MEETING THE CHALLENGES OF THE UN SUSTAINABLE DEVELOPMENT GOALS THROUGH ETHICAL CARTOGRAPHIC AND REMOTE SENSING PRACTICES

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Introduction

With a review of progress on the United Nations Sustainable Development Goals (UN SDGs) in 2023, there is a strong movement underway to call attention to the stagnation on their progress due to lack of frameworks by which to monitor and assess them. Thus, there are calls for action amid uncertainty. Additionally, the UN Climate Agenda and SDG frameworks have been criticized for lacking cultural sensitivity and applicability to complex environmental problems specific to diverse local and Indigenous populations; with a recurring emphasis on GDP-focused growth, these agendas risk undermining Indigenous peoples' holistic development approaches and ecological sustainability practices. [1] Therefore, a further challenge of the SDG framework—as they are guiding policies designed to support equitable climate change solutions for communities—are that without Indigenous peoples bringing their knowledge to the table, peoples of these worldviews will continue to be "left behind" again and again.

Local and Indigenous Knowledge (IK) systems around the world hold an indelible awareness of human-ecological interaction, and these practicable relationships are a cultural approach to meet accelerating environmental crises; researchers now recognize Indigenous leadership in sustainability practices, and that partnerships with these groups are a missing link to approach global ecological crises. [2] A growing body of research calls for a greater recognition of IK, citizen science, and community engagement as valuable tools for policy in ecosystem management [3] and environmental and cognitive equality.[1] Cartographic methods and Earth Observation (EO) remote sensing satellite data and technologies present a unique opportunity to meet the challenges in grappling with the complexities of meeting the SDGs and the climate crises. Importantly, these research-validated methods are co-designed and participatory practices based in equity and justice.

Cybercartography is a proven transdisciplinary, multi-worldview approach to solve complex environmental problems, as a digital EO and community-based form of participatory mapping. [4,5] Cybercartography has enabled local communities around the world to use EO for identifying environmental problems and enacting practical solutions; [6,7,8,9,10,11,12] it is a technological tool and process uniquely-suited to non-

Western, narrative-based Indigenous knowledge systems that integrates cultural, historical, linguistic, economic, and social data with geographic and cartographic information. [13]

This paper argues for an intentional use of cartography and space-based assets that not only meet global agendas for climate change, but address these issues at local and community levels. These practices work to support local ownership of problems and solutions, equitable access to scientific tools and methods, and participation in the processes and policies in place to meet climate change and environmental justice challenges.

Cybercartography and the Method of Knowledge Co-Production

The Cybercartographic method[4,5] is one of knowledge co-production. The process of knowledge co-production is metacognitive approach to truly holistic and participatory research that involves communities in the development of tools and naming problems and solutions. A shift in recent years toward multi-cultural, transdisciplinary academic research incorporates knowledge coproduction as a just and equitable approach as well as a tool to "calibrate climate change assessment, improve management strategies or ameliorate adaptive responses in the face of global environmental change."[14] Being careful not to blithely romanticize 'resilience' or further extract from Indigenous populations who have suffered many forms of extractivism, these practices instead draw attention to the diversity of conceptualizations of ecological restoration and management and climate change resiliency.

One challenge this work seeks to overcome is the inherent linearity and narrow scope of a solely western science-based, reductionist approach; in terms of ecosystem services, this scope effects the measurable variables of ecosystem health and sustainability. Cultural and spiritual health, wealth, and well-being factors may not be well-constrained or measurable, yet may be relational to, and reflect deeper changes in ecological health and well-being. A truly transdisciplinary, cross-cultural approach to the pressing complexities that comprise the challenges we face in the *Anthropocene* calls for a transformation in thinking.

In 1781, Immanuel Kant published *Critique of Pure Reason* which rocked the world of philosophy (since supported by recent advances in evolutionary biology; e.g., Donald Hoffman) by articulating that human sense perception has not evolved to perceive reality as it is, objectively. Rather, sense perception provides an accurate enough map to navigate reality to meet biological fitness imperatives. This is of relevance to the field of cartography and remote sensing science: these fields are now finding such a revolution. Through the modern history of cartography, maps have been created that help accurately navigate a world as it was through one dominant perspective; in this cartographic revolution, mapping is reflecting a world that is complex, multitudinous, comprised of multiple worldviews. Meeting the urgent need for equitable knowledge exchange in a growing digital knowledge infrastructure may mean that qualitative data—referred to as indirect provisions by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) to include data that is of relational, existential, or spiritual value—must be validated as "authoritative data" that can serve as the basis of meeting complex ecological and climate change-related challenges.

