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Mapping Indigenous Knowledge in the Digital Age

Edited by
Romola V. Thumbadoo and D. R. Fraser Taylor

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About the Editors

Romola V. Thumbadoo

Romola V. Thumbadoo is a writer, worked formally in criminal, social and Indigenous justice in Canada (20 years), and at the grass roots level with the Circle of All Nations global eco peace community founded by Late Indigenous Elder William Commanda (20 years). Her MA thesis in Literature examined detribalization in the novels of South African writer Peter Abrahams. Upon return to academia, she completed her PhD thesis entitled "Ginawaydaganuc and the Circle of All Nations: The Remarkable Environmental Legacy of Elder William Commanda" in Geography and Environmental Studies, Carleton University, and undertook further postdoctoral research on his discourse and legacy with particular focus on Indigeneity, cognitive cartography, cybernetics and Cybercartography and photoatlassing in the social media information era. She is CEO of the Circle of All Nations, and a Research Associate at the GCRC.

Interests: indigenous history and culture; Indigenous mapping; cartography; Cybercartography; geo-cybernetics; geospatial Information; tangible and intangible heritage; decolonization, social justice, racism, globalization.

D. R. Fraser Taylor

Dr. D. R. Fraser Taylor is the Chancellor's Distinguished Research Professor, and Director of the Geomatics and Cartographic Research Centre (GCRC), Geography and Environmental Studies, at Carleton University, Ottawa, Canada. A cartographer and award winner of international renown, his current research is focused on developing the field of Cybercartography, which he first defined in 1997. Established in 2003, GCRC undertakes extensive research and publication, technological development of the Nunaliit digital atlas mapping framework, and national and international inter-disciplinary project development with academic institutions, Indigenous communities and others. He supervises postdoctoral and doctoral students, and has edited or co-edited 18 books (most recently, Further Developments in the Theory and Practice of Cybercartography: International Dimensions and Language Mapping and Language Mapping (2019) and Cybercartography in a Reconciliation Community: Engaging Intersecting Perspectives (2019), Developments in the Theory and Practice of Cybercartography: Applications and Indigenous Mapping I (2014).

Interests: cartography; cybercartography; geospatial information processing; geospatial information management; legal and ethical issues; traditional and local knowledge; Indigenous knowledge; community involvement; participatory approaches; human computer interaction; applications in developing nations and the arctic.

Preface to "Mapping Indigenous Knowledge in the Digital Age"

Indigenous mapping is speedily entering the domain of cartography, and digital technology is facilitating the engagement of communities, particularly Indigenous ones, in mapping their own locational stories, histories, cultural heritage, environmental, and political priorities. Increasingly, Indigenous knowledge is being acknowledged as a parallel and equal knowledge system, and the (w)holistic nature of Indigenous mapping, incorporating performance, process, product, and positionality, as well as tangible and intangible heritage, is transforming the conceptual parameters of traditional mapping.

Multimodal and multisensory online maps combine the latest multimedia and telecommunications technology to examine data and support qualitative and quantitative research, as well as present and store a wide range of temporal/spatial information and archival materials in innovative interactive storytelling formats. Researchers are also now examining legal and ethical issues, data sharing, and standards issues concerning what is described as traditional, informal, or community knowledge. There are many ground-breaking mapping initiatives underway with Indigenous peoples across the globe.

This Special Issue explores Indigenous engagement with geo-information in contemporary cartography. The papers show the importance of non-technical issues to both the researchers and communities and their work demonstrates how critical it is to consider the new dimensions in spatial representation that Indigenous thinking introduces.

The guest editors are grateful to the researchers and communities, to the reviewers and to the MDPI ISPRS International Journal of Geo-Information editorial team for the collaboration in the production of this book.

Romola V. Thumbadoo and D. R. Fraser Taylor
Editors

International Journal of Geo-Information

Editorial

Editorial Commentary on the *IJGI* Special Issue "Mapping Indigenous Knowledge in the Digital Age"

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Indigenous mapping is rapidly entering the domain of cartography, and digital technology is facilitating the engagement of communities, particularly Indigenous communities, in order to map their own locational stories, histories, cultural heritage, and environmental and political priorities. Indigenous knowledge is increasingly becoming recognized as a parallel and equal knowledge system, and the holistic nature of Indigenous mapping, incorporating performance, process, product, and positionality, as well as tangible and intangible heritage, is transforming the conceptual parameters of traditional mapping.

Multimodal and multisensory online maps combine the latest multimedia and telecommunications technology to examine data and support qualitative and quantitative research, as well as presenting and storing a wide range of temporal/spatial information and archival materials in innovative interactive storytelling formats. Additionally, researchers are now examining legal and ethical issues, data sharing, and standards issues concerning what is described as traditional, informal, or community knowledge. There are many groundbreaking mapping initiatives underway with Indigenous peoples across the globe.

This Special Issue explores Indigenous engagement with geo-information in contemporary cartography. Its papers demonstrate the importance of non-technical issues to both researchers and communities, and their work demonstrates how critical it is to consider the new dimensions in spatial representation that Indigenous thinking introduces.

A synopsis of a key themes examined in the individual research papers follows, grouped by area of research (South America, United States and Canada).

A Cybercartographic Atlas of the Sky: Cybercartography, Interdisciplinary and Collaborative Work among the Pa Ipai Indigenous Families from Baja California, Mexico (Dominguez) [1]:

This paper examines the pre-existent challenges and distrust experienced in cross cultural and knowledge exchange with Pa Ipai Indigenous Peoples in Mexico; the consequences of a history of deterritorialism, land appropriation, violence and extractive research practices by anthropologists; and the subsequent use of cybercartography as an interdisciplinary methodology to build trust and integrate knowledge in the face of the hyper-fragmentation of current practices in some scientific research. Indigenous mapping includes different semiotic systems: linguistic, visual, spatial and verbal. These dimensions can be understood as multimodal tools, and on the cybercartographic platform, a phenomenon known as syncretism in semiotics occurred in the research: when the names of the stars, songs, narratives, drawings and photographs were recorded on the map, a variety of the different semiotic systems were presented. Consistent with emerging research on cybercartography, the paper notes that it comprises a set of tools and concepts that combine participatory mapping with geographic information systems and multimedia, wherein process is as important as (if not more important than) product. It is also a type of research where problems and problem-solving proposals arise through dialogue between different actors and perspectives, in particular between academics and Indigenous peoples, and it suggests interdisciplinary and collaborative research can become convergent. Here, engagement with young people, already entrenched in the technology of the social media era, and multi-level relationship building with community elders in the creation of a cyber-cartographic atlas on digital technology, is viewed as being located between, through and beyond particular disciplines in a reality composed of multiple levels and dimensions. In this research, we learn that the deployment of spatial and mnemonic skills in traditional Indigenous mapping integrates celestial, social, philosophical, and cosmological elements; this deepened our understanding of heritage, supports youth and community empowerment and sustainability, and adds new research dimensions to international academic collaborations, GIS and multimedia work.

Indigenous Mapping for Integrating Traditional Knowledge to Enhance Community-Based Vegetation Management and Conservation: The Kumeyaay Basket Weavers of San José de la Zorra, México Andrade-Sánchez et al. [2]**:**

As one of several trans-disciplinary initiatives explored in this publication, this paper explores innovative tools for a participatory methodological approach based on the Indigenous community mapping of the Kumeyaay people. This facilitated the empowerment of the community and the integration of local and scientific knowledge to create vegetation management and sustainable conservation actions to support basketmaking. Therefore, this successfully allowed for a plant population analysis and adequate decision-making regarding natural resources management and conservation. An interdisciplinary group of teachers, students and researchers (linked to the master's program in Arid Ecosystems Management (MEZA, for its initials in Spanish) at the Autonomous University of Baja, California) engaged in an iterative, systematic, dynamic knowledge dialogue feedback practice comprised of six phases (preparation, information, training, research, analysis and management) to achieve the objective of building bridges between traditional and scientific knowledge by incorporating mapping, exaltation, analysis, and management and conservation actions.

Participatory Mapping as a Didactic and Auxiliary Tool for Learning Community Integration, Technology Transference, and Natural Resource Management (Eaton et al.) [3]**:**

Further insights and methodologies for participatory mapping with the Kumeyaay community are presented in this paper, emphasizing the critical importance of relationally and respect in the interdisciplinary engagement in Indigenous mapping and conservation. The knowledge dialogue practice already referenced was strengthened by the sustained construction of a learning community approach to ensure participatory data compilation and analysis. In the mapping sessions, instructors and community members jointly engaged in learning, such that the community learned and contributed their knowledge to the development of thematic maps, while the instructors learned and integrated aspects of community culture, including linguistic and cultural expression. Recognizing the diversity and importance of the knowledge of all participants contributed to strengthening collaboration, community self-evaluation and empowerment. The knowledge dialogue exchanges led to (i) concrete results in plant conservation in an arid environment, (ii) the identification and resolution of water/health issues, and (iii) technology transfer (GPS for mapping and field data collection; the creation of printed and digital on-line maps and community cyber atlas story maps). These findings collectively contribute to economic, social, cultural, educational and environmental strengthening.

Traditional Communities and Mental Maps: Dialogues between Local Knowledge and Cartography from the Socioenvironmental Atlas of Lençóis Maranhenses, Brazil (Filho et al.) [4]:

Commencing with the premise that the "map" has always been used to represent inhabited space, communicate, and display paths and routes travelled, researchers note that there are multiple knowledge streams to mapping. While developments in cartographic methods and spatial representations, such as geospatial data sets available in web server maps, have made it possible to expand current mapping systems and trends, the mapping knowledge of local communities, gleaned from Indigenous roots, is critical for survival in a unique geophysical dune zone with extreme physical, geographic and climatic contrasts, particularly in times of economic diversity, emerging tourism and socioeconomic transformation. Researchers deem knowledge sharing as mutually beneficial and scrutinize a sophisticated native guidance (mapping) system, including sensory, memory, ephemeral, cosmic, elemental, sequential toponym signifiers. Cybercartography is operationalized to superimpose geospatial data from different sources and formats on GIS to make spatial relationships explicit and to make interdependencies among geographic phenomena, including Indigenous peoples, comprehensible in geographic analysis, i.e., to unite scientific geo-environmental data and Indigenous mental representations, to provide a comprehensive view of geographical, environmental and social conditions. It is suggested that such cartography can serve as an instrument of planning, understanding and action, both to safeguard the rights of the local residents and in the handling and management of natural resources. It also questions the extent that local communities can engage with the technology for their own benefit.

(Of) Indigenous Maps in the Amazon: For a Decolonial Cartography (Breda) [5]:

Breda examines Indigenous mapping through the lens of decolonial cartography, noting distinctions between the mappings of Indigenous lands, mappings with Indigenous participation, and mappings made by Indigenous people, resulting from distinct cartographic intentions, mapping motives, and representations of spatiality. Her research (re)positions Indigenous peoples as cartographer subjects who possess and produce cartographic/geographic knowledge and questions the Eurocentric legacy of official/academic cartography. Further, she identifies the need to destabilize colonial mapping and pragmatism in order to expand beyond Cartesian knowledge/power conventions and the limitations of myopia via cultural exchange. This trajectory leads to a deeper understanding of the semiotic dimensions of Indigenous mapping, including astronomical knowledge in the linguistic, visual, spatial and verbal mapping practices of a community encoded in history; the architecture of houses; and the organization of villages in material artifacts such as basketry. This requires an expansion of the map concept beyond that graphed in paper. Furthermore, she cautions the motivations of participatory Indigenous mapping, and advocates for an alertness to the originality and authenticity of Indigenous mapping via the cognizant rootedness of colonial pasts in cartography.

Automated Mapping of Historical Native American Land Allotments at the Standing Rock Sioux Reservation Using Geographic Information Systems (Meisel et al.) [6]**:**

Noting that the General Allotment Act of 1887 established the legal basis for the United States to allot individual parcels of tribal land to individual tribal members and sell off remaining "surplus" land, this paper describes the original processes involved in mapping these historical allotments and demonstrates the use of evolving GIS technology to create a custom tool that can take information from tabular-based land descriptions and digital Public Land Survey databases to automatically generate spatial and attribute data of the land parcels. It is argued that the digital allotment mapping using GIS is critical because it provides the cartographic visualization and spatio-analytical capabilities necessary for exploring both the patterns and processes of allotments that are important not only for historical analysis but for investigating and understanding subsequent events and impacts down to the present. This innovative GIS tool was used to auto-map over 99.1 percent of attired lands on the Standing Rock Sioux Reservation and demonstrates its capacity to speedily auto-map other reservations using publicly available spatial databases and land allotment data.

Art and Argument: Indigitization of a Kiowa Historical Map for Teaching and Research (Palmer et al.) [7]**:**

In this paper, an Indigital framework is presented as a way of blending Indigenous knowledge systems with computerized geospatial/GIS systems to support undergraduate education. Here, a particularly historical Kiowa map, created in 1895 by Chál-ko-gái, inclusive of place names and mapped land features and now digitalized, serves to bridge and decolonize current technoscience as students experiment with Indigenous languages, storytelling, symbols, song, dance, calendars or other representations within digital computer environments to examine and interpret them from historical/contemporary angles.

Points on a map become sites for storytelling and analysis, regarding, for example, cultural information, Indigenous ideas, linguistic and semiotic data, pictorial codes, kinship relationships, land allotments etc. Recognizing that all knowledge and information systems change when they become mobile and encounter other people, materials and ideas, the paper argues for the acceptance of multiplicity, reciprocity and bridge building between Indigenous and scientific knowledge, asserting the assumption of ideas of shared power, networking, assemblages, decentralization, trust and collective responsibility. The blended knowledge emergent from such spaces of encounter and exchange presents as an Indigital construct, and Indigenous materials, such as historical maps, are brought back to life and reimagined in university classrooms using digital devices. Indigenous knowledge systems and digital technologies are deemed potentially combinable where the convergent capabilities of the latter interface with the creativity and intent of the student. For example, this entails the transformation of particular information into attribute data, the digitization of historical features as vector models, and the deployment of new coordinate and projection ideas in order to bridge incommensurability and extend counter-mapping and decolonization.

The Importance of Indigenous Cartography and Toponymy to Historical Land Tenure and Contributions to Euro/American/Canadian Cartography (Cole and Hart) [8]**:**

Here, in addition to a chronological examination of historic and contemporary maps, map-related materials, digitized maps and explorers' logs—as well as mapped examples of Native toponymy and territories downloaded from numerous First Nation, tribal, state, provincial, national, university and museum archives and libraries—the researchers affirm that many Indigenous residents were very spatially cognizant of their own lands, as well as neighboring nations' lands, overlaps between groups, hunting territories, populations, and trade networks. They note that, from the start of colonial explorations in North America, European mapmakers relied on Indigenous informants, and there were locations and related information that Indigenous peoples did not reveal. Their paper discusses the relevance of the documentation of toponymy and name-glyphs, and examines contemporary Indigenous mapping in the case of the Sinixt Tribe, who were declared extinct in 1956, but who by 2021, in part via mapping evidence, were affirmed in court as not extinct and with constitutionally protected rights. The combination of historical maps and modern GIS technology is viewed as a means for remapping traditional territories, and supporting the recognition of land rights and access to sacred sites, hunting and fishing.

Mapping Inuinnaqtun: The Role of Digital Technology in the Revival of Traditional Inuit Knowledge Ecosystems (Griebel and Keith) [9]**:**

This paper examines the development of a digital mapping program to document the Inuinnaqtun ecosystem evident in traditional forms of engagement between Inuinnait people, language and land. The authors also aimed to facilitate the continued circulation of knowledge that underlies these relationships, while critically questioning digital technology's ability to represent Inuinnaqtun ontology and exploring the role it can play in facilitating the local relocation of knowledge, objects and relationships dispersed into global contexts. After centuries of geographical isolation and cultural insularity, the Inuinnait of the Central Canadian Arctic transitioned, post-European contact, from cultural synchronicity with a specific environment and ecosystem, including physical engagement, language, beliefs and spirituality attuned to the natural world, to relocation from the rural to urban areas by the mid-1960s with a rapid shift to new materials, technologies, and worldviews. The implications of this post-contact unravelling of the social fabric, leading to inevitable collapse, was already noted in the 1920s. This paper explores the challenges (assimilation, appropriation) and opportunities that digital technology presents to mobilize Inuinnait ecosystems through the preservation and renewal of knowledge, culture, language, heritage. It discusses digital innovations in a Place Names, Thule and Knowledge Bank Atlas project that involves digital reclamation, repository development and renewal in rich detail.

Mapping for Awareness of Indigenous Stories (Pyne et al.) [10]**:**

This article draws on Joseph Kerski's identification of five converging global trends (geo-awareness, geo-enablement, geotechnologies, citizen science, and storytelling) that contribute to the increased relevance of geography in education and society. It examines the spatial perspectives, geotechnologies and digital pedagogy in research and teaching linked to working with students in Italy and Canada, with a particular focus on the analysis of sketch mapping, from interviews with surviving attendees of Canadian Indigenous Residential School, incorporated into the Residential Schools Land Memory (Cybercartogaphic) Atlas. Emerging scholars reflect on sketch mapping undertaken on two primary map-based content management systems, (Nunaliit Cybecartographic Atlas Framework and MEME Multimedia Emergent Mapping for Education) to draw attention to the importance of intercultural literacy and to achieve intercultural reconciliation and geo-, carto- and metaliteracy, (metaliteracy being a concept that refers to the knowledge capacity across disciplinary and other domains). It is suggested that instead of the traditional lecture followed by applied learning, consistent with information acquisition, multimedia learning should be employed as an interactive activity where knowledge is personally constructed and critically reflected on by the learner; this approach to spatial thinking helps to improve surface power relationships and structure problems, seeking answers and expressing solutions within new parameters of critical cartography.

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Article

A Cybercartographic Atlas of the Sky: Cybercartography, Interdisciplinary and Collaborative Work among the Pa Ipai Indigenous Families from Baja California, Mexico

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Abstract: In this article, I discuss how sky mapping was carried out among the Pa Ipai peoples from Baja California in Mexico. This mapping was elaborated through an interdisciplinary study that combined cybercartography, ethnography, cultural astronomy, semiotics, and collaborative work. The central argument of the article focuses on how the cybercartographic sky atlas of the Pa Ipai people responded to the situation and social problems of these communities. Some of these problems are extreme poverty, violence, and conflicts with the Mexican state and the academic world. In this context, the atlas and the collaborative work became tools that created links with indigenous families, especially with the young people. The mapping process also helped to resolve the tensions mentioned above. The article also addresses how the economic and political situation in Mexico has an effect on the preservation of the atlas. Some of the results of this work are that the Pai Ipai atlas allows, conserves, and renews songs, stories, and experiences around heaven. Another remarkable result is that the teenagers have positively received the atlas and the collaborative experience derived from it.

Keywords: cybercartography; sky map; collaborative work; Pa Ipai; indigenous; Baja California; Mexico

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1. Introduction

When I was in the middle of my degree in archeology, around 2003–2004, a book entitled Relatos Pai pai [1] came to my hands. (I spell here the word Pai Pai as it appears in the original title of the book. However, in this text, I will write the word as Paipai since the indigenous communities asked me to do it in that way). This pocket book told stories and myths of the Pa Ipai people, a native indigenous community from Baja California, Mexico, which, according to the back cover, was one of the last hunter–gatherer societies in Mexico. The book caught my attention because it contained some astronomy stories. I thought that this indigenous knowledge had already disappeared in Mexico.

At that time, the professors emphasized how important it was to study the archeology and anthropology of northern Mexico, so I tried to study this region and later I joined to some archaeological projects. The beginning of the war against drug trafficking in 2007 made it very difficult to continue researching in northern Mexico. My colleagues and I moved away for safety.

In 2016, I returned, starting a field work in Baja California with the Pa Ipai people, and I was interested on conducting doctoral research on Pa Ipai astronomy. The objective was to carry out interdisciplinary research that combined semiotics (Semiotics consists on the study of signs and meanings in culture), anthropology, astronomy, cultural astronomy (Cultural astronomy studies how the sky is part of a cultural construction), and cybercartography. From these lines of research, I sought to create a cybercartographic atlas of the Pa Ipai sky.

Despite the expectations and the initial objectives that I had set out for myself, the beginning of the work was a shock. I faced rejection from the community because there was great anger towards anthropologists. There was also fear of strangers as a product of years of violence. Additionally, I assumed that it was no longer true that Pa Ipai people were a hunter—gatherer society.

This article deals with how the initial rejection and the misunderstandings became a source of reflection that led to the development of a collaborative methodological process and in the cybercartographic atlas of the sky Pa Ipai. I also discuss how the contemporary history of Baja California and Mexico had effects on the methodological process.

The main question I am trying to answer is how and why the atlas became a collaborative tool for working with Pa Ipai people. In other words, I want to explain the methodological route followed in its elaboration. As an argument I propose that the atlas built bridges with the Pa Ipai community since its interactive and collaborative characteristics found resonance with the way of life and values of Pa Ipai families, especially among the youngest.

First, I discuss who the Pa Ipai are and where they live. Then, I will raise the background of the research in the region and define cybercartography. The next step is to describe the misunderstandings from which the research started. Then, I explain the celestial atlas and its elaboration. Finally, in the discussion, I interpret and explain the process, as well as the way in which contemporary historical situations shaped it.

2. The Pa Ipai People and the Research in the Region

The Pa Ipai indigenous people are located in the Municipality of Ensenada, in Baja California, Mexico. They are one of the five Yuman groups that inhabit the Baja California peninsula. The Pa Ipai live in the towns of Santa Catarina and Héroes de la Independencia, a town to which they had emigrated for economic reasons. They have also migrated to the cities of Ensenada, Mexicali, Tijuana and Tecate.

They were originally hunter–gatherer fishermen, but currently they are engaged in various activities, such as forestry, handicraft and informal trade. Their language is at risk. During my field work, unlike what INALI (National Institute of Indigenous Languages) (2016) and INEGI (National Institute of Geography and Statistics) [2,3] (2010) report, I found that there were less than 12 fluent speakers of Pa Ipai. Despite this panorama, there are attempts to revitalize it both by the families themselves and by the sporadic and intermittent programs of the Mexican state.

Research in the Region

Gifford and Lowie [4] revealed in the 1920s what the Pa Ipai society was like at the beginning of the 20th century. In this work, the authors revealed the social organization, the belief system and the world of myths of this society.

In the 1930s, Meigs [5] studied the remains of the Santa Catarina Mission as well as the elements that were introduced by the missionaries and the resistance process that culminated in the destruction of the mission. Meigs also constructed a map of the ruins of the mission.

During the 1950s, reports about Santa Catarina were published in Desert magazine. Around this time, Ralph Michelsen worked with Pa Ipai families and made descriptions regarding the collection of the pine nut [6].

In the 1960s, Roger Owen carried out a study about traditional Pa Ipai medicine [7]. This work gives in its first chapter an overview of the life, economy and social structure of families at the end of the 1950s. This work allows us to realize how certain economic activities, such as livestock and agriculture, have almost disappeared among this society. Owen shows how the world of families was already immersed in the modernizing dynamics of the region.

Thus, when reading the pages, we realize how the ranch world, automobiles and the Pentecostal and spiritualist religions were already present and shaped their daily life. At the end of this decade, Owen, Walstrom and Michelsen [8] investigated the renewal processes of Pa Ipai songs. In this decade, Judith Joël also carried out her work on phonology and in the transcription of oral stories [9].

In the 1970s, Mason [10] revealed how the Pa Ipai region of Santa Catarina began to be colonized by the Spanish from the second half of the 18th century, and how it became a strategic space for passage to the territories from the North. In 1994, Garduño wrote a book about the history and ethnography of the Yuman peoples. It is the most comprehensive book on the subject so far. The book includes elements of the history and anthropology of the Pa Ipai families [11].

On the other hand, Everardo Garduño has shown that the identities of indigenous peoples from Baja California have been revitalized and reinvented in a binational context throughout history. Garduño also revealed the existence of four major historical stages: the arrival of the missionaries, the arrival of Mexican ranchers, the arrival of North Americans, and their existence in the 21st century, in which native peoples have built new flexible ethnicities [12].

In 2009, Lee Panich excavated the ruins of the Santa Catarina mission. These excavations evidenced how the arrival of the Dominicans, rather than representing a total displacement of local cultures, represented a process of continuous negotiation in which the inhabitants of the missions conserved their collection, hunting and fishing patterns [13].

Silvia Yee studied contemporary Pa Ipai identity in her Master's thesis, published in 2010. This work also provided a general ethnography that gives an account of the state of the language, the economy, social organization, festivals, religiosity and life cycles. One of the main findings of this thesis was that there are two determining factors in Pa Ipai identity: blood ties and belonging to the town of Santa Catarina [14]. In that same year, Yee published a work on the morphology of Yuman languages, including that of the Pa Ipai [15] (Yee, 2010b).

In the second decade of the 2000s, studies were carried out on Pa Ipai herbalism and local development [16]. In 2015, Ibáñez published a work on the phonology of the Pa Ipai [17].

In the following year, Sánchez carried out a study of the deixis of the Pa Ipai language [18]. In that same year, Nina Martínez's doctoral thesis on Pa Ipai time was also published, in which she discusses contemporary Pa Ipai calendars and seasonality [19]. In 2016, an outreach book for children entitled Pai Pai Numbers and Skies [20] was published. The text explores the Pai Pai numbering system, the lunar calendar and a short story about the constellations.

In 2018, Gerardo Buenrostro published his Master's thesis concerned with how intangible cultural heritage is built among Pa Ipai families as a negotiation strategy [21]. Additionally, in 2018, Ruelas [22] described the processes of coexistence of Pa Ipai music and northern music.

One year after, in 2019, Margarita Parás, Martín Domínguez and Amílcar Morales wrote a text about the indigenous territories of Baja California from a semiotic perspective [23]. Collaborative works are also scarce; however, we have the case of Buenrostro and the ongoing work of Alejandra Velasco on the development of productive projects with Pa Ipai artisans (Velasco, personal communication).

This bibliographic review reveals that the themes of the territory, the sky, technology and young people have hardly been addressed. These four themes, however, are important in this investigation. I realized this during the atlas work with the Pa Ipai families, since I learned that the Earth and the sky are different parts of the same territory. I also realized that technology is a tool for collaboration and that young people are key in this process. These circumstances, as I will relate below, were the context for the development of a cybercartography atlas of the Pa Ipai sky through interdisciplinarity and collaborative work.

3. Indigenous Mapping, Cybercartography and Interdisciplinarity

3.1. Indigenous Mapping in the World and in Latin America

The elaboration of maps, in general, has historically depended on those who possess the resources for their production. Their access was restricted to the population [24], especially to indigenous people. It was not until 1960s when indigenous mapping began in

Alaska and Canada. Its goal was contrary to that of traditional maps and it was sought that these maps became tools to negotiate the rights of indigenous peoples over their lands. Mapping was incorporated into public policy in 1950 in the North Slope of Barrow's Inupiat region of Alaska in order to resolve land-related conflicts. Another project was also developed in the Inupiat region of Cape Thompson. From here, methodologies were derived, such as the map biography, which sought to trace subsistence patterns of individuals through time. This methodology became an official method for land reclamation [25].

In Oceania, South Asia and Latin America, various indigenous mapping projects have been developed in Indonesia, Papua New Guinea, Thailand, Belize, Nicaragua, and Honduras. In these collaborative mappings with indigenous communities, GIS has been incorporated; however, the issue is controversial because there has been a misuse of the term collaborative mapping. This word has been used indiscriminately in environments as diverse as business management, accounting, and conservation, among others [25]. With regard to this, in the discussion of this article, I am going to explain how I define collaborative research.

In Latin America, indigenous maps have played a key role in the recognition of territory and indigenous identity struggles. In this, both the mapping process and the maps themselves have been fundamental; however, it has been the elaboration of the maps that has politicized identity and territorial rights and has contributed to the transmission of the knowledge from the elders to younger generations [26]. The importance of the mapping process is also highlighted by cybercartography and is one of the main themes of this article.

3.2. Cybercartography and Cybercartographic Atlases

Cyber cartography is defined, according to Fraser Taylor, as "the organization, presentation, analysis and communication of spatially referenced information on a wide variety of topics of interest and use to society in an interactive, dynamic, multimedia, multisensory and multidisciplinary format" [27]. In other words, it consists on a set of tools and concepts that combine participatory mapping with geographic information systems and multimedia [28]. The concept of cybercartography has recently been redefined and applied in indigenous and international contexts. Its main product is the cybercartographic atlas.

It is an interactive platform that allows collecting, relating, presenting and preserving information with particular emphasis on maps as a unifying framework. Reflections have begun to revolve around the manufacturing process, rather than the product itself. Finally, emphasis has been placed on how cybercartography summarizes two human characteristics, mapping reality and telling stories [29].

It has also been suggested that cybercartography extends beyond the visuality of traditional cartography and that this methodology proposes the use of all sensory modalities. This allows us to find more efficient, natural modes and to turn on through interactive maps. In the same way, cybercartography not only visualizes, but explores sound and the sense of touch, as it has been proposed by Lean, Lindgaard and Dillon [30].

3.3. Interdisciplinarity

In this article, I propose a knowledge framework for the the cybercartographic atlas based, on interdisciplinarity, which arises from the need to integrate knowledge in the face of the hyper-fragmentation of current science. It is located between, through and beyond the particular disciplines and considers a reality composed of multiple levels and dimensions [31].

It is about transferring concepts, methods and principles, as well as extending beyond the vision of a single discipline. A characteristic of interdisciplinarity is called Modality 2, which consists of a type of research where problems and proposals arise through dialogue between different actors and different perspectives. The dialogue between academics and society stands out especially [31]. This question resonates strongly with the collaborative research proposal. From my point of view, interdisciplinary and collaborative research can become convergent. For this reason, both approaches are used in this work.

I started from an approach in which I used methods and concepts from cultural astronomy, responsible for studying the relationship between the sky, astronomy and human activity [32], ethnosemiotics, understood as the description of the everyday behavior from of semiotic tools [33], and cybercartography, which has already explained above. This work also brought history into the dialogue, as a discipline that studies the past, and ethnography, understood as an experimental history of a present made up of multiple layers of time [34], an issue that implies creating relationships, facing a diverse and multiple network of structures that overlap and intertwine with each other [35]. Also, etnography is about elaborate, observe, create and interpret an empirical reality [36].

4. Elaboration Process

4.1. Difficulties and Misunderstandings

Now, I will start exploring the elaboration process of the Pa Ipai cybercartographic atlas. The ethnographic field work was carried out between 2016 and 2017 with returns in 2018 and 2019. In the first months, I found myself faced with difficulties, such as rejection and silence in the face of my presence and the investigation I was carrying out. I was constantly questioned regarding what I was doing there and what the benefits that the people were going to derive from my presence and research. Keneth, one of the Pa Ipai teenagers with whom I worked, told me that:

> "People are suspicious because other anthropologists have come and taken photos. With them they have made books about the Pa Ipai and they have become rich selling those books in Spain."

As this shows, there is distrust towards the researchers. This rejection is the product of the annoyance of the Pa Ipai people with the institutions of the state, its programs and anthropologists. Anthropologists and institutions are perceived to extract knowledge without giving anything back to the community. Authors, such as Roger Owen [7] and Everardo Garduño [11], have spoken of this rejection of anthropologists and institutions.

The works carried out in the 1950s and 1960s were characterized by extractivism, non-reciprocity, and payment in dollars for the interviews. Even today, there are colleagues on both sides of the border who work along this vein. It should be noted that crafts and language, among other elements, have become a commodity. At the same time, the relationship between anthropologists and social actors has been reified. All of this had an effect on my field work and became a difficulty to overcome since I was associated with this modality of working.

It is felt that researchers and institutions "do not pay what they should" for the information that has been provided to them. This generates very great annoyances that are translated in phrases such as:

> "I no longer work with anthropologists because I don't take anything with me."

This situation of shock and rejection led me to think that I was facing what in ethnography is called misunderstandings or equivocations. An equivocation is a clash, a breaking point between the anthropologist's vision and that of the peoples with whom he works [37] (Viveiros, 2004: 4–5). An equivocation is not just a "a way of behaving or speaking that is not clear or definite and is intended to avoid or hide the truth" [37], but a failure to understand that understandings are necessarily not the same, and that they are not related to imaginary ways of "seeing the world", but to the real worlds that are being seen [38].

Equivocations are also very close to misunderstandings. Anthropologist Michael Taussig points out that" one way of highlighting this is to lay bare what goes on in anthropological fieldwork as a prolonged encounter with others fraught with misunderstandings that actually open up the world more than do understandings" [39]. Thus, for Taussig, misunderstandings in the field reveal more than coincidences.

4.2. Different Visions of Heaven

The mistakes and misunderstandings led me to a systematic methodological and ethnographic reflection with respect to the kind of equivocations I encountered in the field. Viveiros de Castro calls this method "controlled equivocation". This method is based on the review and analysis of the turning points and misunderstandings between the anthropologist and the peoples with whom he works [37]. It is precisely these errors and misunderstandings that lead to the building of bridges and to new understandings of social worlds. In this specific case, this reflection ended up shaping the process of elaboration of the Pa Ipai sky atlas.

One of the misunderstandings I found consisted in my idea of heaven and that of the families. It was a contrast of visions about heaven. While for me the sky was an object of fascination and study, the families saw the sky as something far away, as something that had no direct relationship with them, as something for which there was no time and that it belonged to the past.

However, despite this, the sky appeared at certain specific times, as I will explain, as something that was there latent. This contradiction meant that, throughout the fieldwork, I became more receptive to the interests and needs of families and their relationship with heaven.

Another mistake had to do with my vision, which was centered on my own research and interests about the sky. This vision was alien to local social logic. Rather, these logics focus on family structure and obtaining a livelihood. This structure also seeks for each member to fulfill their social function and to do things "as they should be". Thus, the presence of the anthropologist generates certain ruptures because he does not contribute to the daily sustenance, nor to the family structure. In the section referring to the process of elaboration of the atlas, I explain how these misunderstandings were resolved, but before that, I describe the Pa Ipai sky atlas.

5. Description of the Atlas

The cybercartographic atlas of the Pa Ipai sky consisted of an interactive map of the sky and the territory that allowed to present, relate and preserve knowledge, representations and practices about heaven and Earth, through the use of different senses. It can be found in the following link: https://nunaliitworkshop.centrogeo.org.mx/paipai/index.html?Module=module.skystorymap (accessed on 30 November 2019).

The image on which the atlas is based consists of three levels. Figure 1. It has already published in another text about the study of the territories of the indigenous peoples in Baja California [23]. The first level is the land, in which we find the two coasts of Baja California, the mountainous area, and the towns of Héroes de la Independencia and Santa Catarina; in this dimension, we can also find the sun. In the second level, the moon and other elements of the sky are located. Finally, on the third level are the constellations.

The drawing emerged from the dialogue with the families. It was prepared by the author of this article and summarizes the astronomical knowledge that I found in the field. The drawing was inspired by the style of astronomical drawings that children and families made during the Nunaliit workshop in February 2018.

Each element of the atlas, when touched with the cursor, activates a series of hyperlinks that connect with other documents. These documents consist of audios, songs in Pa Ipai, drawings and photographs about celestial objects. Both the drawings and the photographs were made by the families. The audios are excerpts from the interviews and conversations I had at the end of the fieldwork with the families.

In Figure 2, the scheme summarizes and explains the previous image. First, this diagram allows the audience to visualize the names of each of the elements of the Pa Ipai sky, as well as the three levels in which the image is divided. In the following section, each of the levels of the map is explained, together with the elements that constitute it.

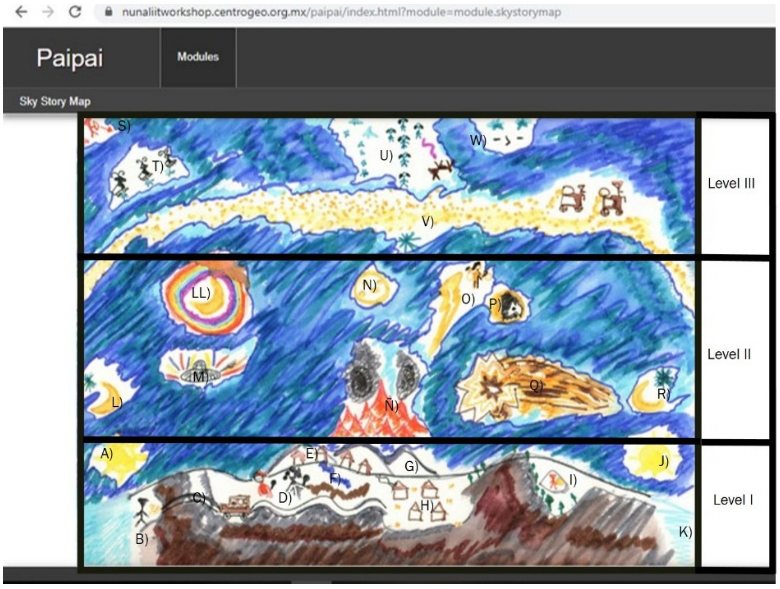

Figure 1. Pa Ipai sky cybercartographic atlas.

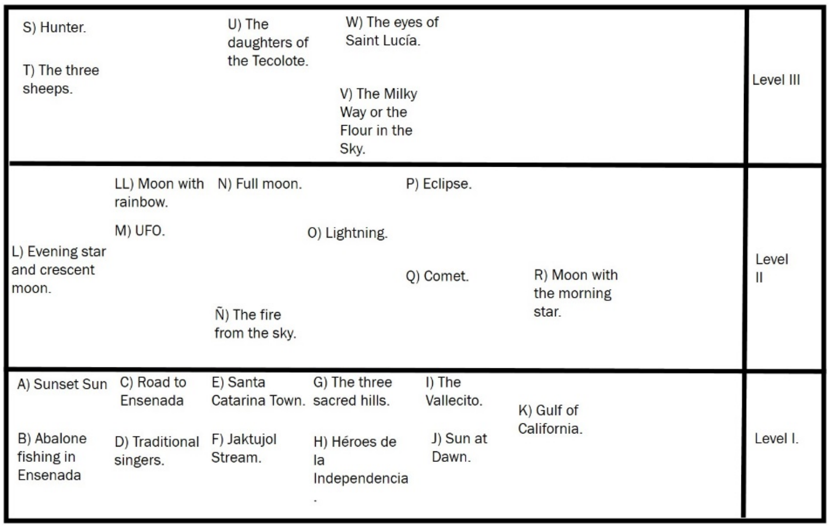

Figure 2. Pa Ipai sky cybercartographic atlas.

5.1. First Level: The Territory

The cybercartographic atlas, in the section corresponding to the territory, graphically summarizes the characteristics of the Pa Ipai territory and their localities. Both Santa Catarina and Heroes of Independence are represented in the atlas. It is precisely because this first section of the atlas summarizes and illustrates the Pa Ipai territory that I proceed to explain and describe it in this section. The aim for the reader to have a clearer image of the territoriality of families, both in the past and in the present.

