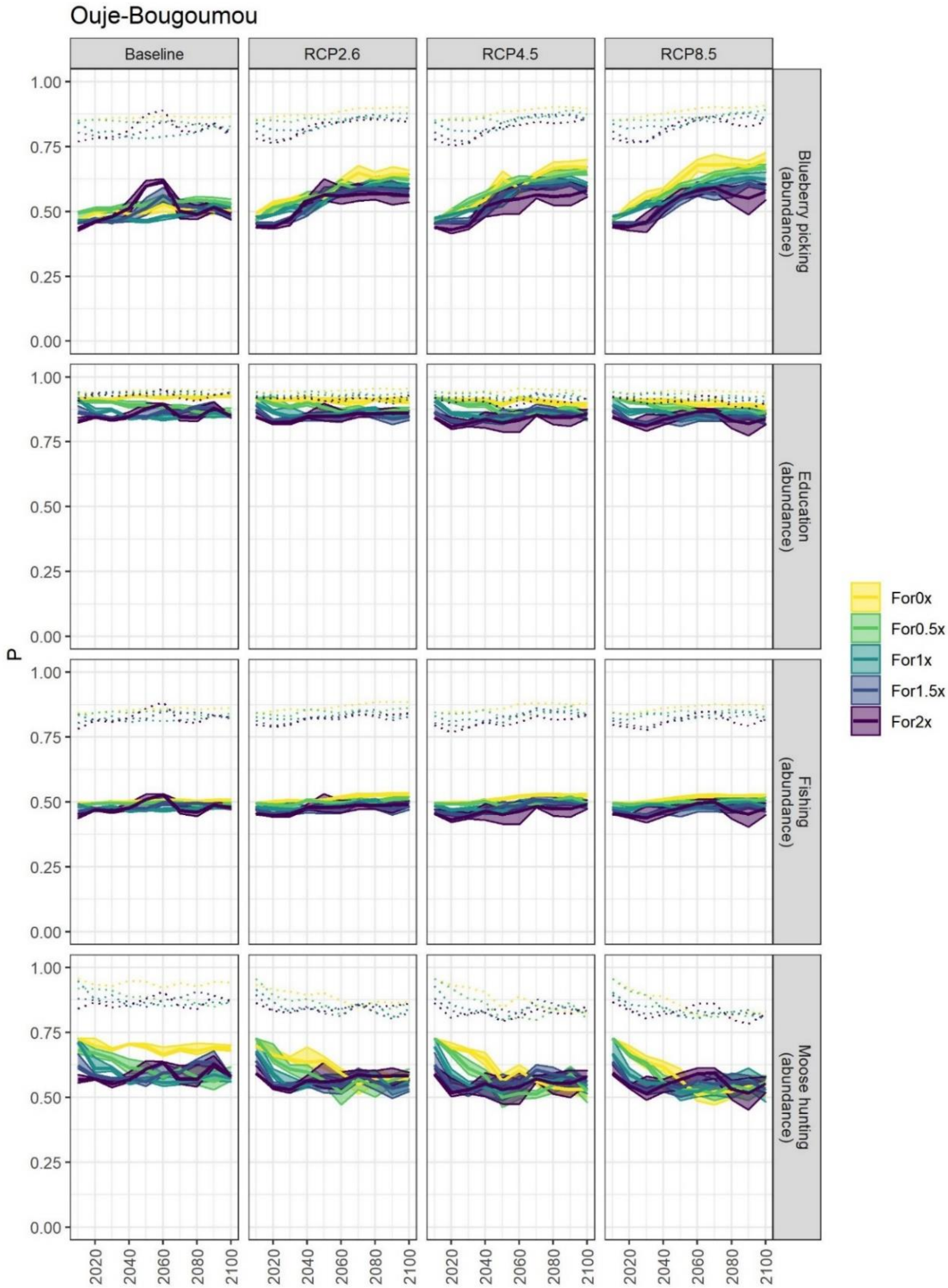


Figure S5.6.1 Suite

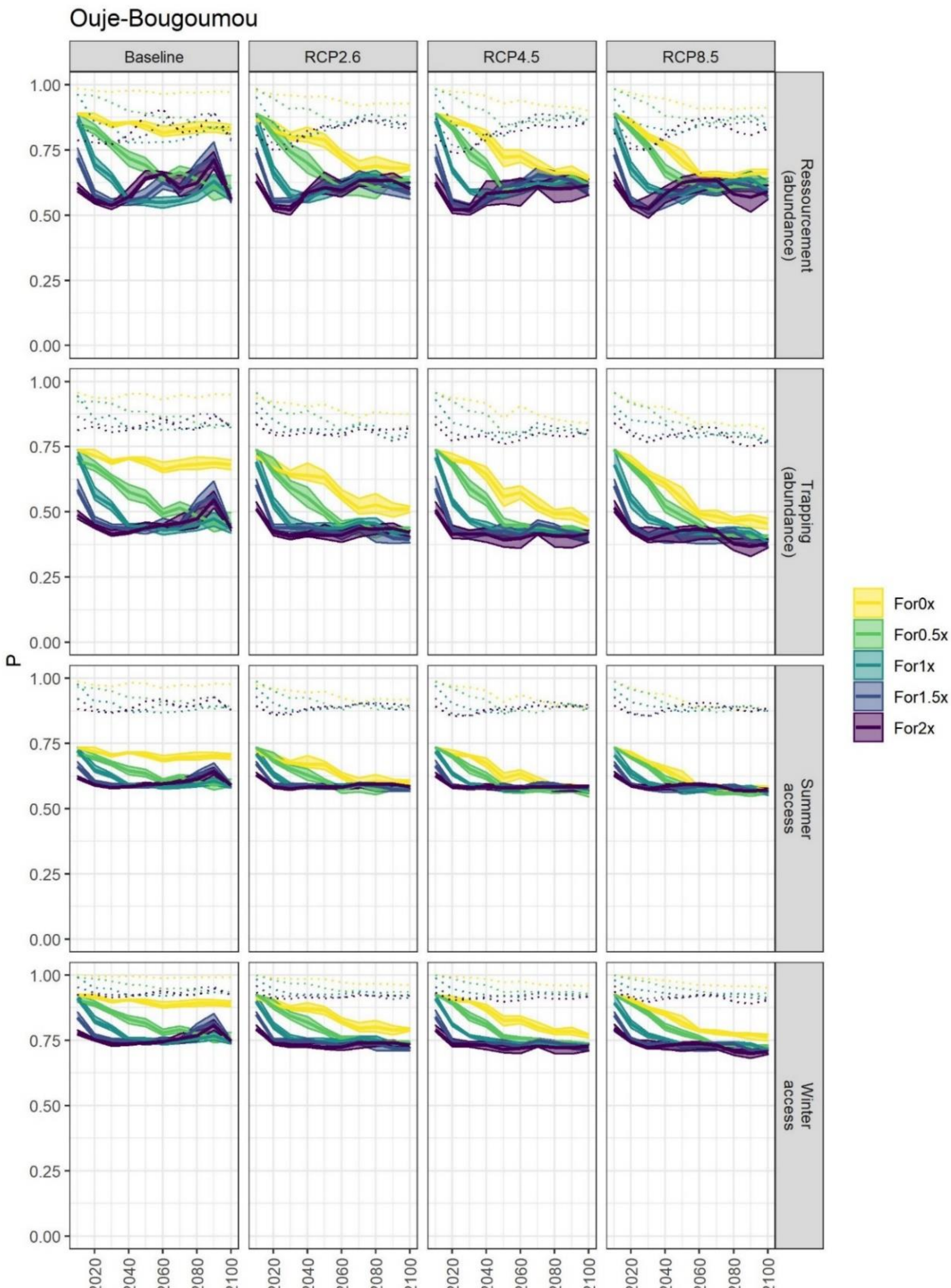


Figure S5.6.1 Suite

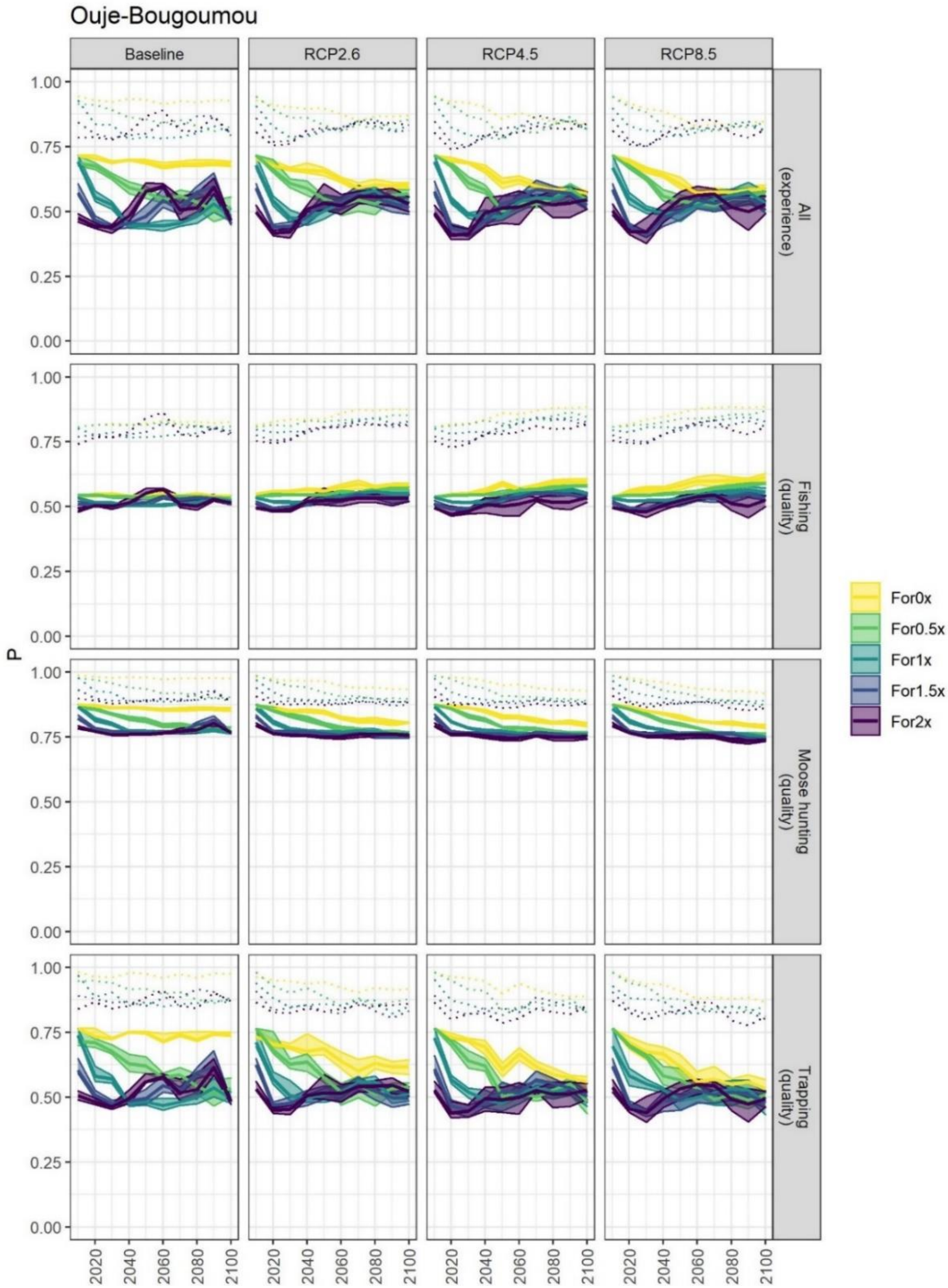


Figure S5.6.1 Suite

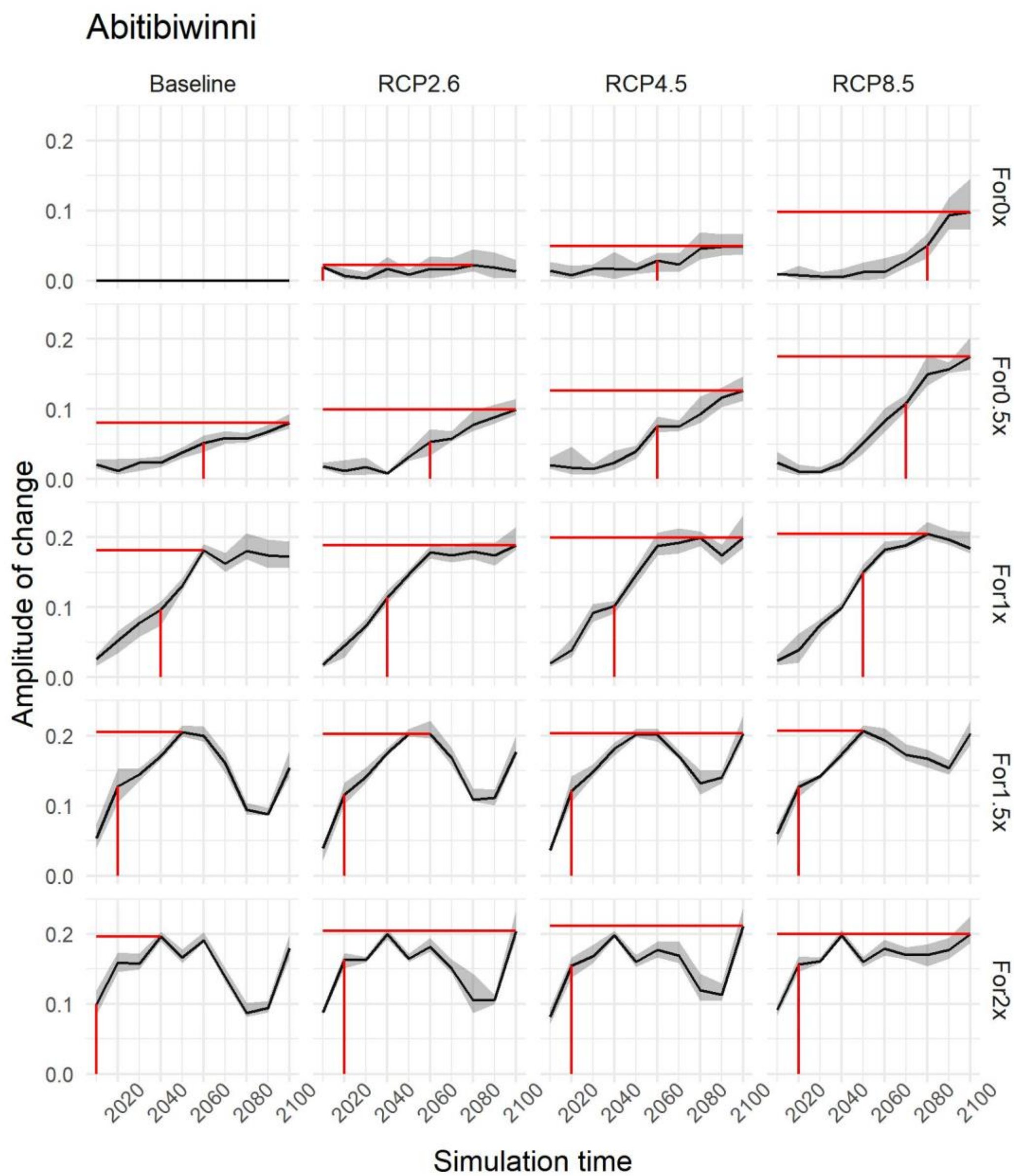


Figure S5.6.2 Amplitude of change (A) of the average probability to fulfill family needs without any constraint P(Yes) versus simulation time (t), with maximum amplitude (Amax –horizontal red line) and time to reach half Amax (t0.5max) (vertical red line) for each climate change and forestry scenario, for the Abitibiwinni and Ouje-Bougoumou First Nations.

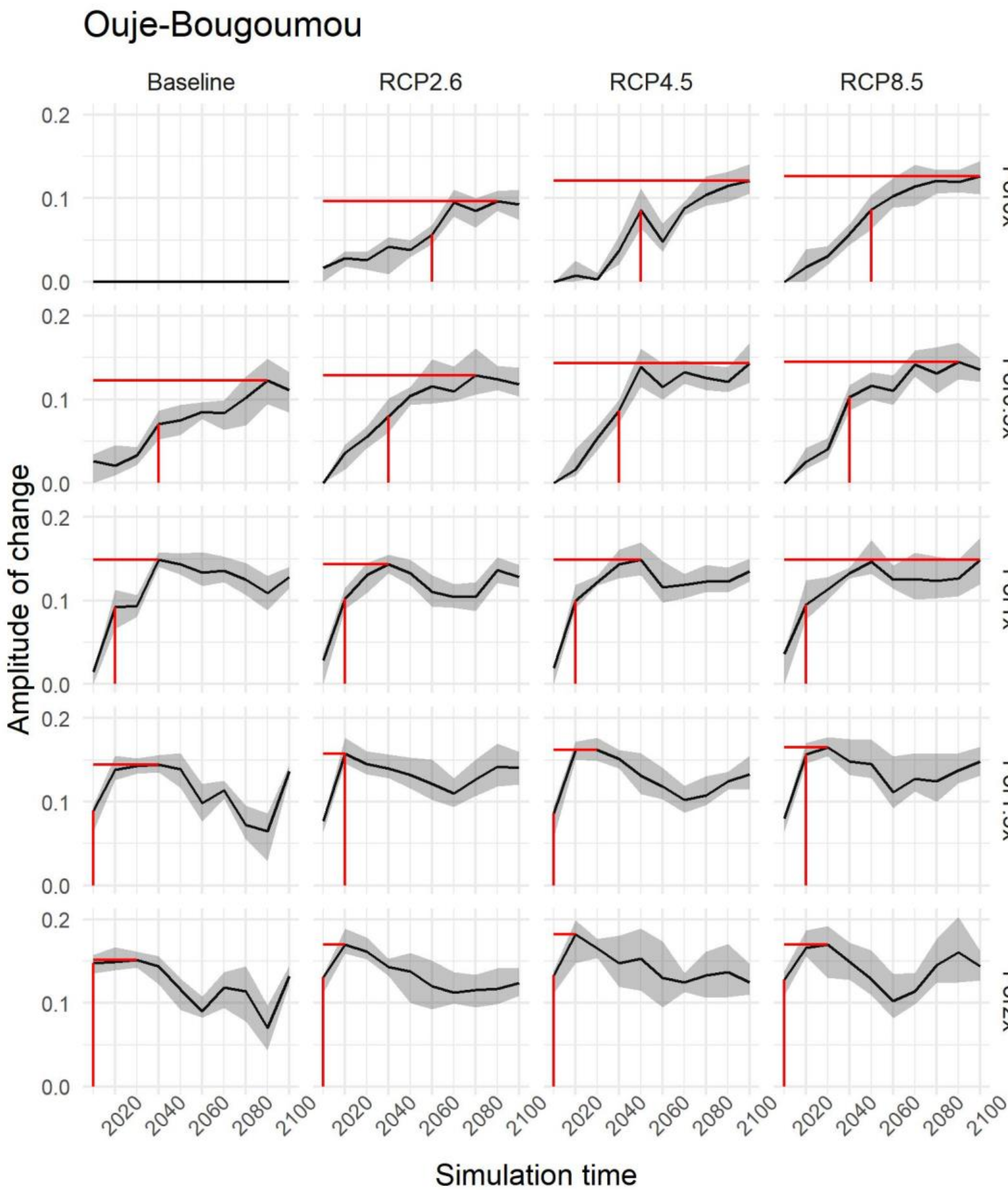


Figure S5.6.2 Suite

CHAPITRE VI

CONCLUSION

L'objectif général de cette recherche était d'analyser les effets cumulatifs des changements environnementaux sur les paysages boréaux depuis la frontière entre les systèmes de connaissances autochtones et scientifiques. Le cœur de la thèse se décline en quatre articles scientifiques présentés aux chapitres II, III, IV et V qui abordent la question des changements environnementaux avec une diversité de méthodes et de perspectives. Cette section fait un bref retour sur les objectifs des travaux réalisés, en présente les principales contributions à l'avancement des connaissances et amorce une réflexion sur les perspectives de recherche et d'application.

6.1 Retour sur les objectifs

Le premier objectif spécifique était de conceptualiser la valeur des paysages autochtones et ses déterminants afin de développer un cadre d'analyse des effets des changements environnementaux (Chapitre II). L'approche qualitative et inductive a nécessité une collecte de données qui a été structurante pour l'ensemble du projet de recherche. Les données recueillies auprès des experts autochtones du territoire ont façonné le cadre conceptuel sur lequel repose l'entièreté de la thèse. La campagne terrain menée à l'été 2016 a permis de consolider les liens avec les co-chercheurs des communautés qui étaient directement impliqués dans le design des outils de collecte, le recrutement des participants et la réalisation des entrevues. La valeur du paysage y est abordée à partir de pratiques autour desquelles s'articule la relation au territoire dans les communautés. Elle y est décrite selon quatre dimensions, soit l'abondance, l'accès, la qualité et l'expérience.

Le second objectif spécifique était de concevoir un « objet frontière » qui fait le pont entre les perspectives autochtone et scientifique sur les effets des changements environnementaux (Chapitre III). Les perspectives autochtone et scientifique ont été respectivement développées à partir d'entrevues avec des experts locaux et d'une analyse bibliométrique de la littérature scientifique. Avec les quatre dimensions de la valeur développées dans le chapitre II, le cadre Driver Pressure State Impact (DPSI) a permis de structurer l'ensemble de l'information recueillie lors des entrevues, de présenter les deux perspectives dans un même format et de les comparer. Les convergences et les complémentarités entre les perspectives autochtone et scientifique ont guidé le développement des analyses subséquentes en déterminant les variables d'intérêt et les synergies entre les enjeux autochtones et scientifiques. Les perspectives rendues explicites ont contribué à mieux situer les résultats des chapitres subséquents et leur portée.

Le troisième objectif spécifique était faire le portrait de l'état actuel du territoire à l'étude (Chapitre IV). Un ensemble d'indicateurs a été développé à partir des variables identifiées dans le modèle DPSI (Chapitre III) et des données spatiales ouvertes disponibles. Il en est ressorti une typologie de l'état des terrains de trappe qui illustre les dynamiques spatiales des changements environnementaux. L'outil d'analyse et de suivi de l'état des terrains de trappe développé permet de tenir compte des changements environnementaux antérieurs dans l'évaluation des projets de développement sur le territoire.