The IPBES 2019 report notes: "Indigenous Peoples and Local Communities, their knowledge and understanding of large regions and ecosystems… inclusion and participation in environmental governance…and positive contributions to sustainability can be facilitated through… improved collaboration". Co-design and co-production models establish community-based expertise, capacity, and information infrastructure. In a co-design approach, there is space for systems and solutions to be guided by other knowledge systems, allowing novel approaches to emerge that integrate higher-level conceptual frameworks for actionable and just capacity-building frameworks.

Knowledge Co-Production and Participatory Approaches and Outcomes

A multitude of case studies and successful implementation of participatory mapping approaches are described in the 2022 International Journal for Geo-Information (IJGI) Special Issue on *Mapping Indigenous Knowledge in the Digital Age*. One study describing a step-wise process of a participatory workshop development and implementation by Andrade-Sanchez and Eaton-Gonza´lez (2019) in working with the Kumeyaay Peoples of Baja California. [6] Workshops of this type are intended to build a team that includes a technical group and the community in a dynamic exchange of knowledge that continues throughout the project. First, the participants developed a community self-diagnosis about natural resources management, conservation and climate resiliency efforts. Second, they identified the main objectives and a community strategic plan to then address the problems. The community was supported in this process by scientists and researchers in the use of cartographic and remote sensing tools and technological platforms. The scientists and community co-developed a Cybercartography participatory mapping approach [15,16,17,18,19] to meet complex community-specific environmental problems; Indigenous leadership was available in critical areas at the intersection of culture and climate change vulnerability. The participatory processes developed in Kumeyaay communities involved the mapping of plant species distribution and assessments of their conservation status which supported community training, mapping of forest pests, and the construction of a Cybercartographic atlas for natural resource management decision-making.

As is key in many of these studies, the local knowledge yielded high-quality data with a 'Systems Mapping' approach—mapping of the relationships among environmental variables and knowledge of their local and broad implications—that resulted in a deeper understanding of the data and actionable mitigation strategies. This understanding incorporates several dimensions into one analysis, including indirect cultural provisions, biodiversity indicators, and local economic stability and resilience. Intrinsic value are indicators that are not well-delineated by western scientific methods, but are nonetheless powerful tools for the management of natural areas, local decision-making, and for adding rich dimensions to solve problems identified by the community.

Cybercartography as a process and practice has been developed at the Geomatics and Cartographic Research Centre (GCRC) at Carleton University over three decades. Their projects include the *Residential Schools Land Memory Atlas; Lake Huron Treaty Atlas;* a Collaborative Visual Repatriation Project with Inuit in Nunavut; and, the *Inuit Sea Ice Use and Occupancy Project*, which involved community youth in conservation while connecting to their elders and conserving culture. Moving beyond consultation and into engagement and participation, the Inuit peoples in Northern Canadian communities began using Sentinel 1 data in low-bandwidth web apps to navigate and monitor sea ice conditions, vulnerable to climate change, for navigation and basic survival. In co-designed apps for custom use, Inuit people used radar satellite data and began making their own observations with and interpretations of the data, having their own classifications of ice and own terminology. Using this data to build the base for the ML algorithms proved to build incredibly reliable datasets that were rich with more than data, but understanding, having relationships of meaning mapped out from interpretations of the satellite data. Cracks and crevices read in the ice charts can map to a multitude of other environmental indicators and multitudinous effects. In a rich complexity that may take current western science methods decades to arrive, IK instead relies on a rich relational knowledge base.

As a proven and powerful tool for integrating narrative-based IK (including intrinsic or spiritual value as well as cultural, historical, linguistic, economic, and social data) with geographic, remote sensing, and cartographic information, Cybercartography works to bridge the digital divide and enhance participation in a global effort for climate change mitigation and resiliency. It can thus be an avenue to meet the challenges posed by the SDGs, bringing radically different understandings of human-nature relations and enabling local communities around the world to use EO for identifying environmental problems and enacting practical solutions. [6,7,8,9,10,11,12] These collaborations build communication channels, bridge data gaps, and enhance remote learning facilitation for Indigenous participants.