In this first section, which is in the lower part, Baja California can be seen as well as the sites in the territory that were and still are important for the indigenous families today. On the left side with an A, we have the sunset, then with the B the coast of Ensenada and a drawing of the abalone and shell of Pa Ipai fishers. Letter C is the road that leads to Ensenada. D shows two Pa Ipai traditional singers, E represents the Pa Ipai town of Santa Catarina, F is the Jaktujol Stream that crosses Santa Catarina and G represents the three sacred hills of the Pa Ipai. H is the town of Héroes de la Independencia. The letter I represents the rock art site known as "El Vallecito", letter J represents the sun dawn and the letter K represents the Gulf of California and the San Felipe port.

5.2. Second and Third Level: Heaven

The second and third levels summarize the knowledge of heaven. The letter L represents the evening star and the crescent moon. LL is the moon with a rainbow around it. It represents a phenomenon that is seen as being associated with war. M is an image of an UFO, N is the full moon, and the Ñ represents the story of the day when there was a fire in the sky. O signifies a lightning bolt and a woman with a baby on her back. By clicking on this image, the narration of the myth unfolds, which tells why the lightning bolts sound. P is the representation of an eclipse, characterized by a moon with a coyote's face inside. This image is associated with a drawing with a text about eclipses made by Delfina Albáñez, and there are also narrations about the eclipses that accompany this image. Q is the image of a comet and, to the right of this section, is R that represents crescent moon with the morning star above it.

In the third section, which is located above, we find the asterisms, the Milky Way and the constellations. In the upper left part with the letter S, a hunter in red can be seen, under him it is the letter T, where there are three mountain sheep, both of which are part of a myth about an ancient hunting. In the center marked with the letter U, the daughters of the Tecolote or owl can be seen. They represent another myth about seven girls that found revenge against the Coyote. Marked with the letter W is another asterism, Saint Lucia's eyes. Finally, there is the letter V, which represents the Milky Way or the story of how flour reached the sky.

These celestial elements make up the Pa Ipai astronomical landscape. However, in this work, I am not going to discuss all of them because of restrictions of space. The items that I chose to explore are those about which I obtained more information in the field, but also those that are more accessible. On the other hand, I chose those elements and knowledge that best illustrate the relationship between heaven and Earth.

5.3. Multimodality

The atlas developed here was a multimodal text that combined several semiotic systems to account for the various meanings of the sky. These different semiotic systems were the linguistic, the visual, the spatial and the verbal. These characteristics are linked to what was mentioned by Lean, Lindgaard and Dillon regarding atlases as multimodal tools [30].

At the same time, on this platform, what is called syncretism in semiotics occurred, since when the names of the stars, songs, narratives, drawings and photographs were recorded on this map, a mixture occurred between the different semiotic systems used, as Rosales explains [40].

6. Atlas Production Process

From the dialogue with the families throughout the months of fieldwork emerged a drawing, made by me, and that summarized the astronomical knowledge that I found in the field. The drawing was inspired by the style of astronomical drawings that children and families made during the Nunaliit workshop in February 2018.

The atlas was co-created during several stages. The first was during collaborative work in the field and started from an attempt to resolve the misunderstandings and equivocations. The second stage consisted of the Nunaliit workshop that was held in the city of Ensenada. The third stage was during a one-month work stay at Carleton University of Ottawa in Canada, in May 2018. The last stage took place when I returned again to Heroes of Independence and I presented the map to the teenagers and adults.

6.1. Collaborative Work in the Field and Methodological Resolution of Mistakes

The difficulties and mistakes described above implied the adaptation of the methodological tools, as well as a change in the methodological strategy during the field work. Thus, instead of conducting interviews and proposing the making of drawings as was proposed in the beginning, I began to extensively interact with the families in their daily activities, and I tried to listen, observe and see how it was possible to work collaboratively with the families.

As time went by, the families mentioned some elements that were important to them, such as songs of their grandparents that had been recorded by the National Indigenous Institute in the 1970s and 1980s. These songs had never reached the community. I located these songs in the library of the Commission for the Develop of the Indigenous People in Ensenada; I asked permission to obtain their recording and began with their digitization. Juana Reza, granddaughter of one of the main singers, helped me and edited part of the songs.

Another request was to hold a workshop for the formulation of cultural projects and to request support. Then, I organized a workshop for that purpose. Finally, the young Pa Ipai and their mothers asked me for help with their homework, as well as with English classes. All of these activities contributed to break the initial rejection and building bridges.

Finally, the families posed two questions to me: on the one hand, they showed interest in being able to have a map of the Pa Ipai territories, and on the other hand, the young people expressed their interest in technologies. The cybercartographic atlas that was subsequently produced resonated with these needs and interests.

6.2. Workshop in the City of Ensenada

The workshop took place in the city of Ensenada in February 2018. Although the three Pa Ipai families with whom I worked were invited, only the Albáñez family attended as the other families had activities that prevented them from attending. The workshop was also attended by the Kumiai families from Juntas de Nejí and San José de la Zorra invited by other researchers and who were interested in collaborative mapping.

The objective of the workshop was to introduce the families to the Nunaliit software tool, so that from it they could make maps and atlases of their interest. As can be seen in Figure 3, the main interest of the attendees revolved around how to develop digital maps of their territories, although a part of the sky atlas was also made. This workshop was organized by the Geomatics and Cartographic Research Centre (GCRC) (GCRC, 2021) from Carleton University in Ottawa, Centro Geo (Centro de Investigación en Ciencias de Información Geoespacial, Conacyt, Mexico. https://www.centrogeo.org.mx/) (accesed 28 December 2021), Ciesas (Centro de Investigaciones y Estudios Superiores en Antropología Social, Conacyt, Mexico. https://ciesas.edu.mx/), (accesed 28 December 2021), and Terra Peninsular (TerraPeninsular, NGO from Baja California, México. https://terrapeninsular.org/en/), (accesed 28 December 2021).

Figure 3. Nunaliit workshop in the city of Ensenada. Pa Ipai families during learning how to use the Nunaliit software. Credits: Martín Cuitzeo Domínguez Núñez.

During the field work, the families expressed this interest; however, I could not fulfill them because neither did I have the technological tools nor the knowledge to elaborate this kind of digital maps. The violence in the region was another obstacle that did not allow traveling through the territory of the Pa Ipai and documenting the geographical elements.

Members of the Nunaliit team from Carleton University in Ottawa participated in the workshop. They worked and conducted research with the Inuit in Alaska and made an atlas about Inuit geography, such as the Siku Atlas [41]. This generated special interest among several of the young Pa Ipai women who asked about the work conducted with the Inuit and by the Inuit atlas.

I was in charge of conducting the workshop during the two days it was held. The workshop had several activities. The first was that the participants collectively raised the problems they had in common, but they also raised them in particular. Among these problems appeared the following: garbage, violence, invasion of land, drug addiction, unemployment, lack of opportunities, lack of services (hospitals, internet signal and schools), loss of language and customs, robberies, looting and massacres (Figure 4).

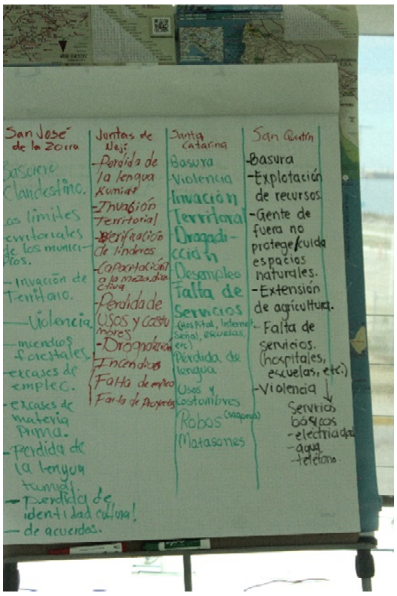

Figure 4. Nunaliit workshop. Enumeration of the problems of the region. Credits: Martín Cuitzeo Domínguez Núñez.

Then, throughout the workshop, the members of the Nunaliit workshop presented the results of the atlases made with the Inuit. For my part, I had to propose and direct some dynamics. One of these dynamics was the rotation in circles. This activity involved the participants forming in two circles. The circles were turning, and the participants introduced themselves to each other. This created trust between the different participants.

Regarding the software and the platform, young Pa Ipai adults, especially the women, showed interest in learning to use the Nunaliit platform. The work that they produced in the first instance was a map of their territory. For this, they located the important geographical points and their names in Pa Ipai. Children and teenagers also participated, although it was more difficult for them than for adults to locate the points on the digital map.

An Inuit video game was presented at the workshop. In it, the challenges and activities were related to Inuit myths and stories. The children were very interested in this video game. It was essentially about an Inuit girl and a white fox that was an Inuit spirit. Together they must overcome obstacles in the middle of the snow. In this context, the teenagers asked how they could learn to play video games.

At the end of the workshop, there were several results. First, we obtained the Pa Ipai geographic maps, where hills, streams, stories and songs were located in Pa Ipai. Another result was the execution of the drawings on the moon, the stars and the constellations (Figure 5). Of special worth was the construction of a list of the names of stars in Pa Ipai.

Figure 5. Nunaliit workshop. Drawing session with adolescents and children. Credits: Gerardo Buenrostro.

6.3. Short-Term Research at the Geomatics Laboratory at Carleton University

Another stage in the elaboration of the atlas consisted of a one-month stay at Carleton University in the Geomatics and Cartography Research Center. During this stage, the programing part and the digital part of the atlas were made. During the stay, I learned basic elements that allowed me to use the Nunaliit platform and to create the interactive maps.

Nunaliit is composed of modules and schematics and is document oriented. In the Nunaliit platform [42], the diagrams are guides and maps that show the way in which the data were collected. Using the platform led me to wonder about the information I had collected and the reason why I had collected it. The more specific question was how I could project the field experience on a map of the sky. The final structure of the atlas was an answer to these questions.

6.4. Atlas Reception

Finally, the last stage was the return to the field and showing the atlas to the families. The interactive features of the atlas were especially interesting to the teenagers who, I must point out, were very interested in the atlas. This is the result of the relationship they have with new technologies, but it is also a consequence of the new construction of their identity as Pa Ipai and young people.

One of the teenagers that was most interested in the atlas was Tatiana, aged 15. After I showed and shared with her the atlas in her aunt's internet cafe, she spent some time interacting with the platform. She also asked me about the use of the platform and its contents. She told me that she did not know some of the stories in the atlas. The platform also had an impact on young adults. Delfina Albáñez encountered the atlas during a visit to Mexico City. She pointed out that she liked the platform and that there were story elements of which she was unaware.

7. Discussion and Interpretation of the Process of Elaboration of the Atlas

7.1. The Atlas as a Collaborative Process

Undoubtedly, an important question to answer in this article is why the atlas became a methodological input for working with Pa Ipai people, especially the youngest among them. The answer, in my view, is related with the entire collaborative process, not only with the atlas itself. In this sense, I must mention again what Taylor pointed out about how recent research in cybercartography focuses on the process rather than on the final product, which is the atlas [29].

The process was collaborative since, from the beginning, the mistakes and the initial rejection led me to reflect from where, for whom, for what and how I was building knowledge about the sky. Leyva precisely points out that these questions are the axis that leads us to a reflective position around non-extractive knowledge production practices [43].

I believe that the process was collaborative because it was conceived as a co-construction of knowledge. In the end, I realize that my initial mistakes contributed to the generation of a dialogue between the social actors and me. Keneth, one of the Pa Ipai adolescents with whom I worked, told me at the end of the investigation that the work was "ours" and that "we were writing it together".

This point allows me to return now to the definition of collaborative research. Andrés Aubry noted that it consists of breaking with the "extractive practice" of anthropology, since only taking "data from a community without returning anything is an intellectual dispossession" [44].

In this regard, both the return of the songs, the workshop on cultural projects and the cybercartographic atlas were a way of returning what learned with the social actors during the field work. In this process, I must point out, there was a transformation both in the social actors with whom I collaborated and in myself and in the methodological procedures. Aubry pointed out in this regard that " ... the encounter of the researcher and the social actor is always transforming, of both and of the observed and analyzed reality" [44].

I return to the question indicated at the beginning of this section, that is, why the atlas allowed us to build bridges especially with the youngest generation. I think this happened because the atlas is an interactive digital format, and being in this medium, it became an attractive language that young people could understand.

Since 2012, when mobile phones arrived in the region, technologies are part of the daily life of the young Pa Ipai. Recently, youths and young adults have started to connect to the internet and become active participants in social media. From this moment on, social media, the internet and the cell phone are tools that allow young people to build and negotiate the representation they have of themselves and their culture in front of others, especially of the identities and daily life of teens and young adults. This happened not only among the Pa Ipai, but also throughout Northern Mexico and in the rest of the country.

Finally, it should be noted that the workshop that took place in the city of Ensenada was understood and interpreted by the families as a return, as an action of reciprocity. Thus, it was within this framework that appeared the drawings of the stars and their names in Pa Ipai and other materials that made up the atlas. It was also in the workshop where the adolescents made their interest in information technology explicit and where their interest in making interactive maps was confirmed.

7.2. Historical Situations and the Elaboration Process

In order to understand and interpret the phases and sequences of the process of making the atlas, it is important to understand the effect of the historical and social situation in Mexico and Baja California today. To this end, I will briefly recapitulate the sequence here so that it can be interpreted. There were four stages:

1. Collaborative work in the field and solution of mistakes and misunderstandings.
2. Carrying out the workshop in the city of Ensenada.
3. Stay in the Geomatics laboratory at Carleton University.
4. Reception of the atlas.

I argue that historical situations in the context of Mexico and Baja California shaped these stages. The first stage, full of equivocations and misunderstandings, is related to the rejection of anthropologists for their extractivism, but it is also linked with the violence that since 1998 has plagued the region. The violence has been provoked by organized crime and drug trafficking [45] and by the militarization of the region, with the presence of a military camp in Santa Catarina. Violence causes strangers to be rejected because they are afraid of people who are not from the community. At the same time, deterritorialization and land theft as well as anger with the different institutions of the Mexican state has contributed to this distancing.

In contrast, the collaborative work that responded to these circumstances is also the effect of changes and transformations in the way of conducting anthropology in Mexico since the indigenous outbreak in Chiapas during the year 1994. The irruption of the indigenous world as a political actor and the claims around indigenous autonomies has changed the relationship of the researchers with the peoples and communities. This has led Mexican anthropologists to develop cooperative work methodologies.

The second and third stages are connected with the cooperation links between academic institutions in Mexico and Canada. Neither the workshop nor the atlas would have been possible without international cooperation, and without funding from the Nunaaliit team.

The reception of the atlas especially on the part of the youth and young adults Pa Ipai responds to a demographic change. Young people are the population base of their communities. They play a key role in the revitalization and redefinition of the Pa Ipai culture and its relationship with the external world.

8. Conclusions

In this article, I tried to show how and why the Pa Ipai cybercartographic sky atlas became a collaborative tool that allowed to build bridges with the Pa Ipai people, especially with the youngest generation. The methodological route followed in its elaboration and the social and historical reasons for which this route was followed were also discussed.

Although, at first, I argued that the collaborative nature of the atlas was due to its interactive and technological characteristics, as the article developed, it could be observed that it was the entire process of elaboration of the atlas that allowed the construction of collaborative links with the community.

This was the case since, from the beginning of the fieldwork, mistakes and misunderstandings led to a reflection and methodological turn that implied that some of the subsequent steps were built collaboratively. However, in addition, each stage adapted to the interests and social needs of the families while building links and restoring elements to the social actors.

The steps followed in the process took their final form, not only derived from the decisions and negotiations between the social actors and the researcher, but from the specific situations of the Mexican and Baja California historical context, because these situations configured the mistakes, the reflections and methodological modifications and, above all, the responses of the young Pa Ipai to the atlas.

The previous results contribute to the existing research in two areas. On the one hand, they contribute to multidisciplinary research among the Pa Ipai people and in general with the Yuman indigenous peoples from Baja California. On the other hand, it contributes to the reflection on the processes of elaboration of cybercartographic atlases. Regarding the study among the families, the results introduce the questioning of the extractive academic practices in the region, at the same time that they emphasize several areas, such as the sky, technology, collaborative work and the role of young Pa Ipai in the construction, renewal and resignification of their own culture.

In the field of methodological reflection on cybercartographic atlases, the aim was to contribute to the think about the role played by mistakes and misunderstandings in the process of developing the atlases. I also invite the reader to reflect on how the historical situations of the regions and countries where the atlases are elaborated influence and configure the stages of the process. I hope all these ideas are useful.

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Article

Indigenous Mapping for Integrating Traditional Knowledge to Enhance Community-Based Vegetation Management and Conservation: The Kumeyaay Basket Weavers of San José de la Zorra, México

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Abstract: Kumeyaay people were historically hunter-gatherers with a strong relationship with their natural resources. Due to various processes, such as missionary colonization, agrarian reform, and the definition of the border between the USA and Mexico in 1838, the Indigenous populations faced reduced mobility within their territory and modified their lifestyles, highly related to landscape and plants. One of their strong traditional practices associated with plant resources, basket-making, has likewise changed. Today, this activity is one of the most important sources of income for many of the families in the community. Nevertheless, this is being now threatened by the loss of vegetation cover, from which they obtain primary basket-making material and is now far from being environmentally and economically sustainable. An interdisciplinary group is addressing this problem from a multidisciplinary perspective and through a participatory methodological approach based on community mapping to enable the integration of local and scientific knowledge and to create vegetation management and conservation actions. Community-based Indigenous mapping has proven to be a powerful tool for the integration of traditional knowledge and its various dimensions, and knowledge integration between traditional and scientific knowledge has been successful. The project allowed for plant population analysis and adequate decision-making regarding natural resources management and conservation. The methods developed in this research represent significant progress in the development of internal capacities and empowerment of the community.

Keywords: transdisciplinary research; knowledge dialog; participatory mapping; qualitative analysis; community-based management

1. Introduction

Yumans are an ethnolinguistic family composed of 15 ethnic groups distributed in the states of Baja California and Sonora in Mexico and in the states of Arizona and California in the United States [1]. The Yuman groups in California are Tipai, Ipai; in Baja California, they are Kumeyaay, Pa Ipai, Kiliwa, and Cucapá; and in Arizona are the Cocopah, Maricopa, Quechan, Mojave, Yavapai, Hualapai, and Havasupai [2]. According to records of European explorers, missionaries, and various ethnographic studies, approximately 1300 years ago, the ancestors of the Yumans inhabited the bi-national region of California/Northern Baja California [3]. The Kumeyaay tribes and their sister Yuman tribes survived in the vast territory of Baja California and California as hunter-gatherers, moving seasonally according to patterns of migration and reproduction of vegetal and animal species, as well as to the seasonality of climatic conditions [4]. The ancient Kumeyaay tribes have lived in wild environments, and their adaptation occurred through their tribal and social practices. These practices were varied and consisted of activities, such as plant gathering and wildlife hunting, as well as complex activities, such as controlled plant pruning, vegetation burning to control soil erosion, manipulation of oak acorn production, and pest control in pine and oak trees [5]. Prehistoric human hands have sculpted the bi-national region of California/Baja California since ancestral times. Anderson [6] compared these modifications in magnitude with the same region's modifications by earthquakes, lava flows, floods, fires, and storms. In the same way, wild landscapes had a remarkable influence on the Kumeyaay way of living and cosmovision. Kumeyaay people view their natural landscape as a living home and have constructed a cultural landscape around it [7].

Due to various processes, such as missionary colonization, agrarian reform, and the definition of the border between the USA and Mexico in 1838, the Indigenous populations faced reduced mobility within their territory and modified their lifestyles. One of the consequences of these processes has been the alarming loss of their language, which is also a loss that diminishes the traditional knowledge because language is the main tool to build and organize the natural world, create taxonomies, and convey that knowledge [8]. Because the historical relationship between the landscape, plants, and the Kumeyaay Indians has been affected by these processes, traditional practices associated with plant resources have changed.

One practice that has been affected by these historical changes is basket-weaving from two plants, Spiny rush (*Juncus* sp.) and willow (*Salix* sp.). Historically, the Kumeyaay made baskets for collecting, preparing, and storing food. Nowadays, basket-weaving is still done in San Jose de la Zorra and to a lesser extent in Juntas de Nejí. Nevertheless, basket-making is nowadays an artisanal craft, and sales from this practice support the group's subsistence, thus representing one of the most important monetary income for many of the families in Kumeyaay communities [8]. To collect plant material for the baskets, leaves from the willow tree and branches of spiny rush are strategically pruned to leave healthy plants to prune in the future. For spiny rush, they collect branches, dry them out for several days, and then unravel and soak the material in water to make it pliable [9]. Among the most common crafts are the "sawil", which is a plate commonly used by the Indigenous people to clean seeds, and the "jilú", a resembling cooking pot to store wild seeds [9].

The Kumeyaay Indigenous people have traditional knowledge about this ancient activity of pruning and basket-weaving. This knowledge is eroded, barely surviving, but there is a crucial body of knowledge that can be traceable through current expressions. These expressions are deeply rooted in the Kumeyaay culture and the self-regulatory moral rules to prevent the overuse of the plants. Examples of these are the fact that they only prune the plants three days after and before the full moon to acquire better quality material; and that women are not allowed to prune during their menstrual cycle because, otherwise, the plants become stained after drying. These beliefs are part of the Kumeyaay's cosmovision and evoke ancient traditional activities and the associated knowledge. This type of ancient wisdom is referred to as traditional ecological knowledge (TEK). This knowledge is a cumulative body of knowledge about the relationships of living things and their environment, evolving through adaptive processes and transmitted through cultural forms from one generation to the other [10].

Nowadays, environmental science tends to prioritize the use of transdisciplinary approaches to incorporate a different kind of knowledge, including TEK. The use of these approaches underlies the recognition that environmental problems are intrinsically complex and need to be approached through a wide diversity of disciplines [11]. This way to do science resides on the shift from "science for society to science with society" [12–16]. These approaches are grounded on an ontological posture that enables logical interaction and communication between tacit and empirical knowledge with scientific knowledge, among other perspectives and epistemologies [11,17]. Due to their intrinsic complexity, rural and Indigenous environmental problems demand this relatively novel way to do science: science with rural and Indigenous people rather than science for them.

In this context, participatory approaches stand out as a framework to address socio-environmental problems in rural and Indigenous backgrounds. Participatory approaches began in the early 1980s with a methodology called Rapid Rural Appraisal, which evolved into a family of approaches and methods now called Participatory Rural Appraisal [18,19]. Nowadays, these approaches are a widely used group of methods, of which participatory mapping is the most widespread vibrant area of practice, recognized as an area of study in its own right [20,21]. In this article, we refer to participatory mapping as the method in a general and broad sense, and Indigenous mapping to refer to the method implemented in this research.

Participatory mapping has proven to be a powerful tool for recovery and integrating traditional knowledge and its various dimensions with scientific knowledge [22–24]. The views and perspectives of local people can be represented spatially through participatory mapping and thus, encouraging an autonomous decision-making process independent of trends or patterns followed by local governments [25–27]. Moreover, it has proven to be useful in increasing public participation [28,29] and in promoting various dimensions of governance [30,31]. This method is also defined as a counter-mapping approach as it enables local communities to take control of the mapped spaces, challenging political limits and altering land use categories [32]. It should also be noted that creating participatory maps in itself claims to be an empowering process that enables local participants to make autonomous decisions and to transform those decisions according to their perspectives and desired outcomes [33–35]. Empowerment has been widely discussed and thus has several definitions. For this, it is necessary to describe how empowerment should be understood. In this research, empowerment is considered as a process of enhancing a group's capacity to make purposive choices and to transform those choices into desired actions and outcomes [36]. Moreover, empowerment can be individual or collective, meaning, in the last case, societal change. Often these changes are described from anecdotal perspectives but are not measured. Thus, we do not know about the extent and duration of these changes [22]. Empowerment should be measured and described beyond anecdotal experiences [22].

In recent times, San José de la Zorra's Kumeyaay community has begun to question the natural resources' conservation status, which is the primary material for their traditional activity. Basket-weaving has changed from an ancient to an economy-driven activity. Because of this, the pressure to increase craft production is a determinant to increase monetary income. Due to this, there is more pressure on the plants and a noticeable reduction of spiny rush and willow coverage in the area. The Indigenous community needs to create a conservation and management plan for spiny brush and willow in order to improve basket-weaving activity to make it economically and ecologically sustainable. To do so, it is not only necessary but fundamental to recover traditional knowledge related to the activity. This conservation and management strategy cannot be conceived in any other manner than as a participatory and transdisciplinary process. Likewise, the participatory mapping should be a crucial tool to enable the recovery of Kumeyaay traditional knowledge and its integration with ecological perspectives.

In this article, we describe a process of participatory research based on a transdisciplinary paradigm. This process used Indigenous mapping as a crucial tool. The objectives to achieve are to map Indigenous knowledge and ecological aspects of spiny rush and willow and create a conservation and management plan that leads a community-based strategy to restore, manage and conserve the plants with importance for basket weavers, to promote the empowerment of the Indigenous community. First, in the material and methods section, we describe the iterative process based on research. Then we describe the results of each phase of the iterative process. After this, results are discussed, and lastly, based on results, a remarkable conclusion in the corresponding section.

2. Materials and Methods

The Kumeyaay community of San José de la Zorra is located between the municipalities of Ensenada, Tijuana and Tecate in Baja California, Mexico, approximately 45 km from the US–Mexico international border (Figure 1).

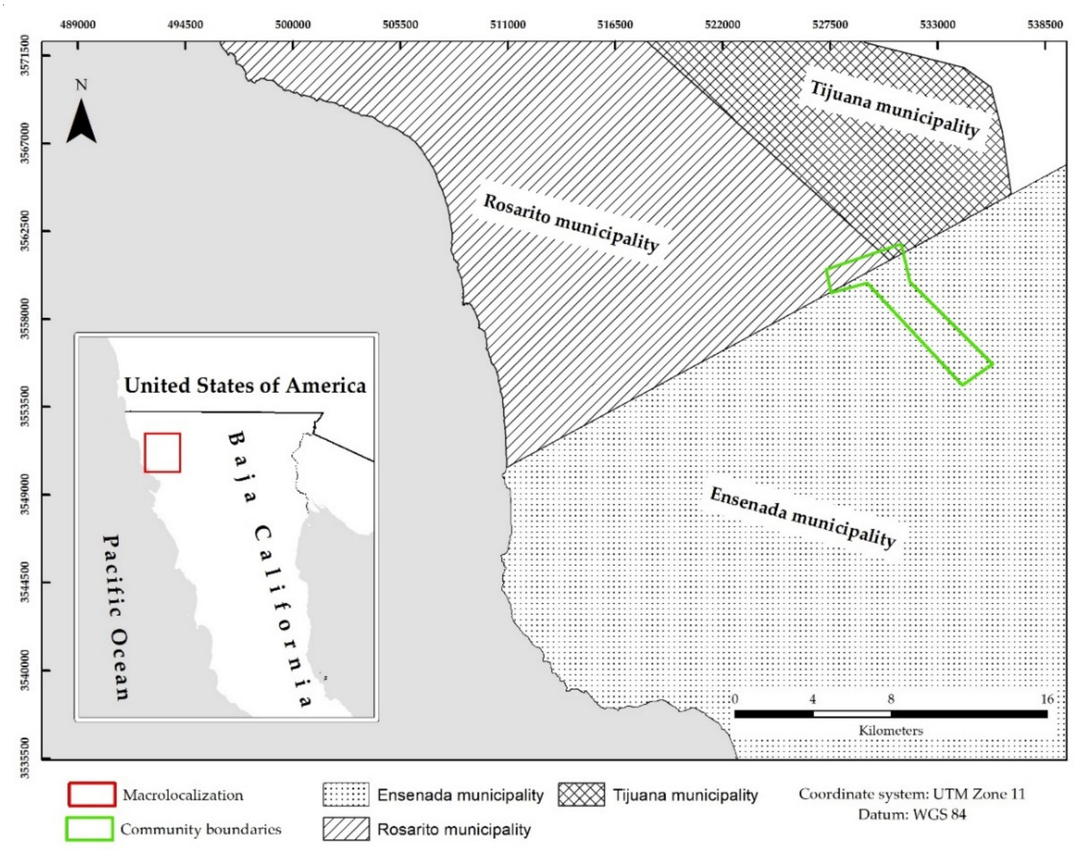


Figure 1. Map with location of the Kumeyaay community. This figure shows the location of the polygon in relation to the municipalities of Ensenada, Rosarito and Tijuana. It also shows its macro-location in Baja California, Mexico and the proximity to the United States of America border.

This work was done by an interdisciplinary group of teachers, students, and researchers linked to the Graduate Master's program in Arid Ecosystems Management (MEZA for its initials in Spanish) at the Autonomous University of Baja California [37]. Due to MEZA's tradition and philosophy, it was possible to address this problem from a multidisciplinary perspective and through a participatory methodological approach. This approach is an iterative process consisting of six phases and various stages [38]. The six phases are:

1. Preparation;
2. Information;
3. Training;
4. Research;
5. Analysis;
6. Management.

Dynamic knowledge interexchange between the technical and local participants occurred during these stages, achieving continuous feedback throughout the process (Figure 2). The members adopt an ontological position of respect and recognition to this different kind of knowledge to address all the phases. This approach is known as knowledge dialog [17].

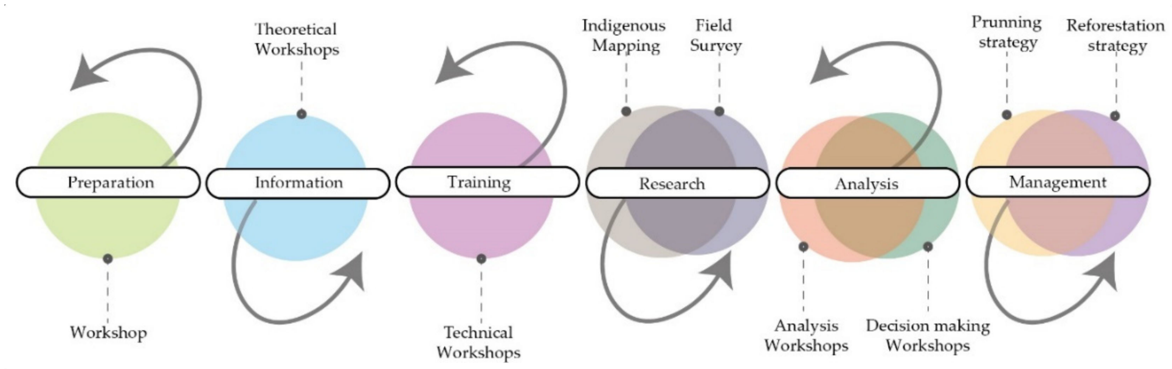


Figure 2. Iterative process of methodological approach. The six phases are shown in different rounded rectangles, and circles of colors represent the main activities of each phase; black arrows represent the continuous feedback on each phase. Source: own production based on Eaton et al. [39] and Jiménez [38].

The material and methods section is described in accordance with the phases of the research. For didactical purposes, this section is described in a broad summarized manner as it underlies a participatory decision process.

2.1. Preparation Phase

The preparation phase corresponds to goal establishment and team members' recognition. This phase is based on workshop development, in, which all team members are acknowledged, and the transdisciplinary team is created.

2.2. Information and Training Phases

According to the iterative process described above, the information stage and training stage follow the preparation phase. These phases have similarities in the sense that both can be labeled as training. The difference lies in that the information phase considers the theoretical training, and the training phase considers the technical learning process or practical training. Nevertheless, both phases were developed based on participatory workshops. It should be highlighted that the workshops were intended to build and strengthen the self-diagnosis and community management of natural resources. Theoretical training (information phase) included topics, such as the life cycle of plants, plant physiology and ecology; sampling techniques of plant species; thematic maps, map projections, coordinate systems, and global positioning system (GPS). All the described topics were fully covered in four workshops. Technical training (training phase) took place in the field and included how to use the GPS, conduct plant sampling techniques, georeference sites, and integrate information in a database. Four workshops were developed in order to cover all areas of theoretical training.

2.3. Research Phase

Once information and training phases took place, the teams conducted the research activities. These activities were divided into Indigenous mapping sessions and participatory field surveys of spiny rush and willow.

Within the framework of the participatory research phase, the transdisciplinary team created a series of thematic maps of the community and the use of spiny rush and willow within the boundaries of the Kumeyaay community. For those thematic maps, the Kumeyaay members of the team took a key role in mapping historical and current pruning sites, as well those where they recognize sites with low and high plant densities. Roads, houses, places with cultural importance for the community, and traditional and economic activities were also mapped using the same method. The method consists of using a high-quality satellite image of the community and translucent paper over it, enabling the team to see the image and to map into detail the features of the satellite imagery (Figure 3). As part of mapping activities, a working session was carried out at the computer lab in the

Faculty of Sciences of the Autonomous University of Baja California (UABC), where the members of the community learned to use Google Earth to generate thematic digital layers.

Figure 3. Kumeyaay members discussing and mapping the historical and current pruning sites of spiny rush and willow. The satellite imagery and transparent paper over it, which correspond to the Indigenous mapping method used in all mapping activities, can be seen in the image above.

Using all the thematic maps as a basis, the team decided on the places to conduct the field surveys. The team was divided into four smaller teams to conduct field activities and to cover all sites more effectively. The willow sampling method consisted of sampling plots of 20 m length per transect lines of 3 m wide separated by 50 m between sampling plots, and for the spiny rush 5 m radius circles with a separation of 50 m between sampling plots. (Figure 4). All teams surveyed a total of 242 sampling plots for Spiny rush and 247 sampling plots for willow, located on 4 four zones, respectively (Figure 5).

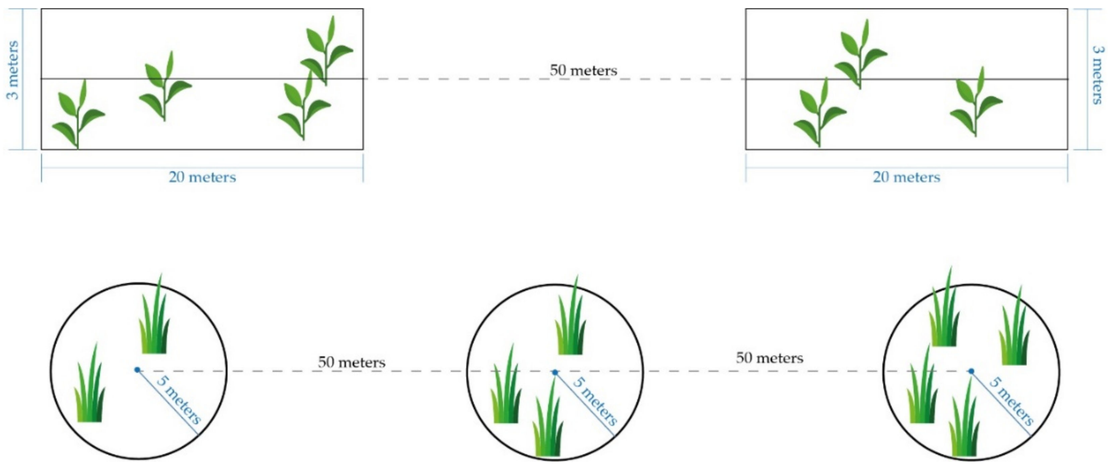


Figure 4. Sampling methods for each vegetative species. Above is the sampling method for willow, which consists of 3×20 m plots separated by 50 m per plot; the second image corresponding to the sampling method for the spiny rush, which is based on circle sampling plots with a 5 m radius separated by 50 m between sampling plots.

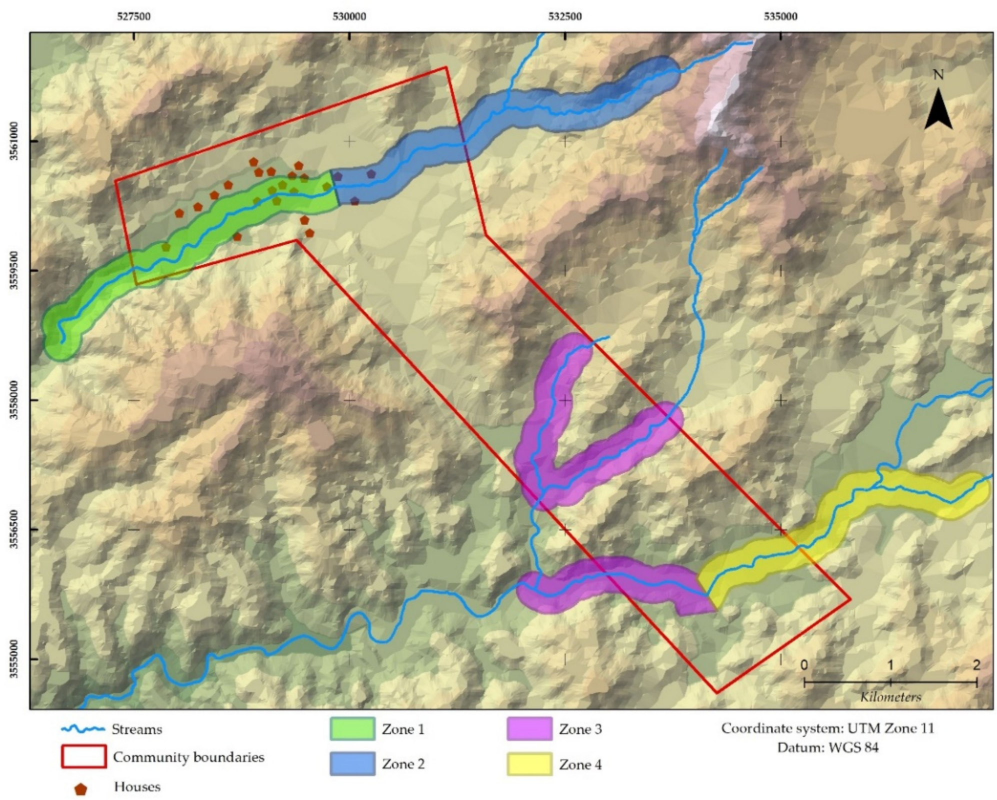


Figure 5. Map with the zones where the transdisciplinary team conducted the vegetation survey. The figure shows in red the polygon of the community of San José de La Zorra; blue wavy lines represent the most important streams. The houses and important sites are represented by red pentagons, and each zone with different colors. The green polygon is zone 1, the blue polygon zone 2, zone 3 is represented with a violet polygon, and the yellow polygon represents zone 4. All zones' polygons are represented with a transparency of 50%.

For each individual of both vegetative species, height and two width measurements were taken (Figure 6). All data were recorded in a paper datasheet. Each sampling plot coordinates were recorded with GPS at universal transverse Mercator zone 11 projection and WGS 84 data.

(**a**)

(**b**)

Figure 6. Sampling vegetation techniques: (**a**) shows a member of the Kumeyaay community measuring the height of a spiny rush plant; (**b**) shows the transdisciplinary team recording measurements of willow plants.

Indigenous maps of the historical and current pruning sites were digitized using a digitizing tablet. The layers generated with Google Earth were compiled and ordered. Both products were exported to a vector format.