Le quatrième objectif spécifique était de mettre en commun les projections d'un modèle de simulation des paysages forestiers et les savoirs d'experts autochtones dans un réseau bayésien (Chapitre V). L'atteinte de cet objectif a mobilisé une équipe de recherche agrandie aux expertises diversifiées. Le modèle de simulation des paysages forestiers LANDIS-II a été utilisé pour évaluer les effets cumulatifs des changements climatiques et de la foresterie sur les terrains trappe. Des méthodes d'élicitation de savoirs d'experts appropriées au contexte autochtone ont été développées en collaboration avec les co-chercheurs des communautés. Les experts locaux ont émis des jugements sur la probabilité de répondre à divers besoins des familles de leur communauté selon l'état de la forêt d'un terrain de trappe.

Le cinquième objectif spécifique était de projeter les effets cumulatifs des changements environnementaux sur la valeur des paysages autochtones selon divers scénarios de changements climatiques et de foresterie (Chapitre V). L'atteinte de cet objectif est l'aboutissement de l'ensemble des travaux menés dans le cadre de cette recherche. Les projections sont riches des savoirs autochtones et scientifiques, reposent sur une méthodologie novatrice et évaluent les principales vulnérabilités liées aux changements environnementaux à court et moyen terme. Elles pourront guider la mise en place d'outils de mitigation et d'adaptation par les communautés et le développement de nouveaux projets de recherche collaborative.

6.2 Principales contributions

Les contributions de cette thèse à l'avancement des connaissances sont intégrées selon quatre axes et trois domaines de recherche rattachés aux sciences de l'environnement (Tableau 6.1). L'axe théorique et conceptuel concerne les contributions à un domaine de recherche par le développement de nouvelles idées, démonstrations ou cadres d'analyses. L'axe méthodologique concerne le développement d'outils de collecte et d'analyses de données. L'axe empirique a trait à l'acquisition de connaissances par l'observation et l'expérience. L'axe appliqué comprend les implications pratiques des résultats de recherche, notamment à la gestion et à l'aménagement du territoire et au design de devis de recherche collaborative.

Le domaine de la valeur des paysages fait appel à des concepts comme la relation au territoire (Bieling *et al*., 2014; Brown et Raymond, 2007), les services écosystémiques (Daily, 1997; Díaz *et al*., 2018; Wallace, 2007) et la durabilité (Opdam *et al*., 2018; Raworth, 2017). Le domaine de la recherche en contexte autochtone comprend l'éthique de la recherche (Asselin et Basile, 2018; McGregor, 2018; Smith, 2012; Wong *et al*., 2020), la recherche collaborative (Cooke *et al*., 2021; David-Chavez et Gavin, 2018; Laniak *et al*., 2013; Voinov et Bousquet, 2010) et les interactions entre les systèmes de connaissances (Agrawal, 1995; Bartlett *et al*., 2012; Hill *et al*., 2020; Löfmarck et Lidskog, 2017; Robinson et Wallington, 2012). Le domaine des changements environnementaux concerne la transformation des systèmes socioécologiques sous la pression des changements climatiques, de l'exploitation des ressources naturelles et des changements d'affectation des terres (IPBES, 2018; Rockström *et al*., 2009).

Tableau 6.1 Principales contributions de cette recherche à l' avancement des connaissances théoriques et conceptuelles, méthodologiques, empiriques et appliquées dans les domaines de l' étude de la valeur des paysages, de la recherche en contexte autochtone et des effets des changements environnementaux.