There are mechanisms, guiding protocols, validated research methodologies, and successful implementation use-cases to rely upon and to embed intentionally in cartographic practices and remote sensing science.

Discussion: Guiding Principles

The CARE Principles for Indigenous Data Governance were developed in consultation with Indigenous peoples, scholars, non-profit organizations, and governments, as part of the CODATA Data Science working group (Committee on Data of the International Science Council (ISC)). It arose from concerns about secondary use of data and limited opportunities for benefit-sharing. These principles are: Collective Benefit; Authority to Control; Responsibility, and Ethics, and complement the existing data-centric approach of FAIR (Findable, Accessible, Interoperable, Reusable) Guiding Principles for scientific data management and stewardship. It is important to note that these guiding principles were established from the tension that Indigenous communities indicated is present between: protecting Indigenous rights and traditional knowledges, and; supporting open data, machine learning, broad data sharing, and big data initiatives.

The First Nations Information Governance Centre developed the *First Nations Principles of OCAP* (Ownership; Control; Access; Possession). These principles assert that Indigenous communities alone have control over data collection processes in their communities, and that they own and control how this information can be stored, interpreted, used, or shared. As enshrined in UN Declaration on the Rights of Indigenous Peoples, essential to indigenous peoples' rights are self-determination of their economic, political, social and cultural development; those enshrined rights go beyond economic and cultural development, and include real-time knowledge and data in all its forms. It is within the realm of self-determination of Indigenous peoples to have control over naming problems and solutions, as well as over narrative, place names, symbols, and data and its use. OCAP trainings are available at their website and are recommended to ensure ethical cartographic and remote sensing practices.

When working with communities, the ICC Protocols are also recommended. The Inuit of the Circumpolar (ICC) is a registered NGO with consultative status with numerous UN specialized agencies and bodies, and have developed protocols for equitable and ethical engagement. Although written from an Inuit perspective, these protocols have wider applicability, as do the CARE, FAIR, and OCAP principles. The eight ICC Protocols are as follows:

1. Nothing About us Without us
2. Recognise Indigenous Knowledge in its Own Right
3. Practice Good Governance
4. Communicate with Intent
5. Exercise Accountability - Building Trust
6. Build meaningful partnerships
7. Information and Data Snaring, Ownership and Permissions
8. Equitably Fund Inuit Representation and Knowledge

Conclusion

The vision of our ongoing work proposes interdisciplinary and applied research that provides capacity-building opportunities for Indigenous peoples as community land stewards. The democratization of data and tools are crucial in building non-specialist technological capacity, making these tools accessible and community coursework actionable.[10,11] Co-production of knowledge and project co-design methodologies can: 1) allow researchers to make pathways for peoples in the study or managing study areas to gain access, tools, and data sovereignty, building multi-faceted capacities among at-risk communities, and; 2) decentralize western ontologies and pedagogies through the formation of research and climate change solutions through a non-western lens. Might the EO community build in novel approaches that edges us collectively closer to decentralizing western science as a primary way of knowing—as the fundamental mechanism that names problems, indicators, and solutions—to best support co-beneficial systems, given the integration of other knowledge systems? Existing frameworks like the IPBES are an incredibly useful tool: necessary, but not sufficient. They do not go far enough in terms of diversity, ethics, and equality. A growing global Geo-verse, where no one is left behind, requires equitable access, participation in scientific and governance systems, acknowledgement and integration of worldviews and the depth of critical understandings of IK, and adherence to principles and protocols as outlined by communities.

As efforts to achieve environmental and social justice converge, we need to understand how mapping—both as a practice that crosses sectors of society, and as an actionable scientific tool—allows us to understand the connections of all things. In mapping out the connections between deeper meaning and inherent, embedded relationships, we all become map-keepers. We suggest that gesturing toward a truly transdisciplinary and collaborative evolution in our field of western sciences can help meet the challenges of addressing the UN SDGs while also addressing greater cognitive justice.

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