2.4. Analysis Phase

For the analysis phase, all data were analyzed on participatory workshops that promoted feedback and discussion about the data and results. All sub-teams evaluated their data and calculated the frequencies, densities, and volumes per site for both plant species. To calculate the volumes of each plant, the following equation was used:

$$v = [(\pi \cdot r^2 \cdot h)/3) \cdot f], \quad (1)$$

This is a general formula to calculate the volume of a cone. We used the cone formula over spherical considering that the overall form of these two species is conical. Given that the plants are not a perfect geometric and solid cone and have spaces between branches and leaves, a correction factor (f) or morphic coefficient is applied, determining the plant volume as a fraction of the solid regular geometric figure of reference [39,40]. For spiny rush, the correction factor was 0.3 and 0.5 for willow. We used these correction factors comparing the volume determined by reference figure against the real volume occupied by the biomass of the plant. Once all the calculations were made, each group presented their results and discussed preliminary management and conservation options based on those results.

In addition, we analyzed the volume needed to create baskets and other art crafts. This calculation was made by the artisans of the team, which determined the required amount of both plants to create baskets and other crafts and calculated the average harvest amount of each plant per month. To see more detail of these calculations, see Eaton et al. [41]. Considering that artisans only prune spiny rush plants that measure over 1.11 m height and 2.51 m height for willow, the team calculated the available volumes per zone by adding the available volumes in the sampled site.

Within the framework of the analysis phase, a specific decision-making session where all the results of each group, including Indigenous mapping and results of vegetation analysis, was conducted to collectively decide the management and conservation actions for spiny rush and willow within the recognized boundaries of the Kumeyaay tribe. The Kumeyaay participants of the transdisciplinary team held a primary and key role during this session as they led the discussion and decided on management and conservation actions. This session was based on visualization of the results through Google Earth, where all vectorized data were presented, and by discussing the conservation status of spiny rush and willow based on the results of the ecological monitoring as well spatial distribution of the calculated volumes for each plant. By categorizing the surveyed zones based on available volumes of plants, their proximity to the houses, and threats for the plants, such as cattle, the Kumeyaay tribe decided the potential use and management rules.

In addition to the iterative process, a semi-structured interview was implemented after concluding the research. The interview was designed according to Soriano's [42] criteria and was applied to learn participant opinions regarding the use of Indigenous mapping in the context of management of natural resources in their community and to evaluate the building capabilities process. It was applied to a representative sampling of 10 community members from a total of 16 participants. This interview asked if they were able to return to take plant samples, mark points with the GPS and generate layers with Google Earth, and regarding the usefulness and potential of these methods and Indigenous mapping.

The interviews were recorded with the proper consent of the people interviewed. For the analysis, the results were transcribed, then coded manually, analyzed and synthesized. This thematic analysis was implemented on the basis of Gibbs et al. [43].

3. Results

Considering that the project's development was based on several phases, this section is described according to these phases to provide a more precise description of the results. Nevertheless, in the discussion section, the results are approached in a broader context.

3.1. Preparation Phase

Regarding the preparation phase, the main result was forming the transdisciplinary team. This team was composed of a wide variety of disciplines coming from natural science bachelor students with different interests, like plant physiology, ecology, community development, management, and conservation; academic/researchers with different backgrounds; Kumeyaay people with different roles in their community, such as artisans and cattle ranchers. Given the nature of the project and considering knowledge dialog as the ontological posture of the team, several ground rules were established to prioritize knowledge exchange. During this workshop, the team decided on the main goal and made agreements regarding the methods and techniques to conduct during the project's process development.

3.2. Information and Training Phases

16 Kumeyaay members, 11 women and five men participated in the whole participatory process. The non-Kumeyaay members of the team were three women and three men. In total, 14 women and eight men participated during the entire process.

A total of four workshops were implemented for the theoretical workshops; four for the technical workshops, including the session in the cartography and computer lab of the Autonomous University of Baja California, and the vegetative reproduction workshop in Mexicali, Baja California.

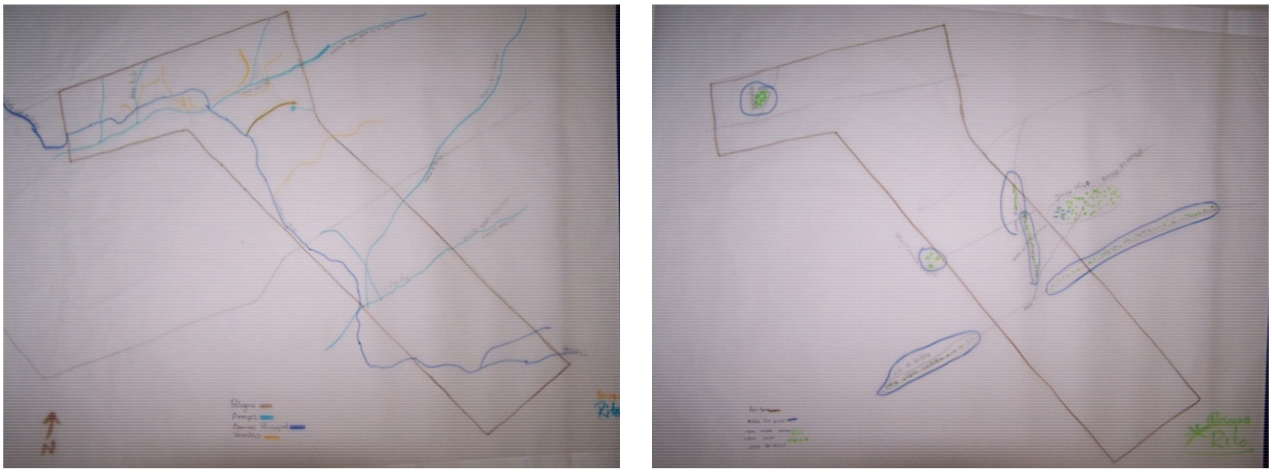
3.3. Research Phase

The transdisciplinary team produced four maps with the location of houses and culturally, social, and economically important sites. On these maps, it is possible to see the houses of the families of the community and sites of shared interest, such as schools and traditional sites. Regard economic activities, the team created four maps with the precise polygons per each economic activity within and outside the boundaries of the tribe-recognized polygon. The mapped activities were cattle ranching and agriculture of local and neighboring ranches. Moreover, the team manages to rescue knowledge of historical pruning sites as well as sites where the Kumeyaay tribe has been collecting other vegetation for traditional activities, such as ceremonies and traditional medicine since ancestral times. Figure 7 shows two examples of these Indigenous thematic maps.

During the participatory research stage, the team evaluated a total of 247 sampling plots of willow and 274 sampling plots of the spiny rush. A total of 965 willow plants and 1112 spiny rush plants were measured.

3.4. Analysis Phase

According to the analysis of volumes and frequencies for willow, zone number 4 showed the lowest number of plants and volumes, followed by zone number 3 and 2, respectively. Zone number 1 showed the highest numbers of plants and volumes (Table 1). In contrast, the analysis of frequencies and volumes for spiny rush showed overall low frequencies and volumes in the zones. Zone 2 had no plants, and zone 1 had low numbers of plants and low volumes, followed by zone 4 and 3 with a few more plants and volumes (Table 2).



(**a**) (**b**)

Figure 7. Indigenous thematic maps: (**a**) Example of a thematic map with the roads and streams of the community; (**b**) example of a thematic map with pruning sites for the spiny rush.

Table 1. Frequencies and volumes of willow per zone. This table shows the frequency and volume of willow per zone according to height categories. The final row represents the totals per zone. The total number of willow plants for all zones was 956, and the volume for all zones was 79.53 m^3.

Height Category	Zone 1	Zone 2	Zone 3	Zone 4
1 (0–1 m)	127 plants/2.48 m^3	0 plants/0 m^3	116 plants/5.02 m^3	7 plants/0. 29 m^3
2 (1.01–2.50 m)	144 plants/107.66 m^3	58 plants/86.44 m^3	36 plants/18.53 m^3	51 plants/73.93 m^3
3 (2.51–5 m)	160 plants/757.53 m^3	78 plants/526.46 m^3	66 plants/645.30 m^3	45 plants/258.38 m^3
4 (5.01–8 m)	46 plants/990.74 m^3	4 plants/56.81 m^3	21 plants/472.78 m^3	2 plants/15.63 m^3
5 (8 m–above)	0 plants/0 m^3	0 plants/0 m^3	3 plants/123.91 m^3	1 plant/46.51 m^3
Totals	477 plants/1858.41 m^3	140 plants/669.71 m^3	242 plants/1265.54 m^3	106 plants/394.74 m^3

Table 2. Frequencies and volumes of spiny rush per zone. This table shows the frequency and volume of spiny rush per zone according to height categories. The final row represents the totals per zone. The total number of spiny rush plants for all zones was 1112, and the volume for all zones was 4188.0 m^3.

Height Category	Zone 1	Zone 2	Zone 3	Zone 4
1 (0–0.5 m)	28 plants/0.18 m^3	0 plants/0 m^3	664 plants/0.13 m^3	15 plants/0.31 m^3
2 (0.51–0.80 m)	2 plants/0.02 m^3	0 plants/0 m^3	67 plants/0.45 m^3	27 plants/0.70 m^3
3 (0.81–1.10 m)	2 plants/0.11 m^3	0 plants/0 m^3	57 plants/2.97 m^3	50 plants/0.64 m^3
4 (1.11–1.40 m)	14 plants/2.22 m^3	0 plants/0 m^3	94 plants/13.67 m^3	22 plants/3.47 m^3
5 (1.41 m–above)	0 plants/0 m^3	0 plants/0 m^3	50 plants/17.44 m^3	20 plant/18.40 m^3
Totals	46 plants/2.54 m^3	0 plants/0 m^3	932 plants/34.67 m^3	134 plants/24.81 m^3

According to available volumes, zone 1 has 2.22 m^3 of spiny rush and 1748.27 m^3 of willow; zone 2 has 0 m^3 of spiny rush and 583.27 m^3 of willow; zone 3 has 31.11 m^3 of spiny rush and 1241.99 m^3 of willow, and zone 4 has 9.88 m^3 of spiny rush and 321.52 m^3 of willow. It is important to highlight here that available volumes were calculated on the basis that the artisans only prune spiny rush plants with a height over 1.41 m and 2.51 m for willow.

Based on the above results, three main conservation categories were defined:

- Conservation;
- Restoration;
- Usage.

The conservation category comprises areas where no pruning was allowed, and conservation actions should be prioritized. The restoration areas were classified as sites with a need to restore the vegetation and to implement actions to ensure reforestation success, and the usage category comprises areas where moderate use of both species was allowed. It is important to highlight that classification of the areas was based on the overall analysis of frequencies and available volumes of each plant species and the socioeconomic factors of the community, such as accessibility to sites. These decisions were taken by the Kumeyaay members of the team.

Given that zone 1 has scarce volumes of spiny rush and even though it has the highest available volumes of willow, it was classified as a restoration area. This decision was made by the Kumeyaay member based on the agreement to designate another zone for the usage of both plants. Zone 2 was also designated as a restoration area because it showed no spiny rush plants even though it is a historical pruning site and the second-lowest volume of willow. These two areas are the closest zones to the houses; therefore, they are the most commonly used as pruning sites and correspond to historical pruning sites. Considering these two areas are historically the most pressured zones, they were classified as restoration areas. Zone 3 has the highest available volumes of spiny rush and has the second-highest volume of willow. Because of this, it was classified as a usage area where pruning of both species was allowed. Zone 4 has a moderate amount of spiny rush and willow; therefore, it was cataloged as a conservation area.

Figure 8 shows the categories in their spatial location in relation to the houses and important sites as well to the community's polygon. It should be noted that the areas go beyond the recognized limits of the current polygon, and the causes and implications of this are discussed in more detail further in the article.

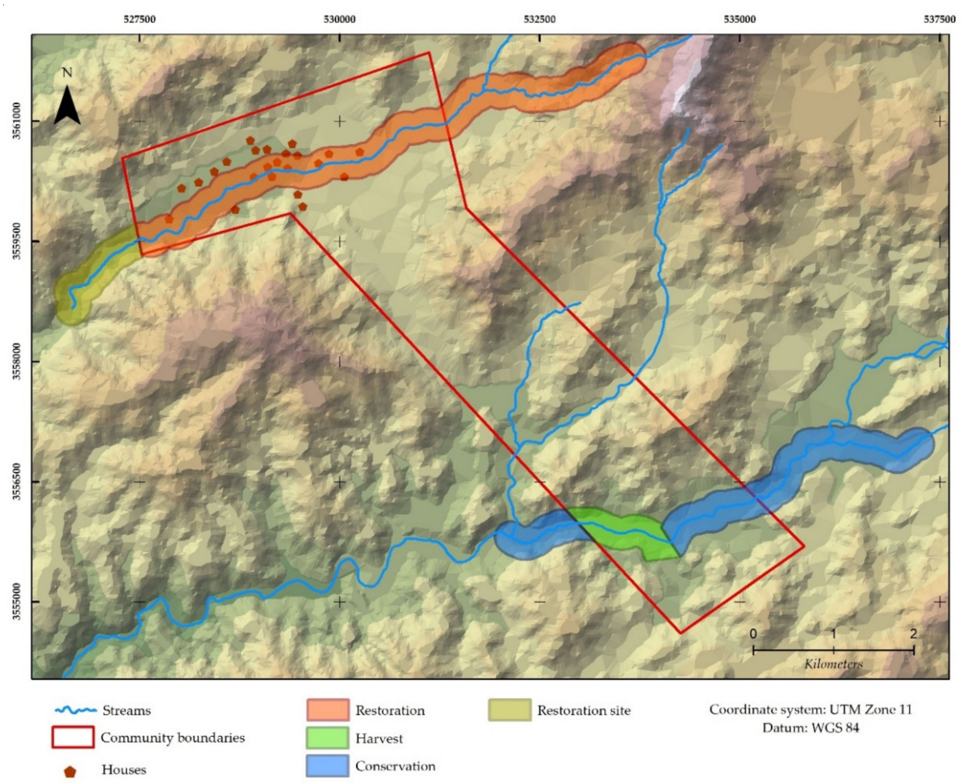


Figure 8. Map with conservation and management categories. The figure shows the restoration category with a red polygon. The specific site designated by the Kumeyaay members as the site to be restored located in the northwest part of the community polygon. The usage category is presented by a green polygon, and the conservation category is represented by blue polygons.

3.5. Management Phase

The management phase corresponds to two main strategies, defined by the transdisciplinary team, the pruning strategy for the harvest areas and the restoration strategy for the restoration areas. It is important to highlight here that three main categories were defined based on the analysis phases: conservation where no pruning was allowed, and conservation actions should be prioritized; harvest areas where controlled and organized use of both species was allowed; and reforestation sites with a need to restore the vegetation and to implement actions to ensure reforestation success. Two main strategies were decided based on the results for harvest and restoration sites. The strategies were articulated on a broad conservation and management plan with detailed activities, goals, monitoring plan, and agreements [41].

For the harvest sites, the Kumeyaay tribe agreed to respect the potential use of each site and to continue with the pruning and basket-weaving activities, considering the attributes and limitations of each area. To conduct so, a set of agreements were made, which declares the actions allowed in each of the areas. Moreover, several commitments were made by each member of the team to continue improving the traditional activity in the context of sustainability. On these rules, the team members expressed the allowed activities and penalty fees in case of breach of the rules. The following list identifies the rules decided by and for the community:

- Avoid generating litter and properly dispose of any trash generated;
- Take care of the fences on the restoration site; it is forbidden to break them, cut them or knock them down. The person who does so will be charged a fine equivalent to the value of the damage caused;
- The door must always be closed when entering or leaving the fenced areas, and these will have restricted access so that only people with permission can access or be accompanied by someone in charge of taking care of the areas;
- It is strictly forbidden to put cattle in the reforestation areas since cows, goats and horses damage the raw material; In case any such animals are found within a reforestation area, the owner of the animal(s) will be fined $500.00 Mexican pesos;
- Cut only the amount of raw material to be worked or used and do it exclusively if you have the knowledge of the appropriate technique for it;
- Carry out raw material cuts in the appropriate areas for harvesting, avoiding doing so in plants that are in recovery;
- Cutting in reforestation areas will be prohibited;
- Take care of the plants; anyone caught mistreating the vegetation will be fined;
- Take necessary precautions to avoid starting forest fires;
- Staying committed to seeking support for reforestation and protection of the areas
- Take care of the signs that are placed in the areas of interest.

This series of rules comprises all the agreements the community-made regarding utilization of all the areas, including restoration areas. Besides the rules, the community agrees on a series of commitments to continue improving the activity. These agreements can be found in the conservation strategy [41]. Although these commitments are secondary outcomes of this process, they are considered as part of the second stage of this process as it underlies management and conservation actions to be implemented in the future.

The strategy for the restoration sites was more technically complex and consisted of several stages. To properly implement restoration actions, the Kumeyaay tribe took a specific workshop to learn vegetative production methods specifically for willow and spiny rush. Once the tribe learned the methods, the transdisciplinary team conducted the vegetative reproduction of both plants within a greenhouse in the community. Naturally, this process took several months, and during these months, the tribe makes decisions regarding which sites to restore and prepare. The tribe decided to restore one site with low to no volumes of willow and spiny rush. It is important to highlight that this site is near the houses of the artisans and corresponds to a historical pruning site. This site is also located within a cattle ranching activities polygon. To prevent the cattle from eating the young plants, the site was isolated by a cattle fence. Given the site is located within a stream, the team constructed a levee to promote water infiltration and to increase the availability of water for the plants. Once the site was prepared, spiny rush seedlings were planted in bulk. This restoration activity implied several stages that correspond to a future project [41] and, because of this, would not be discussed in further detail (Figure 9).

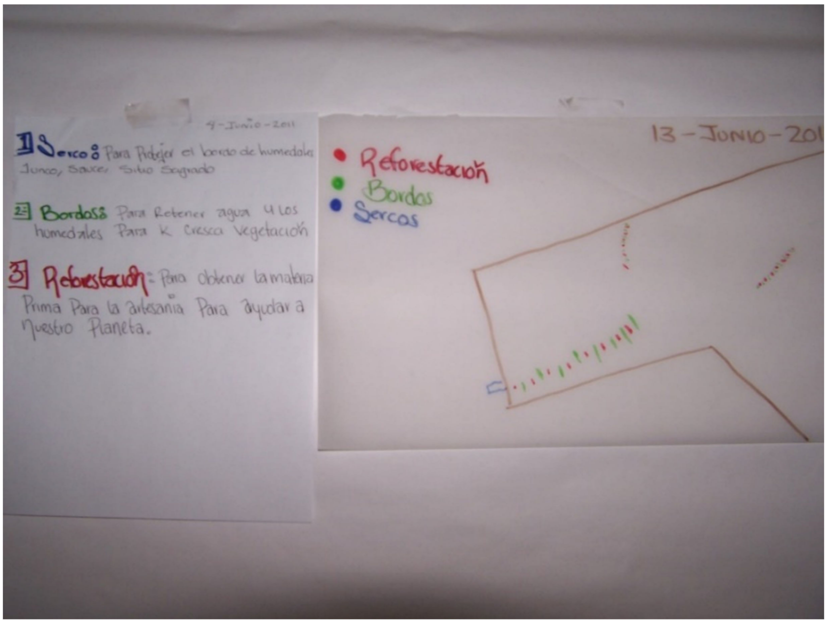


Figure 9. Evidence of the restoration site selection based on socioeconomic and cultural aspects as well as ecological features. The picture shows the site as well as the 3 main conservation actions for the site: Cattle fence, levee, and reforestation actions.

The semi-structured interviews yielded information that allowed us to evaluate the relevance and usefulness of the methods used. Regarding Indigenous mapping, they indicated that it was useful to locate areas with spiny rush and willow. When asked to talk about potential uses of Indigenous mapping, they mentioned that they recognize the usefulness of this activity through the following comments:

- "To learn where the boundaries of the community are located";
- "To identify sites where we have already worked and those that are still pending".

In addition, when asked if they could create thematic maps on their own and without additional training, all the interviewed locals declared themselves feeling capable of doing so.

When asked about their capability to again use Google Earth and use the GPS, two individuals said that they could do it again without further training; four of them that they could only if reminded how to do them; and another four did not attend this workshop thus will not be able to use Google Earth. Regarding plant species sampling, we had a more positive balance; nine people indicated that they would be able to do a sampling without further training, while one person indicated that he could do it, but with additional training. Regarding the use of a GPS, two individuals indicated that they could use it again without additional training; four that they could, but with additional training, and one person mentioned that he would not be able to use it again. The three individuals that did not attend the training on how to use a GPS were not evaluated. Likewise, participants emphasized the importance of plant sampling and the use of a GPS. Following are textual transcripts of some of the participants' comments regarding the importance of sampling:

- "Because that way we know how many we have, and where there is more and where less";
- "To see how much it has grown"; and

- "To know how many plants there are".

GPS:

- "For the position";
- "Yes, because you can mark the places where there is more or less on a map and that way you are not searching for the sites"; and
- "Yes, it shows you where the sample is".

Regarding the Indigenous mapping, participants highlighted its usefulness in managing resources at a community level. They mentioned that it was useful to visualize the areas with greater density for each one of the plants, to visualize resource availability, among other things. Following are some of the textual quotes voiced by participants on the usefulness of Indigenous mapping:

- "To know what we have in the community";
- "To better understand the results; at the end, we all had a good understanding";
- "To locate areas where we can find more material";
- "To learn more about the plant";
- "To find the places where there is more spiny rush and willow, and those that do not have any";
- "To see if the resource is running low, to know where to find it and where not".

4. Discussion

First, we would like to highlight that the current research was triggered by the Kumeyaay's concern about the conservation status of spiny rush and willow and the future of the basket-weaving activity. The Kumeyaay members approached UABC and MEZA's program to express their concerns. Therefore, the project cannot be labeled as academically driven research but research to solve a socio-environmental problem in an Indigenous community by demand or inquiry of the local people themselves. Therefore, the methodological approach used in this research was transdisciplinary and participatory to enable the active participation of Kumeyaay members. The transdisciplinary team was formed by 22 persons, 16 of whom were Kumeyaay members. The iterative method implemented allowed for a gradual increase in involvement and participation of Kumeyaay people until higher participation was achieved. This proves that participatory approaches based on the knowledge dialog, as an ontological posture, can enhance the participation of locals [17]. In general, the transdisciplinary posture and the methodological approach allowed a constant knowledge interchange during all phases, thus enabling the active participation of all the members of the team. The process and phases were constructed based on other experiences and considering a pedagogical framework [38]. This can be used to address similar problems in Indigenous communities in Mexico. Each of the phases could be implemented independently, but we strongly recommend implementing the whole iterative process as it follows a logical sequence. Further work needs to be done, especially regarding theoretical and pedagogical context, to create a general framework applied to different contexts.

Indigenous mapping was an effective method to recover traditional knowledge associated with basket-weaving activity and to spatially represent it. One of the features that the Kumeyaay people managed to represent into a thematic map was the historical pruning sites for both vegetative species used for basketry activities and the culturally important sites (Figure 7). Similarly, Kumeyaay people brought up highly important knowledge about the activity that is not necessarily spatial-related knowledge. For example, during the information phase, the transdisciplinary team widely discussed plant physiology and ecology, among other topics. Due to the nature of the workshops, Kumeyaay members provided insightful information about plants, especially information related to pruning activities of spiny rush and willow. They outlined in detail the pruning process of both plants, including certain self-limitations rules. These internal rules for pruning are consistent with the ones described in the literature [9]. Thus, we can conclude that the process is effective in recovering traditional knowledge, spatially related or not.

Our results also prove that the participatory process enables not only recovery of traditional knowledge, but to integrate it with scientific knowledge, according to other similar studies [23–28]. This was possible due to the knowledge exchange process, which enables bridging between different kinds of knowledge [11,17]. Technical workshops demonstrate that technical knowledge, such as ecological sampling methods of plants and the use of GPS, can be integrated based on these participatory methodological approaches. During the semi-structured interview, the Kumeyaay members expressed that they feel they are able to conduct ecological monitoring, and some expressed that they can use a GPS without additional training. This demonstrates that, at some level, the technical knowledge described successfully passed to the Kumeyaay people. As already described, the Kumeyaay artisans reported that they only prune spiny brush plants that are over 1.11 m in height and willow plants of 2.51 m in height. This information was crucial for the categorization of the areas and assigning management and conservation rules per area. This demonstrates that recovery and integration of traditional and scientific knowledge are crucial in our case for management and conservation decision-making. The challenges in working on recovery and integration of Indigenous knowledge have been addressed over time. We acknowledge that representation of Indigenous knowledge is controversial mainly due to local people's perception as voiceless and marginalized [21]. We consider that both kinds of knowledge have similarities and can be easily integrated into the framework of participatory research because it considers the ontological position of recognizing a different kind of knowledge. Nevertheless, ethical considerations regarding traditional knowledge and local people should be considered when conducting participatory research [21].

The results of ecological monitoring of the research phase showed an arguable historical overuse of spiny brush in the area around the center of the community by identifying that spiny rush is nearly absent in zone 1 and completely absent in zone 2 (Table 2). It could be argued that spiny rush could be found in zones 1 and 2 in low frequencies and volumes because of natural phenomena, but those zones correspond to recognized historical pruning sites and mapped by the Kumeyaay people; they are close to the houses and thus are more available. According to this, these low numbers and volumes are explained by an extended use over time. The ecological explanation for the lack of spiny rush could be partially true, but in our study, we did not evaluate environmental factors that could be affecting the plants, such as changes in hydrological regimes, cattle impacts on the plants, plant diseases, and other. In contrast, zone 1 has remarkably high volumes of willow (Table 1). Our research lacks data to explain why this zone 1 has low volumes of a spiny rush but high volumes of willow even though it is a historical pruning site. Nevertheless, in general terms, willow is more abundant than spiny rush in all zones. Although there is no literature or data that described which plant they use the most, anecdotal experience shows that nowadays, the artisans use more spiny rush over willow. This could be a possible explanation. A participatory ecological assessment regarding ecological aspects of the plants is needed, and we highly recommend conducting these in the future. Besides the ecological inquires derived from our study, the increase of ecological survey capabilities is the main result of the research phase.

During the research phase, the Kumeyaay members actively participated in conducting the ecological monitoring of spiny rush and willow. These capabilities were developed during the technical workshops and were the basis for the monitoring. This means that once the capabilities were acquired, they were immediately used to reinforce knowledge. These ecological assessment methods can be implemented for most Kumeyaay members without additional training. Hence, our results demonstrate that participatory methods are critical for building capacitates on locals, which is consistent with other research [25–31]. Nevertheless, not all local people can use GPS, Google Earth, and conduct field surveys without additional training; further projects should consider proper additional training. In addition, taking into consideration that local people have the capacities to properly conduct these activities without additional training, future technical workshops should consider providing the leading role to those locals already trained in teaching. Trained locals should become trainers and then strengthen the capacities and promote the empowerment and autonomy of the community.

The categorization of the zones was based on visualization of general and available volumes thru maps and digital maps. Although some statistical analysis could have been used, our study focused on enabling the decision-making process based on results of the ecological monitoring and perception of the Kumeyaay people regarding the availability of plants for pruning, using simple and basic numerical methods. This encouraged the autonomous decision process and empowerment of the community at some level, but it still needs to be evaluated. In general terms, categorization of the zones based on research and analysis conducted enabled a decision-making process in which the Kumeyaay took an important and crucial role. This means a strengthening of decision capabilities regarding the decision-making process for management and conservation of natural resources.

The pruning and restoration of zone agreements is a cornerstone for the community management of natural resources, as it underlies a series of rules to follow and the commitment of the local people to conserve spiny rush and willow. These are the core of the management strategy and demonstrate that the community is committed to managing their natural resources and establishing self-limitations. The restoration strategy is described in more detail in Eaton [41] and will not be discussed in further detail since it is not part of our results. Nevertheless, the decision to implement these restoration actions was taken in the current research. Therefore, this can be discussed in a broader sense. The restoration site was selected by the Kumeyaay members and was based on the volumes of spiny rush and willow. The restoration sites have low volumes of spiny rush and high volumes of willow. Despite the relatively high volumes of willow, the community declared the whole zone as a restoration area. Similar to this, part of zone 3 was considered as a conservation area even though it has good volumes of spiny rush and willow. It draws attention that the criteria to divide this area was the polygon of the community. This shows a decision made by political standards. The rest of zone 3 was declared a harvest area. Zone 4 was declared a conservation area as a whole and without dividing it by the community's polygon. All this shows a highly autonomous process on which several factors, such as ecological, cultural, economic, and political, were taken into consideration to make a decision and according to standards that only the Kumeyaay people feel need to be considered.

Another thing to consider is that the restoration site is located outside of the boundaries of the community. The decision to map and implement restoration activities outside the boundaries of the rightful polygon denotes that the Kumeyaay tribe recognizes those territories as their own. Peluso [32] mentions the fact that locals can do their maps, and that allows them to take control of mapped spaces, challenge political spatial limits, and alter land use categories. Our case corresponds to this type of actions because the method used allowed locals to map their plant species and to take decisions on their management; even on areas that are not legally owned by them, but that they acknowledge as an ancestral territory and considered as part of the community's spatial environment. This is an argumentative quality or act of defiance against the government and local rules not observed by their culture [32]. Even though we do not explicitly promote these defiance actions, we do pretend to highlight the fact that these decisions respond to the action-learning process, that generated great strengthening of abilities and thus autonomous decision-making concerning their resources and what they acknowledge as their territory and, in general, as building a vision of landscape and ecosystem conservation where the community takes priority over land tenure.

Another thing to consider about Indigenous mapping is the accessibility to the outcomes by Indigenous people. The results of the interview showed that Kumeyaay people prefer to have the maps in the paper other than stored on the web or other modern ways. Considering that most Indigenous communities do not have access to the Internet [44], this way to store the outcomes is the best alternative. Although our research does not draw concerns about the accessibility and sharing of delicate data that can be used in harmful ways for the community, another project demonstrates that this is a real concern of Indigenous people [45]. Thus, future mapping projects should consider legal procedures to ensure the intellectual property of the data and the accessibility to the data.

The semi-structured interview corresponds to an ancillary analysis that can be conceived as part of the iterative process. However, we conduct this evaluation because this kind of process is not often evaluated. Since our research has several aspects that can be considered subjective, the social instrument implemented as needed. These subjective aspects, such as empowerment, should be measured and described beyond anecdotal experiences [22]. The interview was successful, as it gave data to evaluate the success and reliability of the methods. The semi-structured instrument was selected over other methods because it allows the interviewer and interviewee to talk freely over a question and to adapt the conversation during the dialog and, hence, delve deeper into a topic in a friendlier way, but without losing certain structure [46]. In our case, this instrument allows us to acquire rich conversations that enabled deep analysis. Regarding the subjective aspects of building capacities and empowerment of the Kumeyaay members, the qualitative instrument provided accurate and insightful data to conclude that building capacities were successful. Having literal quotes where local people state the possibility of conducting several methods implemented proves the success of knowledge transmission and strengthens and empowers the local community. At the same time, this provides insightful lessons about the methods conducted and specific guidelines for future projects.

Even though we suggest using semi-structured interviews to evaluate these processes, we also suggest conducting mixed approaches to evaluate participatory interventions. These evaluations should consider both the qualitative aspects of the research, but also quantitative ones. Despite the methods, we strongly suggest not left behind the opportunity to evaluate participatory and Indigenous mapping efforts. These measurements will provide a guideline for the improvement of the participatory methods and transdisciplinary research. Lastly, our research does not discuss restoration strategies and management and conservation actions to be implemented in the future. This is mainly because this project focused on a participatory mapping and research approach and decision-making process. It should be highlighted that the transdisciplinary team identified the next steps to continue working on behalf of management and conservation of spiny rush and willow and for the future of basket-weaving as a traditional and economic activity during this project. Therefore, we suggest continuing working on management and conservation strategies and, more importantly, monitoring and evaluating the success of these actions. This needs to be done in the context of transdisciplinary paradigms and prioritizing participatory approaches to promote the empowerment of the Kumeyaay tribe. Moreover, Indigenous mapping and participatory approaches can easily be added to interdisciplinary and transdisciplinary management and conservation of natural resources strategies worldwide. The scientific community should pay more attention to the benefits of these tools and promote their use in community-based contexts.

5. Conclusions

The iterative process used in the research promoted a dynamic exchange of knowledge and continuous feedback during all stages. This was possible because of the ontological posture called knowledge dialog, which is part of the tradition of MEZA's program and transdisciplinary science. Due to this, this process allowed for building bridges between scientific and traditional knowledge and for incorporating both in order to map, evaluate, analyze, conclude, and decide on management and conservation actions. At the same time, it promoted the empowerment of the Indigenous community.

Indigenous mapping is highly effective in the recovery and integration of traditional knowledge and its different ways of expression and taxonomies. Nevertheless, future projects should consider proper ways to store, reproduce and give access to outcomes. Although our research does not discuss the property of the data, future projects also need to take into account concerns about the intellectual property of data, outcomes, and accessibility.

Qualitative analysis of semi-structured interviews provided an approach to evaluating the success of Indigenous mapping and participatory tools implemented in the research process. This analysis also provided a measurement of subjective outcomes, such as empowerment and building capacities. It also showed that quantitative and mixed approaches need to be implemented in order to evaluate the success, reliability, and reproducibility of the participatory methods.

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Article

Participatory Mapping as a Didactic and Auxiliary Tool for Learning Community Integration, Technology Transference, and Natural Resource Management

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Abstract: Participatory mapping is a tool for community work linked to natural resource management. It is an auxiliary for diagnosis and data acquisition from communities and their natural resources. In Baja California, there are several indigenous communities, some close to urban areas but still unknown to most people in cities as well as visitors. These communities are fighting to restore and maintain their language, tradition, territory, biological, and cultural diversity. This work was carried out by linking members of the indigenous community of San Jose de la Zorra with bachelor's and graduate degree students, to obtain information on the biological, cultural, and economic activities of the community through participatory mapping. The learning experience was significant for all participants; although it was not the intention in this study, students had the unique opportunity to exchange information and learn culture and biodiversity from indigenous people. The indigenous community was involved in field data acquisition and the use of some information and communication technology resources developed for this approach, and used it for natural resource management and decision making. The main results of this experience were wide format printed maps that were placed on several sites inside and outside the community, digital mapping that gave information about natural, cultural, and economic resources of the community for local and foreign visitors, and technology transference to solve problems identified by the community.

Keywords: community mapping; learning community; natural resources management; Cyberatlas

1. Introduction

The Kumeyaay ethnic group is one of 15 ethnic groups of the Yuman ethnolinguistic family and one of the 3 ethnic groups found in the binational Region California, USA and Baja California, Mexico [1,2]. The Yumans came to that region from a series of migrations from the north to the south, entering the Baja California peninsula in a period that comprised from 2500 to 600 years ago [3–5]. While Yumans cannot be considered the first settlers of Baja California, they can be considered to be the ethnic groups that prevailed in the region since ancient times. One of the fundamental reasons why they endured in the region is their ancestral way of life. Originally, they were groups of gatherers who moved through the rugged terrain of the region, following the patterns of migration and reproduction of animal and plant species [6]. The resources they utilized were animals such as deer, bighorn sheep, rabbits, rodents, and reptiles, as well as marine products and plants such as acorns, nuts, pine nuts, and agave [7]. This gave these groups the ability and capacity to survive in vast territories, since pre-Hispanic times to modern times.

The lifestyles of the Kumeyaay tribes and their traditions were affected by different historical processes that had significant demographic, sociocultural, and economic impacts [8].

Today, the Kumeyaay live in sedentary communities and traditional activities are largely replaced by wage-earning economic activities on the nearest ranches, ecotourism activities inside their communities, and temporary employment activities promoted by government entities [1,9].

Considering the above, a revaluation of community traditional knowledge is important to promote current productive economic activities and make them compatible with sustainable development, since some activities, like basketry, are based on the extractive use of natural resources in its limited territory. Spatial, accurate, and reliable information is a crucial element in achieving sustainable development [10] and with that, the deep relationship that the Kumeyaay have with their natural environment allows for obtaining an in-depth knowledge of their environment and the precise spatial location of elements of that environment.

Participatory approaches are widely used to rescue traditional knowledge in rural and indigenous communities. These approaches have their origins in the 70's with a methodology called Rapid Rural Appraisal, which evolved in Participatory Rural Appraisal (PRA) [11]. PRA acknowledges local knowledge and, more importantly, encourages local participants to play a crucial role in the research process [12]. Of all participatory methods, participatory mapping is the most widespread, and it is now considered to be an area of study in its own right [13–15].

For the past two decades, these approaches are widely used in different contexts, and there are several mapping-based approaches with changing terminology, over time [16]. Currently, most are commonly referred to as participatory mapping [17]. This method promotes local participants' autonomous decisions and allows them to control mapped spaces, challenging political limits and altering land-use categories [18]. The promotion of these autonomous decisions is labeled as an empowerment process of locals, because they made those decisions and transformed them, based on their perspectives and desired outcomes [18].

In general terms, participatory mapping approaches are proven to be important in recovering traditional knowledge [19–22]. In this context, participatory mapping approaches help identify place values and thus identify attitudes towards land use and potential conflicts [16,23]. Moreover, participatory mapping was proven useful for the management and conservation of natural resources by improving the decision-making process [24–26] and exploring landscape values for conservation planning processes [27–29]. Additionally, these approaches are useful in increasing public participation [30,31] and in promoting various governance dimensions [32,33]. Some other efforts manage to incorporate several dimensions in the same mapping effort, such as ecotourism practices like socioeconomic activity and biodiversity evaluations [34].

There are several new approaches to participatory mapping, including digital mapping technologies [35–37]. Although these approaches are considered participatory mapping, they are based on a new way to collect and represent spatial data in different formats. Thus, new paradigms and theoretical constructs that embody this new way to see cartography are growing [38–41].

Participatory processes were developed in Kumeyaay communities to map plant species distribution and assess their conservation status [9,25,42,43]; for the diagnosis and training of the community [42]; for the mapping of forest pests, and the construction of a cybercartographic atlas for natural resource management decision-making [35]. Nevertheless, every effort was made to incorporate several dimensions into one analysis, such as cultural, biodiversity, and local economy.

We describe a participatory mapping process based on community mapping in the Kumeyaay community of San José de la Zorra, this community already developed participatory processes [9,25,42,43]. The community economic activity is based on the use of resources for the elaboration of artisanal crafts, and they want and need to publicize its activities and its location to take advantage of the tourism. The mapping results allowed to locate important natural, cultural, and economic resources. From them, several proposals were made for solutions to problems identified by the community through technology transfer processes, for the proper management of natural resources and the management of water supply sources that sustain the life of the community.