	Axes de connaissances			
Domaines	Théorique/conceptuel	Méthodologique	Empirique	Appliqué
Valeur des paysages	A) Cadre d'évaluation de la valeur des paysages autochtones (Chapitre II)		D) Base de données qualitatives sur la valeur des paysages (Chapitre II)	
Recherche en contexte autochtone		B) Utilisation de modèles DPSI pour exposer et comparer les perspectives autochtone et scientifique (Chapitre III) C) Mise en commun de simulations des paysages forestiers et de jugements d'experts dans un réseau bayésien (Chapitre V)	E) Comparaison des perspectives autochtone et scientifique sur les effets des changements environnementaux (Chapitre III)	
Changements environnementaux			F) Portrait de l'état des terrains de trappe (Chapitre IV) G) Projection des effets cumulatifs des changements environnementaux sur la valeur des paysages (Chapitre V)	H) Outil de visualisation de données et d'aide à la décision (Chapitre IV)

6.3 Contributions théoriques et conceptuelles

A) Cadre d'évaluation de la valeur des paysages autochtones

La principale contribution théorique et conceptuelle de cette recherche est le cadre d'évaluation de la valeur des paysages autochtones développé dans le Chapitre II. De plus en plus de recherches s'intéressent non seulement aux valeurs instrumentales et d'existence des écosystèmes, mais aussi à la valeur qui émane de la relation qu'entretiennent les personnes avec la nature (Bieling *et al*., 2014; Brown et Raymond, 2007; Chan *et al*., 2018). Les valeurs dites relationnelles se trouvent d'ailleurs aux côtés des valeurs instrumentales (ou utilitaires) et d'existence dans le cadre conceptuel de l'IPBES (Díaz *et al*., 2015) et font l'objet d'un intérêt scientifique croissant (e.g. Klain *et al*. 2017, Muradian et Pascual 2018, Stenseke 2018). Les pratiques de paysage, à la base du modèle développé dans cette thèse, en sont des manifestations tangibles et mesurables.

Les quatre dimensions de la valeur des paysages ont montré leur robustesse et leur adaptabilité au cours de la thèse. Énoncées en début de projet, les quatre dimensions ont été présentes et structurantes pour toute la thèse. Une conception multidimensionnelle de la valeur des paysages est cohérente avec les approches utilisées par Brinkman *et al*. (2013) pour évaluer la disponibilité de l'orignal en Alaska selon l'accès et l'abondance. Elle rejoint également le cadre proposé par Thompson *et al*. (2020b) qui décrit les variables d'abondance, d'accessibilité et de qualité suivies par les pêcheurs de la Nation Gitga'at en Colombie-Britannique.

Le cadre d'évaluation de la valeur des paysages pourrait être appliqué à d'autres contextes, autochtones ou non, dans la mesure où la relation au territoire y est façonnée par des pratiques qui contribuent au mode de vie, à la culture et à l'identité (p. ex. paysages ruraux en Europe (Bieling *et al*., 2014), propriétaires riverains au Wisconsin

(Stedman, 2003). L'ensemble des pratiques peut être modulé pour inclure par exemple la chasse au caribou en contexte innu sur la Côte-Nord du Québec (Bellefleur, 2019) ou Tłı̨chǫ aux Territoires du Nord-Ouest (Morarin, 2020), ou la chasse aux mammifères marins chez les Inuit (Dale et Armitage, 2011; Huntington, The Communities of Buckland Koyuk, Point Lay, et Shaktoolik, 1999).

6.4 Contributions méthodologiques

B) Utilisation de modèles DPSI pour exposer et comparer les perspectives autochtone et scientifique

Le développement de nouvelles méthodes a été nécessaire pour mettre en commun et comparer les perspectives autochtone et scientifique (Chapitre III). L'approche du double regard, qui s'appuie sur la complémentarité des perspectives, est de plus en plus utilisée pour guider les devis de recherche en contexte autochtone (p.ex. Bartlett *et al*. 2012, Onwu et Mufundirwa 2020, Rayne *et al*. 2020, Reid *et al*. 2021). Toutefois, il n'existe que peu d'exemples d'une application tangible et empirique du double regard en sciences de l'environnement (Abu *et al*. 2019). Le développement d'une méthode pour comparer et faire interagir les perspectives autochtone et scientifique a donc été nécessaire. Deux modèles conceptuels de type Driver Pressure State Impacts (DPSI) ont été développés, l'un alimenté par les savoirs des experts autochtones de l'utilisation du territoire, l'autre par une analyse bibliométrique de la littérature scientifique.

L'utilisation de modèles conceptuels pour comparer des perspectives peut être appliquée à d'autres contextes (Argent *et al*., 2016; Delgado *et al*., 2009). Cependant, l'environnement doit être propice à une telle approche. Dans le contexte de nos travaux, les communautés autochtones étaient désireuses de s'engager dans la recherche collaborative et la mise en commun des savoirs. De plus, la recherche scientifique sur les écosystèmes boréaux est abondante, notamment en raison des industries extractives des ressources naturelles qui y occupent un pan important de l'économie (Brandt *et al*., 2013; Musetta-Lambert *et al.*, 2019). Les environnements côtiers, dont plusieurs sont habités par des peuples autochtones et étudiés pour la gestion des ressources halieutiques, seraient de bons candidats pour répéter l'exercice (Alexander *et al.*, 2019; Dam Lam *et al.*, 2019).

C) Mise en commun de simulations et de jugements d'experts dans un réseau bayésien

Les réseaux bayésiens ont été utilisés par le passé pour mettre en commun les savoirs autochtones et scientifiques (Girondot et Rizzo, 2015; Liedloff *et al.*, 2013; Mantyka-Pringle *et al.*, 2017). La modification de méthodes existantes et le développement de nouvelles méthodes ont été nécessaires pour permettre les interactions entre les systèmes de connaissances. D'abord, les projections des paysages forestiers, habituellement utilisées pour répondre à des questions de recherche en écologie (e.g. Tremblay *et al*. 2018, Cadieux *et al*. 2020, Boulanger et Puigdevall 2021), ont été regroupées par terrain de trappe puis traitées pour en dégager des variables de composition et de structure cohérentes avec la perspective autochtone (Chapitre III). La représentation des états potentiels d'un terrain de trappe sous la forme de cartes schématiques ainsi que le design d'élicitation de probabilités conditionnelles qui y est associé sont une innovation méthodologique de cette recherche. Aussi, l'intégration des projections générées par LANDIS-II dans un réseau bayésien a nécessité le développement de méthodes statistiques et informatiques pour générer des calculs de probabilité itératifs et pour calculer des intervalles de confiance.

La méthodologie développée pourrait être appliquée à d'autres communautés autochtones en zone boréale, d'autant plus que le modèle LANDIS-II est maintenant paramétré pour pratiquement l'ensemble de la forêt boréale commerciale au Québec (Boulanger et Pascual Puigdevall, 2021) et dans d'autres provinces canadiennes (p. ex. Steenberg *et al*. 2013, Cadieux *et al*. 2020). Aussi, la méthode d'élicitation développée pourrait être utilisée pour faciliter la prise en compte des savoirs écologiques autochtones en écologie. Les statistiques probabilistes (bayésiennes) offrent un grand potentiel en ce sens, parce qu'elles permettent la mise en commun des diverses sources d'information pour l'estimation d'un paramètre, sous la forme de distributions de probabilités (Bélisle *et al*., 2018). La méthode d'élicitation pourrait être affinée pour mieux mesurer le niveau d'expertise des participants et pondérer les estimations conséquemment et pour mieux prendre en compte les biais en ajoutant des questions de calibration au design d'élicitation (O'Hagan *et al*., 2006).

6.5 Contributions empiriques

D) Base de données qualitatives sur la valeur des paysages

Les entrevues semi-dirigées, les exercices de cartographie participative et les analyses thématiques menés en début de projet ont généré une base de données qualitatives sur la valeur des paysages et ses déterminants (Chapitre II). La particularité de cette base de données est qu'elle accueille une diversité de dimensions, tangibles et intangibles. De nombreuses études menées en contexte autochtone se sont attardées à une ou à quelques valeurs (ou services) ciblées, comme l'abondance de l'orignal (Jacqmain *et al*., 2008; Tendeng *et al*., 2016), l'occurrence du pin blanc comme espèce culturelle clé (Uprety *et al*., 2013), la salubrité du gibier à proximité des fonderies (Bordeleau *et al*., 2016) ou l'abondance des animaux à fourrure (Suffice *et al*., 2017). Dans cette recherche, nous avons documenté la valeur des paysages associée à des pratiques qui rejoignent à la fois les aspects tangibles de la relation au territoire, comme l'approvisionnement en nourriture et en matériel pour l'artisanat, mais aussi des aspects immatériels comme la transmission des connaissances et le ressourcement .(Basile *et al*., 2017; Chan *et al*., 2012; Saint-Arnaud, 2009).

La principale limite rencontrée dans la description de la valeur des paysages autochtones est la faible représentation des femmes parmi les participants. Malgré des mises au point des méthodes et critères de recrutement au cours des collectes de données, les femmes ont été peu nombreuses à participer à l'étude. Les perspectives des femmes autochtones sur les changements environnementaux sont différentes de celles des hommes (Femmes autochtones du Québec, 2019, Fuentes *et al*., 2020; Löw, 2020). Leur sous-représentation dans la recherche en sciences de l'environnement et lors des études d'impacts est récurrente et problématique (Alexander *et al*., 2019; Desbiens, 2010; Kennedy Dalseg *et al*., 2018). Des recherches qui abordent la perspective propre aux femmes autochtones sur les changements environnementaux et leurs effets sur le bien-être de leurs communautés sont essentielles afin de compléter le portait (p. ex. McGregor 2008, Basile 2017).

E) Comparaison des perspectives autochtone et scientifique sur les effets des changements environnementaux

La mise en commun de données terrain et bibliométriques (chapitre III) a mis en lumière les convergences et complémentarités entre les perspectives autochtone et scientifique sur les effets des changements environnementaux. Il en ressort des sujets d'intérêts communs et propices à la collaboration comme les effets des chemins forestiers sur la biodiversité, ou encore les effets de la récolte et des traitements sylvicoles sur l'état des sols. Les résultats soulèvent également un déficit de recherche sur les effets des industries minière et hydro-électrique sur les paysages, ainsi que sur les interactions entre les milieux terrestres et aquatiques.

Alors que les convergences et complémentarités identifiées concernent principalement la zone d'étude et dans une certaine mesure le Québec boréal, les constats plus généraux s'appliquent à l'ensemble de la recherche en contexte autochtone. Ainsi, la perspective autochtone des changements environnementaux est apparue plus diversifiée et plus intégrée que la perspective scientifique. Une part de cette différence est attribuable à une recherche scientifique encore cantonnée à des silos disciplinaires. Elle fait obstacle à une approche à l'échelle du paysage, interdisciplinaire et intégrée, pourtant nécessaire pour aborder les effets cumulatifs des changements environnementaux. La faible représentation des Autochtones au sein de la communauté scientifique est un autre facteur responsable de l'écart entre les perspectives (Littlechild *et al*., 2021).

F) Portrait de l'état des terrains de trappe

Le Chapitre IV brosse le portrait de l'état actuel des terrains de trappe et expose les dynamiques spatiales des changements environnementaux. La principale contribution empirique de cet article est l'utilisation du terrain de trappe comme unité d'analyse du territoire. Bien que le terrain de trappe soit une échelle cohérente avec la manière dont la vie sur le territoire est organisée dans plusieurs communautés (Ethier et Poirier, 2018; Feit, 2004), peu d'études s'y sont penchées. Les analyses ont révélé que les changements environnementaux varient parmi les terrains de trappe. Ils sont souvent concentrés dans les milieux plus accessibles et les stratégies d'aménagement écosystémique et de conservation tendent à accroître l'écart entre l'état des terrains de trappe au sein d'une même communauté.

La principale limite rencontrée dans la réalisation du portrait de l'état des terrains de trappe a été le manque de données pour plusieurs facteurs d'influence. L'absence de données concernant des facteurs pourtant importants pour les premiers peuples peut s'expliquer par leur exclusion systémique des sphères de décision qui gouvernent les activités de suivi sur le territoire. Plusieurs indicateurs ont été dérivés de données recueillies à d'autres fins. Par exemple, la fréquentation des terrains de trappe a été estimée à partir de la densité de baux de camps de chasse sur les terres publiques et la température de l'eau à partir du chablis dans les bandes riveraines. L'absence de données systématiques sur la qualité de l'eau, la santé des frayères et les parcs à résidus miniers, par exemple, a été un obstacle. L'implication des communautés autochtones dans l'élaboration des programmes de suivi de l'état des paysages boréaux contribuerait à ce que les données disponibles répondent mieux à leurs besoins (Dale et Armitage, 2011; Dam Lam *et al.*, 2019).

G) Projections des effets cumulatifs sur la valeur des paysages

Les projections des effets cumulatifs de la foresterie et des changements climatiques sur la valeur des paysages autochtones sont l'une des principales contributions de ce travail de recherche (Chapitre V). L'approche probabiliste et l'introduction de jugements d'experts autochtones ont permis de considérer des aspects plus intangibles de la relation au territoire, souvent négligés dans ce type d'exercice, comme le ressourcement, l'éducation et l'expérience vécue (Daniel *et al.*, 2012; Klain et Chan, 2012; Plieninger *et al.*, 2015). La comparaison des scénarios de foresterie et de changements climatiques a montré que les changements environnementaux sont en interaction. La combinaison de gradients de changements climatiques et de récolte forestière a mis en évidence l'importance relative de ces deux vecteurs de changement. Alors que la foresterie a des impacts majeurs sur l'ensemble de la région à l'étude, l'ampleur des effets des changements climatiques varie d'une région à l'autre, notamment selon l'activité des feux projetée.