This paper is structured into five sections. Section 2 presents the materials and methods and includes a brief description of the case study area and the methodological approach, where the learning community was integrated, based on participatory mapping and knowledge dialogue. Section 3 presents findings, including results of two participatory community mapping efforts and the results of technology transfer based on said results. Section 4 assesses and discusses findings. Lastly, conclusions and suggestions for recommendations and further steps are presented in Section 5.

2. Materials and Methods

2.1. Case Study Area and Community

Historically, the Kumeyaay territory had its southern boundary in Santo Tomás, Baja California, Mexico; its northern border in Escondido, California, United States; its eastern boundary in the Sierra Juarez Mountains in Baja California and its western boundary on the Pacific Ocean coasts in both countries [2]. The Kumeyaay nation was organized into family clans or "chimules" occupying specific territories and were led by a centralized authority called "kwaipai". Each clan was made up of about 100 people and the internal organization was patriarchal and exogamous, i.e., the clan followed the direct family line of male parent or relatives and the men formed marriage alliances with other clans. It was under these sociopolitical and economic characteristics that the Kumeyaay clans survived within their territory for hundreds of years.

San José de la Zorra is one of the three Kumeyaay communities settled in Baja California (Figure 1). This community, in addition to seasonal hunting and harvesting, typical of the Yuman tribes, developed more complex traditional practices. These included controlled vegetation pruning to promote growth and a proto-agriculture system that was based on controlled burning of vegetation patches and the redirection of water tributaries, by building canals [44,45]. One of these ancestral activities, today perhaps one of the most emblematic Kumeyaay activities, is the production of plant-made artisanal crafts. Historically, spiny rush and willow baskets were used to collect and store the seeds of vegetation they used as food. The Kumeyaay possess an important body of traditional knowledge that allowed them to interact with their environment and establish their forms of sociopolitical and economic organization.

Despite the inherent transculturation process, Kumeyaay communities preserve various traditional activities, such as crafting and plant harvesting for medicinal and traditional purposes. These practices were embedded in the economic dynamics of communities and often represent the only income for Kumeyaay families. These communities are considered to be marginalized because they are historically excluded from the mainstream social, economic, educational, and cultural life; remain oblivious to regional rural development processes; and are often not considered in regional development policies. Likewise, the current legislative framework does not provide the necessary tools to ensure the exercise of its traditional knowledge and activities to ensure economic and social development [39]. As a result, its fledgling economic activities have little visibility, despite being settled in the Guadalupe Valley, a region with more than 35 wine houses, and receives more than 50,000 visitors a year, due to its wine and gastronomic activity.

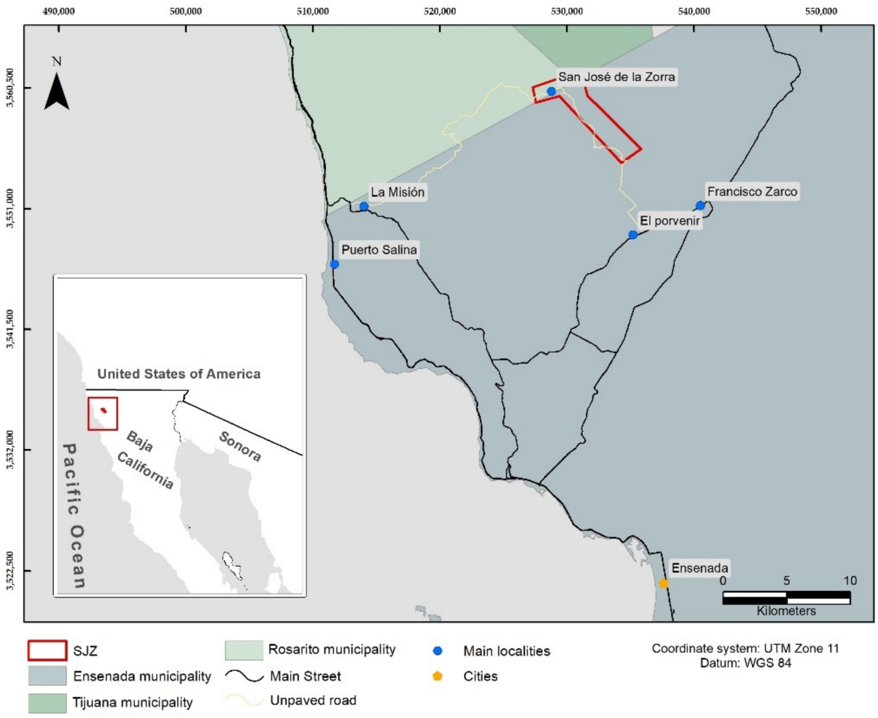


Figure 1. Location of San Jose de la Zorra Kumeyaay Community. Figure shows the community limit polygon and its location related to Ensenada, Rosarito, and Tijuana municipalities and principal towns. It shows in macro localization the location related to the United States of America border. Source: Own elaboration.

2.2. Participatory Mapping and Research: General Approach and Process

The natural resources mapping occurred in the context of a participatory development process carried out through various workshops [9,42,43]. For thematic maps development, the community indicated the need to spatially locate plant resources that are important for handicrafts and their conservation status. Participatory data compilation and analysis was developed through the knowledge dialogue and the construction of a learning community approach [42,46]. In mapping sessions, instructors and community members engaged in learning, so the community learned and contributed their knowledge for the development of thematic maps, while the instructors learned and demonstrated aspects of community culture, such as words and linguistic expressions. This participatory mapping process consisted of six stages (Figure 2), based on a previous work with this community [42]. All stages were sequential and required the participation of community members and academia, always with expressed consent for participation and with the commitment to return the information products to the community. These stages were as follows.

1. Preparation. The academic-technical team was formed, the team was organized according to the participants and their profiles; the agenda was developed and established based on the work that would be carried out in the community.

2. Information. A first meeting was held with the community, and the objective of the work was stated; the forms and participation schedule, and the products to be obtained were agreed upon. This stage might require two sessions.

3. Training. In this stage, the learning community began to form, and knowledge dialogue was promoted. Interexchange and community self-evaluation occurred, and there was horizontal and open communication between all parties. Here, the main technical skills, community problems, and needs were examined.

4. Mapping and Research. The acquired knowledge on previous stage was used either by collecting field data, making physical thematic maps, or applying group discussion and consensus techniques. This was the data generator and participatory research activities

stage. Interdisciplinary team members use a GPS for data acquisition; digital data collection forms on smartphones; physical maps; digital cameras, and any available and previously learned tool in the training stage.

5. Integration and Analysis. The information obtained in the previous stage was synthesized, shared, and confirmed. Not only to inform, but rather to analyze and draw conclusions. Generally, the technical team synthesized and presented, the community confirmed and analyzed, and conclusions were reached together.

6. Products. At this stage, cartographic products were generated, presented, and verified. Additionally, decisions were made for resource management, conclusions were formalized, and possible future works were also established. This was an important step to make commitments for new problem-solutions approach.

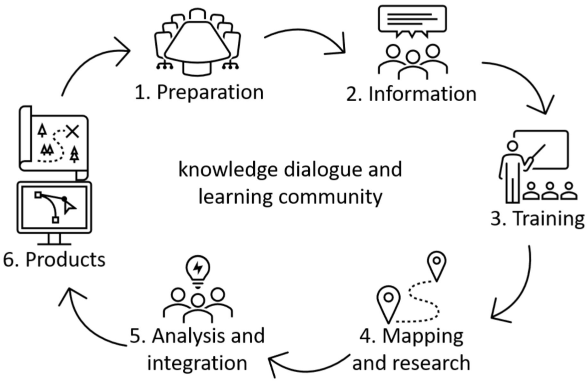


Figure 2. General approach and process for participatory mapping and research. This process was repeated each time the different groups interacted for a new project or initiative. In this work, this was relevant, given that the products of the first mapping effort were the baseline for second participatory mapping and technological transference. Source—own elaboration.

2.3. 1st Participatory Mapping and Research Process for Important Basketry Plant Species

On this 1st participatory mapping and research effort, twenty community members and technical team (three students and a professor) participated in the bench and field work. The community mapping process was based on a satellite image with the community boundary printed on wide format paper, with dimensions of 70 × 95 cm (width × height) and a translucent paper of the same dimensions over it, so the community boundary, the terrain, and objects in the satellite image were observed and used as reference for the community mapping process. The community members could then draw the thematic maps with color markers on the translucent paper. One of the sessions consisted of a digital mapping using Google Earth, where the community members located their houses and the main roads. These digital layers were combined with the physical maps. The final thematic map layers represented location of houses and cultural, economic, and social importance sites, as well as ubication of current and historical harvest sites for plant resources such as spiny rush (*Juncus* sp.) and willow (*Salix* sp.).

Once the thematic maps were generated, a participatory research process that included field data collection, confirmed the location and available volumes for each plant species in several areas of the Kumeyaay community of San José de la Zorra. This process was carried out by 4 community teams, and 5 community zones were evaluated within the territory. Each community team was trained for field data collection, GPS use, and data analysis. In each zone, width and height measurements were taken for each of the plant species. Band sampling, with sampling units of 3 × 20 m separated by 50 m between each sampling unit was used for willow sampling. Circular sampling units of 5 m radius were used for spiny rush, separated by 50 m between each unit. Each of the sampling unit of both spiny rush and willow were georeferenced. Subsequently, participants calculated the available biomass volumes of spiny rush and willow in the five areas evaluated and the results were indicated in the thematic maps previously developed. For cartographic products used in the decision-making process for the management and conservation of plants species, see [25] for more details. Once this process was completed, the maps were printed, so all community members and visitors would locate the conservation and restoration, and use areas for plant species, as well as the historical and current sites of spiny rush and willow harvest sites. The process and results of this first mapping effort were extensively reported in this same special issue [25].

2.4. 2nd Participatory Mapping and Research Process

A second participatory mapping effort was carried out through a group mapping, where 51 people participated, including 12 community members who accompanied each technical team collecting community data. Thirty bachelor and eight graduate students, and the professor of cartography and Geographic Information Systems from the Faculty of Sciences of the Autonomous University of Baja California (UABC) visited the Kumeyaay indigenous community of San José de la Zorra (SJZ), Ensenada, on March 24 and 25 of 2018. The purpose of this visit was to compile data on cultural, economic, and biodiversity aspects, through participatory mapping and community member validation. Mapping activities were divided by specific topics, as well as routes for field data collection within the community. Several teams were formed according to the interests and knowledge of each area and topic under study. On this two-day field work, each team performed the activities described in Table 1 and the community members were always present, helping in obtaining field data, validating, and authorizing the data recorded.

Table 1. Themed activities developed by each team.

Mapping Theme	Activities Carried out
Biodiversity	Monitoring representative flora and fauna
	Photographic record of the species found
	Conversations with community members to learn about traditional knowledge and uses of biodiversity
	Mapping plants and animals using KoboCollect application
Economic	Search for sites where economic activity is carried out (livestock, agriculture, commerce)
	Photographic record of sites
	Conversations with site owners to determine activities they do
	Mapping economic sites using KoboCollect application
Cultural	Search for cultural and social relevant sites, as well as homes with cultural activity
	Photographic record of cultural and social relevant sites
	Conversations with community members who provide information of social and cultural relevance sites.
	Mapping relevant sites in the community, as well as homes with cultural activity.

Each team had a GPS, camera, and a digital data collecting form using the KoboCollect application in their smartphones, with which the field data was collected, and the geoinformation database was automatically integrated. The fields in the databases were filled according to the mapping theme (Table 2).

Subsequently, the geoinformation database was analyzed, and duplicate records and those with incomplete information were deleted. Using the QuantumGIS program, vectors of points and routes of each theme were generated, and with them and through the ESRI platform Story Maps, a cyberatlas was created, encompassing the three mapping main themes, using a visual format with photographs and audio files. In addition, with the same field information, digital and physical mapping products were developed that tell the history of the community and its current activities.

Table 2. Data fields in the digital data collection form for each mapping theme.

Biodiversity	**Economic**	**Cultural**
Coordinates	Coordinates	Coordinates
Biological group	Type of activity	Type of site
Species	Owner's name	Demographics
Common name	Regime (private—public)	Site/person´s name
Kumeyaay Name (audio)	Use	Use and description of the site
Uses	Type of production	
Photography	Production market	
	Species or product	
	Temporality of production	
	Photography	

2.5. Application of Participatory Mapping Results to Solve Community Problems

2.5.1. Development of a Solar Dryer for Basketry Plants

After the 1st participatory mapping work and the results of the analysis of basketry plant stocks, which is widely reported in [25], the community understood the importance of conservation and good postharvest handling of basketry plants. For this reason and through a request to the Technological University of Tijuana, several participatory work sessions were held in the community to document the plant drying problems, decide the possible solutions for the development of a solar dryer prototype, community training for the development of their own dryers, the location of dryers according to solar radiation conditions, orientation, terrain, associated infrastructure, logistics of harvesting, transporting, and storing of plants, in order to guarantee an optimal raw material for the intended use. All this work was based on the participatory mapping and research process described (Figure 2).

2.5.2. Water Sources Sampling and Analysis

Another important aspect is the adequate management of the water resource, based on the knowledge of the water quality of the wells used as the main source of water supply for the community. This is crucial because there are no drinking water supply services in the community, the water source comes from the extraction of groundwater that is used without any treatment, and there are also no sewer systems, so human waste disposed in septic systems and latrines represents a source of biological and chemical contaminants for groundwater [47–49]. This poses a public health risk, given the possible presence of pathogenic organisms, which compromise the quality and safety of the water [50,51]. After the 2nd participatory mapping conclusions, and by request of and participation of the community itself, we carried out a participatory research project to analyze physicochemical and microbiological parameters of water in the community; we followed the previously described process (Figure 2). Participatory sampling of 24 water wells, located on an approximate 450 Ha, was carried out on the basis of the results of the second participatory mapping. This sampling involved 12 people from the community, and 45 students and five professors from the environmental technology, renewable energy, and biotechnology careers of the Technological University of Tijuana (UTT). Each water sample was evaluated in situ (pH, temperature, and electrical conductivity) and then transported and analyzed in the UTT laboratories. The physicochemical parameters evaluated were hardness, total dissolved solids, chlorides, and sulfates. The presence of pathogenic organisms was determined through total and fecal coliforms, within 24 h after collection, using the NMX-AA-042-SCFI-2015 [52] method. The determination of fecal contamination indicator of microorganisms showed if the water was contaminated with fecal matter and represented a risk for diseases caused by enteropathogenic organisms [53].

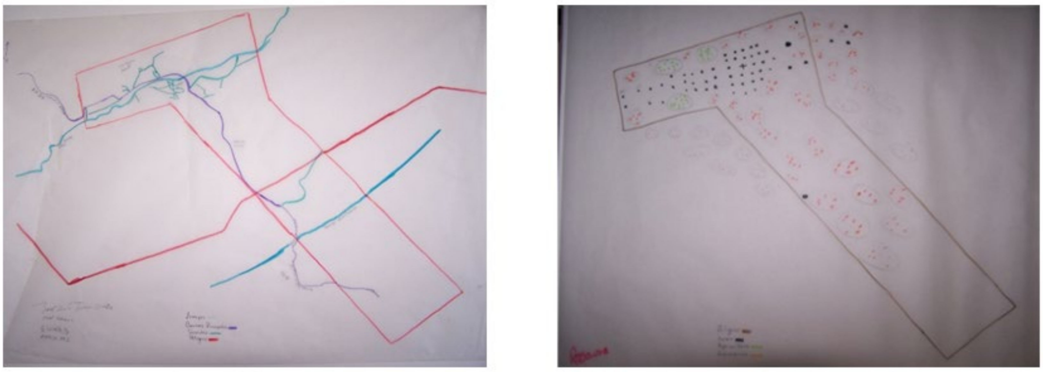
The results of the analyses were compared with the quality criteria for drinking water, established by National regulations [54]. A map was developed to present and make available to the community the water quality information, indicating the condition of each water well through a color system, according to the permissible maximum limits established for the parameters evaluated.

3. Results

3.1. 1st Participatory Mapping Process

The first participatory community mapping (Figure 3) allowed the San Jose de la Zorra community to make four general thematic maps with the location of houses and cultural, social, and economic importance sites (Figure 4). These maps show the location of the houses of each of the families of the community and public interest sites such as schools and churches. In a subsequent workshop, the community developed four thematic maps for productive activities, with the precise polygons of natural resources harvesting sites associated with productive activities within and outside the community, such as livestock, agriculture, and historical spiny rush and willow harvest sites, as well as the location of current harvesting areas for both species. Spatial and quantitative analysis of field data through participatory sessions, indicated that some areas were being overexploited (lower biomass) and allowed the community to conclude that it was necessary to implement resource management actions through the development of a community management plan, based on the rotation of spiny rush and willow harvest areas and other simple management rules [25].

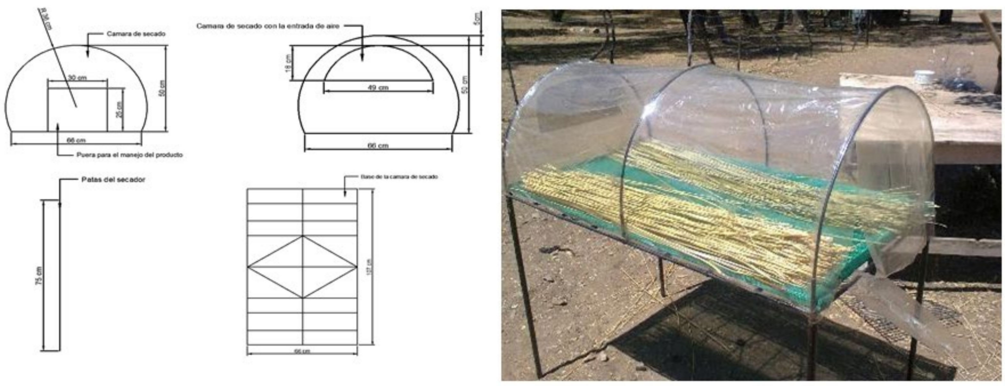
Figure 3. Community mapping. (**a**) Community mapping process using satellite images, transparent paper, and color markers (**b**,**d**). Field data collection for plant species measurement and biomass calculation. (**c**) Digital Community mapping through Google Earth in the computing facility in UABC.



(**a**) (**b**)

Figure 4. Community maps. (**a**) Map showing roads, streams, important sites, and ranches. (**b**) Map with the location of productive activities such as agriculture, livestock, spiny rush, and willow collection sites.

Another aspect derived from the interpretation and discussion of the 1st participatory mapping results was that the post-harvest management of plant material was not adequate, since more than 20% of the biomass collected was lost in the drying process, thus the need to implement a solution to improve the process and reduce or eliminate loss of plant material arose. It was also necessary to make the harvest 100% effective, and therefore more sustainable. This led to the participation of researchers from the Technological University of Tijuana, who developed a solar dryer that they installed in an ideal location, considering the conditions of solar radiation and orientation, according to the terrain and associated infrastructure (Figure 5).



(**a**) (**b**)

Figure 5. Solar dryer. (**a**) General scheme of dryer design. (**b**) Image showing the dryer installed and in operation for spiny rush drying.

3.2. Implementation of Solar Dryer

The results of the implementation of the dryer, reduced the drying from up to six months to 4 weeks, obtaining a product with the characteristics of humidity, resistance, color, and malleability, necessary for its use in the elaboration of baskets by the artisans of the community. Once the efficiency of the dryer design was evaluated, members of the community were trained to develop their own dryers. In this activity, the training of five artisans who built and used their dryers was achieved during a period of two weeks, in which the efficiency in the drying treatment was documented, based on the analysis of the texture and humidity of the material.

3.3. 2nd Participatory Mapping Process and Databases

Data collected (Figure 6) through the mapping and participatory research process is presented in the Supplementary Material Tables. All locations were recorded using geographical coordinates and horizontal Datum WGS84, but in this work all locations were omitted to maintain the confidentiality of community information. The Supplementary Table S1 presents biodiversity data, including species name, common name, and its cultural use.

Figure 6. Field data collection for participatory mapping. (**a**) Students and community members collecting information on vegetation. (**b**) Water sources sampling. (**c**) Data collection on agricultural areas. (**d**) Data collection on social and cultural aspects.

A total of 49 species were recorded, 14 corresponded to plants, 4 to fungi, and 31 to species of fauna (three amphibians, three arthropods, three mammals, five reptiles, and seventeen birds). A total of five types of uses were documented—food, ceremonial, artisanal, medicinal, and utilitarian. Of the total registered species, 17 have diverse uses, 10 species are used as food, and two species are used in ceremonial activities or rituals. Oak (*Quercus agrifolia*) is the species with a higher record of uses like food, artisanal, utilitarian, and ceremonial (Supplementary Table S1).

The Supplementary Table S2 showed the demographic and cultural data. This database contained gender data, the number of speakers of the Kumeyaay language, whether they were native to the community or not, and whether any artisan, dancer, or community members lived in the recorded house. According to field data, there were 31 houses in the community, inhabited by 122 people, 59 women, and 63 men. Only 47 people were Kumeyaay speakers; artisans lived in 15 houses, and Kumeyaay dancers lived in four houses.

Information and spatial location were also obtained from public and cultural places, and whether it was a ceremonial, historical, or public place. One ceremonial site, two historical sites and six sites for public or common use were registered (Supplemental Table S3).

Lastly, the economic data were compiled by three sub-themes—agricultural, commercial, and livestock activities (Supplementary Tables S4–S6). Data compiled through participatory mapping indicated that there were 10 farmers planting around 10 plant species in the community, both in greenhouses and in traditional agricultural fields; most of its production was marketed outside the community. There were nine people who were dedicated to intensive and free cattle and goat farming, products of this activity were for the outdoor community markets. Some community members owned equine cattle, which were generally used as service animals. In terms of trade, seven people traded food products, such as honey, cheese, fruits, and typical meals. In addition, some of them produced and traded wines and handicrafts, and one person was dedicated to ecotourism.

3.4. Cyberatlas

With all data from the mapping and participatory efforts, digital layers of geographic information about community biodiversity, cultural and economic activities were developed (Figure 7). Wide format printed maps were also developed about the location of environmental, cultural, and economic importance sites, such as including ecotourism, and commercial and cultural routes that would be visible to visitors (Supplementary Figure S1). This spatial data contributed to the visualization of the community of San José de la Zorra, as well as products and services offered. With these digitized information, two digital products were developed—the biodiversity, cultural, and social Cyberatlas for the SJZ community (Figure 8a), and the history of the SJZ community through maps (Figure 8b).

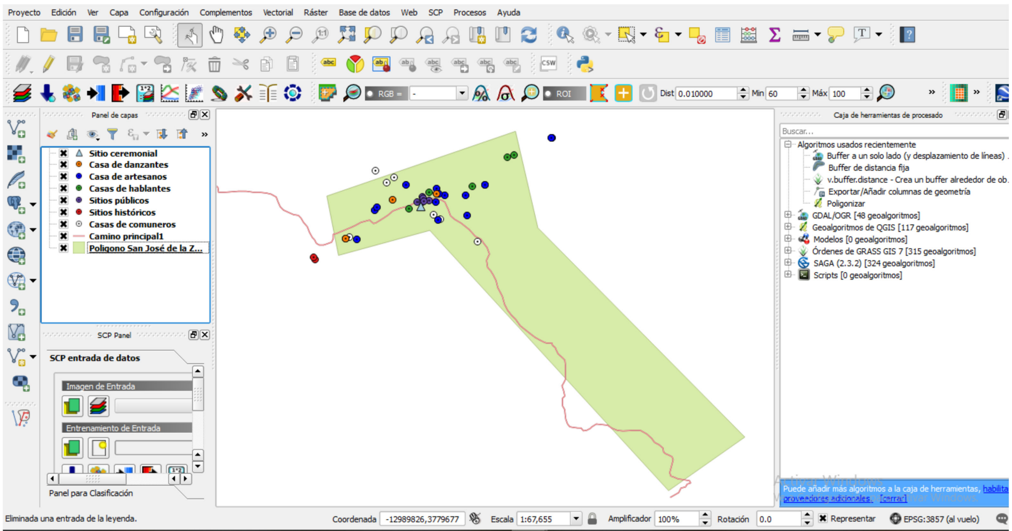


Figure 7. Digital layers of information developed to be used in the digital atlas using the QGIS software.

Figure 8. (**a**) Home page of the Cyberatlas showing the diversity of georeferenced flora and fauna in the community of San José de la Zorra. (**b**) Information layer derived from participatory mapping where the database is displayed, in this example, for agricultural sites.

The Cyberatlas helped the community of San José de La Zorra to become known in social networks and was visible in the regional context, in addition to some aspects of its biological diversity. Photographs show common plants and animals in these areas, helping in the incipient ecotourism activities. It also included cultural sites, school locations, health centers, important community gathering sites and sites linked to their ancestral history. Economic activities were also shown, including livestock, crafting sites, and the location of the ecotourism center, a central site in the community with the largest influx of visitors (Figure 8a). The Cyberatlas is publicly available and a link is given in the Supplementary Materials.

The digital history of the community through maps describes the San Jose de la Zorra community as part of the Kumeyaay indigenous group; the history of its creation seen from its cosmogony, its interaction with the first European missionary groups and explorers, and the loss of much of its ancestral territory. The current story included how the name San José de la Zorra was born and the census data were made in participatory mapping. Currently, the economic activities focus on the elaboration of handicrafts and other products such as wine, cheese, and preserves. One of the arising important economic activities is the ecotourism center with cabin rental, camping, and recreation areas, as well as livestock and agriculture activities (Figure 8b). This digital resource also included commercial and cultural routes proposed for visitors (Supplementary Figure S1), which started at the ecotourism center. Link to this resource cold be found in the Supplementary Materials.

3.5. Analysis of Water Sources

As a result of the 2nd mapping effort, 40 water wells were registered within the community, samples were obtained from only 24 (Figure 9), the remaining 16 water wells were inaccessible for sampling or were abandoned. The analysis of the physicochemical parameters indicated that 15 of the 24 water wells evaluated had pH values within the limits set by the standards, five presented values within a range comparable to other water wells in the region, with pH values between 6.5 and 8 units [55]. Total dissolved solids (TDS) measurement, which is widely used as an indicator of groundwater salinization problems, showed values above the norms in seven of the samples analyzed. For all samples, chloride and sulfate levels were found to be within the limits set by the norms, and slightly lower than those reported in the region [56]; this could indicate low concentrations of organic compounds contamination in soils.

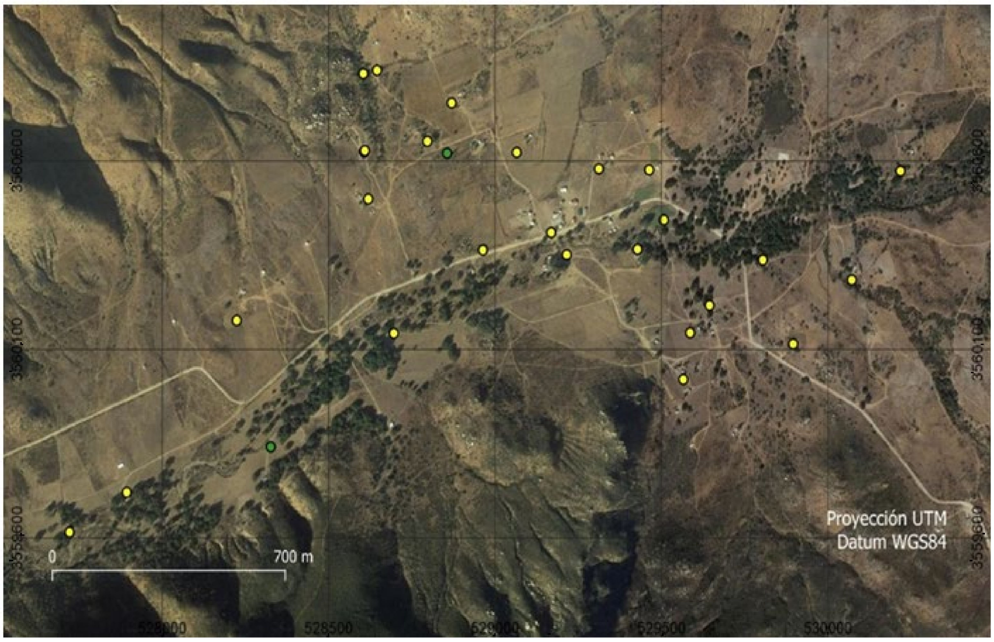


Figure 9. Location of water sources in the community, where quality status is indicated with colors according to physicochemical and microbiological parameters. Red is health risk, yellow is health concern, and green indicates suitable for use without concern.

Finally, for the hardness parameter, concentrations were found below the norms level for the water quality criteria, so this was not considered to be a health risk. However, the microbiological analyses to assess the presence of pathogens in water showed the presence of fecal coliform bacteria *(Escherichia coli)* in 91% of the sampled water wells.

With the information from the analysis of the sampled wells, a water quality with basic information was generated that allowed the monitoring of water quality and its human consumption usage—red indicates a health risk; yellow indicates a health concern, and green indicates suitable for use without concern. This information, available as a resource in the Cyberatlas, would allow the community to know the condition of its water supply sources with time and promote treatment strategies that guaranteed access to a resource with optimal conditions for use and consumption, without compromising the health of the community's inhabitants.

4. Discussion

The results of this work showed that community mapping is an important tool for recovering and communicating traditional and spatial knowledge. This is shown by the thematic maps produced by the community, as these reflect knowledge not only of contemporary socioeconomic aspects, but ancestral aspects such as traditional sites for harvest, and the location of sites of historical and cultural importance. This was consistent with other efforts where similar results were achieved in the recovery of traditional knowledge [19,20]. Therefore, we can ensure that the community mapping sessions were successful, and that the integrated learning process strengthened community interaction and goal development. However, it is worth emphasizing that community mapping was possible through the research and community participation process, which has a premise of recognizing the diversity of knowledge of all participants, strengthening collaboration, community self-evaluation, and the appreciation of community members and their knowledge. This is acknowledged in the third and fourth stage of the participatory mapping process (Figure 2).

Thematic mapping, physical or digital, aims to optimize the communication process, i.e., obtain the most information with the last effort. This communication approach produces an efficient graphic message and allows to spatially show, places, culture, traditions, and part of the life of a community [57].

This research bears obvious similarities to Bocco et al. [34] as it addresses diverse themes such as biodiversity, cultural, socio-economic, and health aspects. This mapping effort is multi-thematic and multipurpose, while other physical and local maps allow us to locate points of interest that can be found within the community, helping community visitors, and ecotourists. Digital atlases allow stakeholders, government, and visitors to locate the community, as well as its natural, cultural, and commercial resources. Several tools were used to acquire data, such as traditional mapping techniques and digital mapping apps like KoboCollect, similar to other digital mapping efforts [34–37]. Moreover, the acquired data are presented through various forms, such as printed and digital maps. Even though digital techniques to collect and present spatial data were used, this was clearly a participatory mapping effort because community was always involved in evaluating and validating all information. Thus, this information becomes theirs and for them. Nevertheless, we consider this research to contribute to theoretical constructs and new paradigms based on the collection and representation of spatial data on a wide variety of formats [38–40].

Historically, participatory mapping, is considered to be a useful tool in the fight for the rights and resources of indigenous and other minority communities [18,58]. Our study showed that when enabling the community to map landscape features located outside of the boundaries of the community's polygon, as shown in Figures 4 and 7, they acknowledge that some features of cultural importance, which were once within their traditional territory, are nowadays outside of their boundaries. However, they manifest established verbal agreements with current land owners to continue using and benefitting from those resources, mainly plant harvest for the elaboration of artisanal crafts. These agreements, and access to culturally important resources are important topics to include in future research. Moreover, it allows to build community aspects through a knowledge dialogue [46], in which community members actively participate in the construction of information. In addition to this, natural resource management plans could be more effectively applied, thanks to the aspects and perspective provided [59]. It also allows geographical visualization of their community; homogenize the internal, spatial, and social vision, as well as the sites where they obtain their resources, and contribute to resolve possible conflicts through resources or territory [60]. This is consistent with other works in which participatory mapping aided to evaluate place values and thus identify potential conflicts [16,23]. In contrast, the collection of geospatial information with other tools such as the use of aerial photography or satellite images, without the participation of community members, excludes them in defining the characteristics of their territory and its important structural elements, identifying problems, or even deciding on sites not accessible to foreign people, for example, reserving for themselves their sacred sites. The importance of these tools is based on the diversity and enrichment of research, since the community directly provides information about its natural resources, customs, culture, and way of life and livelihood. This integrates the characteristics of its culture and environment from the first source, which is otherwise impossible to obtain and use for community internal process and decisions. Physical and digital maps, were only possible with the community participation in fieldwork and sharing of its knowledge.

The development of maps with the participation of community members allowed for understanding the organization of the community space and how social, economic, and biological relations between its members are woven. They were also informative tools that made the community visible through stories, generated by the joint work between community members and field data collecting facilitators. In this sense, it was not only the location of objects in a physical space but also the representation of the perception of space and resources, as seen by its inhabitants. In addition, participatory research methods and results were similar, demonstrating that this type of research is applicable and replicable in rural and indigenous contexts. Participatory mapping also allowed for identification of problems beyond the geographical space, as happened in our study. The spatial location of water sources enabled for planning, sample collection, and analysis of water wells, with a focus on the health of community and visitors. According to results of water samples analysis and based on national and international regulations where the maximum level of pathogenic organisms in water for human use and consumption of public water systems is zero [54,61], the community's water sources are over the maximum tolerance levels. Although there are no testing requirements, nor objective values for assessing well water quality, it is recognized that their proximity to septic systems poses a health risk [49]. The results of the physicochemical and microbiological tests were integrated into a map (Figure 9); green indicates if the water is safe to drink, mainly because both physicochemical and biological parameters were within regulations. Any site indicated with yellow means that it was not suitable to be used as a source of drinking water supply without prior treatment. This posed health risk through a visual and easy-to-assimilate indicator for the community. This information should be leveraged to determine those sources that pose risk to the community and encourage water well users to take steps to reduce the risks associated with the use and consumption of water from wells in poor condition; practices that are not currently followed since water is consumed directly from the water well. This proved that participatory mapping is a crucial tool for the decision-making process regarding natural resources, as it provides easy–to-use data to make an autonomous decision with common health implications [9,28–35]. We suggest continuing monitoring and presenting continuous results to the community and providing solutions for water treatment for an autonomous decision-making process led by the local community. The projects for technology transference carried out with the community of San José de la Zorra, were developed and implemented in order to address problems arising from the various needs in a rural region without access to basic public services, such as drinking water and sewer systems, which in turn provided the opportunity to promote the use of technologies to meet those needs, and solutions for optimization of plan artisanal crafts´ raw materials, on which its economy depended. This would not be possible without participatory mapping and decision-making. In this sense, the use of the solar dryer contributed a double benefit—the time in drying spiny rush for the elaboration of artisanal crafts was reduced; and the total biomass harvested could be used by eliminating the loss of raw material due to mismanagement, environmental factors, and damage by local fauna, making the artisans´ activity more sustainable and profitable.

The rapprochement with the Kumeyaay community was gradual. However, problem-solving proposals were provided to and readily accepted by the community. However, despite the good reception on their part, the real challenge was to achieve community engagement in the adoption of these practices.

5. Conclusions

This project demonstrated a regional unprecedent effort, where two higher education institutions collaborated for the solution of real problems in a rural community, through feedback between results and actions, achieving the development of the solar dryer and the analysis of water sources carried out. This was based on the results and analysis of the 1st and 2nd participatory mappings carried out. This could also be the beginning of a network academic–community collaboration. This is a good example of collaboration between community and academia for problem resolution through technological transference, based on community knowledge and information interchange.

The intervention process that took place in this project was based on the position of recognition of knowledge diversity of all parties, and clear and productive dialogue with community members, where all members were enabled to participate horizontally, internally in the community and abroad with the academic sector, which could provide solutions to community problems and needs, this is what we called the learning community.

It is critical for processes such as this that community members take a key and leading role in mapping aspects of their culture, economy, society, and biodiversity, through sessions based on a learning community. This allowed the community to gather data, analyze it, and as a result make decisions; to achieve sustainable use and development of a management program for harvesting the plant resources they use for artisanal crafts, with simple solutions such as rotating harvest areas and simple coexistence rules for community life, which were now visible on a map; and allowed to request water wells analysis and the solar dryer projects, which led to technology transfer to the community.

Technology transfer allowed to decrease plant material drying times and the obtention of a product with the necessary characteristics for its use in the manufacture of handicrafts, represents an important benefit. This is reflected in the improvement in the economy of the Kumeyaay community of San José de la Zorra and makes this activity more sustainable, because artisans are avoid raw plant material thrashing.

The diagnosis of water sources in the community bring to its agenda an important health issue, the results indicate that a solution must be found in collaboration with the academia allies. The community showed concern about this situation and interest in solving it. Hence, it represented a crucial element for the community-based decision-making process regarding a local health issue and a cornerstone for community–academia long-term collaboration.

This alliance between community and academia is the baseline for a long-term collaboration, with a view for community development through ongoing training, social organization, and spatial knowledge of its resources. Never before had the community produced a summary of environmental, social, cultural, and economic aspects, providing the opportunity for the community to be known through digital resources. This promotes linkage with the academic sector and establishes processes for the transfer and adoption of technology (use of GPS for mapping and field data collection). In addition, the maps generated, would be an information basis for future comparison for environmental, social, and economic conditions of the community, all through a participatory mapping process.

Participatory mapping is the most reliable and widespread participatory tool, and in this effort, demonstrated its robust and strong use as a didactic and auxiliary tool for learning community integration, technology transference, and natural resource management. It is crucial to recover and represent traditional knowledge, economic activities, use of biodiversity, cultural expressions, and represent all these in various formats, including printed and digital online maps, as generated by the Cyberatlas and the community story maps. With this tool, it is possible to approach community development strategies where spatial knowledge, social organization, and constant technical training are the basis for a success story. The Kumeyaay indigenous community of San José de la Zorra has the right conditions for a systematic and long-term application of this technique. Participatory mapping for natural resources uses knowledge as well as history and culture; sets an important precedent and adds importance to the conservation of the Kumeyaay culture in Baja California.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijgi10040206/s1. Table S1: Biodiversity data from participatory mapping in SJZ. Table S2: SJZ community demographic and cultural data, each register represents a commoner house. Table S3: Cultural, public, and common use sites. Table S4: Agriculture activities in SJZ. Table S5: Trade activities in the SJZ community. Table S6: Livestock activities in the SJZ community. Table S7: Links to San Jose de la Zorra Cyberatlas and Story maps. Figure S1: Cultural and medicinal plant route, image of physical map made for cultural and medicinal plant route proposed. This map was printed in wide format and installed in the ecotourism center.

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Article

Traditional Communities and Mental Maps: Dialogues between Local Knowledge and Cartography from the Socioenvironmental Atlas of Lençóis Maranhenses, Brazil

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Abstract: The Lençóis Maranhenses region, located in the state of Maranhão in northeastern Brazil, constitutes an area that includes a national park and presents extreme physical, geographic and climatic contrasts in addition to economic diversity and emerging tourism. Scattered throughout this portion of the Brazilian territory are local inhabitants whose traditional lifestyles are characterized by agricultural, extractive, fishing and animal husbandry activities. These local residents use guidance systems and mental maps developed through their long history, interaction with nature, and knowledge of the environment in which they live and work. Based on sketches prepared by residents and by Health Agents serving the communities, and with the support of cartographic-based materials produced by the team of the Socioenvironmental Atlas of Lençóis Maranhenses (ASALM, Portuguese abbreviation for Socioenvironmental Atlas of Lençóis Maranhenses), we present a set of digital and interactive cartographic materials that reproduce the movements, uses and practices of the families of these communities as well as the environmental dynamics of this vast region. Such cartography can serve as an instrument of planning, understanding and action, both to safeguard the rights of the local residents and for the handling and management of natural resources. Based on the dialogue between local knowledge and cartography, we present the methods, processes and results of our research project.

Keywords: native guidance system; Lençóis Maranhenses region; Maranhão coast; traditional communities; Cybercartographic Atlas

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1. Introduction

Since ancient times, the map was used to represent inhabited space, to communicate, and to display paths and routes travelled. New developments in cartographic methods and spatial representations, such as geospatial data sets available in web server maps, have made it possible to expand current mapping systems and trends [1]. The capability of superimposing geospatial data from different sources and formats on Geographic Information Systems makes spatial relationships explicit, and helps us understand interdependencies among geographic phenomena. Such cartographic representations, generated in a computational environment combined with human knowledge about these processes, can result in advances in geographic analysis [2].

In this paper we demonstrate the complexity of combining data from different sources and formats, but also the richness of this data for studying the socioenvironmental dynamics of the Lençóis Maranhenses region located in the state of Maranhão in northeastern

Brazil [3]. This region, which includes a national park, presents extreme physical, geographic and climatic contrasts, in addition to economic diversity and emerging tourism (see Section 2.1 below). Scattered throughout the territory are several traditional communities whose inhabitants participate in agricultural, extractive, fishing and animal husbandry activities. We are developing a Cybercartographic Atlas, the Socioenvironmental Atlas of Lençóis Maranhenses (ASALM), that aims to present cartography that displays, on the one hand, the environmental dynamics of Lençóis Maranhenses, and, on the other hand, the activities of those living in the region's traditional communities.

ASALM's software platform, the Nunaliit Cybercartographic Atlas Framework, is ideal for uniting representations of traditional knowledge, land use and occupation with geospatial data from different sources. Developed to support the explicit demands of cybercartography, Nunaliit is an open-source web-based data management system that uses maps as a unifying framework for connecting information and presenting narratives [4]. Cybercartography was first introduced in 1997 as an approach to cartography that linked theory and practice in an ongoing, iterative feedback loop between cartographic research and production [5,6]. The importance of mapping as a process and the map as a concept and a product was emphasized in the following elements: the multisensory, multimedia and interactive nature of cybercartography; its application to socially relevant topics beyond location finding and the physical environment; its integration into an information/analytical package; and the involvement of teams from different disciplines [6]. The concept of cybercartography has evolved since then with its emphasis on the co-production of knowledge that gives control and voice to local communities and the diversity of their opinions and perspectives [7]. More than simply a web-based technique, cybercartography includes a strong qualitative element that recognizes the importance of societal issues and relationships.

Pyne [8] (pp. 238–239) classifies cybercartographic atlases as a member of the "critical cartography clan," based on an analysis of the critical cartography literature, e.g., [9–12], among others. She observes that cybercartography and critical cartography share the following: a concern about adequately reflecting and communicating "experience, sense of place, and diversity in world views in a non-dominatory manner"; the exploration of new ways to both deconstruct and reconstruct maps; the recognition that maps are social constructions that have systematically excluded perspectives which do not align with imperialistic and colonial goals; an awareness of the power of maps to influence people's world views; and "a preoccupation with contributing to social justice, a broad ontology of mapping, reflexivity and inter-, multi- or transdisciplinary."

Participatory mapping is an important component of both cybercartography and critical cartography. In ASALM the mental maps of the region sketched by local inhabitants of the Lençóis Maranhenses region are combined with the geoenviormental data collected by members of the research team. Following cybercartographic principles, ASALM brings together researchers in geography, cartography, oceanography and biology with local inhabitants of the Lençóis Maranhenses region to co-produce and share knowledge of this unique and beautiful land.

The Lençóis Maranhenses region presents unique geoenvironmental dynamics, characterized by the presence of extensive dune fields shaped continuously by the action of winds and rainwater [13,14]. There are two distinct seasons, rainy and dry. The trails through the dunes and floodplains are constantly changing, making travel difficult for those who visit Lençóis Maranhenses. However, this difficulty is not experienced by the local inhabitants, who use guidance systems developed from their long history in the region, interaction with nature, and intimate knowledge of the environment in which they live and work. In Section 3 we present in detail the mental maps and native guidance system they have developed through generations of individual and collective memory and experience.

The mental map has been defined as both a concept and a geographical document [15]. Such maps exist only in the memory and spatial knowledge of their creators, yet when transcribed into graphical representations they have been shown to be highly accurate [16].

The centrality of mental maps in representing and preserving traditional knowledge was reported in many diverse cultures. These include knowledge of travel routes by the Inuit in the snow-covered Arctic [17,18], detailed knowledge of the Lough Neagh lake bed by fishermen in Northern Ireland [16], and the spatial knowledge of indigenous tribes in the mountains of Taiwan [19]. The term "memoryscape" has been used to describe the travel routes of the Inuit who follow traditional trails that, like those in Lençóis Maranhenses, physically disappear with changes in weather and seasons but are embedded in the cognitive memory of their users [18]. Such routes incorporate memories of physical territories and people's relationships with their environment, and are essential for safe and reliable travelling in ever-changing landscapes.

McKenna et al. speculate that an accurate mental map of local ecological knowledge consists of the following characteristics: a relatively homogenous society; local use or exploitation of natural resources (e.g., fisheries, forest products or pasture); inter-generational transmission of knowledge; economic dependence on the resource; and sufficient time for self-correction [16]. The guidance system employed by the local residents of Lençóis Maranhenses (and its surroundings) fulfill all these conditions, as they live in small communities comprised of several close-knit families; their orientation practices are crucial for fishing, subsistence collecting, animal husbandry and tourism (all important sources of income); their routes are transmitted orally through experience; and they have a long history of navigating across their territory.

In ASALM, the information gained from mental maps, sketches and figures will be superimposed on a geospatial database, strengthening the dialogue between local knowledge of orientation and geospatial data collected for cartographic research. Through cartography, the knowledge of native guidance systems will be documented and accessible, in the same way that Aporta's GPS documented the "ephemeral tracks" left by Inuit hunters [18] (p. 252).

Knowing and mapping the practices developed by the residents of the region of Lençóis Maranhenses—in particular productive activities in the primary sector of the economy, i.e., agriculture, livestock, fishing and plant extraction—is also essential to understanding the impact of socio-spatial transformations that the region has experienced [20,21]. For example, the construction of new state highways connecting municipalities in the Lençóis Maranhenses region has resulted in increasing tourism and urban expansion. In such cases, cartography can serve as an instrument for planning, understanding and action, both to safeguard the rights of local residents and for the handling and management of natural resources.

2. Materials and Methods

In this section we present the study area (Section 2.1), and the three steps in our research project. Step 1 involved establishing and strengthening relationships and partnerships among project members and institutions. In Step 2 we collected the geospatial data for developing ASALM's cartographic base. Step 3, as shown in Figure 1, consisted of fieldwork and data analysis. The multidisciplinary perspective and participatory methodology, implemented in cooperative activities between institutions (universities, managing bodies, associations) and local leaders, and through conversations facilitated by ASALM in Step 1, made it possible to collect data and gather knowledge of the traditional ways of life to further the purpose of mapping this extensive and diversified area.

2.1. Study Area

The Lençóis Maranhenses region is located on the east coast of the state of Maranhão in northeastern Brazil. It includes a national park and overlaps with other Conservation Units such as the Extractive Reserve of Tubarão Bay, the Parnaíba Delta Environmental Protection Area and the Pequenos Lençóis Environmental Protection Area (Figure 2). The area presents extreme physical, geographic and climatic contrasts, in addition to economic diversity and emerging tourism. It presents unique geoenvironmental dynamics, with its extensive dune fields shaped continuously by the action of winds and rainwater [13,14,22]. A geologically rare phenomenon, it is the largest recorded area of dunes formed in the active dune field of Quaternary [23–25].

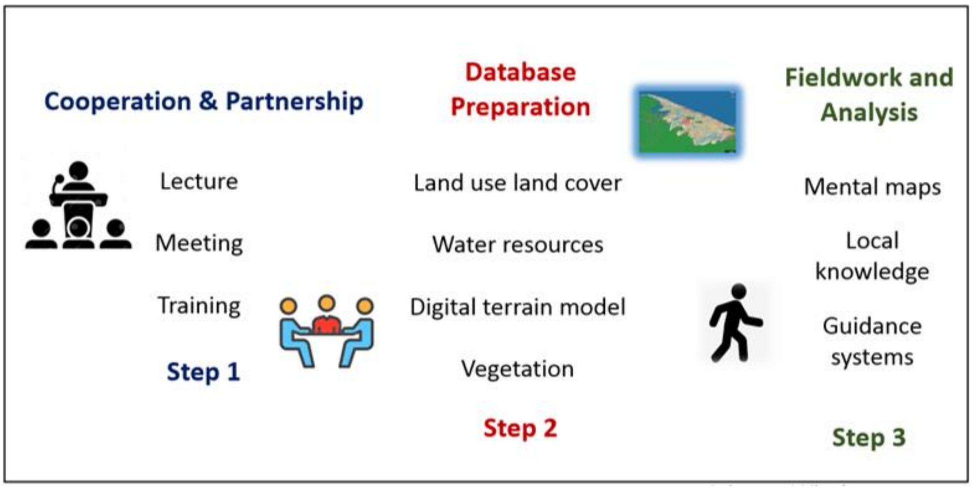


Figure 1. Steps in the Socioenvironmental Atlas of Lençóis Maranhenses (ASALM) research project.

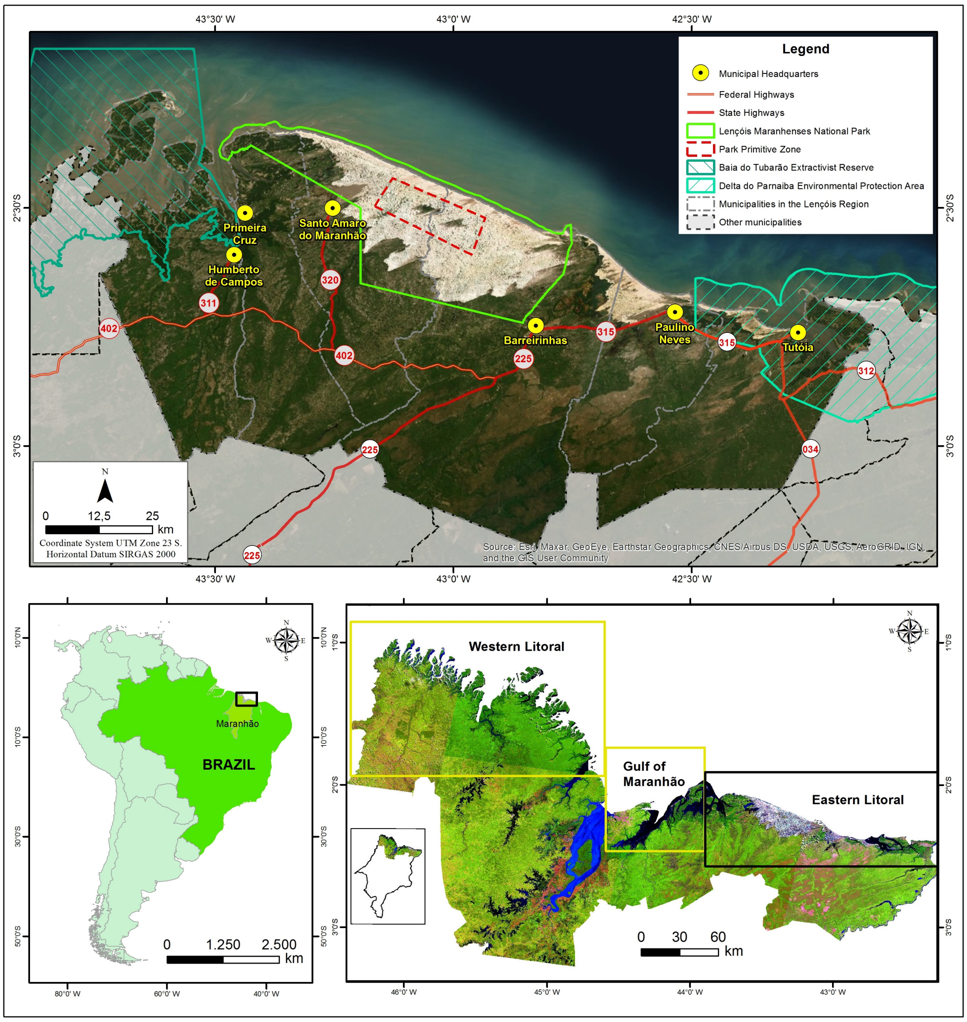
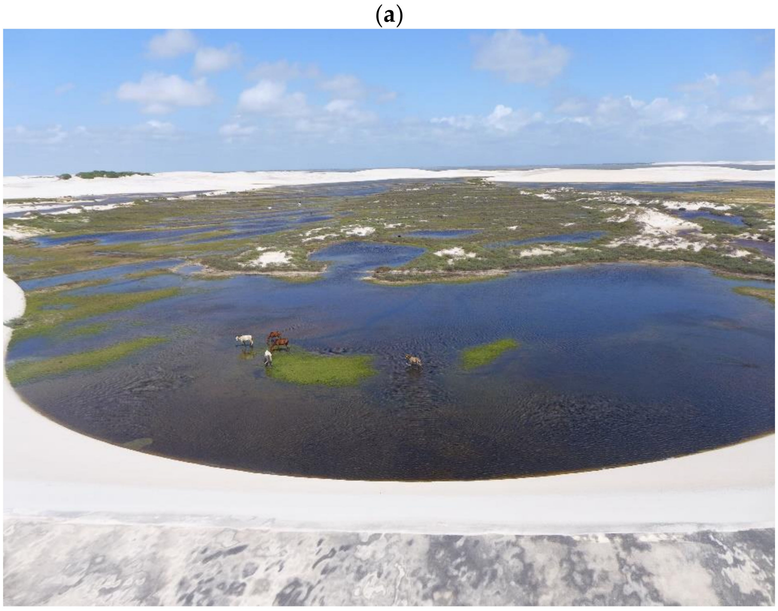


Figure 2. Location of the Lençóis Maranhenses Region.

The Lençóis Maranhenses region is characterized by the dynamics of two distinct periods: the rainy season (high rainfall, full lakes) and the dry season (low rainfall, dry or low-water lakes) [22,24,25]. The lakes and watercourses in the fixed dune areas depend almost exclusively on rainfall to sustain their ecosystems. In the interdune areas are *vargens*, grasslands that are used to feed animals and are important for the physical and economic survival of the local populations (Figure 3). This mosaic of landscapes, in which water fills the interdune depressions at certain times of the year, is exuberant and paradisiacal. The mobile dunes, locally called *morrarias*, continuously advance inland over the vegetation in a predominantly northeast-southwest direction, and have now reached a distance of approximately 27.5 km from the coast. *Morrarias* is typically defined as a succession of hills, but in the Lençóis Maranhenses region it applies to sand dunes, including ones covered by vegetation, and even old, consolidated dunes (paleodunes). In addition to perennial and temporary dunes and lagoons, there are strips of straight beach, perennial rivers (Rio Preguiças, Rio Periá), bays, tidal channels, mangroves and islands located in the Extractive Reserve of Tubarão Bay in the western part of the study area.

(**a**)



(**b**)

Figure 3. (**a**) Mobile dunes; (**b**) Animals grazing on the grasslands (*vargens*).

2.2. The Socioenvironmental Atlas of Lençóis Maranhenses—ASALM

The Socioenvironmental Atlas of Lençóis Maranhenses is a project that originated from a partnership between the Department of Geography at the University of São Paulo, Brazil and the Geomatics and Cartographic Research Centre at Carleton University in Ottawa, Canada. Other partners include the Federal University of Maranhão (UFMA), the Federal Institute of Maranhão (IFMA), and the Department of Geography of Durham University. The project uses traditional cartographic visualization and representation techniques associated with modern data collection and processing systems, but also explores new techniques of cybercartography, specifically the Nunaliit Cybercartographic Atlas Framework [3,26]. The ASALM research team has collected data and generated information that compose the 14 thematic sections of the Atlas. In this article we focus on the following four sections: society and nature; vegetation; land use, coverage and occupation; and cartographic support.

2.2.1. Step 1: Cooperation and Partnership

The objective of the first stage of the project was to establish and strengthen relationships between the institutions, researchers, technicians and students who are involved in or wish to participate in the ASALM project, through meetings, lectures and workshops in Brazil. The following are some highlights from the activities carried out in the first stage: (1) a lecture at the Department of Geography at the Federal University of Maranhão (UFMA), entitled "Conservation Geography: Landscape Approaches," which marked the opening of ASALM's activities; (2) a meeting with researchers from the National Center for Research and Conservation of Sociobiodiversity Associated with Traditional Peoples and Communities (CNPT), focusing on data and information from the Extractive Reserve of Tubarão Bay [3,27]; (3) a training seminar on Cybercartography given by research partners from Carleton University, which brought together, in addition to the Maranhão professors collaborating on the project, representatives of Instituto Amares, and graduate students in Geography, Social Sciences, and Oceanography from UFMA, for a total of 40 participants; and (4) a meeting to plan the field stages with the team of researchers and technicians from the University of São Paulo (USP) (Figure 4).

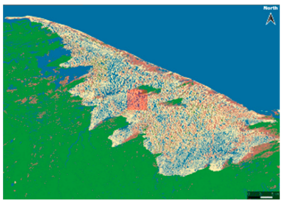
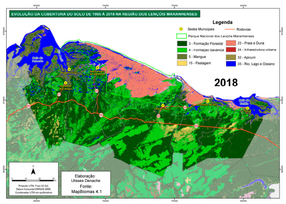
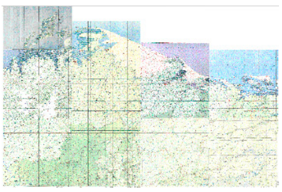
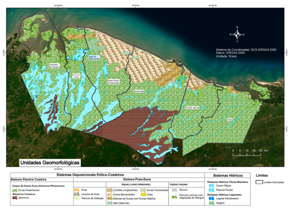
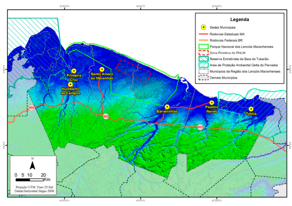
Figure 4. (**a**)—Lecture at UFMA; (**b**)—Meeting at CNPT; (**c**)—Training on the Nunaliit platform; (**d**)—Meeting at USP.

2.2.2. Step 2: Data Collection and Preparation

In this stage of the project, geospatial data were collected to develop ASALM's cartographic base. The data collected are being used in the development of both a digital Atlas of Lençóis Maranhenses (ASALM) using the Nunaliit Cybercartographic Atlas Framework and a traditional paperbound atlas with the same name. The data collection process involved travelling by foot or in motorized vehicles during the field trips, and the work of multidisciplinary teams from diverse areas such as geomorphology, biogeography, tourism, anthropology, and cartography. Together, a wealth of images was collected, including maps, videos and hundreds of photos taken from the surface or by using drones.

In particular, as shown in Table 1, data were obtained on the following: (1) The geoenvironmental dynamics in periods of high and low rainfall; (2) Classification of Land Use and Coverage; (3) Planialtimetric charts in scale 1:100,000; (4) Mapping of the main sets of geomorphological features in the area; and (5) Overlaying geospatial data on Alos Palsar images (used to extract terrain information).

Table 1. Surveyed Geospatial Data, source and scale of origin of data.

Data	Theme	Scale	Source
	Geoenvironmental Dynamics in periods of high and low rainfall	1: 100,000	USGS (2020) [28] Landsat 8 and Sentinel 2 imagery
	Land Use and Coverage	1: 100,000	Mapbiomas (2020) [29] Collection 5.0
	Mosaic of Planialtimetric Charts	1: 100,000	BDGex (2020) [30] Geographic Services Division—DSG Brazilian Army
	Geomorphological Features Map	1:250,000	ASALM Geomorphology Team [31]
	Alos Palsar Mosaic	1:250,000	EarthData (2020) [32] Alaska Satellite Facility

Note 1: Mosaic of Planialtimetric Charts: chart from Sertãozinho nº 500, São Benedito do Rio Preto nº 611, Urbano Santos nº 612, Rio Gengibre nº 613 Carrapatal nº 495-A and that of Magalhães de Almeida nº 614, made available through the Army Geographical Database—BDGEX. Note 2: The following figures are available in high resolution online as Supplementary Materials: Land Use and Coverage; Geomorphological Features Map; Alos Palsar Mosaic.

After preparing the cartographic base, the location of natural resources, equipment and important features for mapping were incorporated into the database, such as *restinga* (sandbanks) and mangrove areas, the riparian forest, and the locations and uses of the main watercourses. Data were also added on highways [33], municipal boundaries and headquarters [34], villages [35], churches, associations, and the movements of community members for fishing, raising animals, taking care of crops, visiting relatives, and accessing services at municipal offices. Stage 2 was essential so that the surveys and data collected in the field could also be used to validate the data used for the preparation of the cartographic base.

We have developed a prototype of the graphical interface and data layers within the boundaries of the study area, the toponymy of the locations studied, the satellite image background, and the preliminary structure of the Cybercartographic Atlas (The Lençóis Maranhenses Atlas prototype [36] can be found at this link: https://atlas.fflch.usp.br/index.html) (accessed on 31 August 2021). During the first stage of the project it was possible to prepare, in partnership with Carleton University's Geomatics and Cartographic Research Centre, a layout for the Atlas displaying three types of information (Figure 5). Item A, the Layers Button, allows you to choose the background information base (relief, images, maps); item B allows you to enable layers of information to be overlaid on the background information (Municipal Limits, Location of Communities, points of Observations); and item C shows the Atlas study area where the points visited and monitored by the team are spatialized.

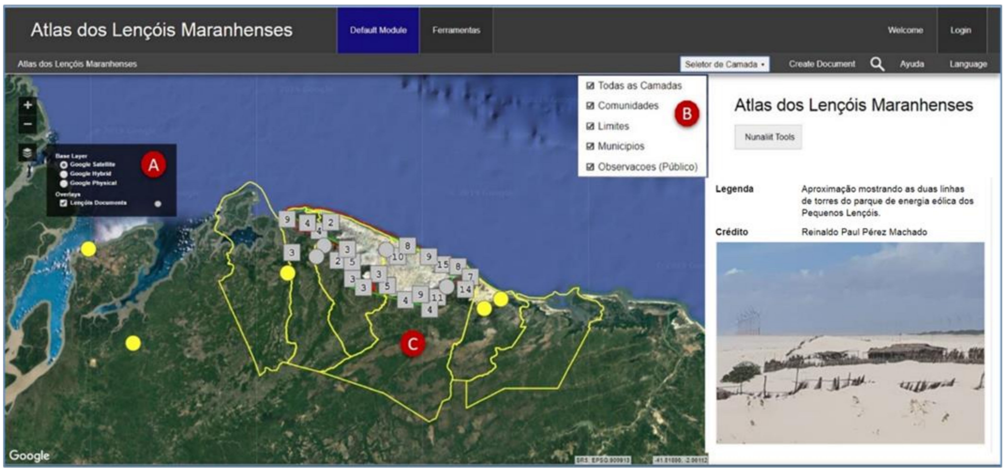


Figure 5. Layout of the Socioenvironmental Atlas of Lençóis Maranhenses in preparation.

2.2.3. Step 3: Fieldwork and Analysis

In the extensive territory of Lençóis Maranhenses, the national park itself is already 155,000 hectares, according to Decree-Law n. 86.060, of 2 June 1981 [37]. Since certain sections of the research area are difficult to access, joint planning was required of the research teams in order to optimize resources and timing of visits to the traditional communities. The fieldwork took place in the two most distinctive seasonal periods. In March 2019 (winter-rainy season), joint work was undertaken between Brazilian and Canadian researchers, and in November 2019 (summer-dry period) work was carried out by the multidisciplinary team of Brazilian researchers (Figure 6). A subsequent field trip planned for the rainy season in April–May 2020 was postponed due to the coronavirus pandemic.

(**a**) (**b**)

Figure 6. (**a**)—Field activity in the community of Baixa Grande – Primitive Zone of Lençóis Maranhenses National Park. (**b**)—Production of mandioca flour in the community of Mairizinho, municipality of Primeira Cruz—MA, located in the extreme western part of Lençóis Maranhenses National Park.

During the fieldwork it was possible to visit all the Conservation Units included in ASALM, with a focus on Lençóis Maranhenses National Park and the surrounding area, in particular the Extractive Reserve Tubarão Bay. The fieldwork activities were divided into three routes that made it possible to visit the eastern and western boundaries and the central area mapped in ASALM. The first route started from the municipalities of Humberto de Campos and Primeira Cruz in the west and reached the fishing communities of Mairizinho and Santaninha. The second stage began on the route from the city of Barreirinhas to Atins, navigating the Preguiças river on the east side to Lençóis Maranhenses National Park, and from there following the Grandes Lençóis beach to the primitive area of the park (locality of Baixa Grande) [38], completing the third stage. The objective of this journey was for researchers to gain an understanding of the nuances of the area. As a result of this field activity, several important points for ASALM were located and georeferenced, such as geomorphological features along the Grandes Lençóis beach consisting of sandstones and areas of consolidated outcrops resulting from coastal erosion in recent years.

After a round of conversation with local guides, leaders and community residents, the points that should be photographed and georeferenced using the GPS were defined. Some of these places were only accessible by boat. The locations included sites of common use by the communities, sources of natural resources, and the main trails and routes used by local residents in different seasons. These were all important data for cartography and to understand the native guidance system of the Lençóis Maranhenses region (Figure 7). In the next section we discuss the results of the fieldwork sessions, focusing on the navigation system used by the local residents in defining their routes of travel in their vast region.

(**a**) (**b**)

Figure 7. (**a**) Resident of the community of Betânia, Santo Amaro—MA drawing the mental map of the trails he uses. (**b**) Roundtable with community members and guides to introduce the ASALM project.

3. Results

After walking along the trails, visiting workplaces, and mapping areas of common use with the availability of natural resources, the main routes of movement in the Lençóis Maranhenses region were defined. These routes are used by local residents for performing activities such as fishing, raising animals, taking care of crops, visiting relatives, shopping and accessing municipal services. Figure 8 shows the fishing paths in four sectors of Lençóis Maranhenses.

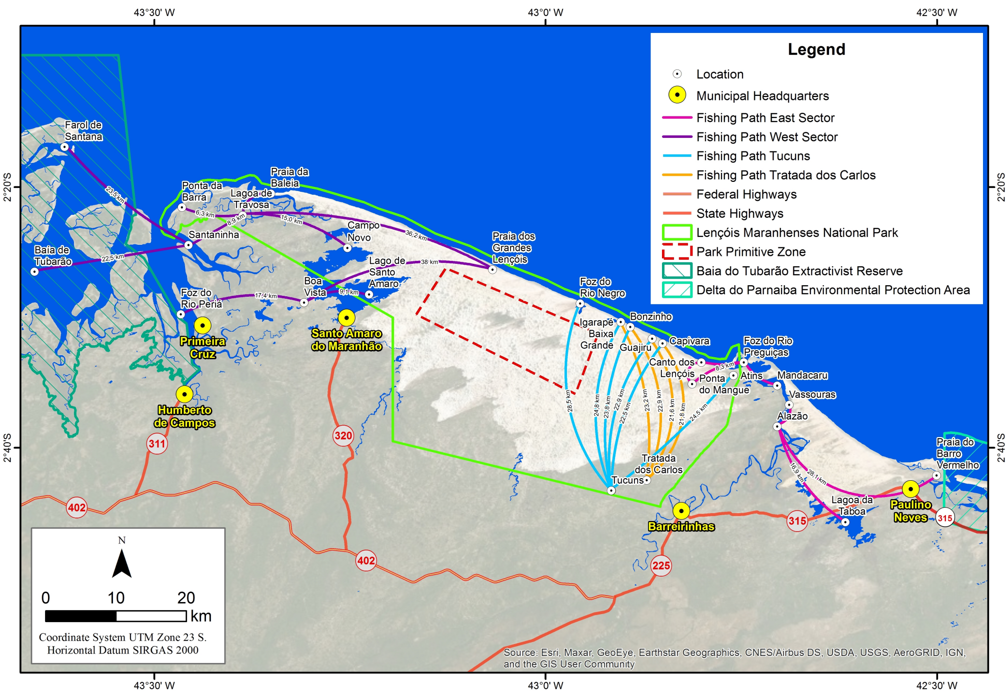


Figure 8. Travelling paths are used by the local inhabitants for various activities.

Navigating in the mobile dune fields [38] and surrounding vegetation of the Lençóis Maranhenses region is not an easy task, especially for those who are not familiar with the landscape of this fully protected conservation unit. The local residents have their specific routes, travelling on land by foot or in pickup trucks and tractors, and crossing bodies of water by boat and speedboat. Visiting these places outside the season in which they are used is important to establish the movement flows and practices associated with each time of year [20]. Due to their familiarity with the Park's environment resulting from their economy-based activities such as fishing [39–41] and animal husbandry [42,43], the local inhabitants have developed their own sophisticated guidance system. In this section we describe and illustrate the particular forms of guidance, defined here as the "Native Guidance System", used by the residents of traditional communities that historically live and work in Lençóis Maranhenses National Park (PNLM). The complexity of this native knowledge deserves to be highlighted because it is activated in an environment that is subject to constant ecological and seasonal changes.

The local residents' historical relationship with the environment in which they reside and work has allowed the families of traditional communities in PNLM to develop and consolidate their knowledge and skills. Such knowledge is associated, for example, with the links between the cycles of nature and the organization of social and economic life, as well as with the ability to navigate in this vast region. The action of winds and rainfall, and the positions of the sun, stars and other celestial bodies are factors in the organization of these forms of knowledge, which allow the local residents to conduct their work-related activities and also travel to communities located far from their homes.

In order to discuss native guidance systems in the PNLM, we must consider the relationship between culture and nature [44], that is, the interaction between humans and the biophysical environment responsible for the families' ways of life. The relationship between the environmental hyperdynamics of PNLM and the social dynamics of families living in the communities in the park also need to be considered. By "environmental hyperdynamics" we mean the constant transformations in the landscape of the PNLM environments caused by the action of winds, dune movement and rainfall. The combination of these factors, seasonally or over the years, allows for continuous changes in the appearance of the dunes (shape and size), in the diversion of river courses, in the burial of vegetation and houses, in the formation of lakes with periods of high-water concentration and others of drought. PNLM's traditional communities, in their social dynamics, have always found cultural responses to accompany these constant changes in the landscape.

The native guidance systems are structured around different subsystems, each organized by elements such as the sun, moon, stars, natural accidents, wind direction, and even plant and fruit odors. The senses play a crucial role: vision allows the identification of natural accidents (dunes) and celestial bodies (sun, moon, and stars), and the sense of smell allows one to perceive smells of native plants and fruits such as *mirim* and *murici* and water containing decomposing vegetation. *Mirim* and *murici* are typical fruit plants of the Cerrado biome that are important for the food security of residents of traditional communities. In the Lençóis region, they are found predominantly in the Restinga vegetation. Appreciated for their citrus flavor, they are used in local cuisine, in jams, juices, and ice cream. The local inhabitants exhibit a hyperawareness of tactile senses. For example, they use parts of their bodies to feel the action of the winds and help identify the direction they should follow. Where they feel the wind—on the front or side of the face, or on the back of the head—indicates the orientation of the destination, whether when travelling to other locations or to places where tourists' attractions are located.

The sun is also used as a guide in their navigation system. The position of the sun in relation to the body—above the head, right shoulder, left shoulder—indicates the orientation of the destination, depending on the time of day. Like the sun, the stars and the moon—and their respective phases—are used to guide travel at night. There are some celestial bodies that are used by the natives as an orientation reference, such as the Dalva star, and the Seven Sisters and Southern Cross constellations.

In terms of location knowledge, to the inhabitants who live and work in PNLM, what would be an unknown world to an outside observer is remarkably familiar, as they operate within two dimensions: geographic volume and mental volume. Marcel Mauss borrows these two notions from Ratzel: "We know what Ratzel called the geographic volume and mental volume of societies. The geographic volume is the spatial extent actually occupied by the society in question; the mental volume is the geographical area that it manages to cover with the thought" [44,45]). The entire extent of the Park used in the local residents' activities, notably animal husbandry and fishing, is entrenched in their minds from their mental maps of the natural elements and environments that make up the landscape. Such mapping is carried out through naming processes used to identify features such as *vargens* (grasslands/pastures), *lagoas* (lakes), *morros* (hills/dunes), *lavados* (washed), *córregos* (creeks), and *praias* (beaches) (*lavados* are tide plains, with silt and clay surfaces, salty or brackish, without vegetation, where in the past salt was produced. When these areas have vegetation, rainwater, river, or groundwater, they are called "*banhados*" (wetlands)). Their naming of such features reinforcess their perceptive awareness of both their extensive territory and the location references that do not require sophisticated technological mapping and guidance systems (Figure 9).

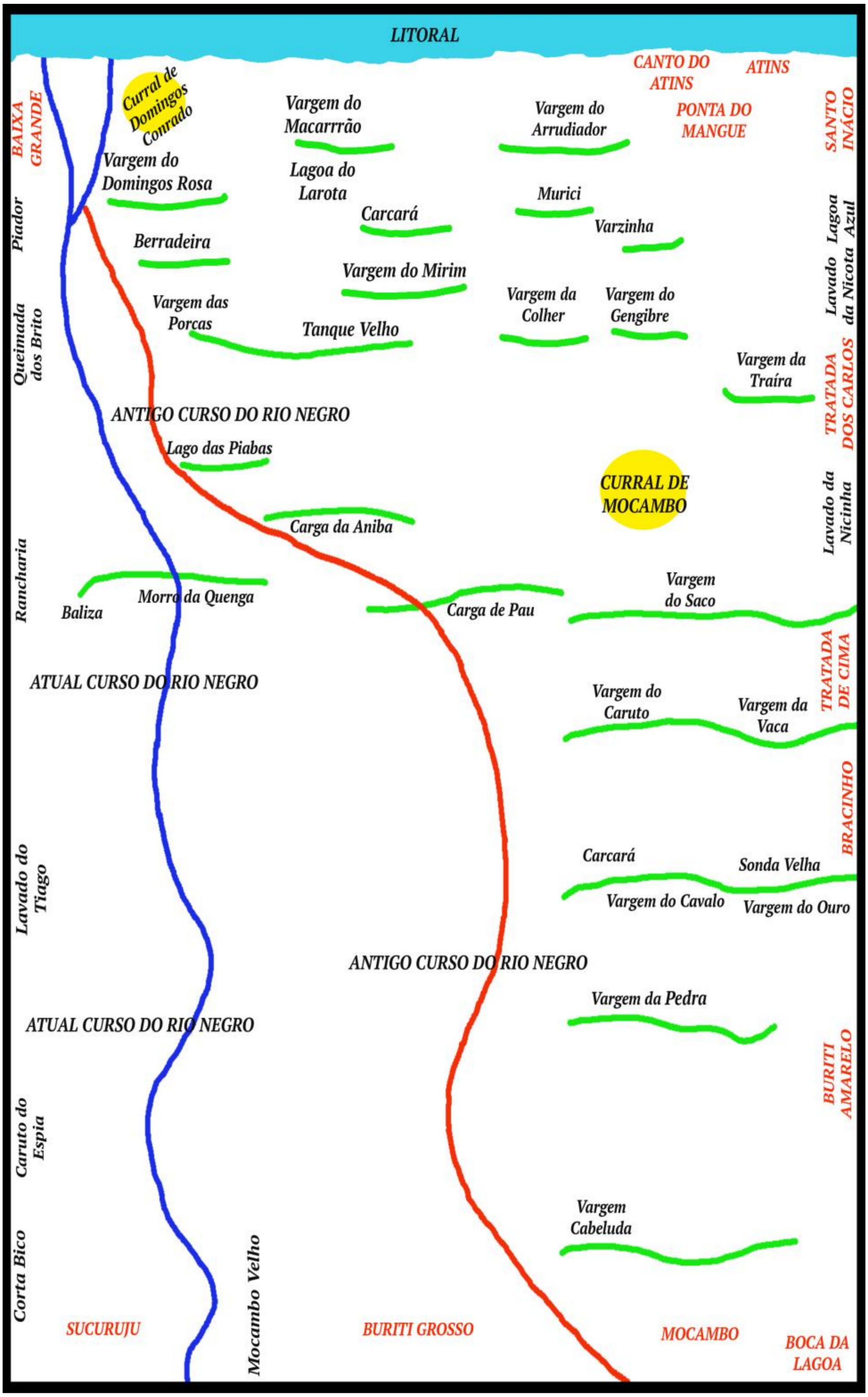


Figure 9. Native inhabitant's mental map of a region of Lençóis Maranhenses National Park. In this mental map, Mr Inácio, 75 years old, indicates the *vargens* (pasture areas for goats and sheep—in green), the old and current courses of the Rio Negro (red and blue, respectively), the layout of corrals (in yellow) used in animal husbandry activities, and the arrangement of some traditional communities, highlighted in red font. Created by Mr. Inácio, from Mocambo. Reproduced by Benedito Souza Filho.

Despite undergoing modifications, some dunes, because they are higher, act as navigational aids for local residents who work as tour guides. Such dunes are used as reference points for localization by the guides when leading tourists to natural attractions in PNLM.

Familiarity with their environment has allowed the residents of the PNLM communities to develop ways to survive in this vast region when carrying out their activities, such as digging small holes in the sand to obtain water to drink; using dried cattle feces to make a fire to prepare food; and digging holes in the so-called ribs of the hills (the steepest and frontmost part of the dunes) to shelter from the rains.

Native guidance systems are related to the families' way of life and their economic activities, especially the raising of animals (goats, cattle and sheep) and fishing (fresh and saltwater. Saltwater fishing is carried out on the beaches located on the 70 km-wide coastal strip of PNLM. Freshwater fishing is carried out in seasonal and perennial lakes and also in rivers, wells and weirs. (For more details on fishing activities, see [39,40].) Such activities, carried out in different environments and far from their homes, allowed the local inhabitants to develop forms of guidance that combine knowledge about relief (identification of dunes and *vargens*), astronomy (orientation using the sun and stars), and wind movement in winter and summer and are still used today.