La portée des effets cumulatifs projetés des changements climatiques et de la foresterie est limitée par la variabilité spatiale des effets des changements climatiques sur les régimes des incendies forestiers (Boulanger *et al.*, 2013). Des différences importantes quant aux effets des changements climatiques ont été observées au sein même de l'aire d'étude, le territoire de la Première Nation Abitibiwinni étant moins exposé à une augmentation de la fréquence des feux que celui de la Première Nation d'Oujé-Bougoumou. Les projections pour les terrains de trappe d'Oujé-Bougoumou pourraient être en partie transférables à d'autres communautés dont le territoire est situé en forêt commerciale et dans une zone où l'activité des feux est importante. Pour ce qui est des résultats obtenus pour la Première Nation Abitibiwinni, ils pourraient être applicables à d'autres communautés dont le territoire est situé en ceinture d'argile, donc moins exposées aux feux et avec une valeur commerciale limitée pour l'industrie forestière, comme certaines communautés en Ontario.

Par ailleurs, plusieurs vulnérabilités identifiées, par exemple l'abondance de la martre et d'autres animaux à fourrure, sont associées à la raréfaction des forêts matures, que ce soit à cause du feu, ou à cause des coupes. La raréfaction des vieilles forêts est un enjeu qui concerne l'ensemble de la forêt boréale au Québec (Bergeron *et al*., 2017). C'est surtout la vitesse à laquelle les changements sont anticipés qui varie entre les régions.

Un retour dans les communautés, auprès des participants, sera nécessaire afin de valider et d'approfondir l'interprétation des résultats. Un tel exercice n'a pas été possible jusqu'à présent à cause des contraintes sanitaires en lien avec la pandémie de covid-19, mais est prévu avant la soumission du Chapitre V pour publication.

6.6 Contributions appliquées

H) Outils de visualisation de données et d'aide à la décision

Des outils de visualisation de données spatiales et d'analyse de l'état des terrains de trappe ont été développés en soutien à la décision (Chapitre IV). Les outils sont disponibles gratuitement en ligne[16]. Les requêtes spatiales et les codes pour développer les indicateurs, analyses et outils de visualisation de données sont libres d'accès. Les outils développés ont été conçus pour faciliter la prise en compte de l'échelle du terrain

[16] https://github.com/acbelisle/Hunting-ground-indicators-and-typology

de trappe dans l'analyse de l'état du territoire et pour mieux considérer les transformations antérieures dans les analyses d'impacts.

6.7 Perspectives

Le parcours ayant mené à la réalisation de cette thèse, les résultats obtenus et les limites rencontrées ont permis de dégager de nouvelles avenues à explorer. Les perspectives de recherche et d'application qui ont émergé de ce travail sont discutées pour les domaines de la valeur des paysages, de la recherche en contexte autochtone et des effets cumulatifs des changements environnementaux.

6.8 Valeur des paysages

Les travaux de recherche menés dans le cadre de cette thèse s'inscrivent dans une transition qui est en train de s'opérer dans les sciences de la durabilité. L'économiste Kate Raworth (Raworth, 2017) schématise la durabilité sous la forme d'un beigne. La frontière interne illustre le fondement social de la durabilité et délimite les conditions du bien-être humain (Nussbaum, 2011; Sen, 1979). La frontière externe illustre un plafond écologique (O'Neill *et al*., 2018; Rockström *et al*., 2009). L'aménagement durable du territoire vise la zone entre les deux, décrite comme un « espace juste et sûr » (Raworth 2017 p. 22). La conception de la valeur des paysages autochtones développée dans cette recherche est compatible en plusieurs points avec la proposition de Raworth (2017). La frontière du bien-être pourrait être définie par la capacité qu'ont les familles autochtones à accomplir les pratiques importantes pour le maintien de leur mode de vie, leur culture et leur bien-être (Chapitre II). La frontière des systèmes environnementaux pourrait reposer sur les indicateurs de l'état du territoire (Chapitre IV). L'exploration d'un nouveau cadre d'aménagement durable du territoire, à la lumière de la proposition de Raworth (2017) et des résultats de cette thèse, a été entamée dans un chapitre de livre à paraître.

La portée des résultats de cette recherche est limitée par l'étendue spatiale de la zone d'étude (ouest du Québec boréal) et le petit nombre de communautés partenaires. Elle fournit toutefois un cadre d'analyse de la valeur des paysages qui pourrait s'appliquer à plus grande échelle. La combinaison de l'approche des pratiques de paysage (Chapitre II) et de la structure DPSI (Chapitre III) pourrait être utilisée pour recueillir et mettre en commun les savoirs et enjeux d'autres communautés dans la zone boréale. Des bases de données à l'échelle continentale, souvent alimentées par la science citoyenne, existent en Australie et en Europe notamment (Fagerholm *et al*., 2020; Feldman *et al*., 2021; Kienast *et al*., 2015; Pecl *et al*., 2019). Elles permettent de déceler des phénomènes qui ne sont pas perceptibles à des échelles plus fines comme les déplacements des limites des biomes (Gauthier *et al*., 2015a; Scheffer *et al*., 2012) et les contributions des territoires autochtones à la biodiversité planétaire. Le développement d'une base de données sur les effets des changements environnementaux à l'échelle du biome boréal faciliterait l'échange d'information entre les communautés et permettrait un suivi longitudinal avec une diversité de perspectives autochtones.

6.9 Recherche en contexte autochtone

L'importance du travail collaboratif entre les scientifiques et les communautés autochtones en sciences de l'environnement est de plus en plus reconnue (Ford *et al*., 2016; Rathwell et Armitage, 2015; Tengö *et al*., 2017). Une recherche collaborative réussie génère des connaissances substantielles, légitimes et utiles aux communautés, mais requiert un travail approfondi à la frontière entre les systèmes des connaissances (Blackstock *et al*., 2007; Robinson et Wallington, 2012). Le devis de recherche collaborative développé et peaufiné tout au long de cette thèse peut guider l'élaboration de recherches futures en contextes autochtones. Il s'articule autour de trois étapes clés. D'abord, une analyse qualitative et inductive en début de projet permet d'ancrer la question de recherche dans la réalité terrain. Elle assure la pertinence des étapes subséquentes pour les communautés partenaires. Ensuite, une comparaison empirique et explicite des perspectives des parties prenantes au projet (autochtones et scientifiques pour cette recherche) selon une approche de type double-regard, permet d'identifier les synergies et divergences, de générer des questions de recherche et d'accroître la compréhension mutuelle (Abu *et al*., 2019). Finalement, le développement d'un modèle comme objet frontière lie les systèmes de connaissances et permet la cocréation de connaissances (Mantyka-Pringle *et al*., 2017; Sandström, 2015; Tengö *et al*., 2014).

Quelques éléments facilitant la collaboration sont ressortis de ce travail de recherche. D'abord, une équipe de recherche interdisciplinaire comprenant des chercheurs en sciences naturelles et en sciences humaines, favorise la mise en commun des méthodes (qualitatives et quantitatives) et des approches (géographie, écologie, psychologie cognitive…) (e.g. Liedloff *et al*. 2013, Mantyka-Pringle *et al*. 2017). Ensuite, la disponibilité de personnel dédié à la recherche dans les communautés autochtones partenaires est un facteur de succès (Reid *et al*., 2016). Finalement, la réalisation d'un devis de recherche séquentiel mixte, dont chaque étape repose sur la précédente, requiert un temps qui va souvent au-delà des délais prescrits pour le financement d'un projet de recherche. Des programmations de recherche collaborative prévues et financées sur plusieurs années sont souhaitables.

6.10 Effets cumulatifs des changements environnementaux

Dans une perspective plus appliquée, les résultats de cette recherche fournissent des lignes directrices pour améliorer les protocoles d'étude d'impacts en contexte autochtone. En effet, l'évaluation de l'acceptabilité d'un projet de développement repose sur une étude d'impact qui doit prendre en compte non seulement les effets directs du projet, mais aussi le contexte environnemental dans lequel il s'inscrit. D'abord, l'étude d'impact doit être réalisée à une échelle qui est cohérente avec l'échelle à laquelle la relation au territoire est vécue, comme l'a été le terrain de trappe dans cette étude. Ensuite, l'évaluation de l'état préalable de l'environnement devrait permettre de discerner si le projet s'inscrit dans un contexte d'effets individuels ou cumulatifs. Le type de risque encouru (dépassement de seuil vs basculement vers un type différent) devrait guider l'évaluation de la capacité des familles à s'adapter et la mise en place de mesures de mitigation et de compensation adéquates (Chapitre IV). Finalement, l'étude d'impacts doit considérer les changements environnementaux projetés, notamment dus à la foresterie et aux changements climatiques (chapitre V). Elle devrait statuer si les impacts prévus sont de type :

i. additif, en exerçant par exemple une pression supplémentaire sur les forêts matures;
ii. compensatoire, par exemple en permettant la renaturalisation de paysages perturbés;
iii. multiplicatif, par exemple en se superposant à des lieux déjà affectés par une coupe ou un incendie forestier

D'autre part, cette recherche a souligné la capacité des familles autochtones à s'adapter aux changements qui ont cours sur leur terrain de trappe. La capacité adaptative dépend non seulement du niveau d'exposition aux changements environnementaux, abordé dans cette recherche (Chapitre V), mais aussi de facteurs culturels et sociaux (Adger *et al*., 2009, 2013; O'Brien *et al*., 2007). On en connaît encore peu sur les stratégies mises en place par les familles pour faire face aux changements qui ont cours sur leur terrain de trappe. Des recherches futures pourraient documenter ces stratégies et déterminer les actions à mettre en place pour les soutenir.

Enfin, même si les changements environnementaux sont une menace significative à la valeur des paysages autochtones, des opportunités pourraient s'en dégager. Cette recherche a, d'une part, montré l'ampleur de l'influence de la foresterie sur l'état des paysages boréaux, tant depuis une perspective autochtone que scientifique. D'autre part, les changements climatiques, tendront vraisemblablement à diminuer la valeur commerciale des forêts d'ici quelques décennies dans plusieurs régions (Boulanger et Pascual Puigdevall, 2021; D'Orangeville *et al*., 2018; Price *et al*., 2013). Alors que l'industrie forestière pourrait perdre de son influence sur les paysages boréaux, des valeurs alternatives à la récolte forestière pourraient être appelées à occuper une plus grande place dans la gouvernance et l'aménagement du territoire. Les experts des communautés autochtones trouvent une valeur non seulement dans les forêts dites productives, mais aussi dans les brûlis, forêts en régénération et landes à lichens. Au-delà de la menace et du défi d'adaptation, les changements environnementaux doivent constituer une opportunité pour les communautés autochtones de jouer un rôle prépondérant dans la redéfinition de la valeur des paysages boréaux.

6.11 Mot de la fin

Cette thèse est l'aboutissement de travaux qui ont mobilisé de nombreuses personnes de la communauté scientifique et des communautés autochtones. L'approche collaborative adoptée a fourni un contexte d'apprentissage riche tant du côté humain qu'académique. Il en est ressorti non seulement une compréhension plus large des effets des changements environnementaux sur la valeur des paysages autochtones, mais aussi une communauté de travail aux expertises diversifiées qui pourra, je l'espère, perdurer.

Au-delà des perspectives de recherche et d'application, quelques messages plus spécifiques s'adressent aux aménagistes forestiers du gouvernement du Québec et de l'industrie, aux communautés autochtones et à la communauté scientifique.

Aux aménagistes forestiers, une diminution de la possibilité forestière (et conséquemment du taux de coupe) contribuerait non seulement à accroître la durabilité de l'aménagement forestier face aux changements climatiques, mais allongerait aussi le temps disponible pour que les communautés autochtones puissent s'adapter. Nos résultats indiquent également que l'échelle du terrain de trappe devrait être considérée en amont de la planification forestière, avec ses propres indicateurs et seuils à ne pas dépasser.

Aux communautés autochtones, des changements environnementaux sans précédent se produiront vraisemblablement dans les prochaines décennies. Les brûlis, forêts jeunes et feuillues et landes à lichen seront vraisemblablement de plus en plus présents sur le territoire. La mise en valeur des savoirs détenus au sein des communautés sur ces écosystèmes est une stratégie d'adaptation prometteuse. Aussi, les outils d'aide à la décision devront être mis à jour au fur et à mesure de la transformation du territoire et de la disponibilité de nouvelles données pour demeurer utiles et pertinents.

À la communauté scientifique, les travaux de recherche présentés dans cette thèse ont mis en évidence un écart important entre les perspectives autochtone et scientifique sur le territoire. Pour combler cet écart, l'adoption d'une approche interdisciplinaire, collaborative et à l'échelle du paysage est préconisée. Des partenariats de recherche à long terme, soutenus par des programmes de financement conséquents, contribueraient à ce que les besoins et questionnements des communautés soient davantage pris en compte dans la recherche scientifique.

ANNEXE A

CERTIFICAT ÉTHIQUE ET FORMULAIRES DE CONSENTEMENT

Référence : 2016-04 – Asselin, H.