In an environment subject to constant changes, activities such as animal husbandry and fishing involve a sophisticated guidance system used by people from different parts of the Park. Those who are dedicated to raising animals or fishing, in constant contact with the natural spaces where these activities are carried out, operate with elements of native cartography such as those found in the *morrarias* (sand dunes) or on the coast.

Fishing is an activity developed in several places in the study area, even populations that reside in areas farthest from the sea. Around the Conservation Units, in particular PNLM and the Preguiças River Environmental Protection Area, the local residents fish in the sea on a seasonal basis, i.e., during the rainy season when there is a greater abundance of fish in the ocean waters. To carry out their fishing activities, they install themselves in small "ranchos" huts built on the Grandes Lençóis beach and along the mouth of the Preguiças River (Figure 10).

(**a**) (**b**)

Figure 10. (**a**) Fishermen in activity at Lençóis Maranhenses beach; (**b**) Support ranch on Grandes Lençóis beach; the format, type of deck and position of the ranch considers the direction of the winds, solar incidence and thermal comfort, in an environment with temperatures above 40 °C.

Using their native guidance system, residents of communities far from the sea are able to travel through the dune fields and arrive precisely at certain beaches located about a 4- or 5-h walk away (Figure 11).

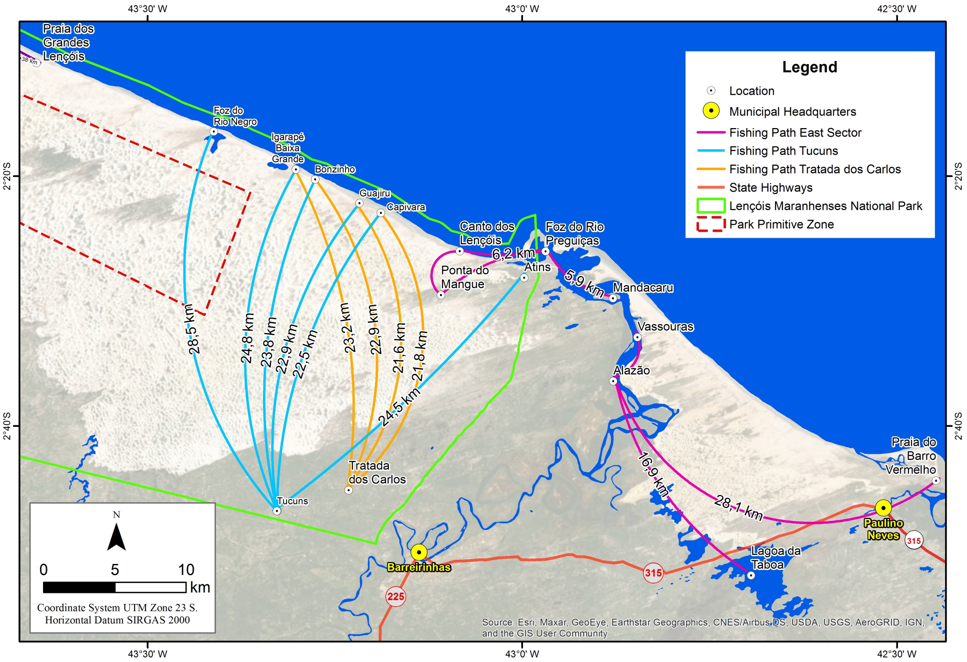


Figure 11. Enlarged section of Figure 7 showing the travelling paths (distances and times) used by the local inhabitants to fish on the coast.

Seasonality is an important aspect of native guidance systems. The features of the Park's environment change in the summer (June to December) and winter (January to May) periods. The knowledge of the local inhabitants helps them find cultural solutions that enable them to continue living in a region with constant changes in the landscape.

The social life of the local residents adapts to the changing conditions during periods of rain and drought, and activities are carried out according to the changes observed in the environment. This is because "the movement that animates society is synchronic to that of environmental life" [28]. In Lençóis Maranhenses National Park, a vast region subject to constant transformations, native guidance systems play a decisive role in the social and economic organization of local families.

4. Discussion

Local residents of the Lençóis Maranhenses Region have developed native guidance systems that allow them to manage and thrive in the intense environmental dynamics of their territory. They constantly update their mental maps according to the seasons. The mapping of these paths helps us understand their use and occupation of this region, including how, where and when they develop their activities, in addition to demonstrating the rich local knowledge acquired through interactions with the elements of nature.

It is impossible not to associate the ancestral survival methods and forms of guidance of the Lençóis Maranhenses residents with those living in extreme weather conditions in other parts of the world, such as the Tuaregs in the Sahara Desert [46] and the Inuit who inhabit the vast territories of northern Canada [17,18,47]. In all these cases, the seemingly barren landscape of sand or snow consists of networks of "physically ephemeral" trails that are not permanent features of the landscape but exist in people's memories and experiences [47]. This shared local knowledge, passed down through the generations, allows the same routes to be traced consistently every year despite seasonal and ecological changes to the environment. For the local residents of Lençóis Maranhenses, their landscape is transformed in the dry and rainy seasons, while for the Inuit in the Arctic, winds, blizzards and seasonal changes in snow and ice conditions are responsible for the transcience of their trails.

To navigate through terrain with no permanent travel routes, local inhabitants use landscape features prevalent in their environment as navigational aids. These include the tall dunes in Lençóis Maranhenses, shore profiles, hills, and river bends in the Arctic, or mountain ranges, pastures and water sources in the Sahara Desert. Another commonality among the native inhabitants of such environments is the use of the sun's position as a point of reference during the day, and of stars and other celestial bodies at night. The feel and direction of winds are also important for spatial orientation.

Figure 9 above shows the place names that are used by the local inhabitants of Lençóis Maranhenses to identify landscape features. Local place names are a crucial component of Inuit navigation as well, as they are used extensively for describing travel routes. Aporta observes that "Inuit trails are connected to a sequence of place names" [47]. Like the Portuguese place names in Figure 9, Inuit place names are associated with topographic features such as rivers and lakes, valleys and hills, rocks, bays, and ice ridges, as well as identifying places for hunting and fishing, and where plants and berries may be found.

As shown in Figures 7–9 above, in the current ASALM project, the activities and movements of the local inhabitants of Lençóis Maranhenses are being documented in digital maps. Through our research we know that groups of local residents leave their fixed homes to engage in fishing activities on the coast during the rainy season, when traditional activities are reduced and fishing productivity is higher. At the end of this period they return to their homes and continue their usual activities, demonstrating patterns of transhumance (i.e., seasonally moving livestock to various grazing grounds) rather than nomadism, as sometimes claimed by the media. The use of geoprocessing techniques in the treatment of data collected in the field, combined with the information collected by ASALM and mental maps, show that the activities of the local residents create a constant and complex flow of people, vehicles and animals. Moreover, depending on the time of year, accessibility conditions, and availability of natural resources, some sectors of the Lençóis Maranhenses region are utilized more than others. Improving studies on the dynamics of the flow and use of natural resources, and the impact of projects such as the installation of wind towers, power lines, solar energy plants, new roads, and resorts will help us understand the implications of these factors for the environment and for the social life of those who live and work in that area.

Knowing and mapping the practices developed by the residents of Lençóis Maranhenses is essential for understanding the impact of socio-spatial transformations [39] that the region has experienced. Currently, some residents also work as tour guides, conducting walking tours with individuals or small groups of tourists, guiding them through areas previously used only by local residents. The ecological impact of vehicles like quadricycles, pickup trucks and motorcycles on these trails needs to be studied [41]. With the construction of new state highways connecting municipalities in the Lençóis Maranhenses region (e.g., the MA-315 and MA-320), the number of tourists is growing, and urban expansion in the municipal areas is clearly on the rise. In addressing such issues, cartography can serve as an instrument for planning, understanding and action, both to safeguard the rights of local residents and for the handling and management of natural resources.

It should be mentioned that this situation changed dramatically during the coronavirus pandemic, especially in the initial period of March–July of 2020. Many of the hotels, posadas, and restaurants were forced to close, with some never reopening. The Brazilian government's Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) officially closed the National Park to the public for several months. These circumstances so greatly impacted the towns, citizens, and local inhabitants of the Lençóis Maranhenses region that another section will be added to ASALM to document this dark period. In this way, ASALM is holding true to the principles of cybercartography, defined in part as "the application of location-based technologies to the analysis and understanding of issues of importance to society" [7] (p. 4).

5. Conclusions

Built on the principles of cybercartography, ASALM's goal is to unite scientific geoenvironmental data and mental representations of local residents' orientation systems to provide a comprehensive view of the geographical, environmental and social conditions of the Lençóis Maranhenses region. Spatializing information such as areas of natural resources and traditionally used routes will make it possible to estimate the areas of common resource use and the directions and intensity of the flow of people, enabling effective planning and implementation of public policies in the Lençóis region. Future plans include the development of interactive tools to capture geolocation data on cell phones, so that local residents can participate in collecting data that will be of benefit to them. A mobile version of ASALM would also allow communities with no internet service to access maps and information on the regions where they live and work. As traditional cultures and knowledge worldwide become increasingly threatened with extinction by the dominant nation-states in which they live, we hope that the cybercartographic version of ASALM will contribute to the digital inclusion of local communities, providing a platform for the inhabitants of Lençóis Maranhenses to preserve their local knowledge of navigation, ecology and resources. It remains to be seen, though, whether, or how, local communities will embrace new technology as they strive to survive in a world of environmental and social change.

Furthermore, we hope that the methodology of developing both the cybercartographic and traditional printed versions of the Socioenvironmental Atlas of the Lençóis Maranhenses could be applied to other socially and environmentally endangered regions in Brazil, in partnership with other states and universities throughout the country.

Supplementary Materials: The following figures from Table 1 are available in high resolution online at https://www.mdpi.com/article/10.3390/ijgi10110755/s1, Land Use and Coverage; Geomorphological Features Map; Alos Palsar Mosaic.

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Article

(Of) Indigenous Maps in the Amazon: For a Decolonial Cartography

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Abstract: There are mappings of indigenous lands, mappings with indigenous participation, and mappings made by indigenous people, all of them resulting from cartographic intentions, mapping motives, and distinct meanings of spatiality. Starting from the questioning around *the drives of the subject towards his search for knowledge of the space and its mapping*, this article seeks to both identify the key points that these three types of mapping typically resemble and intersect, as well as to distinguish and debate them while highlighting maps made by indigenous people. This approach is based on interpretations of Mebêngôkre (Kayapó) and A'uwe (Xavante) mappings, seeking to understand them as a device of spatial organizations and representations. In doing so, we (re)position indigenous peoples as cartographer subjects who possess and produce cartographic/geographic knowledge while we question the Eurocentric legacy, expressed in an exclusivity of official/academic cartography.

Keywords: indigenous mappings; decolonial cartography; mythical spaces and indigenous orientations

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1. Introduction

> "Our thoughts expand in all directions and our words are old and many. They come from our ancestors. Yet, we do not need, like banks, image skins to prevent them from escaping our minds. We don't have to draw them, as they do with theirs. However, they will not disappear, as they are engraved within us. So, our memory is long and strong"
>
> (Writing Drawings—Davi Kopenawa)

As a result of the European colonial civilizing process, many societies have been annihilated or silenced where geographic observations and descriptions—with their detailed information about the "new" lands—were decisive. In addition to a detailed narration of the Brasilia lands (such as the letter by Pero Vaz de Caminha), many maps were produced with the "support" of indigenous communities, which Whitehead [1] called *colonial cartography*:

From the moment Columbus reached the New World, geographical information was critical to further exploration and exploitation. Such knowledge was required not only to identify the location of critical resources or plunder, but also because the enlargement of the world that the event implied upset the European worldview; an unknown region needed to be incorporated into existing European cosmography [1] (p. 324).

In this process, traditional knowledge regarding the spatial representation of astronomical mappings and the marking of time by means of cyclical calendars [2] were affected, resulting in a mixture of indigenous and European conventions of spatial representations [1], with the Eurocentric norms supremacy and an appropriation of indigenous power/knowledge.

In this context, when studying South America cartographies of some cultural-linguistic groups such as Carib, Arawak and Tukano and Gê, Whitehead [1] defined three types of indigenous mappings (Table 1).

Table 1. Types of indigenous mapping from Whitehead Source: Elaborated by the author from Whitehead [1].

Categories	Types	Characteristics	Examples
Strictly indigenous mapping	Astronomical mappings	Closely related to cosmographic mapping, usually representing the shamanic visions content during the flight of the soul in distant regions, or representing the spatial relationships codified in the telluric tradition.	A very common theme is the earth and the sky connection in a complex cosmographic system, in which the design of terrestrial features is closely reflected in the patterns of stars in the sky.
Indigenous (or collaborative) mapping of non-indigenous interest or influence	"Ordered" mappings by non-indigenous people	In the colonial period, much of this information was literally extracted under death threat or torture and was strictly for the purpose of mapping "conquered" lands.	They aimed to obtain geographic information such as missionary work, military conquest, border demarcation and the search for various natural resources such as minerals, cocoa and rubber.
		Recently, such information has been offered "voluntarily" to ethnographers and anthropologists	Many researchers request indigenous peoples maps for cosmological studies.
	Native spatial ideas incorporated into non-indigenous maps	Many researchers request indigenous peoples maps for cosmological studies.	There is an interest mainly in the telluric spatial relationships graphic representation.

For this article in particular I will focus the analysis on the first category, that of "strictly" indigenous maps of some Amazon peoples. A greater emphasis will be given to the debate on decolonial cartography because it is interesting here, and at that moment, to discuss the cartographic knowledge-power relationship beyond Cartesian methods invented by the non-indigenous. If, on the one hand, we have made progress in terms of research, development, and production of the collective construction of cartographic bases, acting directly in indigenous communities that inhabit the mapped place, on the other hand, many of these mappings are within the Cartesian cartographic reason. Thus, the intention is to join forces with these movements that question universal cartographic codes based on "typically" indigenous mapping processes.

It is important to clarify that it is not a matter of carrying out a study on the application of these maps, but of trying to understand them as a device for spatial organization and representation, positioning indigenous peoples as cartographers subject who possess and produce cartographic/geographic knowledge. Such an opening is not an ultimate end, which would only add indigenous maps (or maps of indigenous peoples) to our cartographic collection. It is a process that can destabilize the universal and pragmatic forms of mapping, stimulating a decolonization of cartography. This is how Laplantine [3] provokes us when writing about the "need" for strangeness that can be caused by cultural encounters:

In fact, trapped in a single culture, we are not only blind to that of others, but myopic when it comes to ours. The experience of otherness (and the elaboration of that experience) leads us to see what we would not have been able to imagine, given our difficulty in fixing our attention on what is usual, familiar, every day, and which we consider "evident". [. . .] The (anthropological) knowledge of our culture inevitably passes through the knowledge of other cultures; and we must especially recognize that we are a possible culture among so many others, but not the only one [3] (pp. 12–13).

2. What Moves a Subject to Want to Know the Space and Map It?

> *"What elements of society's culture and physical environment affect people's spatial skills and knowledge? What conditions encourage people to experience their environment and be aware of it to the point of trying to capture its essence in words and maps?"*
>
> (Spatial skills, knowledge, and place—Yi-Fu Tuan)

Tuan, in contrasting societies with different cultures—some with characteristics of subsistence agriculture restricted to a locality, others with pioneering and expeditionary characteristics, or even semi-nomadic ones—brought important contributions to cultural diversity and the development of spatial skills. Some of them are the questions in the heading that opens this section [4] (p. 101). I add others, more specific to our dialogue for this text: *Cartographic knowledge is only valid when the map is written on a material means of communication? What moves a subject to want to know the space and map it? Are the motives and interests of indigenous mapping the same? What are the indigenous cartographic forms and intentions?*

I share these questions here not with the intention of answering them in a single article. They are here as gears that have the purpose of stimulating us to possible reflections on "mapping reasons", based on the need (or the absence!) of permanent records. Therefore, they involve a specific conception of knowledge and relationship with the world.

Many indigenous cultures are marked by oral tradition, in which, until colonization, there was no need for permanent records, either of linear writing or of spellings with spatial information, in durable materials characteristic of Western society, as we can see in the words from shaman Davi Kopenawa:

> "I don't have old books like them, in which the stories of my ancestors are drawn. The *xapiri's* words are engraved in my thoughts, deep inside me. [. . .] I didn't learn to think the forest things by fixing my eyes on paper skins. I saw them for real, drinking my ancients' breath of life with the *yäkoan* powder they gave me [. . .]. Omama did not give us any book showing the drawings of *Teosi's* words, like the white people. He put his words inside of us." [5] (pp. 65, 75, 77).

It is important to emphasize with this that the record forms and functions of the transmissions of indigenous spatial information are distinct from those of non-indigenous societies. If we are going to look for indigenous maps, we need to expand the map concept beyond maps that are graphed on paper. Tuan [4] when talking about short-lived maps, questions for example what the occasions are when a "physical", "drawn" map would be necessary, and when a *mental map*, with only the verbal description of the path and nature of the terrain would be enough.

Woodward and Lewis [6] present a production and spatial records cartesian classification of non-Western cultures, organized into three categories that can help us here in our reflection (Table 2).

Table 2. Categories of Representations of Non-western spatial thought and expression. Source: Woodward e Lewis [6] (p. 3).

Internal (Inner Experience)	**External (Processes and Objects that Realize or Externalize the Internal Experience)**	
Cognitive Cartography (Thought, Images)	**Performance Cartography (Performance, Processes)**	**Material Cartography (Record, Objects)**
Organized images such as spatial constructs	*Nonmaterial and ephemeral* Gesture Ritual Song Poem Dance Speech *Material and ephemeral* Model Sketch	In situ Rock art Displayed maps *Mobile comparable objects* Paintings Drawings Sketches Models Textiles Ceramics Recording of "performance maps"

From this perspective, what we could often judge to be just a cultural artifact are also *cartographies in processes* [7] of *mapping movements* [8] that register a spatial organization, a way of being in the world that still does not fit into the molds and cartographic models that we (the non-indigenous) created. Many of them use oral and performance communication to convey meaningful information. "The actions, lasting hours or days, carry greater meaning than any object they produce." [7] (p. 3). Perhaps the transfer of spatial information to permanent communication materials, creating forms and norms for cartographic visualizations, is particularly a Western interest where "seeing is knowing and picturing is power" [1] (p. 321).

It is as stated by Whitehead "The issue here seems to be less a question of cartographic ability than an issue of cartographic forms and purposes" [1] (p. 320). In the same sense, Pinheiro [9] (p. 154) reminds us that "[. . .] the cartographic map is not the surface on which it is placed. The physical environment works only as a support because the true map is an abstraction". Tuan already provided important reflections for these arguments, stating that "[. . .] spatial skill is essential for subsistence, while spatial knowledge, at the level of symbolic articulation in words and images, is not" [4] (p. 97). A person may not know how to give his location or draw a "precise" map (which would be the systematic spatial knowledge linked to cartographic techniques in Western culture), but they may have the ability to find themselves, to have a direction intuition in their own action with the environment. Thus, the absence of conscious and/or conceptualized geographic knowledge does not directly refer to the lack of spatial skills and (spontaneous) geographical competences [10].

Tuan endorses this dialogue by stating that "[. . .] conscious knowledge can even hinder the performance of a skill" [4] (p. 90). Knowing the cardinal and collateral points or knowingly handling topographic maps is not enough of a guarantee for a trip in an unknown forest, for example. This may require other spatial and mnemonic skills.

Looking at this direction, we can see that many indigenous mappings integrate spatial skills with celestial, social, philosophical, and cosmological elements, and are encoded in their origin's history, in the architecture of houses, in the organization of villages and in material artifacts, particularly in basketry.

This integration is evident in the east–west layout of villages, the encoding and placing of village structures in accordance with the daily movement of celestial entities, the cardinal directionality of ceremonial processions, the movement of men to different houses in the village during their life cycles, the location of particular kinship units within the village, and the coordinated positioning of villages that exchange marriage partners. [1] (p. 305).

Cardinal Points and the A'Uwe People Path of the Sun

For the *A'uwe*, the distribution of houses and the divisions of the *Poreza'õno* (tadpole) and *Öwawê* (big water) clans, the *hö* (boys' house) location and the delimitation of some paths symbolically express alignments of the path of the sun (east–west cardinal points) and are connected with the universe creation history (Figure 1). During my visit to the *Êtêñiritipa* village, I asked the chief about his origins. Jurandir Siridiwê Xavante, pointing towards the east, told me: "we came from there. There, where Siruro comes out, that very big star from where the sun comes (Figure 1)".

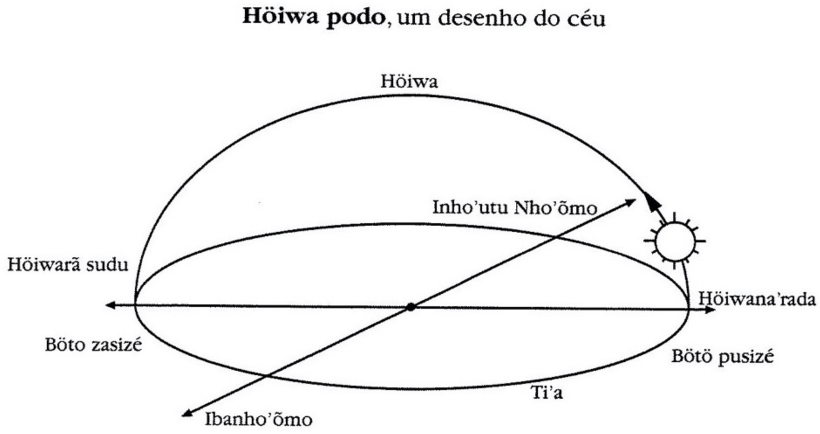

Figure 1. Illustration of the Xavante world concept and forms of spatial orientations. Source: Shaker [11] (p. 79).

Shaker [11], when recording in writing the A'uwê (*höiwana'rada*) origin and the history of the darkness time creation (*Rómraréhã rówasu'u*) of the Xavante world, claim that:

> *Höiwana'rada* is the root from which the *A'uwê* originate. It is the root of everything. The stories will tell: it is the heaven root; from there the sky arose, and from there the movement of its closing and spreading will take place; it is the moon, sun and stars root. The A'uwê also originated there; it was from there that they started walking. It is the east, the birthplace of everything that was created. Etymologically, it is the root, the origin (*na'rada*) of the sky (*höiwa*). It is the root of space, of places (ro). It is a place, pointed out by the gestures of ancients, "the people always pointed there (the East)". But it is more than a physical place; it is the cosmological root from which what will be created is born, the sky, the moon, the sun, the stars, the *A'uwê* people. The other end of the sky, the west, the sunset, the tip of the sky down, is *höiwarã sudu*, where, with its spreading, the sky will close. *Höiwana'rada* is origin as a physical and temporal space; it is origin as a cosmological root. And it is the door through which you enter the postmortem path. (p. 54).

In this sense, I would like to detail some notes taken during my stay in *Êtêñiritipa*. They were drafted right there, and now organized for the writing of that text [10,12].

Field Notes—October 2017

In one of our conversation circles about A'uwe geography and Waradzu geography, Eurico Xavante, the school coordinator, took out of the gray metal locker a compass that he had received with other school supplies, and asked me how to use it. I made a sketch on the blackboard indicating the cardinal points marked on the compass and quickly Valmir Xavante (one of the teachers) made a drawing on the paper indicating the terms böto puisizé (where the sun rises) and bötö zasizé (where the sun goes down) (Figure 2). When I asked about the north and south points, Valmir, Eurico and Vinicius looked at each other, talked to each other in gê and told me that they didn't have a term (for it). They called one of the oldest elderly and there they started a long conversation in Gê. At times, they translated the questions raised. Some suggested terms, others disagreed. One of them mentioned the terms romhöimo and ropi'reba. But there was quickly a rejection of the others. At the time, I did not understand the reason for the disagreement. I just wrote down the terms in my diary. At the end they informed me that they reached to the decision that they did not have a word in Gê to express these two points (north and south). They were not interested there at that time to "translate" them. They indicated the points in the sketch, ended the subject, handed me the diagram saying, "here is the höiwa podo, the drawing of the sky". One of them quickly complemented "botö nebdzé rob u". There was consensus on this second term. I asked if it was the translation of cardinal points. I was told not, but actually, that it meant "the path that the sun takes to a place of reference". On another day, when one of the women showed me the Xavante = Portuguese dictionary of the Salesian mission, I found the following definition for the terms: Romköimo, ro (place) and köimo (top); and ropi'reba, ro (place) and pi'reba (bottom).

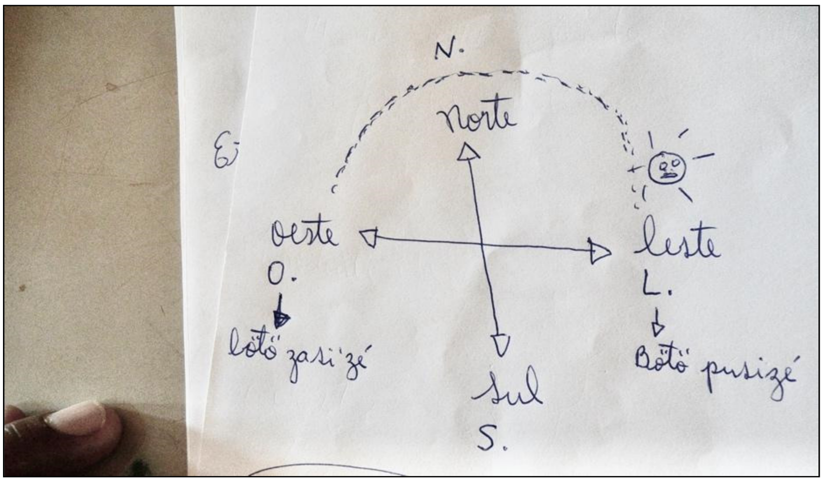

Figure 2. The path of the sun (east-west axis)—Drawing by Valmir Xavante. Source: Field record, 2017.

From the report we can bring up two discussions: the first is about the use of cartographic references nomenclatures related to vernacular geographic knowledge with the cosmology of that culture and that can reveal skills, senses and spatial representations that are beyond conceptual apprehension. They can guide themselves and move easily without the concept or nomenclatures of the cardinal points appearing, or even without directions being graphed/mapped.

The Xavante of Êtêñiritipa, for the most part, no longer travels great distances. Their trips are often for fishing, hunting, collecting eggs and fruits. This is limited by the indigenous lands marking, unlike before colonization, when they presented characteristics of semi nomadism. Today, they have a detailed knowledge of the Indigenous Lands (IL) and landmarks in the sky and in the relief, constituting a "true mental map" [10]. As Tuan points out: "[. . .] it is possible to determine the path through position calculations without using astronomical observations and through considerable experience in trying to draw global spatial relations of locality" [4] (p. 101).

The second point is about the "forced" translation, the result of the *non- indidigenous* needs to find a translation for the Eurocentric reference points and which, apparently, for the Xavante, are of no use, since they rely on natural aspects to guide themselves. Only east and west are visible points from the "path that the sun takes" in the sky. It is added that these two points are differentiated not only as east or west, but also as an analogy of the sunrise associated with the light and the sky, and the west with the darkness and the earth.

The problem is further intensified by the fact that the translation made by the Salesian missionaries is based on an image that fixes the north "above" and the south "below" from the east "to the right", and the west "to the left", as we are usually used to drawing in the wind rose and orienting our bodies (turning our back to the south!).

If we observe the trajectory of cartography, for many years the east (orient) direction was the main reference to the attitude of orienting oneself. The very origin of the verb "to orient" comes from the Latin "to go to the east". It was only with the compass invention, through the discovery that the magnetized needle aligns with the Earth's magnetic axis, that the direction of north-south orientation was defined. With this, throughout the European Renaissance, it was agreed that the compass would point to the north, painting the N red, and/or creating an arrow with a north direction (Figure 3). Thus, determining that the compass "points" to the north is a European cartographic convention, since the needle does not point in a single direction (with the insistence on the north), but rather its tips (or magnetic poles) align with the terrestrial magnetic poles: the north pole of the needle points to the magnetic south pole of the Earth (geographic north) at the same time that the south pole of the compass needle points to the magnetic north pole of the Earth (geographic south pole).

Figure 3. Compass with an indication of the north direction. Source: the author.

3. Oriented Mythical Spaces and the *Mebêngôkre* People Universe

The east–west (sunrise–sunset) axis orientation mentioned above also occurs in Kayapó society; however, with some differences. According to Campos [13,14], instead of standing up to look for points Káikwa nhôt (west) and Káikwa krax (east) as is normally done in Western culture, they lie on the floor with their feet facing east and belly button facing upwards, as shown in Figure 4:

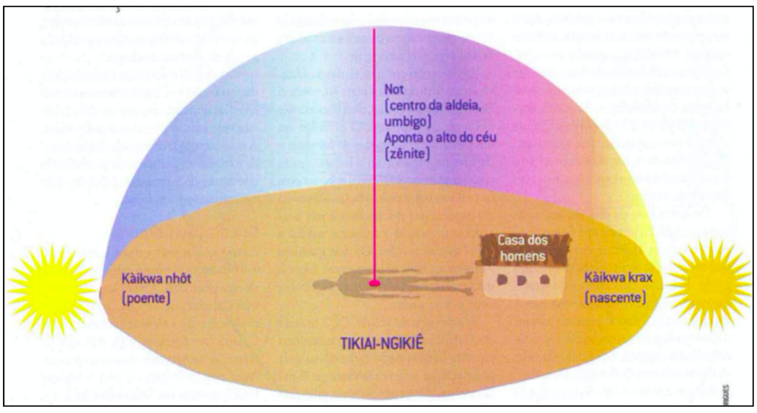

Figure 4. Kayapó orientation. Source: Campos, [13] (p. 66).

This would be a cosmological scheme in which man is not only positioned in the center to orient himself, but also, he is the "center of the world" and the spatial plane is defined by the sun-body reference points. Tuan called these characteristics a mythical space, stating that "[. . .] it satisfies the intellectual and psychological needs; saves appearances and explains events" [13] [p. 118]. Therefore, some characteristics of these representations are common among ethnic groups, namely:

It organizes the forces of nature and society by associating them with significant locations or places within the spatial system. It tries to make the universe understandable by classifying its elements and suggesting that there are mutual influences between them. [. . .] Assign personalities to the space, consequently transforming the space into place [13] (p. 117)

As Whitehead [1] (p. 316) points out, in the indigenous conceptions:

> "[. . .] ideas about the interconnection between persons and the cosmos may be enacted directly in ritual, through the design of costume and dance movements, or in songs through ritual that the cosmic order is maintained. Both the costumes of dancers and the shamanically prescribed movements refer to the cosmos ".

The *mekutom* ceremonial headdress and the helmet used by the Kayapó, for example, contain highly symbolic codes linked to their creation history and reveal much of these conceptions that include spatial references (Figure 5).

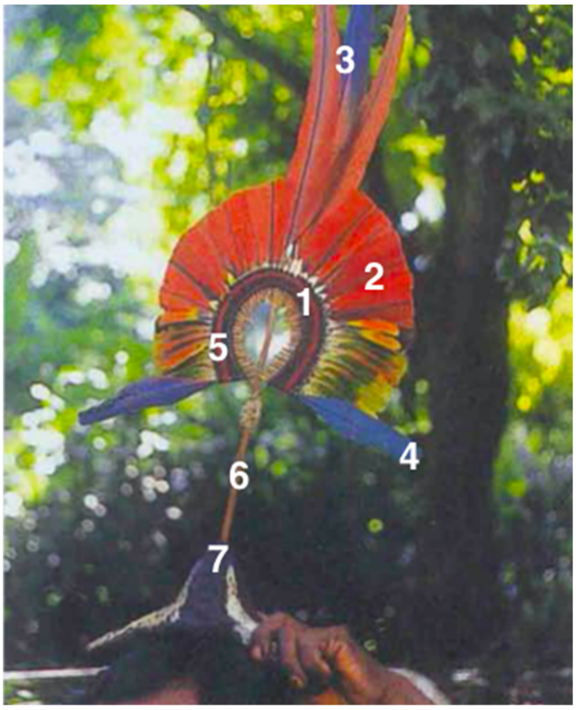

Figure 5. *Mekutom* ceremonial headdress and helmet. (1) The arch that supports the feathers represents the layers of the upper world (pykra). (2) The feathers red macaw, blue macaw and parrot feathers represent the face of the sun. (3) The three most elongated central feathers are the nose and the eyes of the sun. (4) The more elongated feathers on the sides portray the ears of the sun. (5) The path of the sun in this world is represented by the red stripe, uniting the east and the west. (6) The rod symbolizes the cord used by ancestors to descend into this world. (7) The helmet framed with beeswax mixed with remnants of dried vegetables is shaped like a freshwater turtle or *tracajá*. The highest part of the helmet symbolizes the center of the world and the location of the first village.

Thus, the mekutom represents regions of these disks, expressing not only the location, but also the Kayapó identity and some relations with the deities, provoking analogies that delineate the physical space and the spiritual space, encoded in the headdress. They are, therefore, "[. . .] physical maps and metaphysical terrains, since it is vital to establish the correct place of human with regard to multiple domains, not just the geographical" [1] (p. 312).

This importance given to the east–west axis that we mentioned earlier, as well as the mapping of the universe "real" and "imaginary", incorporating elements of celestial deities in the *mekutom*, have already been realized by the European cartography of the beginning of the Renaissance [1], as well as for medieval Christian cartography and its representations of religious mysteries, heaven and hell [15].

4. Final Notes

> "Brazil's mother is indigenous, although the country is more proud of its European father who treats him as a bastard son. His root comes from here, from the ancestral people *who wear a story, who write their culture, their prayers and their struggles on the skin.*"
>
> (Brazil's mother is indigenous—Mirian Krexu)

As we have seen here, some maps produced by indigenous people are not necessarily mappings centered on their spatial references, cosmological beliefs and living conditions. In some projects, the reasons for mapping are stimulated by the researcher and the concern is linked more to environmental conservation in defense of the environment than to issues that are properly indigenous. We often call on indigenous communities as mapping agents to make a commitment to preserve the environment—that is, natural resources [16]. However, the concern for environmental conservation today is markedly around the the non-indigenous lifestyle. It's how Aguiar provokes us: "[. . .] if there was no concern with environmental conservation, would there be a focus on the discussion on the creation and demarcation of indigenous areas" [16] (p. 239).

It is essential to recognize the importance of this type of mapping when including, for example, indigenous communities as subjects who map their own territories. But it is also necessary to recognize that, if on the one hand this mapping has been useful and desired and gives visibility to some indigenous spellings (mainly in the choices of the maps subtitles), on the other hand it has created a confusion that these maps are indigenous mappings (or mapping of indigenous peoples).

Although many cultural/social cartography projects involve participatory maps in sensitive attempts to incorporate indigenous elements/themes, as in the themes determination (mapping reasons), for example, these maps are not always configured as indigenous maps (or maps of indigenous peoples). When ordered/induced by non-indigenous people, a certain way of conceiving and representing space is implicit, and they are often incapable: "[. . .] thought as applied to cartography, focusing especially on its inability to account for mapping in non-textual, non-Cartesian cultures where action and process are often crucial, and "[. . .] even more paradoxical is the aim to include the excluded—to empower the disempowered—and to make no claims for textual superiority," [7] (pp. 1, 6).

Thus, caution is required when referring to "indigenous map (or maps of indigenous peoples)", since this term has been used in several situations, including participatory mapping in which the interest and the cartographic reason are of the researcher, ethnologist, or even of curious people. Given the ideas exposed here in our dialogue, my understanding is that we should use this term for mappings that explicitly contain indigenous representational knowledge, motives and forms, even if these are "abstract", "indecipherable" or "impossible" for us non-indigenous geographers. My intention here is not to create elements or criteria that identify what is indigenous cartography (or cartography of indigenous people), but to verify signs of an originality in their mappings.

In this sense, Whitehead points out that many cartographic representations have been produced today by indigenous people to help exogenous learning:

> "[. . .] and to make up for the interrogators' lack of linguistic, as much as geographic, understanding. As a result, we cannot simply assume that such exercises were part of a native tradition. They should be seen as providing evidence of the flexibility of indigenous cartographic practice as well as highlighting the differing cartographic needs of "locals" and "strangers" [1], (p. 319).

Much of what we call "indigenous maps" are formed as a palimpsest, in which colonialist cartographic motives for dissecting natural wealth are erased to engrave new reasons over those that existed before, even if still within Western cartographic reason, with Cartesian traditions and codifications. Change the style and color of the spelling, but the paper is the same! As a result, the erasure is imperfect and evident, leaving traces of a western dualism of mind and world, and of an objectification of the Earth. The point of view of a mapping from the high, distant and detached from the Earth, prevails [7]). Man and nature remain unified, and the Earth is mapped as a provider of natural resources. We cannot forget that understanding nature as outside of man was and still is a maneuver that allows us to explore the "empty" space [17].

In some indigenous cosmologies, nature is understood in its global sense, in which everything is nature, including each one of us [18]. This means that, unlike (my) naturalistic Eurocentric Christian cosmology, which objectifies (and explores) the Earth, many indigenous ethnic groups "personify" it through the presence of spirits in animals, plants, objects, or places. It is necessary, as Rundstrom warns us, to be careful not to be nihilists and to suffocate, distort or isolate indigenous mappings (or mappings of the indigenous peoples) from our projects/research of cross-cultural cartographic/geographical situations that also include worldviews and our place in it. Becoming aware of the colonial/colonizing cartographic heritage requires, as Rundstrom says, "a balance between keeping some differences and overcoming others if we are to achieve a society that is tolerant of difference and yet fair to all of us." [7] (p. 5), and that has been one of the decolonial turn challenges.

When analyzing decolonial thinking in geography, Cruz [19] points out that even with the end of the economic and political colonial period (historicized between the 16th and 19th centuries), coloniality is still an irreducible residue in our social formation and in our way of produce knowledge, "[. . .] manifesting itself in the most varied ways in our political and academic institutions, in the domination/oppression relations, in our authoritarian sociability practices, in our memory, language, social imaginary, in our subjectivities [. . .]" [19] (p. 15). By eliminating ways of living, relating and representing, or self-representing ourselves, we commit an epistemicide [20] that makes it impossible or expropriates (from) the other (from) their subjectivities and, in the cartography case, their cosmological symbolic systems that the other (person) has of the world and of themselves"[. . .] as well as of their concrete forms of representations and record of their memories and experiences " [19] (p. 17).

The criticism of the colonial form of cartographic representations implies an epistemological, political, and ethical commitment to participatory mapping of/with/for indigenous people. That is why I defend a decolonial cartography and not a counter-cartography. This movement is not against it, but it takes a different path, which follows in the same direction as social and cultural cartographies, which have generated precious debates by "tensioning" the western official/academic cartography. In other words, decolonial cartography is a movement that, by "[. . .] placing our colonial past as a starting point to press the specificity of our societies" [19] (p. 23) questions the cartographic exclusivity linked to the modern science and its society project, marked by a Eurocentric worldview that conceives space as a resource [21], as a surface to be dominated [17], and as a marketing product/property [19].

An indigenous decolonial mapping proposes to be a fairer and more inclusive approach, which allows us to know and recognize a way of living, of being, of thinking, of representing differently from the predominant model of westernized society. It makes room for maps that are not just prescriptive, centered on the usefulness or need of the capitalist system of territory control and resources exploitation written on paper skins [22].

Finally, I would like to make it crystal clear that this is a reflection of a white, Brazilian researcher, of European descent, and who has been developing projects in this area. For this reason, I have shared here some cartographic anxieties and cosmological care that seem important to me when we talk about indigenous cartographies. Having decoloniality as an epistemological stance and being motivated by cross-cultural interests have led me to radically review my uncomfortable place as a researcher and as a person in the world. Just as Théo Evan [23] was concerned with delivering a compass to the Tuschaua leader, we need to become aware of our cartographic acts/projects with/from/for indigenous people.

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Article

Automated Mapping of Historical Native American Land Allotments at the Standing Rock Sioux Reservation Using Geographic Information Systems

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Abstract: The General Allotment Act of 1887, also known as the Dawes Act, established the legal basis for the United States government to break up remaining tribally-owned reservation lands in the U.S. by allotting individual parcels to tribal members and selling the remaining "surplus." This research explores the processes involved in mapping these historical allotments and describes a method to automatically generate spatial data of allotments. A custom geographic information systems (GIS) tool was created that takes tabular based allotment land descriptions and digital Public Land Survey (PLSS) databases to automatically generate spatial and attribute data of those land parcels. The Standing Rock Sioux Tribe of North and South Dakota was used as the initial study area to test the mapping technique, which resulted in successfully auto-mapping over 99.1% of allotted lands on the reservation, including the smallest aliquot parcels. This GIS technique can be used to map any tribal lands or reservation with allotment data available, and currently it can be used to map over 120 individual reservations using publicly available data from the Bureau of Land Management (BLM).

Keywords: Dawes; allotment; GIS; map; automation; PLSS; geographic information systems; reservation; indigenous; Standing Rock

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1. Introduction

The Standing Rock Sioux Reservation located, along the border of North and South Dakota, has undergone major disruptive changes in land tenure over the past 150 years (Figure 1). Standing Rock, originally a part of the Great Sioux Reservation established in the Fort Laramie Treaty of 1868, is the seventh largest Indian reservation in the United States (3572 sq. mi., 9251 sq. km.), yet has one of the highest poverty rates of anywhere in the country [1]. Despite the vast tracts of land and resources within the reservation, tribal members still experience the consequences of historic decisions made far away in both space and time.

1.1. The Dawes Act and Land Allotment

The biggest contributor to the ongoing land issues on the reservation was the Dawes Act, also known as the General Allotment Act of 1887 [2]. This Act of Congress forced allotment in severalty on tribal members residing on reservations, meaning that tribes as a whole no longer owned their reservation land; instead, individual tribal members received their own parcels of land, known as allotments. The remaining unassigned lands were deemed "surplus" and sold on the open market, most often to white settlers.

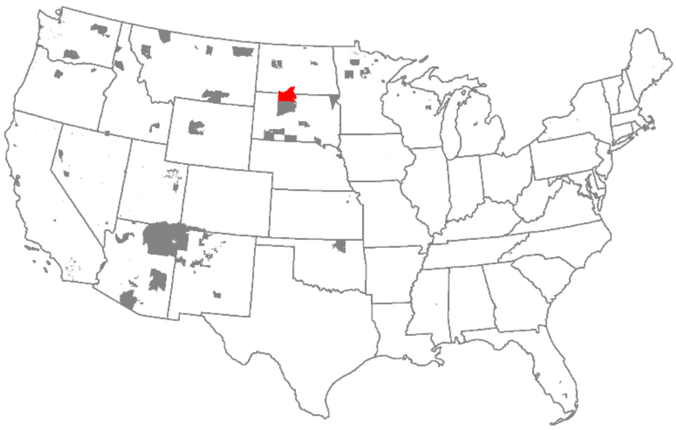


Figure 1. Map of American Indian reservations in the contiguous United States. The Standing Rock Sioux reservation is highlighted in red. Data source: U.S. Census Bureau Federal American Indian Reservations (AIR).

Reformers and federal officials promoted land allotment as a progressive step towards the civilization and assimilation of American Indians as farmers and ranchers. However, the Dawes Act was not solely a process of giving Indians private ownership of their land; it was a way to break up the reservation, destroy tribal ideologies of land held in common, weaken the authority of tribal leaders and traditions, and open unallotted reservation lands for white settlement. Theodore Roosevelt described allotment as a "mighty pulverizing engine to break up the tribal masses" [3]. During allotment, traditional practices and patterns of land tenure were replaced by the efficient but relentless rectangular grid of the U.S. Public Land Survey System (PLSS). Allotment further tightened the legally binding relationship between the federal government and tribal nations, designating the federal government as the fiduciary and authority of tribal trust assets stemming from treaties, lands, and all tribal resources. This is known as the trust responsibility, which is carried out by the Department of Interior within the Executive Branch of the federal government of the United States.

Under the terms of the Dawes Act, heads of household received 160 acres of land, single persons over age 18 and orphans under 18 received 80 acres, and children under 18 received 40 acres. It is notable that married women were not awarded allotments, although widowed and divorced women qualified to receive allotments as heads of household. Actual parcel sizes and allotment provisions varied from reservation to reservation, depending on such factors as the amount of land available, the climate (allotments in arid regions were often larger), access to water, timber and other resources, and political considerations, including requests from the tribes themselves. In some cases, a person's allotment consisted of a single rectangular parcel containing the entire acreage to which the person was entitled; in other cases, a single allotment might consist of several different parcels, sometimes not even adjacent to each other.

Allotment had and continues to have lasting effects for American Indians in three significant ways [4]. (1) Land loss. In total, over the course of 47 years, from 1887 when the Dawes Act was instituted until its repeal under the Indian Reorganization Act in 1934, an estimated 90 to 120 million acres of land left Indian hands by a variety of means, including sale of surplus reservation lands, fraud, and sales of land by individual allottees. (2) Fractionation. The Dawes Act failed to provide for what would happen to an allotment parcel when its owner died; thus, upon the death of an allotee who died without a will, title to the land went to his or her heirs according to the laws of the state in which the land was located. When this was repeated over several generations, the number of owners easily reached dozens to sometimes hundreds, all of whom held undivided interests to a fraction of the original parcel. This problem is commonly referred to as fractionation or the heirship problem and is the subject of numerous ongoing legal and policy proceedings [5,6].

For example, it is not uncommon for an individual Indian land owner to have as little as 1/4000th of an undivided interest in a parcel of land. Furthermore, it is often the case that a person may have fractional ownership interests in a number of different land parcels, sometimes scattered over several reservations, because of the residence locations and intermarriage of that person's ancestors. (3) Checkerboarding. The post-allotment influx of white settlers onto reservations in many cases created patterns of interspersed parcels owned or operated by white settlers, a pattern known as checkerboarding. Advocates of allotment actually viewed this pattern as desirable because they assumed that Indian allotment holders would benefit by observing the agricultural practices of their white neighbors. In fact, it disrupted existing agricultural, living, and social patterns, thereby further diminishing traditional ways of life.

1.2. Research Context

The allotment era of American Indian history is a well-covered topic, as numerous articles and books have been published on the subject, ranging in scale from the national [4,7–10], to state and regional areas [11–13], to individual tribes [14,15]. Allotment has been explored from political, historical, social, and legal perspectives, but relatively few studies have explored allotment from a spatial perspective. Imre Sutton, the late professor emeritus of Geography at California State University, was one of the first academics to make a national call for more work to examine the vastness and irregularity of the cartographic record for Indian lands. While there exist many maps of Indian lands, Sutton questioned the veracity of land ownership maps as it is "hard to ascertain how accurate field maps at BIA or tribal offices are today, and the published record gets out of date very quickly" [16]. If studies of allotment and the consequences of this failed policy are to be seriously examined, there exists a need for a method to be able to generate, synthesize, and analyze allotment information.

In the past, a major problem with geographic research on Indian allotments has been the lack of readily available spatial data for land surveys and allotments, as well as reliable and accessible digital sources of these datasets. Previous allotment mapping has largely been done by hand, either with traditional cartographic ink-on-paper methods or by manually digitizing paper maps or photographic images using GIS software and adding attribute data from archival allotment records. One of the earliest geographers to map and analyze land tenure patterns on a reservation was Dr. Harold Hoffmeister, of the University of Colorado Boulder in 1945, who studied the disparities in land tenure on the Consolidated Southern Ute Reservation in Colorado and Utah [17]. Later, in 1985, John Hartwell Moore performed an early spatial analysis of allotments among the Cheyenne in Oklahoma [18]. He utilized allotment records to manually map land ownership of the Cheyenne and used that dataset to analyze social connections within tribal groups using census information.

In the early years of the twenty-first century, several studies used manual methods to digitize maps and allotment records for use in GIS analysis. Middleton [19] analyzed historical allotments of former Maidu reservation lands in northern California utilizing National Archives and local county records to trace land ownership for the Mountain Maidu in Plumas County, California. She manually constructed spatial features of allotments using GIS to follow the historical lineage of land ownership of original Maidu allotted lands. Greenwald, in her comparative studies of the experiences of the Nez Perce, Jicarilla Apache, and Cheyenne River Sioux tribes, analyzed allotment era land maps and employed a manual digitizing technique to generate spatial data of allotments in GIS [14,20]. Greenwald has noted the difficulties and limitations of manually digitizing allotments, as well as obstacles presented by a lack of data for some reservations of interest [21]. Palmer later employed a mixture of manual digitization of historical maps as well as modern land ownership data obtained from tribal offices of the Kiowa tribe of Oklahoma to examine the loss of Kiowa allotment lands [22]. Kretzler and the Grand Ronde Land Tenure Project developed GIS data for allotments at the Grand Ronde reservation in Oregon [23,24].

Working with the Grand Ronde tribal Historical Preservation Organization, the team was able to retrieve and digitize maps and other archival documents of historical land tenure on the Grand Ronde reservation to create a digital database of land allotments for visualizing allotment patterns and understanding the loss of allotment lands

All of these previous allotment studies utilized manual methods to generate maps and, in the more recent studies, to create GIS spatial data of Indian lands. However, within approximately the past five years, the public availability of accurate and detailed digital datasets for the Public Land Survey System (PLSS) has created the potential for detailed mapping of Indian land allotments, and several recent studies have demonstrated the utility of these datasets in combination with the analytical capabilities of GIS. Egbert and Smith used a commercial software extension for ArcGIS to map and explore Kickapoo allotments in Kansas using a digital PLSS database and allotment records transcribed from archival records [25]. They found that allotment selections were primarily located in fertile stream bottomlands and their associated riparian woodlands. Allen used the same method to map and analyze allotments on the Omaha Reservation in Nebraska, finding that allotment preferences varied between groups of tribal members who favored adhering to traditional values, choosing allotments near traditional village locations, and those who saw advantage in taking allotments adjacent to future railroad lines because of their access to markets [26]. Sun Eagle likewise used the digital PLSS and archival allotment records for visualizing allotments on the Pawnee Reservation in Oklahoma [27]. She discovered that family and clan relationships were reflected in spatial patterns of allotment selections and that, as Egbert and Smith had found, there was an overall strong preference for fertile stream bottoms and woodlands.

Most recently, Dippel and colleagues in several studies utilized a different technique to map Indian lands by using digital Indian land records obtained from the Bureau of Land Management (BLM) General Land Office (GLO) online database and matching them to PLSS quarter-section 160-acre units [28–31]. The major advancement made by Dippel et al. was the use of the two digital databases in tandem to match allotments to land descriptions. This avoided the team having to perform map digitization, archival work, or having to purchase additional software extensions for an already expensive software package. Their method, however, did not actually map allotment parcels of less than one quarter-section (160 acres) in size, of which there are many, but rather assigned them to the quarter section to which they belong. This was adequate for the broad-scale analyses they performed but does not permit analysis at the fine scale required for exploring numerous specific questions on individual reservations.

1.3. Mapping Allotment at Standing Rock

An act of the Fiftieth Congress in 1889 authorized the president to direct that the Standing Rock Reservation be surveyed and that allotments in severalty be granted to its residents, as follows: one half-section (320 acres) to heads of family; one quarter-section to single persons over age 18 and orphan children under 18; and one eighth-section (80 acres) to children under 18 [32]. Two features of the enabling act are noteworthy: first, the allotment sizes were twice the size of those stipulated in the Dawes Act, likely due to the arid climate and the amount of land available, and second, as in the original Dawes Act, married women were not authorized to receive allotments. However, the Fifty-Ninth Congress (1906–1907) subsequently granted allotments to married women and to children who had not previously been allotted [33]. (These allotments were made after the initial allotments under the terms of the 1889 Act were completed.) Actual allotment did not begin at Standing Rock until 1906 with the appointment of Special Allotting Agent Carl Gunderson. The vast majority of allotments were completed by 1910, but additional allotments continued to be made up through 1934. In all, 4726 persons at Standing Rock received allotments, consisting of a total of 13,324 parcels. In addition, because of the scarcity of timber on the reservation and its value for fuel and construction, small timber allotments, generally of 2.5 to 10 acres in size, also were made.

This project began in 2016 with funding from the Indian Land Tenure Foundation (and later from the University of Kansas General Research Fund). The overall goal was to explore the feasibility of using the information in land allotment ledgers to create a digital spatial database of allotments on the Standing Rock Reservation to use as the basis for visualizing and exploring patterns of allotment.

In the first phase of the project, information from the Standing Rock archival allotment records was manually transcribed into Excel spreadsheets and then ingested into an ArcGIS add-in tool that used a digital database of the Public Land Survey (PLSS) at the section level to create a spatial database of all allotments that consisted of standard subdivisions (aliquots), e.g., quarter sections, half sections, quarter-quarter sections, and so on). Non-standard parcels such as government lots could not be mapped by the add-in program and subsequently were added manually. Although this method produced a map that showed the overall pattern of allotments and permitted exploration of the spatial data, we discovered two major problems with the process. The first was the time-consuming, expensive, and error-prone nature of the transcription process itself. Hundreds of labor hours were required to enter and cross check the thousands of allotments and their associated attribute data. Even after the cross-checking process, numerous errors in transcription were discovered, necessitating additional reference to the original ledger sheets and the online General Land Office database created by the Bureau of Land Management (which itself was being updated during the course of the project) in order to make corrections. The second problem was that the add-in parcel subdivision tool created thousands of duplicate lines and vertices in the output map, which were frequently offset from each other. This was because each allotment parcel, with its topology, was created independently of all the other parcels, including its neighbors. This was in addition to the program's inability to handle non-standard aliquots and government lots, as noted above. The net result was that additional large inputs of labor were needed to correct the underlying spatial database of allotments.

Although the methodology in the initial phase of the project ultimately produced a largely accurate map of allotments at Standing Rock, it was apparent that a more efficient and accurate mapping method was needed, one that could take advantage of the digital databases rapidly coming online to produce allotment maps of reservations in a few days, rather than weeks or months. Thus, the next phase of the project focused on the development of the tool described in this paper.

1.4. Goals

Digital allotment mapping using GIS is critical because it provides the cartographic visualization and spatio-analytical capabilities to explore both the patterns and processes of allotment. These are important not merely for satisfying historical curiosity but for providing a background for investigating and understanding subsequent events and impacts down to the present. The new allotment mapping tool fills the gaps in previous methods by developing a technique in which Indian allotments can be automatically mapped in a GIS software environment using common GIS tools and publicly available spatial databases and land allotment data. This new method generates complete and accurately sized and shaped GIS data of nearly all Indian allotments down to the finest scale. These GIS methods and techniques are repeatable and re-creatable in other GIS software; however, it was designed to be used in tribal offices on the reservation where ESRI's ArcGIS is the standard software. This method is intended specifically to automate the process of mapping historical allotments on Indian reservations, but it can also be used by anyone wanting to map land property descriptions recorded in PLSS format. These tools are explained and preliminary allotment datasets are open-source and will be available at www.haskellgeography.com (accessed on 18 March 2021).

2. Materials and Methods

2.1. Data Sources

We used two major data sources in this study: historical allotment data extracted from handwritten allotment ledger books and digital spatial data for the Public Land Survey System. The nature of each of these datasets and the means of obtaining them are described below.

2.1.1. Allotment Data

Tribal allotment data are openly available from at least two different sources. The Bureau of Land Management stores copies of the original allotment ledger books for many reservations in their various district offices, as does the National Archives at both its headquarters location in Washington, DC and branches located across the country. For the Standing Rock reservation, allotment ledger books are located at the National Archives branch in Kansas City.

Allotments were recorded in two types of ledger books, generally known as Tract Books and Allotment Registers, and several copies of each were made at the time of allotment. Both types of allotment ledgers contain both spatial and attribute data: the spatial data consist of the legal description of allotment parcels in PLSS format, while the attribute data contain information about each allottee, such as name, age, and gender. Tract books, as their name implies, were organized geographically according to the rectangular Public Land Survey System. In this case, the legal description of the land came first, followed by the allottee's name and allotment number and sometimes other information. Allotment registers, on the other hand, were organized by allotment number in numerical order (the first allottee being number 1, and so on). Information generally included, in addition to allotment number, the allottee's name (both "English" name and "Indian" name), age, marital status, and gender, and sometimes the relationship of the allottee to the head of household. This information was followed by the legal description of the parcel(s) making up the person's allotment and the total acreage allotted. For this study, high-resolution photographs of the Standing Rock allotment register and timber allotment register were made at the Kansas City Branch of the National Archives for subsequent transcription into Excel spreadsheets for use in conjunction with the PLSS to create a GIS database of allotments.

In addition to the original handwritten allotment ledgers, allotments now can also be mapped using digital allotment data available from the Bureau of Land Management (BLM) General Land Office (GLO) online database (hereafter referred to as the BLM/GLO database). The BLM/GLO data, transcribed from original allotment records, are already in a digital tabular format that only needs slight modification to prepare for mapping with GIS software. However, the BLM/GLO dataset lacks the additional social/demographic information (age, gender, family relationships) available in the archival allotment ledgers. The full BLM/GLO digital allotment data for Standing Rock only became available after we had transcribed the handwritten allotment register, but we found it highly useful in the later stages of this project. We were able not only to compare the nature and value of each of the datasets, but also to supplement the incomplete allotment register data with the BLM/GLO digital data, as we note below.

2.1.2. Digital Land Survey Data

The Public Land Survey System (PLSS) or Rectangular Survey System is a system for surveying and dividing land for settlement and sale and is the dominant land description system in the majority of the U.S., primarily in areas west of the Appalachian Mountains, although there are notable exceptions, especially in areas originally settled under French or Spanish colonial authority. The PLSS is a popular source of historical information used by researchers to investigate various topics, such as exploring historical cultural landscapes [34]. It also has been used as a base layer in several of the previously discussed allotment mapping studies. However, in a larger sense the PLSS grid ultimately changed the way Indigenous people tenured their lands under the evolving land systems in the United States. The insatiable desire of Euro-Americans for additional land further opened up Indian lands to settlers, squatters, and speculators. Survey grids like the PLSS that were used in this process are problematic to many Indigenous people, since they overlaid a rigorous grid system of land division over already existing Native systems of land tenure, occupation, and use. They therefore represent one of the methods by which land was explored, partitioned, and obtained from Native peoples [35]. It is a harsh reminder, and for many Native people a tangible representation, of the methods used to disenfranchise, marginalize, and assimilate them, the effects of which are still present.

As a survey system, the PLSS splits much of the US into a massive grid of squares (Figure 2). At the largest scale there are *township* and *range* lines which create 6 by 6 square mile grids across the landscape. Within these townships the PLSS has smaller 1 square-mile units called *sections*. Each section is further divided into quarter sections and quarter-quarter sections; these various regular divisions of a section are called *aliquots*. In addition to standard aliquot units, there are *government lots*, which are generated where the grid is slightly altered to compensate for errors that occur when laying a 2-dimensional grid on top of the 3-dimensional Earth, or where the grid meets the meander of a river or shoreline of a lake.

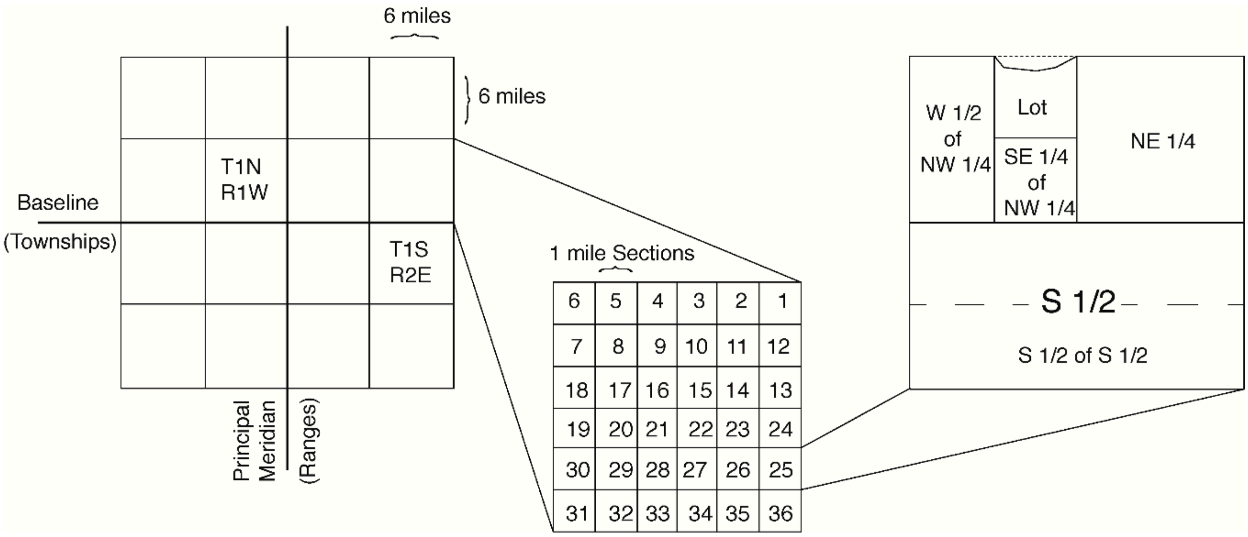


Figure 2. Public Land Survey System (PLSS) structure and aliquot examples.

The PLSS is available in digital format from the FGDC Cadastral Subcommittee Outreach Web Site (www.nationalcad.org) in both shapefile and geodatabase formats. The PLSS datasets come in multiple different layers, based on the size of the grid subdivisions. The "second division" of the PLSS, referred to here as quarter-quarter sections, is the most commonly available atomic level of PLSS data, each grid square representing 40 acres. The "intersected" PLSS layer contains all quarter-quarter sections, government lots, and parcel slivers created by river meanders and bodies of water. The intersected layers are used to map allotments using the tool described here as it contains the necessary attribute data. The attribute fields of the PLSS have been standardized by the FGDC, which makes this GIS technique universal for all states with PLSS data availability.

2.2. Methods: Tool Development

The implementation of the allotment mapping tool was created using ArcGIS Model Builder and involves the following four general stages. First, using the digital PLSS data, create a master aliquot spatial base layer of all possible aliquot subdivisions with unique parcel IDs (Figure 3); second, create a database of allotment parcels containing both land description data and attribute data with unique IDs for each parcel that correspond to the format for unique parcel IDs in the PLSS master aliquot database; third, merge the allotment database with the aliquot database using matching parcel IDs to create a map of allotments; and finally, map the few remaining unmapped non-standard parcels by (1) creating "micro" aliquot databases for unmapped small aliquots and merging them with the allotment database and (2) manually digitizing the few remaining allotments that could not be mapped using the tool. In the discussion that follows, we first describe the procedures followed for each step and then, where appropriate, discuss its implementation for the Standing Rock project. A schematic summary of the basic allotment mapping tool will be referred to throughout the article (Figure 4).

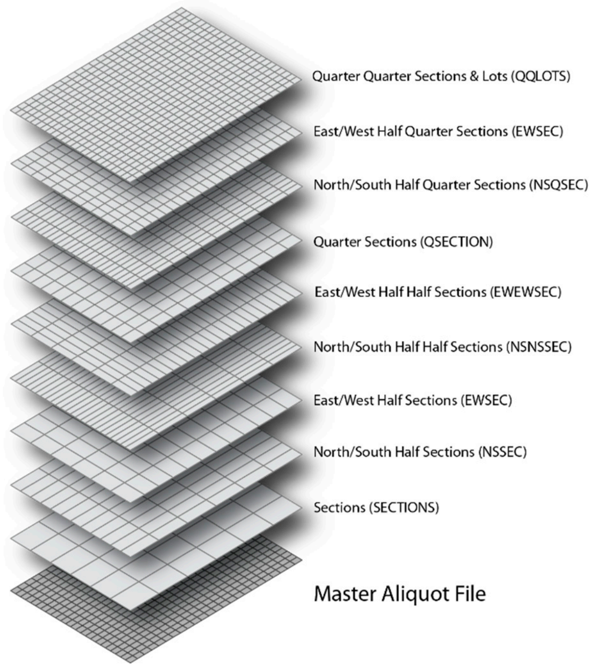


Figure 3. The "master aliquot" is a GIS data layer that contains the shapes of all possible aliquot parcels within a section merged together into one comprehensive file. Each parcel contains a Unique ID which is used by the allotment mapping tool to join the allotment spreadsheet and create the allotment parcel shapes with accompanying attribute data.

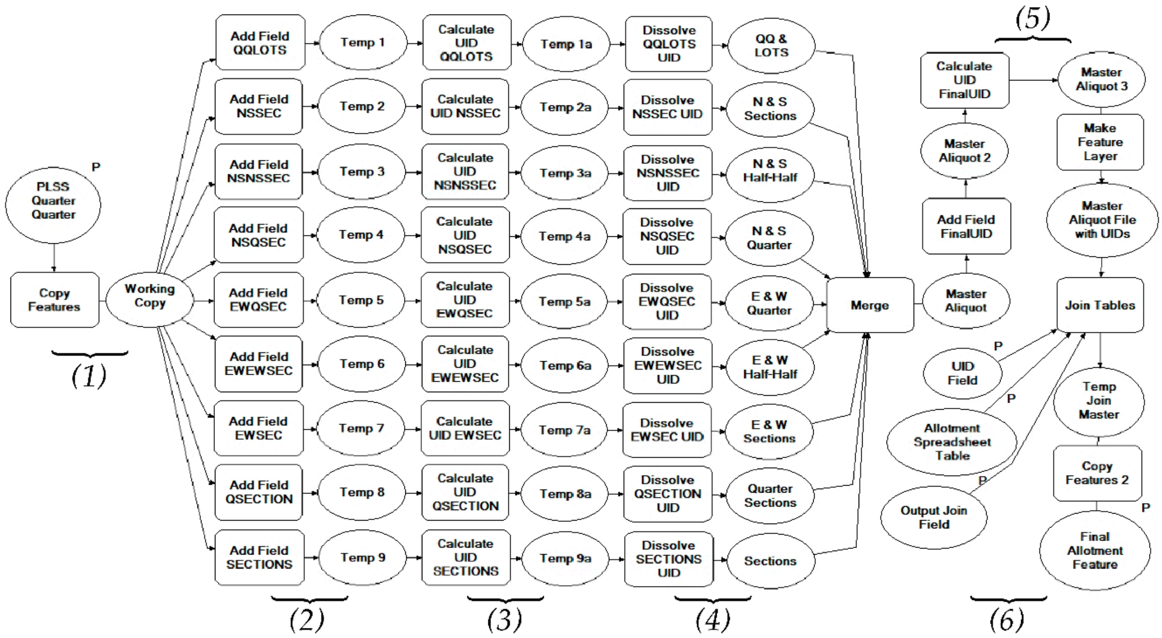


Figure 4. Schematic summary of the allotment mapping tool in ArcGIS ModelBuilder. Allotment mapping can be performed using simple and commonly available GIS processes. Step (1) create a copy of the original PLSS quarter-quarter data files. Step (2) generate new attributes fields for each class of land aliquot. Step (3) calculate the unique ID values for each type of land class. Step (4) dissolve borders of PLSS base layer polygons based on common unique ID, creating new shapes for each aliquot. Step (5) merges and concatenates the "master aliquot" file and its attributes. Step (6) joins the "master aliquot" with the tabular data of land descriptions generating the final data layer.

2.2.1. Create the Master Aliquot Database

The digital PLSS databases as they currently exist are useful for basic cadastral mapping and as a way to systematically identify, locate, and partition large tracts of land, but they do have two significant limitations for mapping tribal allotments. First, the digital PLSS data layers do not typically contain spatial data for anything smaller than a quarter-quarter section (40 acres). Many allotment parcel units on a reservation were smaller than 40 acres, and it is essential to have these data available in order to properly and completely map a tribe's original allotments. Second, the digital PLSS layers do not make available other common land description units such as half sections (320 acres), or half-quarter sections (80 acres), or half of a half of a quarter-quarter section (10 acres). However, these limitations can be addressed and the PLSS can be easily manipulated within a GIS software to generate all varieties of land aliquots using simple and available techniques.

The first limitation of the digital PLSS can be solved by simply splitting the PLSS data into smaller and smaller aliquot quadrants. With GIS software this task can be performed a number of ways, effectively creating smaller grids within the base PLSS grid system (Figure 5) [36]. The second limitation of the digital PLSS can be solved by using the atomic level PLSS as "building blocks" to create different size and shape aliquots such as the "northern half of section 15" or "the western half of the southeast quarter of section 34." These complex aliquots can be generated in the GIS software by merging together adjacent base units by altering the existing PLSS attributes and dissolving interior borders between features with the same altered attribute values (Figure 6a,b). If performed systematically within a section, new spatial data representing all of the various shaped and sized aliquots by doing nothing more than grouping adjacent parcels and dissolving boundaries.

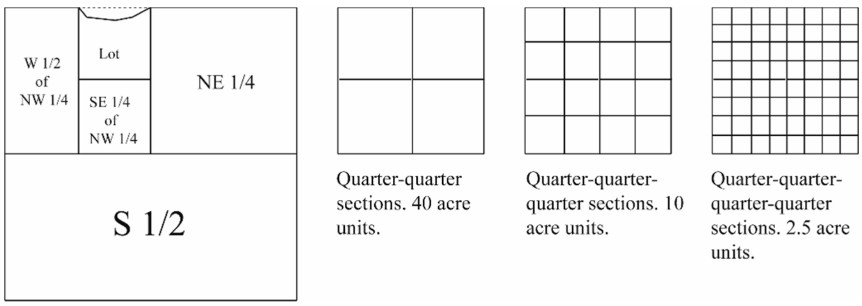


Figure 5. On the left is an example of the various PLSS-based parcel aliquots one may encounter. Quarter-quarter sections are typically the smallest sub-unit within the Public Land Survey System. Quarter-quarter sections can be quartered further using Ian Broad's Custom Grid Tools [36].

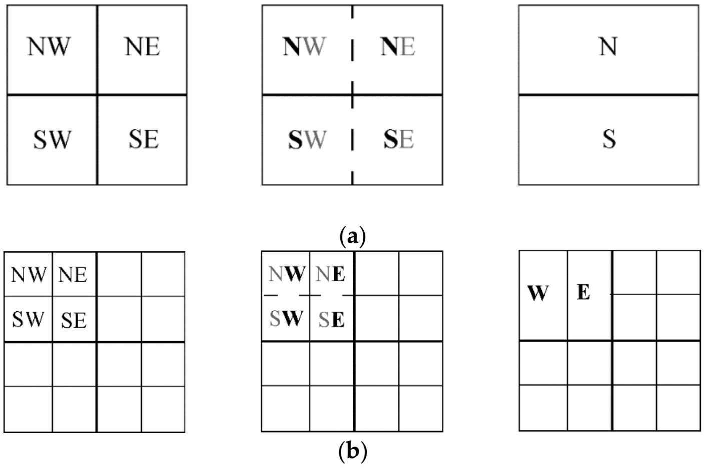
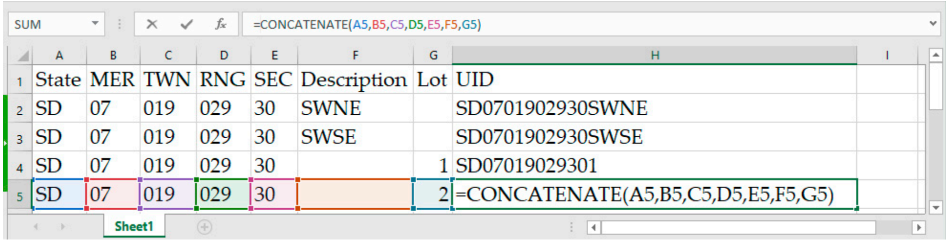


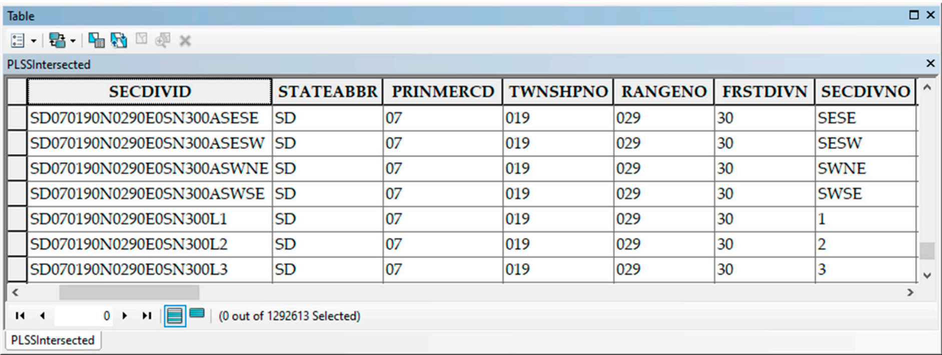
Figure 6. (**a**) Quarter sections are merged together to form northern and southern half sections. Removing the second string-character in the label field creates matching labels for two different Quarter Sections, northwest (NW) and northeast (NE), or southwest (SW) and southeast (SE). The Dissolve Tool uses these matching field values to combine quarter sections and generate the Half Sections. (**b**) The above illustrates how to generate east/west half-quarter sections, using the technique of removing string characters from the label field, in this instance the first character is removed from the label field. A Dissolve combines features with matching labels.

Creating new parcels features for the different aliquot descriptions recorded in the allotment records is only the first step. Having features to map is good, but it is the additional data recorded in the allotment ledger books that is arguably more important. The land owner's name, their age, gender and family relations are all recorded in the allotment books, and need to added to the newly created GIS features. The key to our mapping method is the ability to code each parcel in the allotment spreadsheet and each record in the PLSS base layer with matching unique identifiers (Figures 7 and 8). The unique identifiers act as addresses for individual land parcels, with each parcel having a unique string of characters used to identify, locate, and differentiate it from other parcels. These unique identifiers are essential to this mapping technique and are used for two processes in the map automation tool: first, as a way to generate a "master aliquot" file of every possible land aliquot within a section, and second, as a way to link the allotment spreadsheet data to this newly generated "master aliquot" file. We used the following terms in our databases: MER = prime meridian for the survey (two-digit code), TWN = township row number in the PLSS system (3 digits), RNG = range column number in the PLSS system (3 digits), SEC = section number within the six square mile township (2 digits), Description = aliquot designation within the section, Lot = government lot number within the township, if applicable.


=CONCATENATE(A5,B5,C5,D5,E5,F5,G5)

State	MER	TWN	RNG	SEC	Description	Lot	UID
SD	07	019	029	30	SWNE		SD0701902930SWNE
SD	07	019	029	30	SWSE		SD0701902930SWSE
SD	07	019	029	30		1	SD07019029301
SD	07	019	029	30		2	=CONCATENATE(A5,B5,C5,D5,E5,F5,G5)

Figure 7. Transcribed allotment ledger books in the spreadsheet. Concatenating land description information to generate unique IDs for each parcel. Note the similarity between the UID column in the spreadsheet with the PLSS default SECDIVID attribute field in Figure 8.



SECDIVID	STATEABBR	PRINMERCD	TWNSHPNO	RANGENO	FRSTDIVN	SECDIVNO
SD070190N0290E0SN300ASESE	SD	07	019	029	30	SESE
SD070190N0290E0SN300ASESW	SD	07	019	029	30	SESW
SD070190N0290E0SN300ASWNE	SD	07	019	029	30	SWNE
SD070190N0290E0SN300ASWSE	SD	07	019	029	30	SWSE
SD070190N0290E0SN300L1	SD	07	019	029	30	1
SD070190N0290E0SN300L2	SD	07	019	029	30	2
SD070190N0290E0SN300L3	SD	07	019	029	30	3

(0 out of 1292613 Selected)

Figure 8. PLSS attribute table viewed in ArcGIS. SECDIVID (PLSS second division identification) field needs only slight modification to match the UID from the allotment ledger spreadsheet.

The allotment mapping tool first creates copies of original data files so as not to destroy source data, see step 1 of Figure 4. Blank attribute fields are generated for each possible parcel aliquot within a section in the attribute table of the downloaded PLSS Intersected GIS data (Table 1), see step 2 of Figure 4. A Field Calculation is performed by the GIS software, which essentially creates a modified SECDIVID field, and generates new unique IDs for each of the different aliquots in a section by modifying and concatenating field values, step 3 of Figure 4. PLSS features with the same unique ID are then spatially merged together generating new shapes for every possible land combination within a section, step 4 of Figure 4. For example, an allotment may be described as the "western half of the southeast quarter of section 34, township 10, range 9." This particular unique ID for StandingRock would be SD0701000934WSE. This unique ID is generated by parsing through the attribute fields to extract the values needed, and then combining them back together. In the PLSS attributes the following field names are described: STATEABBR = State abbreviation, PRINMERCD = Principle Meridian Code, TWNSHPNO = Township number, RANGENO = Range number, FIRSTDIVNO = section number, and QQSEC = quarter-quarter section aliquot label. The following is an example Field Calculation that is used to generate unique identifiers for the eastern and western half-quarter sections, and see Table 2 for additional field calculation examples: [STATEABBR]&[PRINMERCD]&[TWNSHPNO]&[RANGENO]&[FRSTDIVNO]&RIGHT([QQSEC], 3). For this particular example, the eastern and western half-quarter sections are created by simply removing the first letter, either an "N" or "S", from the quarter-quarter attribute values in the PLSS data (Figure 9). The RIGHT function is used here to truncate the quarter-quarter section aliquot description by returning three string characters from the right side of the QQSEC attribute, thus removing the first letter in the aliquot abbreviation and creating an aliquot description for the eastern/western half-quarter sections. This creates eight sets of duplicate unique IDs within the 16 quarter-quarters in a section, each of them either an eastern or western half of one of the four quarter sections. Dissolving boundaries in step 5 of Figure 4 uses matching unique IDs for all eight possible east/west half-quarter sections within a single section (Figure 10a–c). This process is repeated for each type of land description and merged together creating the master aliquot file Geodatabase of stacked and overlapping aliquot parcel shapes. The master aliquot can be imagined as a single stack of data layers, with each layer representing a different type of section aliquot from Table 1 all merged together in one comprehensive data file, (Figure 3).