UQAT
UNIVERSITÉ DU QUÉBEC EN ABITIBI-TÉMISCAMINGUE

Comité d'éthique de la recherche avec des êtres humains

Certificat attestant du respect des normes éthiques

Le Comité d'éthique de la recherche avec des êtres humains de l'Université du Québec en Abitibi-Témiscamingue certifie avoir examiné le formulaire de demande d'évaluation éthique du projet de recherche et les annexes associées tels que soumis par :

Pr Hugo Asselin

Projet intitulé : *« Résilience des communautés autochtones aux impacts cumulatifs de l'exploitation des ressources naturelles et des changements climatiques dans le Québec boréal »*

Décision :

☒ Accepté

☐ Refusé : Suite aux dispositions des articles 5.5.1, 5.5.2 et 5.5.4 de la Politique d'éthique de la recherche avec des êtres humains de l'Université du Québec en Abitibi-Témiscamingue

☐ Autre :

Surveillance éthique continue :

Date de dépôt du rapport annuel : 12 avril 2018

Date de dépôt rapport final : À la fin du projet

Les formulaires modèles pour les rapports annuel et final sont disponibles sur le site web de l'UQAT : http://recherche.uqat.ca/

Membres du comité ayant participé à cette évaluation :

Nom	Poste occupé	Département ou discipline
Marguerite Mowatt-Gaudreau	Représentante communautés autochtones	
Saïd Echchakoui	Professeur	UER sc. de la gestion
Mélanie Chartier	Représentante de la communauté	
Judy-Ann Connelly	Étudiante	UER sc. de la santé
Saïd Bergheul	Professeur	UER sc. développement humain et social
Anaïs Lacasse	Professeure	UER sc. de la santé
Gilles Gendron	Membre versé en droit	
Maria-Lourdes Lira-Gonzales	Professeure	UER sc. de l'éducation

Date : 12 avril 2017

Anaïs Lacasse, Ph.D., présidente du CÉR-UQAT

Pour toute question : cer@uqat.ca

Formulaire de consentement –

Cartographie participative et entrevues semi-dirigées (2016)

FORMULAIRE DE CONSENTEMENT – VOLET C
(ADAPTÉ DES TRAVAUX DE SUZY BASILE)

TITRE DU PROJET DE RECHERCHE : Impacts cumulatifs des changements climatiques et de l'exploitation des ressources naturelles sur la provision des services écosystémiques aux communautés autochtones de la zone boréale.

NOM DES CHERCHEURS ET LEUR APPARTENANCE : Annie Claude Bélisle, étudiante au doctorat en sciences de l'environnement, UQAT; Hugo Asselin, professeur au département des sciences du développement humain et social, UQAT.

COMMANDITAIRE OU SOURCE DE FINANCEMENT : Conseil de recherche en sciences humaines du Canada, Conseil de recherche en sciences naturelles et en génie du Canada, Consortium Ouranos sur la climatologie régionale et l'adaptation aux changements climatiques.

DURÉE DU PROJET : Quatre ans

CERTIFICAT D'ÉTHIQUE ÉMIS PAR LE COMITÉ D'ÉTHIQUE DE LA RECHERCHE DE L'UQAT

PRÉAMBULE

Nous vous demandons de participer à un projet de recherche qui vise à mieux comprendre le lien entre les caractéristiques écologiques de la forêt boréale et la relation avec les utilisations qu'en font les Cris et les Anicinapek. Avant d'accepter de participer à ce projet de recherche, veuillez prendre le temps de comprendre et de considérer attentivement les renseignements qui suivent.

Ce formulaire de consentement vous explique le but de cette étude, les procédures, les avantages, les risques et inconvénients, de même que les personnes avec qui communiquer si vous avez des questions concernant le déroulement de la recherche ou vos droits en tant que participant. Nous vous invitons à poser toutes les questions que vous jugerez utiles aux chercheurs impliqués dans cette recherche.

La recherche proposée s'appuie sur les principes de recherche prescrits dans le *Protocole de recherche des Premières Nations du Québec et du Labrador*.

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BUT DE LA RECHERCHE

Ce projet vise à mesurer et à mieux prévoir les impacts des changements climatiques et de l'exploitation des ressources naturelles sur les paysages boréaux et sur la relation qu'entretiennent les communautés autochtones avec la forêt. Il permettra de développer des outils d'aide à la décision dont pourront se servir les conseils de bande pour évaluer les conséquences de divers projets d'aménagement du territoire.

DESCRIPTION DE VOTRE PARTICIPATION À LA RECHERCHE

Nous souhaitons connaître la valeur que vous accordez aux diverses composantes de votre terrain de trappe pour la pratique de vos activités en forêt. L'entrevue proposée prend une forme semi-dirigée et est couplée à un exercice cartographique. Vous devrez identifier, sur une carte de votre terrain de trappe familial, les lieux que vous considérez les plus importants pour la pratique de certaines activités en forêt, par exemple la chasse, la coupe de bois de chauffage ou l'éducation des enfants. Vous devrez aussi identifier les lieux où la pratique de vos activités traditionnelles est menacée. L'entrevue pourra avoir lieu dans les locaux du conseil de bande ou dans un autre lieu à votre convenance. Les services d'un interprète en cri ou en anicinapemowin seront mis à votre disposition. L'entrevue durera environ 90 minutes et sera enregistrée pour en faciliter l'analyse. Selon votre horaire, l'activité pourra être répartie en plusieurs (deux ou trois) rencontres.

AVANTAGES POUVANT DÉCOULER DE VOTRE PARTICIPATION

Votre participation à ce projet de recherche vous permettra avant tout de vous exprimer sur la valeur et l'importance que vous accordez à votre terrain de trappe familial. Vos perceptions, idées et utilisations de la forêt pourront être mises en commun avec celles des autres membres de la communauté afin de dresser un portrait d'ensemble de la valeur du territoire aux yeux des Cris et des Anicinapek. Vous aurez l'occasion de participer concrètement à un projet de recherche en environnement et de suivre son évolution tout au long de sa durée. Les résultats de l'étude seront mis à la disposition du conseil de bande.

RISQUES ET INCONVÉNIENTS POUVANT DÉCOULER DE VOTRE PARTICIPATION

Le seul inconvénient à participer à cette recherche est le temps qu'il vous faudra consacrer à répondre aux questions et à cartographier votre utilisation du territoire. La durée de l'entrevue semi-dirigée pourrait exceptionnellement être rallongée, avec votre consentement, voire complétée par des moments passés ensemble sur votre terrain de trappe, dans le but de mieux comprendre le lien entre les caractéristiques écologiques de la forêt et les activités que vous y pratiquez.

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ENGAGEMENTS ET MESURES VISANT À ASSURER LA CONFIDENTIALITÉ

Afin d'assurer la pleine confidentialité des renseignements que vous partagerez avec nous, les mesures suivantes seront prises :

- Votre nom ne paraîtra dans aucun document, présentation ou communication;
- Si nous utilisons des parties d'entrevues recopiées textuellement dans une publication ou une présentation, nous utiliserons un code en remplacement de votre nom et nous éviterons de révéler des informations pouvant permettre de vous identifier;
- L'enregistrement et la transcription de l'entrevue permettront de faciliter le travail d'analyse. Les transcriptions (codées) seront remises à votre communauté deux ans après la publication finale des résultats;
- L'équipe de recherche ainsi que l'interprète s'il y a lieu auront accès aux données et ils s'engagent à respecter leur confidentialité;
- Les données seront conservées sous clé, dans le bureau du chercheur principal (Hugo Asselin) situé à l'UQAT, au campus de Rouyn. Les ordinateurs avec lesquels les données seront traitées (Annie Claude Bélisle et Hugo Asselin) sont munis de mots de passe.
- Les données seront conservées cinq ans après le dépôt final de la thèse de doctorat.

INDEMNITÉ COMPENSATOIRE

Une carte de votre utilisation de votre terrain de trappe familial vous sera remise en fin de projet, ainsi qu'une compensation symbolique (cadeau à l'effigie de l'UQAT, par exemple une tasse, un T-shirt, une casquette) en témoignage de notre appréciation pour votre participation à cette recherche.

COMMERCIALISATION DES RÉSULTATS ET / OU CONFLITS D'INTÉRÊTS

Les résultats de cette recherche ne seront pas commercialisés. Les chercheurs certifient ne pas être en conflit d'intérêt, apparent ou réel.

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DIFFUSION DES RÉSULTATS

- Les résultats de la recherche seront vérifiés auprès du conseil de bande de votre communauté avant diffusion.
- Les résultats feront l'objet d'une thèse de doctorat dont une copie sera transmise aux instances cries et anicinape concernées. Une copie de la thèse pourra également vous être acheminée sur demande.
- Les résultats de la recherche seront publiés dans des articles scientifiques.
- Un résumé des principales conclusions sera rendu disponible, en français, en anglais, en cri et en anicinapemowin, à toute personne qui en fera la demande (orale ou écrite). Ce résumé, rédigé en langage clair et accessible, sera également disponible sur le site internet de la Chaire de recherche du Canada en foresterie autochtone.
- Une page web sera alimentée tout au long du projet et pourra être consultée pour connaître les avancements, résultats et activités réalisées.

CLAUSE DE RESPONSABILITÉ

En acceptant de participer à cette recherche, vous ne renoncez à aucun de vos droits ni ne libérez les chercheurs et les institutions impliquées de leurs obligations légales et professionnelles à votre égard.

LA PARTICIPATION DANS UNE RECHERCHE EST VOLONTAIRE

Votre participation à cette recherche est entièrement volontaire. Vous avez le droit de vous retirer de la recherche à tout moment sans préjudice et sans aucune justification de votre part. Il vous suffira d'en informer les chercheurs. Les données vous concernant seront alors détruites, dans la mesure où, devant tenir compte du degré d'avancement de la recherche, il sera possible de retracer les données vous concernant et de les éliminer des documents produits.

Pour tout renseignement supplémentaire concernant vos droits, vous pouvez vous adresser au :

Comité d'éthique de la recherche avec des êtres humains
UQAT
Vice-rectorat à l'enseignement et à la recherche
445, boul. de l'Université, Bureau B-309
Rouyn-Noranda (Québec) J9X 5E4
Téléphone : 1-877-870-8728 # 2252
maryse.delisle@uqat.ca

CONSENTEMENT :

Je, soussigné(e), accepte volontairement de participer au projet « Impacts cumulatifs des changements climatiques et de l'exploitation des ressources naturelles sur la provision des services écosystémiques aux communautés autochtones de la zone boréale».

____

Nom de la participante (lettres moulées)

____________________________ ____________________________

Signature du participant Date

Ce consentement était obtenu par :

____

Nom du chercheur(e) (lettres moulées)

____________________________ ____________________________

Signature Date

QUESTIONS :

Si vous avez d'autres questions plus tard et tout au long de cette recherche, vous pouvez contacter :

Annie Claude Bélisle, 1-877-879-8728, poste 4353, annieclaude.belisle@uqat.ca

Hugo Asselin, 1-877-870-8728, poste 2621, hugo.asselin@uqat.ca

Veuillez conserver un exemplaire de ce formulaire pour vos dossiers.

Formulaire de consentement –

Ateliers d'élicitaiton (2019)

FORMULAIRE DE CONSENTEMENT
ATELIER AVEC LES EXPERTS DE PIKOGAN
IMPACTS DES CHANGEMENTS ENVIRONNEMENTAUX SUR LE TERRITOIRE
25 AVRIL 2019
(ADAPTÉ DES TRAVAUX DE SUZY BASILE)

TITRE DU PROJET DE RECHERCHE : Impacts cumulatifs des changements climatiques et de l'exploitation des ressources naturelles sur la valeur des paysages autochtones en zone boréale.

NOM DES CHERCHEURS ET LEUR APPARTENANCE : Annie Claude Bélisle, étudiante au doctorat en sciences de l'environnement, UQAT; Hugo Asselin, professeur au département des sciences du développement humain et social, UQAT.

POUR CONTACTER L'ÉQUIPE DE RECHERCHE

Annie Claude Bélisle, UQAT
annieclaude.belisle@uqat.ca
1-877-870-8728 poste 4353

Benoît Croteau, Conseil de la Première Nation Abitibiwinni
benoit.croteau@pikogan.com
(819) 732-6591 poste 2314

COMMANDITAIRE OU SOURCE DE FINANCEMENT : Conseil de recherche en sciences humaines du Canada, Conseil de recherche en sciences naturelles et en génie du Canada, Consortium Ouranos sur la climatologie régionale et l'adaptation aux changements climatiques.

DURÉE DU PROJET : Quatre ans

CERTIFICAT D'ÉTHIQUE ÉMIS PAR LE COMITÉ D'ÉTHIQUE DE LA RECHERCHE DE L'UQAT LE : 26 AVRIL 2016

PRÉAMBULE

Nous vous demandons de participer à un projet de recherche qui vise à mieux comprendre le lien entre les caractéristiques écologiques de la forêt boréale et la relation avec les utilisations qu'en font les Cris et les Anicinapek. Avant d'accepter de participer à ce projet de recherche, veuillez prendre le temps de comprendre et de considérer attentivement les renseignements qui suivent.

Ce formulaire de consentement vous explique le but de l'étude, les procédures, les avantages, les risques et inconvénients, de même que les personnes avec qui communiquer si vous avez des questions concernant le déroulement de la recherche ou vos droits en tant que participant. Nous vous invitons à poser toutes les questions que vous jugerez utiles aux chercheurs impliqués dans cette recherche.

La recherche proposée s'appuie sur les principes de recherche prescrits dans le *Protocole de recherche des Premières Nations du Québec et du Labrador*.

BUT DE LA RECHERCHE

Ce projet vise à mesurer et à mieux prévoir les impacts des changements climatiques et de l'exploitation des ressources naturelles sur les paysages boréaux et sur la relation qu'entretiennent les communautés autochtones avec le territoire. Il permettra de développer des outils d'aide à la décision dont pourront se servir les conseils de bande pour évaluer les conséquences de divers projets d'aménagement du territoire.

DESCRIPTION DE VOTRE PARTICIPATION À LA RECHERCHE

Nous faisons appel à vous en tant qu'expert du territoire dans votre communauté. L'atelier d'une journée a pour objectif de connaître votre jugement quant à la valeur d'un terrain de trappe fictif pour y pratiquer diverses activités traditionnelles et culturelles (chasse, pêche, enseignement…). Vous devrez estimer les chances de combler vos besoins pour divers scénarios fictifs de types de forêt et de perturbations du territoire. Les scénarios présentés sont basés sur l'analyse d'entrevues réalisées en 2016 avec les membres de la communauté. L'atelier durera une journée complète (9h00 à 16h30). Un dîner et des collations seront servis.

AVANTAGES POUVANT DÉCOULER DE VOTRE PARTICIPATION

Votre participation à ce projet de recherche vous permettra avant tout de vous exprimer sur la valeur de votre terrain de trappe familial et sur l'importance que vous y accordez. Vos perceptions, idées et utilisations de la forêt pourront être mises en commun avec celles des autres participants afin de dresser un portrait d'ensemble de la valeur du territoire. Vous aurez l'occasion de participer concrètement à un projet de recherche en sciences de l'environnement et de suivre son évolution tout au long de sa durée. Les résultats de l'étude seront mis à la disposition du conseil de bande.

RISQUES ET INCONVÉNIENTS POUVANT DÉCOULER DE VOTRE PARTICIPATION

Il n'y a pas de risque qui découle de votre participation

ENGAGEMENTS ET MESURES VISANT À ASSURER LA CONFIDENTIALITÉ

Afin d'assurer la pleine confidentialité des renseignements que vous partagerez avec nous, les mesures suivantes seront prises :

- Votre nom n'apparaîtra dans aucun document, présentation ou communication. Un animal vous a été attribué (voir l'image sur la page de signature) et fera office de code afin de préserver votre anonymat.

- L'équipe de recherche ainsi que l'interprète s'il y a lieu auront accès aux données et ils s'engagent à en respecter la confidentialité;
- Les données seront conservées sous clé, dans le bureau du chercheur principal (Hugo Asselin) situé à l'UQAT, au campus de Rouyn. Les ordinateurs avec lesquels les données seront traitées (Annie Claude Bélisle et Hugo Asselin) sont munis de mots de passe.
- Les données seront conservées cinq ans après le dépôt final de la thèse de doctorat.

INDEMNITÉ COMPENSATOIRE

Une compensation de 100$ vous sera offerte en guise de dédomagement pour la journée consacrée à l'atelier.

COMMERCIALISATION DES RÉSULTATS ET / OU CONFLITS D'INTÉRÊTS

Les résultats de cette recherche ne seront pas commercialisés. Les chercheurs certifient ne pas être en conflit d'intérêt, apparent ou réel.

DIFFUSION DES RÉSULTATS

- Les résultats de la recherche seront vérifiés par des représentants du conseil de bande de votre communauté avant diffusion.
- Les résultats feront l'objet d'une thèse de doctorat dont une copie sera transmise aux instances cries et anicinape concernées. Une copie de la thèse pourra également vous être acheminée sur demande.
- Les résultats de la recherche seront publiés dans des articles scientifiques.
- Un résumé des principales conclusions sera rendu disponible, en français, en anglais, en cri et en anicinapemowin, à toute personne qui en fera la demande (orale ou écrite). Ce résumé, rédigé dans un langage clair et accessible, sera également disponible sur le site internet de l'UQAT.
- Une page web sera alimentée tout au long du projet et pourra être consultée pour connaître les avancements, résultats et activités réalisées.

CLAUSE DE RESPONSABILITÉ

En acceptant de participer à cette recherche, vous ne renoncez à aucun de vos droits ni ne libérez les chercheurs et les institutions impliquées de leurs obligations légales et professionnelles à votre égard.

LA PARTICIPATION DANS UNE RECHERCHE EST VOLONTAIRE

Votre participation à cette recherche est entièrement volontaire. Vous avez le droit de vous retirer de la recherche à tout moment sans préjudice et sans aucune justification de votre part. Vous ne perdrez pas le droit à la totalité de la somme convenue pour la compensation. Il vous suffira d'en informer les chercheurs. Les données vous concernant seront alors détruites, dans la mesure où, devant tenir compte du degré d'avancement de la recherche, il sera possible de retracer les données vous concernant et de les éliminer des documents produits.

Pour tout renseignement supplémentaire concernant vos droits, vous pouvez vous adresser au :

Comité d'éthique de la recherche avec des êtres humains
UQAT
Vice-rectorat à l'enseignement et à la recherche
445, boul. de l'Université, Bureau B-309
Rouyn-Noranda (Québec) J9X 5E4
Téléphone : 1-877-870-8728 # 2252
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CONSENTEMENT :

Je, soussigné(e), accepte volontairement de participer au projet « Impacts cumulatifs des changements climatiques et de l'exploitation des ressources naturelles sur la valeur des paysages autochtones en zone boréale. »

____

Nom du participant(e) (lettres moulées)

____________________________ ____________________________

Signature du participant(e) Date

Ce consentement a été obtenu par :

____

Nom du chercheur(e) (lettres moulées)

____________________________ ____________________________

Signature Date

QUESTIONS :

Si vous avez d'autres questions plus tard et tout au long de cette recherche, vous pouvez contacter :

Annie Claude Bélisle, 1-877-879-8728, poste 4353, annieclaude.belisle@uqat.ca

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ANNEXE B

GUIDE D'ENTREVUES SEMI-DIRIGÉES ET DE CARTOGRAPHIE PARTICIPATIVE

Annie Claude Bélisle

Guide d'entrevue, été 2016, Ouje-Bougoumou et Pikogan)

Assessment of the link between trapline use and characteristics of the land (English version – Ouje-Bougoumou).

1. Presentation

Objectif	Consigne	Activité du répondant	Activité de l'interviewer
Présenter les chercheurs	*Hi, my name is Annie Claude Bélisle. I am a PhD student at Université du Québec en Abitibi-Témiscamingue. I introduce you (assistant) who will translate if needed.*	Se présenter. Mentionner si une traduction est nécessaire.	
Présenter le projet	*The research project we would like you to participate in was designed by a collaborative team including researchers from UQAT and*	Regarder l'entente de recherche si désiré.	Montre l'entente de recherche.

	representatives from your community (nommer). *The objective is to study the impact of resource exploitation and climate change on the forest and on its value for First Nations. A research agreement was signed between UQAT and your community. You can have a look at it if you want.*		
Expliquer la tâche à accomplir	*The objective of our meeting today is to understand what provides value to your trapline, for you and your family. We will start by reading you a consent form explaining the project and your participation in it. You will have the opportunity to ask any question about the project, your participation and your involvement. If you decide to participate, I will ask you questions about your activities in the forest. You will have to indicate on a map of your trapline the places that you consider important or more valuable for different activities.*	Écouter et assimiler la tâche à accomplir. Observer la carte de l'aire de trappe déposée sur le bureau.	Présente la carte de l'aire de trappe.
c. Inviter le répondant à poser des questions	*Do you have questions regarding the consent form? If you think of other questions, please feel free to ask them at any moment.*	Poser des questions sur le formulaire de consentement ou autres.	Répond aux questions du répondant.
Matériel :			

- Copie de l'entente de recherche - Copie de l'engagement à la confidentialité signée.

2. Lecture et signature du formulaire de consentement

Objectif	Consigne	Activité du répondant	Activité de l'intervieweur
a. Présentation du formulaire de consentement	*The consent form explains what your participation in the project involves and your rights throughout the process. Your signature means that you agree to participate to the research project by taking part to this interview. It is important that you take notice of your rights and the way we will process information you will provide. Would you like to read it yourself or the interpreter to do it?*	Prend connaissance du formulaire de consentement. Utilise un traducteur au besoin.	Présente le formulaire de consentement.
b. Retour sur le formulaire de consentement. Rappel des éléments importants	- *No information allowing to identify you will be communicated to anyone.* - *Information that you will give me will not be shown in their original format. They will only be used for statistical purposes, plotted with all information collected in the community. For example, your specific moose hunting locations*	Pose des questions sur les implications de la participation.	Montre le formulaire d'engagement à la confidentialité.

	will not be shared. Each member of the research team signed a confidentiality engagement, therefore you can rest assured that information you will communicate to me today will remain confidential. - *You can withdraw from the study at any time, even after the signature of the consent form.*		
d. Signer le formulaire de consentement.	*If you agree to participate in this research, please sign the two copies of the consent form. One is for you and I will bring the other one back at the University.*	Signer le formulaire de consentement en deux copies.	Signe le formulaire de consentement et rappelle où trouver les coordonnées d'Annie Claude.
Matériel : Deux copies codées du formulaire de consentement.			

3. Informations sur le répondant

Objectif	Consigne	Activité du répondant	
Recueillir des informations de base sur le répondant	*"The interview will be audio recorded. The record will be kept on this computer protected with a password. Nobody but me and the research team will have access to the record, which will only be used to facilitate note taking and data analysis".*	Répond aux questions	-Démarrer l'enregistreuse (et l'annoncer au participant). -Prendre en note les réponses sur la feuille réponse.

<table>
<tr><td></td><td>Q3.1 Is your main residence in (nommer la communauté)? If not, where is it?
Yes/noQ 3.5 Are you a member of (community)?" If not, what community are you a member of?
Q3.2 For how long have you lived in the community during the last year?
a) Less than a month
b) Between 1 and 3 months
c) Between 3 and 6 months
d) Between 6 and 9 months
e) More than 9 months
Q3.3 Are you a man or a woman?
M/W
Q3.4 How old are you?
a) 18-25
b) 25-34
c) 35-44
d) 45-54
e) 55-64
f) 65 and more</td><td></td><td></td></tr>
<tr><td colspan="4">Matériel:
- enregistreuse numérique
- Une feuille réponse codée</td></tr>
</table>

4. Caractérisation de l'utilisation du territoire et repérage

Objectif	Consigne	Activité du répondant	Activité de l'intervieweur
Présenter le choix des services écologiques	*« We have been working with representatives of your community to identify activities practiced in the forest that are important to community members and that could be jeopardized by climate change or natural resource exploitation. »*	Prend connaissance de la direction que prendront les prochaines questions.	Prend en note les services concernés (réponse oui)
Identification des services dont répondant bénéficie ** ressourcement et legs s'appliquent à tous les répondants.	Q4.b.1 *« Do you practice those activities on your trapline?* *1. Moose hunting* *1) Fishing* *2) Trapping* *3) Goose hunting* *4) Children upbringing/education* *5) Traditional activities (gathering material for art craft… specify)*	Répond par oui ou non pour chacune des activités.	
Identifier le terrain de trappe familial	*Q4.a.1 Which trapline do you use the most? Please point it on the map.*	Identifie son aire de trappe familiale par son numéro et la pointe sur la carte du territoire de la communauté	Valide qu'on travaille avec la bonne trapline et prend en note le numéro sur la feuille réponse.
Mesurer la fréquentation de l'aire de trappe	*Q4.b.3 Generally, how often do you go on your trapline?* *a) Most of the days* *b) 1 to 3 times a week* *c) 1 to 3 times a month* d) *1 to 3 times a year*	Répond a, b, c ou d	Prend en note les réponses sur la feuille réponse.
Matériel : Feuille réponse			

Repérage cartographique

Objectif	Consigne	Activité du répondant	Intervieweur
Se repérer sur la carte de l'aire de trappe.	*« We will work on the paper map as well as on the map displayed on the screen. »* *« Do you understand this map? »* *« What helps you locate yourself? Roads, lakes, rivers? »*	Se repère sur la carte et explique ses repères (pour validation).	Discute de manière informelle pour le repérage.
Matériel - Carte 1:60 000 de l'aire de trappe - Petite carte des aires de trappe de la communauté			

5. Localisation et identification des infrastructures

Objectif	Consigne	Activité du répondant	Activité de l'intervieweur
Localiser les lieux de résidence sur l'aire de trappe.	*Q5.a.1 « Are there places where you live, even if only a few days a year, on your trapline? Can you identify them by placing a house sticker on the map? ».*	Dépose les petites maisons sur la carte.	Présenter les petites maisons au répondant Numéroter les maisons sur la carte. Éditer le shp residence. Valider le positionnement avec le répondant
Communiquer la fonction des lieux de résidence	*Q5.a.2 « Please describe briefly each of these places and their use, for instance an occasional cottage, a house or a hunting camp ».* *Q5.a.3 Would it be possible to relocate if those places became unusable?*	Énonce les fonctions/usages des lieux de résidence identifiés.	S'assurer que le numéro des résidences est mentionné à haute voix lors des explications.
Sources d'eau potable	*Q5.b.1 ."We are now interested in sources of*		S'assurer que le numéro des

	drinking water on your trapline. Please put a blue sticker on the sources of drinking water you use on your trapline." *"Are there some threats to your sources of drinking water? Please show them on the map"*		points d'eau est mentionné à haute voix lors des explications.
Matériel - 10 petites maisons (ou collants) - Collants bleus			

6. Attribution de valeurs aux lieux sur le terrain de trappe *** À répéter pour chaque activité pratiquée selon la réponse à la question 4.b.1

Objectif	Consigne	Activité du répondant	Activité de l'intervieweur
Disposer les jetons	*« For now on we will concentrate on the activity x, Here are 30 green chips representing values granted and 10 red chips representing threats. »* *« You have to display the amount of your choice of green chips on your trapline to indicate locations having a value for the activity x. You also have to display red chips on locations where the activity is threatened.* *e.g : «Identify sites of values for moose hunting. The more chips you put on a site, the more you grant a value for it, or a great quality for moose hunting.»*	Disposer les jetons sur la carte	Distribuer 40 jetons verts et 10 jetons rouges au répondant Inscrire un numéro à côté de chaque pile de jeton Prendre en note le nombre de jetons associé à chaque numéro sur la feuille réponse.

	***Voir les consignes spécifiques à chaque pratique à la fin du document.		
Tracer le contour des zones	*« For each site where you have placed green or red chips, please draw the outline of the location you have identified so that we can recognize its boundaries. »*	Tracer les contours des zones identifiées	- Valider le traçage
Identifier les caractéristiques écologiques et environnementales qui donnent une valeur ou qui menacent les lieux identifiés	*« Please explain the reasons why these places have a special value for you ».*	- Expliquer les valeurs attribuées. *Possibilité de changer la répartition des jetons lors de l'étape des questions ouvertes.	- Les valeurs qui semblent aberrantes ou irrégulières sont questionnées plus en profondeur. - Une attention particulière sera portée aux critères d'accès (routes cours d'eau…) - Prendre la carte en photo à la fin de l'exercice, pour chaque service.
Estimer la variabilité temporelle de la valeur du terrain de trappe familial	*Q6.e.1 « We will compare the current state of your trapline to its state in 2002, at the moment of the signature of the Paix des Braves. Would you say the general value of the trapline for the activity x, since the Paix des Braves, has increased, decreased, or remained the same? »*	Se prononcer sur le changement (+, -, =)	- Prendre en note la réponse codée: +, - ou = sur la feuille réponse.

Mesurer l'expertise du répondant et constituer une banque d'expert.	*Q6.f.0 On a scale from 1 to 10, how would you qualify your expertise lregarding activity x, 1 being really low, 10 being the one with the most expertise in the community? »* *Q6.f.1 Who in your community do you consider an "expert" for the activity x ?*	Autoévaluer son expertise	- Prendre en note l'estimation /10 sur la feuille réponse Prendre en note le nom des experts.
Attribution d'une valeur à l'ensemble de l'aire de trappe.	*Q6.f.2 On a scale from 1 to 10, what value would you attribute to your trapline for activity x. ?*	Évaluation de la valeur de l'aire de trappe pour chaque service.	Prendre en note le score attribué /10 sur la feuille réponse Ramasser les jetons Nettoyer la carte
Matériel : -30 jetons verts - 10 jetons rouges	- crayons à acétate - brosse à tableau		

7. Conclusion

Objectif	Consigne	Activité du répondant	Activité de l'intervieweur
a. Satisfaction générale vis-à-vis de l'état de l'aire de trappe	*Q7.a.1 Finally, I would like you to tell me about the current value of your trapline, on a scale of 1 to 10.* *If not : What would your trapline need to increase its value to your eyes?*	Discussion sur la satisfaction à l'égard de l'aire de trappe	Écoute!
b. retour et validation	*« We have now finished. Do you have questions, comments or doubts to communicate me before we end the interview? »*	Pose les questions qui demeurent.	Fait les changements demandés et les prend en note. Répond aux questions du répondant.

	« Are there details or changes you would like to bring up? »		
c. Boule de neige	*Q7.a.0 Could you tell us if there are other people attending your family trapline whom we should contact for the exercise?* If possible, we would like to make the exercise with women attending the territory. To whom should we talk to?*	Réfère des personnes qui fréquent l'aire de trappe.	Prend en note le nom des personnes référées sur la feuille réponse et établit une stratégie pour entrer en contact avec eux avec le répondant.
d. Contacts	*"You can follow the updates on the project on our Facebook page" "Don't hesitate to contact me or my supervisor for any question, our contact information is at the end of the consent form. " You can also ask Roger Lacroix for questions about the project."*		Montre les coordonnées à la fin du formulaire de consentement.
e. Remerciement	*"Here is a little gift from our team to thank you for your participation".*		Distribution d'un cadeau symbolique à l'effigie de l'UQAT en guise de remerciement. - Incitation à discuter du projet avec toute personne qui pourrait être intéressée à faire le même exercice.

À faire à la fin de l'entrevue :

- Copier les photos dans le dossier approprié et les effacer de la carte mémoire
- Renommer les shapefiles en y ajoutant le code du répondant.
- Entrer les données prises sur la feuille dans la base de données.
- Ranger la feuille de données dans la voiture vérouillée
- Copier l'enregistrement dans le dossier approprié et l'effacer de l'enregistreuse.

Consignes spécifiques aux pratiques :

<u>Moose hunting</u>

«Identify places of value for moose hunting. The more chips you put on a site, the more you grant a value for it»

<u>Goose hunting</u>

«Identify places of value for goose hunting. The more chips you put on a site, the more you grant a value for it»

<u>Trapping</u>

«Identify places of value for trapping. The more chips you put on a site, the more you grant a value for it»

<u>Fishing</u>

«Identify places of value for trapping. The more chips you put on a site, the more you grant a value for it»

<u>Ressourcement</u>

"The next questions regard a little more the value of your trapline in accordance with your feeling about it. "

« I would like you to indicate the places that makes you feel better, or provides you good feelings on your trapline, where you go to recharge your batteries. Again, the more chips you put on a place, the more you grant a value for it»

<u>Child care and education</u>

"Now, I would like you to indicate where are the best places to spend some time with your children on your trapline."

<u>Future generation</u>

"Where are the places you consider important to provide heritage to future generations"

ANNEXE C

PROTOCOLE D'ÉLICITATION

<table>
<tr><th colspan="2">Mot de bienvenue (9h00-9h25)</th></tr>
<tr><td colspan="2">Objectifs
- Établir un environnement de travail agréable
- Informer les participants des objectifs de l'exercice
- Informer les participants de leur rôle d'expert
- Informer les participants de leurs droits (formulaire de consentement, confidentialité)</td></tr>
<tr><td colspan="2">Matériel
- Formulaires de consentement
- Crayons
- Café, thé, lait, sucre
- Tasses</td></tr>
<tr><td>Actions de l'équipe</td><td>Action des participants</td></tr>
<tr><td>Sophie Laliberté (SO):
• Invite les participants à s'asseoir. Avec James, essaie de regrouper les participants du nord et les participants du sud.
• Tour de table de présentation (nom). Sophie-AC et participants /équipe mêlés
• Horaire de la journée
Annie Claude Bélisle (AC) :
• Présentation du projet de recherche.
• Basé sur des entrevues faites avec certains d'entre vous et d'autres membres de la communauté en 2016.</td><td>Se présentent
Prennent connaissance de formulaires de consentement
Font part de leurs questions, réserves, craintes…
Signent le formulaire de consentement.</td></tr>
</table>

<table>
<tr>
<td>

- Objectif : Mieux comprendre et chiffrer l’impact des changements climatiques et de la foresterie sur le territoire – sur les écosystèmes, mais aussi sur vos activités sur le territoire). On parle de chasse, de pêche, d’éducation, de ressourcement, de trappe.

Remerciement + souligner l’importance des savoirs-expertise.

- Discussion sur le consentement.

Éléments du formulaire de consentement

- Votre participation est volontaire
- Vous pouvez vous retirer à tout moment durant et après l’exercices
- Confidentialité des données recueillies : Nous ne partageons que les résultats compilés, personne ne pourra identifier vos propres réponses.
- Numéros de téléphones importants, n’hésitez pas à communiquer avec nous durant l’atelier et après.

Hugo Asselin (Hu) :

- Se présente comme maître du temps
- Présente l’importance de la collaboration entre Pikogan et UQAT.
- Signe le formulaire de consentement

Louis-Joseph Drapeau (LJ) et Julia Morarin (J) :

- S’assurent du bien-être des participants (café, thé, confort…)
- Distribuent les formulaires de contentement et ramassent les formulaires de consentement signés.

</td>
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</tr>
<tr>
<td colspan="2">Entraînement (9h25-9h45)</td>
</tr>
<tr>
<td colspan="2">Objectifs : Exprimer une probabilité et son incertitude en répartissant 10 points dans l’une ou l’autre des cases sur la feuille réponse et en situant son incertitude sur une échelle graphique.</td>
</tr>
</table>

<table>
<tr><td colspan="2">Matériel :
- Cahier du participant
- Estampe à bingo
- Crayon
- PPT- exemple
- Feuille de compilation météo
- Programme de compilation des résultats</td></tr>
<tr><td>Action de l’équipe</td><td>Actions des participants</td></tr>
<tr><td>So :
Présente le cahier du participant :
• Animal (symbole) – Respect de l’anonymat. Il faut retenir son animal qui servira à identifier les réponses d’une même personne.
• Feuilles réponses- numéro de pages – exemple power point.
AC :
• « Quelles sont les chances qu’il pleuve demain? La météo, c’est toujours incertain. C’est pour ça qu’on parle de « probabilité » d’averses. Selon vos connaissances actuelles (saison, vent, meteo media)… vous devez vous prononcer sur les chances qu’il pleuve demain. Distribuez 10 points (chacun une chance sur 10) parmi les deux boîtes. » Montrer l’exemple de 3 chances sur 10 (ou 30 %).
• À quel point est-ce que je suis confiant de ma réponse (sur quelles informations je me base… météo, saison, est-ce que j’ai consulté météo-média). Indiquer sur la feuille réponse.
Hu :
• Guide les participants dans la tâche à accomplir, répond aux question</td><td>Distribuent 10 points dans l’une ou l’autre des cases.
Indiquent leur niveau de certitude sur l’échelle.</td></tr>
</table>

<table>
<tr><td>• S’assure qu’on ne prenne pas trop de retard dans l’horaire et informe le groupe sur le temps restant durant l’exercice.

LJ&J :

• Assistent les participants, s’assurent que la tâche est bien accomplie.</td><td></td></tr>
<tr><th colspan="2">Présentation du matériel (9h45-10h10)</th></tr>
<tr><td colspan="2">Objectifs :

• Former les équipes
• Se familiariser avec les cartes.</td></tr>
<tr><td colspan="2">Matériel :

• Présentation powerpoint
  - Photos et légendes
  - Carte du nord et carte du sud (sans fond de carte)
• Légende</td></tr>
<tr><th>Actions de l’équipe</th><th>Actions des participants</th></tr>
<tr><td>AC :

Présente l’origine des cartes (nord et sud)

So :

Présente les deux régions du territoire (nord et sud) avec la carte et invite les participants à se placer en équipe avec un voisin de la même région).

Présente les cartes sud et nord

- Valeurs moyennes (pas réel)
- Taille : environ 400 km^2 ET 200 km^2
- Eau et tourbières (un peu plus d’eau au nord, beaucoup plus de tourbières)
- Abris sommaires (plus au sud) (pas autochtones, avec un bail)
- Routes principales (en noir)</td><td>Se placent en équipe de deux

Prennent connaissance des cartes.

Communiquent les ambiguïtés et incompréhensions.</td></tr>
</table>

<table>
<tr><td>Réseau routier (on ne mentionnera pas tout de suite la disparition et l’apparition de route selon le scénario). (Transport, roule vite…)

Présentate des types de végétation (photos, classes d’âge, composition) avec le powerpoint et les images.

Hu :

Valide la bonne compréhension des participants individuellement.

Assure le respect du temps.

LJ&J :

Distribuent le cahier du participant et les cartes

S’assurent que les participants comprennent la signification des cartes.</td><td></td></tr>
<tr><td colspan="2">Pause (10h15-10h30) Café, thé, biscuits, dégourdissement.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Test – Quantité d’orignal (10h30-11h15)</td></tr>
<tr><td colspan="2">Objectif : Formuler un premier jugement.</td></tr>
<tr><td colspan="2">Matériel :
- ppt types de forêts
- cahier du participant (légendes)
- cahier du participant (feuille réponse)
- estampe à bingo
- crayon
- ordinateur – modèle de visualisation des résultats</td></tr>
<tr><td>Actions de l’équipe</td><td>Actions des participants</td></tr>
<tr><td>AC/So:

Invitation à évaluer son propre terrain de trappe (ou celui qu’on connaît le mieux) au cours de la dernière année.

• Inscrire le numéro en s’aidant de la carte (p. x du cahier)
• Insister sur la notion de probabilité.. c’est un peu comme si on demandait est-ce qu’il a plut hier.</td><td>Inscrivent le numéro de leur terrain de trappe.

Inscrivent leur évaluation de leur terrain de trappe.

Répartissent les points parmi les 3 cases</td></tr>
</table>

• Description des trois options : Pas de contrainte : Durant la dernière année, mes besoins ont été comblés sans contrainte. Exemple : J'ai eu assez d'orignal pour moi et ma famille. Adaptation : Durant la dernière année, j'ai dû m'adapter pour répondre à mes besoins. Exemple : Changement de période, de technique, de zone de chasse…) Contraintes majeures : Durant la dernière année, ma limite d'adaptation a été dépassée dépassée. Mes besoins n'ont pas été comblés. Exemple : J'ai dû aller chasser en Ontario, mon cousin m'a donné de l'orignal, je n'ai pas mangé autant d'orignal que j'aurais voulu cette année. (exemples tirés des entrevues) • Invitation à placer en ordre de valeur pour la quantité d'orignal. La quantité dépend de l'habitat mais aussi du nombre de chasseur. Ne pas considérer l'accès ou l'expérience, qui seront évalués séparément. **« Pour le scénario x, quelles sont les chances que je réponde à mes besoins durant une année sans contrainte majeures, que je doive m'adapter et que ma limite soit dépassée? Tout à l'heure, vous vous êtes prononcés sur les chances qu'il pleuve demain. De la même manière, veuillez vous prononcer sur les chances qu'un terrain de trappe fictif réponde à vos besoins durant un an. Autrement dit, si j'y vais pendant 10 ans, combien d'années vont être sans contrainte, en adaptation et avec trop de contraintes? »** • Répartition des points pour le scénario le **meilleur (1) (borner)** • Répartition des points pour le scénario le **pire**. **(7)** • Répartition des points pour les scénarios centraux (3-5). • Évaluation de son niveau de certitude (est-ce que j'ai assez d'information pour répondre correctement?). AC :	Situent leur propre jugement par rapport à celui de leurs pairs. Corrigent leur réponse s'ils le souhaitent.

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- Compile les données et projette le résultat
- Analyse les résultats, repère les tendances et les anomalies
- Lance une discussion et rétroaction
  - Différences entre participants
  - Différences Nord-sud
- Invite les participants à corriger leur réponse s'ils le souhaitent.

Hu :

- S'assure qu'il y a dix points et que la répartition est cohérente avec l'ordre.
- Intervient auprès des participants qui auraient « mal » répondu (mauvaise compréhension de l'exercice).
- S'assure du respect de l'horaire.

LJ&J :

- S'assurent qu'il y a dix points et que la répartition est cohérente avec l'ordre.
- Inscrivent les résultats sur la feuille de compilation et les transmettent à AC aussitôt que possible.
- Aident les participants à faire les changements lorsque nécessaire.

</td><td></td></tr>
<tr><td colspan="2">Élicitation Access (été et hiver) (11h15-12h00)</td></tr>
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IDEM original

So / AC:

« L'accès au territoire est un enjeu important qui est influencé par l'aménagement forestier. Les contraintes changent selon les saisons.

<u>Exemples sans contrainte</u> : je peux y aller une fin de semaine, c'est facile, je peux accéder à toutes les parties importantes du terrain de trappe.

<u>Exemples d'adaptation</u> : Je change de moyen de transport, je conduis moins vite, je retarde un peu la saison de trappe, je change mon horaire de travail…

</td><td>

Inscrivent le numéro de leur terrain de trappe.

Inscrivent leur évaluation de leur terrain de trappe.

Répartissent les points parmi les 3 cases

Situent leur propre jugement par rapport à celui de leurs pairs.

Corrigent leur réponse s'ils le souhaitent.

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<u>Exemples de contraintes majeures</u> : Je ne fréquente pas certaines parties importantes du territoire, j'y vais moins souvent, ça coûte trop cher d'y aller…

« Veuillez évaluer votre propre terrain de trappe, au cours de la dernière année pour l'accès en hiver ».

« Veuillez placer les scénarios en ordre de facilité d'accès en hiver (lorsqu'il y a de la neige) »

- Répartition des points (toujours dans le même ordre : meilleur scénario, pire scénario, scénarios mitoyens) selon les chances que l'accès en hiver soit sans contrainte, requiert une adaptation et dépasse la limite d'adaptation.
- Évaluation de l'incertitude… rappeler- **« est-ce que j'ai assez d'informations et de connaissances pour bien répondre. »**

« Veuillez évaluer votre propre terrain de trappe, au cours de la dernière année pour l'accès en été ».

« Veuillez placer les scénarios en ordre de facilité d'accès en été (lorsqu'il n'y a pas de neige) »

- Répartition des points (toujours dans le même ordre… meilleur scénario, pire scénario, scénarios mitoyens)
- Évaluation de l'incertitude… rappeler- **« est-ce que j'ai assez d'informations et de connaissances pour bien répondre. »**

**** On peut faire le retour sur les résultats avant ou après dîner**

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Lunch Tacos !!! (12h00-13h00)

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Élicitation pêche (13h00-13h40)

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IDEM

Quantité (à sauter si on est en retard dans l'horaire)

AC/So : **« Qui va à la pêche (tout le monde va sûrement répondre oui), la ligne ou au filet… Nous nous intéressons maintenant à la quantité de poisson sur le**

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terrain de trappe. La quantité de poisson dépend bien sur de la qualité de l'eau, mais aussi de la quantité de pêcheurs. »

Exemples sans contrainte : Il y a en masse de poisson sur mon terrain de trappe.

Exemples d'adaptation : J'ai dû changer d'endroit pour pêcher, j'avais l'habitude de pêcher à la ligne mais quand ça ne mord pas, j'installe mon filet…

Exemples de contraintes majeures : Je dois aller pêcher ailleurs si je veux du poisson. Mes enfants m'en amènent d'ailleurs parce qu'il n'y a plus assez de poisson chez moi…

« Veuillez situer votre propre terrain de trappe, relativement à la quantité de poisson. »

« Veuillez placer les scénarios en ordre d'abondance de poisson. Il se peut qu'il n'y ait pas de différence entre certains scénarios. L'ordre importe alors peu, vous n'aurez qu'à attribuer le même pointage. »

- Répartition des points selon les chances que le terrain de trappe réponde à mes besoins en termes de quantité de poisson. (toujours dans le même ordre… meilleur scénario, pire scénario, scénarios mitoyens)
- Évaluation de l'incertitude… rappeler- **« est-ce que j'ai assez d'informations et de connaissances pour bien répondre. »**

Qualité

AC/So : **« Au-delà de la quantité de poisson, leur qualité peut changer selon l'état du territoire : »**

Exemples sans contrainte : Les poissons sont gros, sont sains et bons pour ma santé. J'aime la truite, l'esturgeon et le doré. Il y en a en masse!

Exemples d'adaptation : Je préfère la truite, mais quand il n'y en a pas, je pêche le doré. Je mange un peu moins de poisson à cause des contaminants .Je vérifie l'état des poissons que je pêche et je ne mange pas ceux qui sont mal formés ou qui ont une chaire altérée.

Exemples de contraintes majeures : Je ne pêche pas sur mon terrain de trappe. Je n'ai pas confiance en la qualité du poisson, j'attrape juste de la barbotte et j'aime pas ça, les poissons sont trop petits, ça ne sert à rien…

« Veuillez situer votre propre terrain de trappe, relativement à la qualité du poisson. »

« Veuillez placer les scénarios en ordre de qualité du poisson. »

- Répartition des points selon les chances que le terrain de trappe réponde aux besoins de ses occupants pour la qualité du poisson (toujours dans le même ordre… meilleur scénario, pire scénario, scénarios mitoyens)
- Évaluation de l'incertitude… rappeler- **« est-ce que j'ai assez d'informations et de connaissances pour bien répondre. »**

AC : Validation, retour et rétroaction

Élicitation Éducation (13h40-14h10)

Quantité et qualité ensemble

Le territoire est un lieu privilégié pour que les enfants apprennent la culture Anicinape. Ils se familiarisent avec les techniques de chasse, de trappe, d'artisanat, ils développent une relation au territoire, ils apprennent la langue. Nous aimerions savoir dans quelle mesure est-ce que l'état du territoire affecte la qualité de l'environnement éducatif. »

<u>Exemples sans contrainte</u> : J'organise des ateliers pour les jeunes. Il y a tout ce qu'il faut ici, des animaux, la rivière, du bois…

<u>Exemples d'adaptation</u> : J'évite certaines parties du territoire parce que les jeunes n'ont pas à voir les coupes. Il n'y a rien à apprendre dans les coupes. La route est dangereuse, mais les enfants font attention.

<u>Exemples de contraintes majeures</u> : Il n'y a pas les ressources nécessaires pour que les enfants apprennent ce qu'ils ont à apprendre. Ce territoire est trop différent de l'environnement que je connais, je ne saurais pas quoi leur apprendre. C'est trop dangereux ici, j'évite d'amener des enfants.

Consignes : idem que pour les précédents.

Élicitation Trappe (14h10-14h55)

Quantité : en termes de diversité (richesse + abondance). Seulement si on est en avance sur l'horaire.

« Plusieurs animaux sont d'intérêt pour la trappe. La martre et le castor bien sur, mais aussi le lynx, le rat musqué, le lièvre, la loutre… Nous aimerions savoir dans quelle mesure l'état du territoire affecte l'abondance et la diversité des ressources pour la trappe. Pensez à la quantité d'animaux à fourrure en général. On va avoir une question spécifiquement pour la martre ensuite. »

<u>Exemples sans contrainte</u> : Il y a beaucoup d'animaux sur le territoire. Je pose des pièges le long de ma ligne de trappe habituelle et j'attrape toutes sortes d'animaux.

<u>Exemples d'adaptation</u> : Il y a pas beaucoup de martre ni de lynx, mais en masse de castor, alors je trappe le castor. J'ai appris à trapper le pékan y'a pas longtemps parce

qu'il y en a sur ce genre de territoire. J'ai changé ma ligne de trappe de place à cause des coupes.

Exemples de contraintes majeures : Il n'y a pas assez d'animaux sur le territoire. Il n'y a que du castor et je n'aime pas ça. Je ne trappe pas ici.

Consignes : idem que pour les précédents.

Qualité – spécifiquement sur la martre (qualité ici en terme de $$)

« La trappe de la martre a une importance particulière. En plus d'être une activité traditionnelle importante, la fourrure a une valeur marchande un peu plus importante. Nous aimerions savoir le potentiel des différents scénarios proposés pour la trappe (commerciale) de la martre»

Exemples sans contrainte : Je peux trapper la martre ici et ça me fait un revenu d'appoint. J'ai ma ligne de trappe, toujours la même. Mes prises sont assez constantes. Je suis satisfait.

Exemples d'adaptation : Ce n'est pas bon partout pour la martre. J'en attrape un peu, mais je ne peux pas me fier là-dessus pour mon budget. Des fois j'en attrape, des fois pas.

Exemples de contraintes majeures : Je ne trappe pas la martre. Ce n'est pas assez payant pour ce que je peux attraper ici.

Consignes : idem que pour les précédents.

PAUSE (14h55-15h05)

Élicitation ressourcement (14h55-15h25)

Quantité et qualité ensemble.

« Parlons maintenant de ressourcement sur le territoire. Passer du temps sur le territoire permet parfois de se recentrer, de recharger ses batteries, de retrouver son énergie, de se remplir de sentiments positifs. Nous aimerions savoir le potentiel des scénarios à permettre le ressourcement.»

Exemples sans contrainte : Je me sens bien sur le territoire. Chaque fois que j'y vais, je me sens calme et plein d'énergie.

Exemples d'adaptation : Je me sens bien sur le territoire, mais parfois je suis triste quand je regarde les changements et tout ce qui s'y passe. C'est important pour moi d'y passer du temps malgré tout, ça m'aide à me sentir bien.

<table>
<tr><td colspan="2">Exemples de contraintes majeures : Quand je passe du temps sur le territoire, je me sens inconfortable. Je n’arrive pas à me reposer ou à me sentir bien. Je reviens avec moins d’énergie.

Consignes : idem que pour les précédents.</td></tr>
<tr><th colspan="2">Élicitation expérience (15h25-15h45)</th></tr>
<tr><td colspan="2">«L’expérience sur le territoire, positive ou négative, peut être affectée par divers événements. Par exemple, se sentir chez soi, avoir le sentiment de connaître le territoire sur le bout de ses doigts, passer du temps en famille sont des facteurs qui contribuent à une expérience positive. À l’inverse, les conflits entre les utilisateurs, le sentiment de dépossession, l’écart entre l’état du territoire observé et désiré sont des irritants qui affectent négativement l’expérience. Pour les différents scénarios proposés, nous vous demandons de vous prononcer quant aux chances d’avoir une expérience généralement positive durant une année.»

Exemples sans contrainte : Mes expériences sur le territoire sont toujours positives, quoiqu’il arrive.
Exemples d’adaptation : Il y a quelques irritants (autres utilisateurs, foresterie) mais j’arrive à passer par-dessus et à avoir une expérience positive.
Exemples de contraintes majeures : Il y a trop d’irritants. Mes expériences sur mon terrain de trappe sont négatives.
Consignes : idem que pour les précédents.</td></tr>
<tr><th colspan="2">Mot de la fin (15h45-16h00)</th></tr>
<tr><th>Actions de l’équipe</th><th>Actions des participants</th></tr>
<tr><td>S : Remercie les participants, les invite à vérifier si leur cahier est complété. Lance une discussion de retour sur l’activité (orientée sur le format, les thèmes abordés et la constitution de l’équipe d’experts).

H : L’importance des savoirs traditionnels et de la recherche collaborative

Qu’est-ce que vous attendez des projets de recherche

AC : De quelle manière aimeriez-vous qu’on vous communique les résultats (rapport à la communauté, application téléphone, site web, affiches, livrets, film…).

J&LJ : Récupèrent les cahiers et formulaires de consentement. S’assurent que tout est rempli, qu’il ne manque pas de données.</td><td>Expriment comment ils se sentent par rapport à l’atelier

Font des commentaires sur le format (scénarios, cartes, probabilités-bingo…).

Formulent leurs attentes vis-à-vis des projets de recherche (celui-ci et d’autres).</td></tr>
</table>

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