Table 1. Possible aliquots within a section, size of each aliquot, and count per section and township.

Section Aliquot	Example	Abbr.	Acres	Sections	Townships
Half	Northern half	N	320	4	144
Quarter	Southeast quarter	SE	160	4	144
Half-half	Northern half of the northern half	NN	160	8	288
Quarter-quarter	Southeast quarter of the northwest quarter	SENW	40	16	576
Half-quarter	Northern half of the northwest quarter	NNW	80	16	576
Half-half-quarter	Southern half of the northern half of the southeast quarter	SNSE	40	32	1152
Quarter-quarter-quarter (QQQ)	Southwest quarter of the northwest quarter of the northeast quarter	SWNWNE	10	64	2304
Half-quarter-quarter	Southern half of the southeast quarter of the northwest quarter	SSENW	20	64	2304
Half-half-half-quarter	Northern half of the southern half of the northern half of the southeast quarter	NSNSE	20	64	2304
Half-half-quarter-quarter	Northern half of the southern half of the northwest quarter of the south west quarter	NSNWSW	10	128	4608
Half-QQQ	Southern half of the northeast quarter of the northwest quarter of the southwest quarter	SNENWSW	5	256	9216
Half-half-QQQ	Southern half of the southern half of the northeast quarter of the southwest quarter of the southeast quarter	SSNESWSE	2.5	512	18,432

Table 2. Example Field Calculations performed in GIS on the PLSS Intersected base layer. This generates Unique IDs for various parcel aliquots. A dissolve function is later performed using the Unique IDs, thus generating the final parcel shape. This is step 3 in Figure 4.

Aliquot	Field Calculation
Section	[STATEABBR] & [PRINMERCD]& [TWNSHPNO] & [RANGENO] & [FRSTDIVNO]
North/South Half	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO]& [FRSTDIVNO] & LEFT([QSEC],1)
East/West Half	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO] & [FRSTDIVNO] & RIGHT([QSEC],1)
North/South Half Half	[STATEABBR] & [PRINMERCD]& [TWNSHPNO] & [RANGENO] & [FRSTDIVNO] & Left([QQSEC],1) &Mid([QQSEC],3,1)
East/West Half Half	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO]& [FRSTDIVNO] & Mid([QQSEC],2,1) & Right([QQSEC],1)
Quarter	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO] & [FRSTDIVNO] & [QSEC]
North/South Half Quarter	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO]& [FRSTDIVNO] & Left([QQSEC],1) & Mid([QQSEC],3,1) & RIGHT([QQSEC],1)
East/West Half Quarter	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO] & [FRSTDIVNO] & RIGHT([QQSEC],3)
Quarter Quarter and Lots	[STATEABBR] & [PRINMERCD] & [TWNSHPNO] & [RANGENO] & [FRSTDIVNO] & [SECDIVNO]

Table

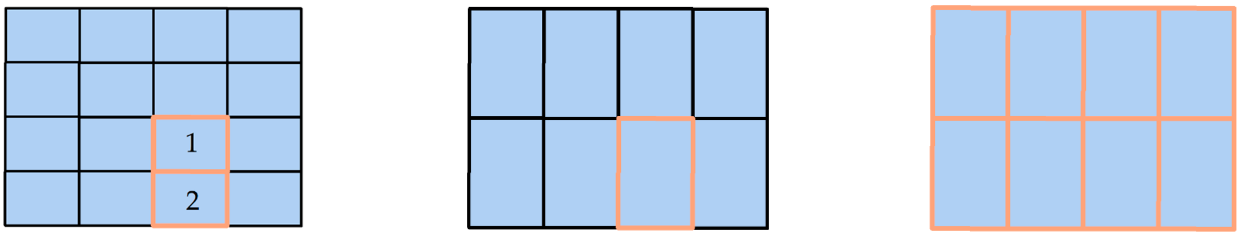
PLSS_UID_Calculations

STATEABBR	PRINMERCD	TWNSHPNO	RANGENO	FRSTDIVNO	QQSEC	E/W Half Q Sect	UID E/W Half Quarter Sect
SD	07	010	009	34	NENW	ENW	SD0701000934ENW
SD	07	010	009	34	SWSE	WSE	SD0701000934WSE
SD	07	010	009	34	SENE	ENE	SD0701000934ENE
SD	07	010	009	34	SESE	ESE	SD0701000934ESE
SD	07	010	009	34	NWSE	WSE	SD0701000934WSE
SD	07	010	009	34	SWSW	WSW	SD0701000934WSW

(2 out of 17 Selected)

PLSS_UID_Calculations

Figure 9. PLSS attribute table opened in ArcGIS. A field calculation in step 3 of Figure 4 is used to concatenate attribute values and generate Unique IDs. This example creates eastern and western half-quarter sections by removing the first character of the QQSEC field values, which are then concatenated together with other PLSS attributes to create the final aliquot Unique IDs. See Figure 8 for Field Calculation equation.



(a) (b) (c)

Figure 10. (**a**) The NW quarter of the SE quarter (1), and the SW quarter of the SE quarter section (2) are highlighted above and also in the attribute table in Figure 9. (**b**) The two quarter-quarter sections are merged together with the Dissolve tool, see step 4 of Figure 4. (**b**) The two quarter-quarter sections are merged together with the Dissolve tool, see step 4 of Figure 4. (**c**) For each section, 8 eastern/western half quarter sections are created. This is just one example of a typical land description. See Table 1 for other aliquot combinations.

For large reservations like Standing Rock, the master aliquot step requires a significant amount of computational time simply because of the large number of parcels generated in the master aliquot file. For example, when generating half sections, the GIS software creates 4 new spatial features for each section, each representing the four possible half sections (northern, southern, eastern, and western halves). When generating half-quarter sections, the software produces 16 new spatial features for each section. And, when generating half quarter-quarter sections, the software produces 64 new spatial features for each section. The Standing Rock reservation encompasses approximately 150 townships, or nearly 5400 sections, which makes generating the master aliquot a highly intensive computer process for larger reservations.

2.2.2. Create the Allotment Parcel Database

There currently are two primary ways to create an allotment parcel database. The first is to manually transcribe the handwritten allotment entries from the allotment ledger book for a reservation—either the allotment register or the allotment tract book can be used. The entries can be transcribed into Excel or any other spreadsheet or database that can be ingested into the GIS. It is important to record and store the information from the ledger books in the same schema used for the PLSS data, such as three-digit numbers for townships and ranges, and two-digit numbers for sections, government lots, and meridian codes. Aliquot descriptions in the allotment spreadsheets also must be standardized to match the PLSS nomenclature, such as SENW for the "southeast quarter of the northwest quarter section." The transcription process is laborious; depending on the size of the reservation and the number of allotments, hundreds of hours of labor may be required.

Since the total number of data cells for a reservation's allotment database may reach into the tens of thousands, the possibility of inadvertent errors in transcription, especially errors in transcribing the PLSS information, is significant. Some errors can be detected rather easily by cross checking, while others may require an iterative process of mapping and correction.

The second method of creating a database of allotment parcels is to download all the allotment data for a reservation from the GLO website, which is the method used by Dippel et al. [29–31]. This method has the significant advantages of already having been checked for accuracy and being in the appropriate format for matching with the PLSS database. The GLO allotment data have three limitations, however. The first is that identifying all the allotment parcels for a given reservation is not always a straightforward process. Although the GLO land parcel online database has fields that can be useful for identifying allotment parcels, such as "Indian Allotment" and "Tribe," these fields are sometimes left blank or use a variety of terms rather than a single, uniform one. This means that it often is necessary to use a variety of search terms to obtain a complete dataset of allotments for a reservation. The second limitation of the GLO database is that, as noted earlier, it does not contain all the attribute information for allottees contained in the ledger books, e.g., age, marital status, sex, and family relationship, making it inadequate for performing numerous kinds of spatial analysis such as examining the spatial pattern of allotments within families or the relationship between allotments of husbands and wives or the distribution of allotments for adult women, to give just a few examples. The third limitation of the BLM/GLO database is that it only represents those tribal members who received patents for their allotments. In the case of Standing Rock, this represents nearly 99% of allottees, but this number varies from reservation to reservation.

As described above, allotment information for the Standing Rock reservation was photographed and transcribed from the allotment registers available at the Kansas City branch of the National Archives (Figure 11). These allotment registers contain information for the majority of Standing Rock allottees up until about 1910–11, a total of 4026 allotment recipients. However, allotments continued to be distributed up until allotment was ended in 1934. The remaining Standing Rock allottee information was obtained from the BLM/GLO website by querying the GLO Web Services for the unaccounted-for allottees between numbers 4027 to 4726. A total of nearly 700 additional Standing Rock allottees were recorded between the end of the ledger books and the end of the allotment period in 1934. These 700 extra allottees received an additional 1095 parcels which were added to the parcels from the allotment register to create a complete dataset of the original allotments at Standing Rock.

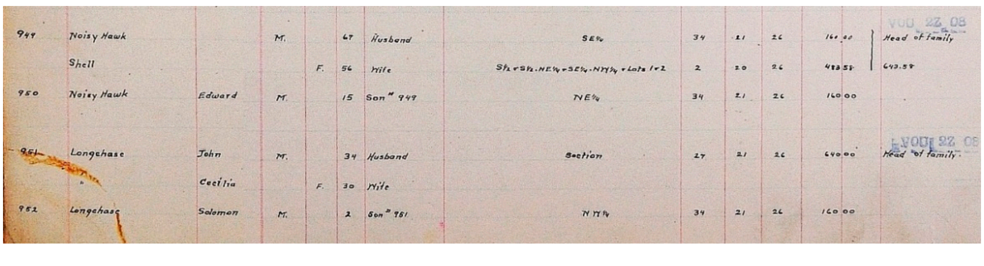


Figure 11. Sample image from the allotment ledger books, available from the National Archives. Note the variety of land descriptions in the middle column: one full section, one half-section, three quarter-sections, two quarter-quarter-sections, and two lots.

2.2.3. Merge Matching Parcel IDs in the Two Databases to Create the Allotment Spatial Database

The final step in creating the allotment mapping tool is to use a table join to match each spreadsheet allotment record's unique ID to a correct parcel in the "master aliquot." Each allotment record in the spreadsheet has a unique ID that perfectly matches one of the parcels contained in the "master aliquot." Only matching records are kept during the join, leaving only those parcels that are Indian allotments. In addition to automatically extracting the shapes of each parcel from the master aliquot, this join also adds the attribute data from the allotment spreadsheet, allowing for further analysis of the social demographic attribute data recorded in the allotment ledger books.

2.2.4. Map the Few Remaining Non-Standard Parcels

A validation process is performed after the initial allotment mapping tool is completed to determine which parcels in the spreadsheet were not mapped. This validation process, using a reverse join, matches the output of the allotment mapping tool back to the original spreadsheet, while keeping all unmatched records. This type of join will generate "Null" values for any unmatched records, and those records are then isolated and extracted. This creates a list of all allotment parcels that the tool could not map, and it can be then checked for transcription errors and other potential reasons why the tool failed.

After running the allotment parcel-mapping tool, there invariably will be a few parcels that remain unmapped. These consist of "micro-level" aliquots that are smaller than, or different from, the parcels in the master aliquot file, and non-standard parcels whose boundaries are expressed in metes-and-bounds descriptions rather than as aliquot subdivisions and thus cannot be mapped by the mapping tool. These problems are resolved using two different methods: (1) creating "micro" aliquot databases for remaining unmapped small aliquots and merging them into the allotment database and (2) manually digitizing the few remaining allotments that could not be mapped using the tool.

3. Results

The allotment mapping tool, using only the quarter-quarter section PLSS building-blocks, produced 12,953 mapped parcels, or 97.2% of total allotment parcels (13,324) (Table 3). After performing a validation check (see Section 2.2.4), the mapping tool produced a report of unmapped records from the original spreadsheet. At Standing Rock, only 371 parcels from the allotment ledger books could not be mapped by the tool at the quarter-quarter level. As noted above, these consisted of aliquots smaller than those in the master aliquot database or parcels expressed in non-aliquot terms, for example "the north 10 chains of Lot 4," or "From center of section 24, hence west 5 chains; 8 chains to river; southeast along river to line between SE4 of SW4; North to place of beginning." (One chain = 66 feet in the U.S. survey system.)

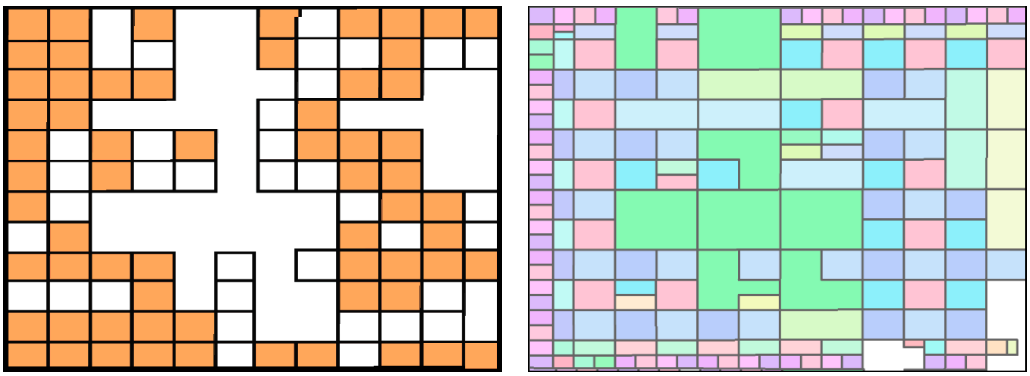
Of the 371 remaining unmapped parcels, 251 were aliquot parcels but were smaller than the smallest parcel size in the master aliquot file and therefore required a modified PLSS building block to map. The quartering tool was used to split the sections containing unmapped parcels into quarter-quarter-quarter sections (10-acre aliquots) and quarter-quarter-quarter-quarter sections (2.5-acre aliquots). Rather than doing this for the entire reservation area, only the specific section for each of the unmapped parcels was used by the quartering tool as a way to decrease unnecessary processing and therefore the time needed to generate these few, small-sized parcels. A second pass of the tool was then performed on these "micro" aliquots and they were added to the allotment map. This brought the total of successfully auto-mapped parcels to 13,204 or 99.1% (Table 3).

The remaining 120 parcels could not be drawn by the tool because they contain non-standard land descriptions, as noted above. Ordinarily, all these parcels would need to be measured and drawn manually; however, at Standing Rock the majority of these parcels fortunately already exist in the PLSS data as newly renamed government lots. The GLO plat maps of Sioux County, North Dakota and Corson County, South Dakota (which comprise the Standing Rock Reservation) were used to verify these locations as well as extract the new PLSS government lot number. These were then merged with the allotment database, resulting in a final successful mapping rate of 99.7% using automated methods (Table 3). Only around two dozen of the last 120 parcels remained unmapped after this process, and they were manually digitized and merged with the allotment database.

Table 3. Results of allotment mapping tool at Standing Rock. The vast majority of parcels can be mapped using only the quarter-quarter sections and government lots available in the PLSS Intersected data set. A modified quarter-quarter-quarter-quarter section file was generated on a second-pass of the tool to create the remaining small-area parcels. Manual digitization was only needed on less than 1 percent of the allotments on the reservation.

Mapping Method	# of Parcels Mapped	% of Total
Quarter-quarter PLSS	12,953	97.22
Modified QQQQ PLSS	251	1.88
Manual methods	120	0.90
Total Parcels	13,324	100.00

In addition to successfully mapping nearly 100% of the allotment parcels at Standing Rock, the automated mapping tool created an allotment map with an unprecedented level of detail by mapping even the smallest aliquot parcels (Figure 12a,b). In their landmark studies, Dippel et al. claimed the ability to map 97.7% of all allotments at the quarter-section level of the PLSS [29]. It must be remembered, however, that their approach only mapped parcels at the quarter-section (160-acre) level, and did so by assigning parcels smaller than that size to the quarter section in which they lie (Figure 12a). The new allotment mapping tool easily generates these smaller sized allotment parcels, achieving a near-complete dataset of allotment for a reservation in a matter of hours. By using 160-acre parcels as base units, Dippel et al. overestimated the size of all allotments under 160-acres, and failed to produce spatial features for a large number of smaller allotments that were available from the BLM GLO database. The new allotment mapping tool has an advantage over these and other techniques because it accurately maps allotment parcels down to the finest aliquot, while automating the most time-consuming aspects.



(**a**) (**b**)

Figure 12. (**a**) Pine Ridge reservation allotment parcels adapted from Dippel et al. [29–31]. (**b**) The same area at Pine Ridge mapped using the new allotment mapping tool described in this study, random color scheme assigned by GIS software.

The spatial distributions of allotments at Standing Rock displayed in the preliminary maps reveal several interesting patterns. Based on previous studies of allotment, it was expected that the allotments at Standing Rock would roughly align with the spatial distribution of rivers and streams and their associated woodlands, and the map of allotments confirmed that this was the case (Figure 13). In addition to streams and rivers, lands near existing and proposed railroad lines were also heavily allotted, implying that connectivity, mobility, and proximity to resources that the railway would provide were important to at least some individuals when selecting their allotments.

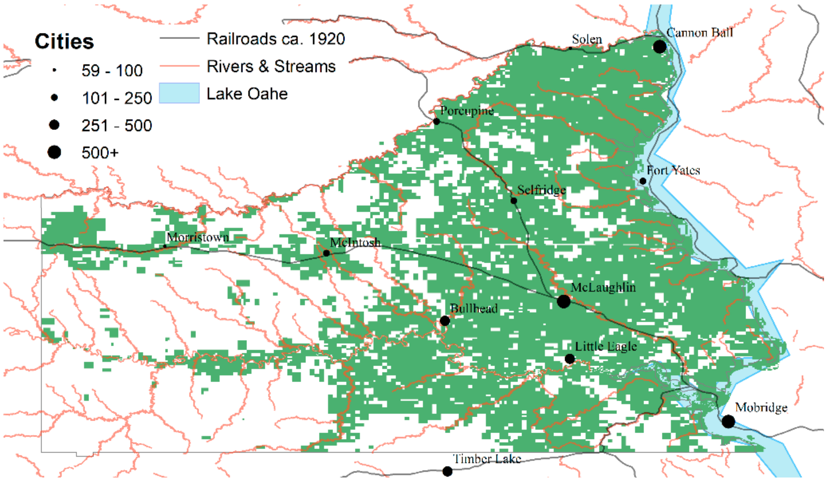
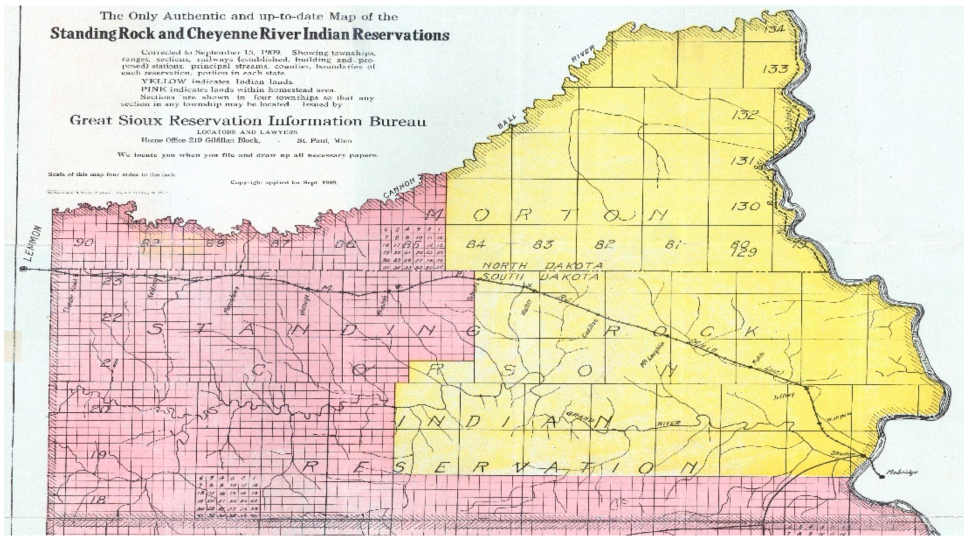


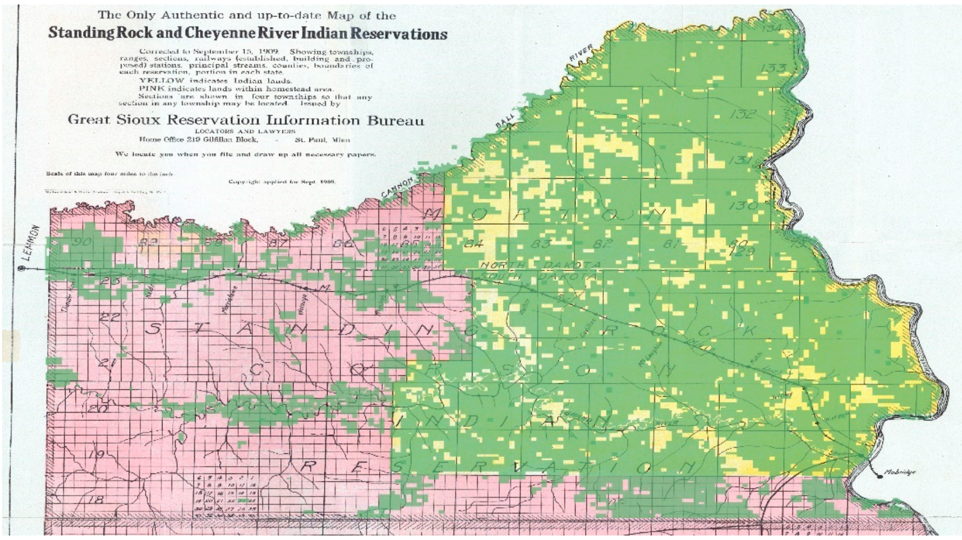
Figure 13. The overall allotment pattern at the Standing Rock reservation.

The spatial pattern of allotments also closely matches previously generated "surplus land" maps that were created in 1911 and 1925 by the Office of Indian Affairs (renamed the Bureau of Indian Affairs, BIA, in 1947) to aid non-Indian settlers in choosing available parcels on the newly opened reservation (Figure 14a–c). Despite Sutton's observation that Indian land maps can be unreliable since they are updated and modified so often, the surplus land maps and the allotment data line up quite well after overlaying them with the newly created allotment features.

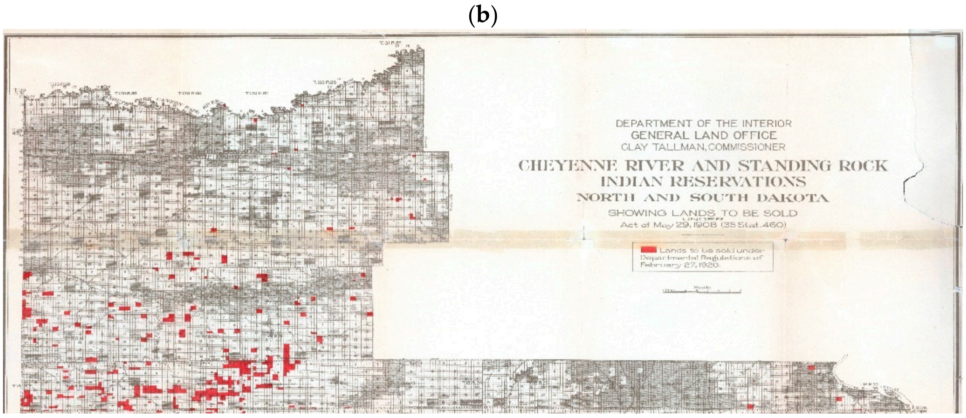


(**a**)

Figure 14. *Cont.*



(**b**)



(**c**)

Figure 14. (**a**) 1909 map of surplus reservation lands available for sale to non-tribal members after allotment (pink) versus lands set aside for the tribe (yellow). (South Dakota State Historical Society Digital Archives: 2019-09-25-0004). (**b**) Allotments (green) overlaid on the map, confirming that the majority of land allotted on the reservation lies within the designated yellow area. (**c**)1920 map showing remaining surplus lands after allotment. Dark grey areas are allotments outside of the previously designated areas to the east. These areas match green areas in Figure 14b. (South Dakota State Historical Society Digital Archives: 2019-09-25-0006).

Since allotments were made sequentially by allotment number, it also is possible to examine the temporal patterns of allotment based solely on the allotment numbers and a knowledge of the allotment process at Standing Rock (Figure 15). One major temporal pattern shows that the special allotting agent began allotting parcels in the far southeast corner of the reservation first and worked methodically across the reservation in tiers, with later allotments further west and north.

A second spatio-temporal pattern focuses on the relative locations of allotments between two groups of allottees. In practice, there were two waves of allotment at Standing Rock. The first wave began in 1906 and was completed with individual allottee number 2495, sometime in 1908 or 1909. These allotments were made to all those who were authorized to receive allotments under the initial enabling act. However, as noted earlier, in 1906 the married women of Standing Rock and other Sioux reservations petitioned for their own allotments, separate from their husbands, which they later received during a second wave of allotment [33]. In addition, children born during the initial wave of allotments were also awarded allotments during this later period. The spatial patterns in Figure 14 illustrate this complex process. Since the majority of allotments in the first wave were located in the eastern part of the reservation, there were relatively few remaining parcels in that region, meaning that many of the married women and unallotted children of the second wave were forced to select lands further to the west. This pattern is visible in Figure 15. Although a few of the second-wave allottees (allotment numbers 2496 through 4726) were able to select scattered parcels in the east (and presumably closer to parcels selected by their husbands or other allotted family members), the vast majority of these lands were located to the west of those in the first wave.

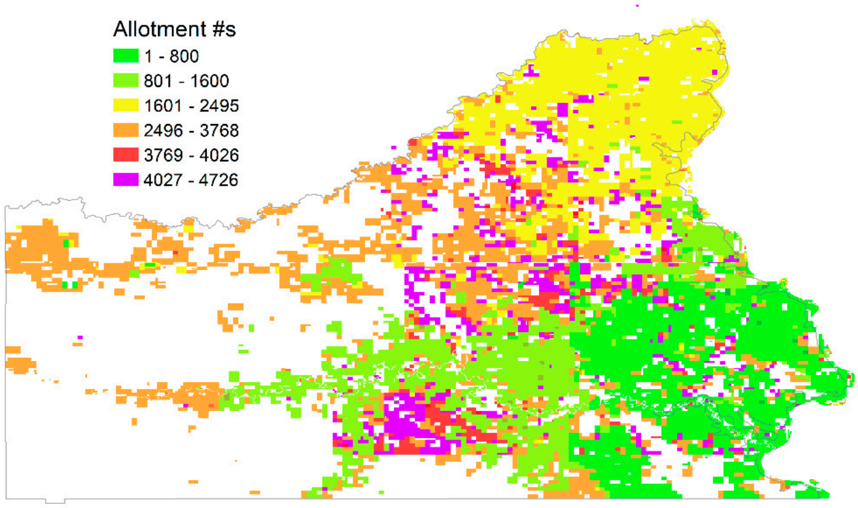


Figure 15. Categorized allotment data based on allotment number. The pattern illustrates the temporal progress of allotment across the reservation as it spreads from the southeast corner.

4. Discussion

4.1. Significance of this Research—A Tool to Extend Tribal Sovereignty

Access to accurate data has been and continues to be of paramount importance for American Indians. The work to understand individual Indian's land ownership and property rights and thus the residual effects stemming from allotment land is a complex undertaking and access to data is key. This GIS tool opens up the possibility for each tribe to map its historical allotments, at least where the data are available. The BLM/GLO has near-complete allotment data for 124 out of 326 current federally recognized Indian reservations, and it also has a significant amount of uncategorized allotment data, where tribal affiliation or allotment number was not recorded.

Data sovereignty, or the control of data that helps individual Indians understand these rights, is a burgeoning topic regarding tribal lands and was a central tenet of the largest class action lawsuit filed and successfully decided in favor of individual Indians. In *Cobell v. Salazar* (2009), Eloise Cobell, a member of the Blackfeet Nation in northern Montana brought a class action lawsuit against the Department of Interior (DOI) representing individual Indian land owners. Cobell asked the DOI for an accurate accounting of individual Indian moneys generated by leasing and extraction of resources such as gas and oil from individual allotment lands, but the DOI was unable to produce an accurate accounting of nearly 130 years of residuals and the case was settled at $3.4 billion. In the process of the lawsuit, the flaws of allotment, i.e., fractionation and the deficiencies in the trust relationship, further came to light. *Cobell v. Salazar* illustrates the need for tribes to be able to be transparent stewards of their own land data and records and not rely solely on the federal government for this information. Work is already underway to map the available BLM/GLO allotment records and make the data available to the tribes. Organizations such as Indian Land Tenure Foundation, Village Earth, Indian Agriculture Council, Native American Agriculture Fund, and a handful of interested parties are working with tribes and other agencies to make this a reality. This tool can be a significant building block for achieving those goals.

4.2. Potential Improvements to the Mapping Tool and Its Databases

The GIS methods used here to automatically generate spatial data from text-based land descriptions has room for optimization. This is an early version of the tool that was created to verify that it works on multiple different reservations and, so far, it has performed as expected. However, large reservations are difficult to map without splitting up the reservation into smaller units for processing. The creation of the master aliquot data file is arguably the most computationally intensive process and has the most potential for improvement. Generating millions of parcels only to select a few and delete the rest seems wasteful. On the Standing Rock reservation, most of the smallest parcels that required the most computation time were grouped together in only a select number of sections. Isolating these sections for separate processing decreased the time needed to generate these smaller aliquots, but there are potentially other ways to speed up processing time. In addition, future versions of the tool will be modified to run in ArcGIS Pro. ArcGIS Pro is a 64-bit software, while ArcMap is 32-bit, which should speed up the mapping processes significantly. It also is anticipated that future versions will be ported to R and Python for those not using ESRI software products.

It was noted earlier that each of the two major sources of allotment data (archival ledgers and the BLM/GLO database) has its strengths and weaknesses. Although the BLM/GLO online datasets offer the clear advantages of being accurate and ready to ingest into the tool, they lack important attribute information that is critical for certain types of spatial analysis. One solution to the problems associated with each of the methods of creating a database of allotment parcels is to begin by downloading the digital allotment data from the BLM/GLO website and then filling in its missing fields (age, marital status, etc.) with information found in the archival allotment ledgers. This could be further added to, if desired, by entering information found on land patents, leasing records, Indian censuses, and others. This method would have the advantage of beginning with a spatial database of parcels that already is correct and complete (or nearly so) and augmenting it with attribute data fields that are necessary for performing spatial analyses of the type needed for more fully understanding the impacts of allotment.

4.3. Future Avenues of Research at Standing Rock

There is still much work to be done to fully understand how the process of allotment played out at the Standing Rock Reservation. Now that spatio-demographic data are available for the reservation, further analysis of the policy, practices, and patterns of allotment at the reservation can be performed. For example, since transportation and connectivity seemed to be important in the preliminary analysis of the allotment map, it would be interesting to add known wagon trails, dirt roads, and highways to the transportation layer. GIS could be used to calculate the distance from each allotment to existing roads, rivers, and railways, and then test these measures for statistical significance.

Pre-allotment settlement patterns were discussed by Indian agents at Standing Rock in their annual reports, which confirmed that the reservation was largely settled prior to the allotment era, with families self-allotting on personal plots of land. One spatial pattern that deserves further exploration is that of family connections, as family relationships, both in the nuclear and extend family, were extremely important to tribal members. It will be recalled that the Standing Rock allotment ledgers recorded information about families and about how each allottee was related to the head of the family. This information can be mapped and analyzed to answer questions about what allotment strategies family members might have used in selecting allotments? Did they select allotments that were adjacent to each other where possible, or did they put primary emphasis on selecting the best available lands (e.g., those with access to water), perhaps resulting in more dispersed patterns? Preliminary exploration at Standing Rock appears to indicate that allotments of related family members exhibited a wide variety of patterns (Figure 16).

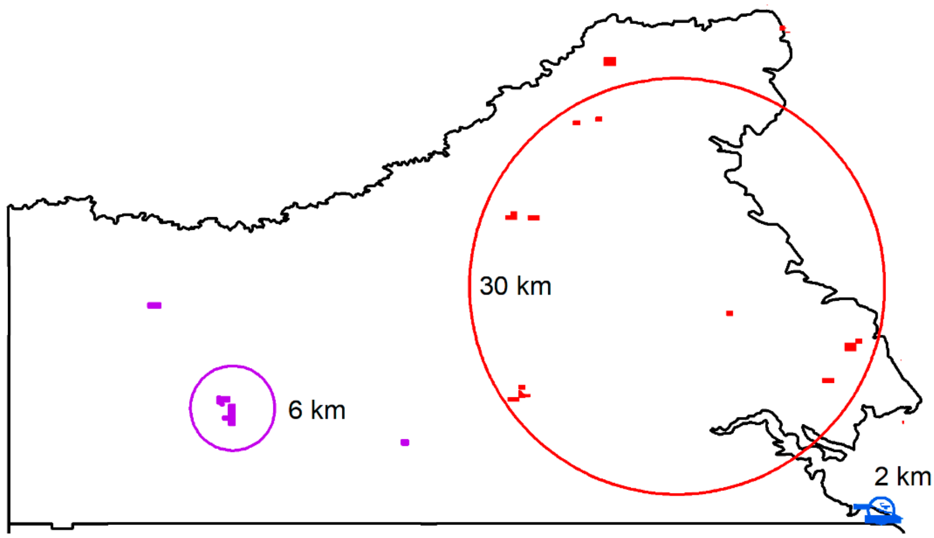


Figure 16. Spatial patterns of three different Standing Rock families in purple, blue and red. The circles are Standard Distances, or a measure of dispersion around a geometric mean center of these family allotments. Some families received allotments in clusters, in blue and purple, and other families were widely dispersed, in red.

A related question focuses on group settlement patterns within the reservation. As with several reservations, multiple groups were settled on the Standing Rock reservation. The four different Lakota and Dakota bands living at Standing Rock by the time of allotment were the Hunkpapa, Sihasapa (Blackfeet), Lower Yanktonai, and Upper Yanktonai. Indian agents noted that they settled separately in rough spatial groups, which would align with similar clan or tribal settlement patterns found on the Cheyenne, Pawnee, Nez Perce, and other reservations. It would be possible to map allotments by band affiliation by combining allotment data with information found in several of the annual Indian censuses taken by the Office of Indian Affairs that contain band affiliation information for the Standing Rock reservation. Each of the four Lakota/Dakota bands on the reservation was surveyed separately for a number of different years in the late 1890s. In addition, some Indian censuses in the 1920s and 1930s also recorded allotment and annuity numbers for each tribal member. Names from these Indian censuses could be used to crosscheck and update each allottee's tribal affiliation in the GIS data.

Ultimately, the story of allotment is one of land dispossession, as million acres of tribal land were lost as a result of this failed assimilation policy. A question remains as to how many acres of land were allotted at Standing Rock to tribal members, how many acres were sold as surplus, and how much Indian and tribally owned land is left today? Quantifying and visualizing the dispossession of Indian lands is core to understanding the scope of how the Dawes Act affected and affects reservation life. County atlases and modern land tax parcels can be used in conjunction with the digital allotment database to update the status of the original allotments—to determine if they have been sold or leased to non-tribal members, purchased by the tribe, or remain in trust status.

4.4. A Framework for Future Research on the Spatio-Temporal Impacts of Allotment

Each Indian reservation had the Dawes Act applied to it differently, resulting in a variety of different outcomes that need to be explored. However, the process of mapping allotment data and the ability to spatially analyze the data in GIS has been proven to be fundamental to the future of allotment research. The subject of the impacts of Indian land allotment policy is largely a spatial issue, and geographic information systems provide a framework, methodologies, and toolsets to answer many of the remaining questions about allotment. Toward that end, seven broad categories of questions initially suggest themselves for GIS mapping, visualization, and analysis:

1. Overprinting. When allotment came to a reservation, it was almost always the case that its Native residents already had long resided there, in some cases for decades or longer, and had established well-defined patterns of residency and land use. Thus, allotment's rectangular grid survey system was overlaid on top of the existing pattern of land tenure, a process sometimes referred to as overprinting, resulting in potential disruption and conflicts. How do mapped patterns of allotment represent the impacts of overprinting and of efforts by both allotting agents and allotment recipients to resolve them?
2. Environmental factors. Each reservation was characterized by a unique combination of physical environmental factors, including climate, vegetation, soils, wild game and other animals, hydrology, and others that varied in quality and quantity across the reservation. When allottees (or sometimes the allotting agent) made land selections, what factors were considered most desirable or, conversely, least desirable?
3. Social factors. As noted above, prior to allotment Native people were often long settled on their reservations according to well-established patterns of social relationships and residency. In making allotment selections, did people maintain those patterns by selecting allotments close to other family members, friends, or clan groups? Or, conversely, did they avoid certain groups?
4. Economic factors. Did allotment recipients favor locations that gave them access to towns or trading centers or to transportation routes such as rivers, trails or roads, and prospective or existing railroad lines? Likewise, did they select allotments near to agency or subagency locations, or to existing or planned schools and churches?
5. Impacts of local allotment policies. Although Congress set broad guidelines for allotting each reservation, the local special allotting agent had considerable leeway in setting detailed on-the-ground policies for allotments. How did those policies reveal themselves in observed patterns of allotment? For example, were allottees encouraged, or perhaps forced, to take their allotment as a single parcel or could they select multiple parcels and, if so, how many and of what sizes, and where? How were conflicts over desired allotment parcels settled among contending allottees? And what was done in the case of individuals who refused to accept allotments?
6. Post-allotment policy changes. After allotment, and even while it was still ongoing, the defects of allotment became glaringly apparent. Numerous, sometimes bewildering, policies regarding inheritance, land leasing, land sales, and fraud prevention, among others, were implemented, modified, and then modified again in vain attempts to prevent loss of land and to shore up the original goals of turning American Indians into successful farmers and ranchers. How did these various policies impact land holding (or land loss), land management, and even patterns of living?
7. Long-term broad impacts. How can the impacts of fractionation, checkerboarding, land loss, widespread land leasing to non-Native farmers and ranchers, and other widespread results of allotment be represented and explored in spatial datasets?

This framework is merely a starting point, and we anticipate that other sets of questions will be added as our research continues.

The new mapping tool described here provides a way to rapidly and accurately produce high quality spatial data of Indian allotment lands on reservations, data that are important to tribal members and future generations. It allows for the creation of this same dataset, not only for the Standing Rock reservation, but many other reservations across the United States that underwent allotment. Currently work is underway to establish partnerships with Native American and tribal non-profit organizations to continue this work and make training and data available to tribal land offices and the general tribal communities. Baseline datasets are necessary to answer a large range of questions, and this research provides that essential first step. It is difficult to ask and answer questions without available data. This allotment mapping technique will allow tribal members and researchers access to accurate spatial data for their reservation lands.

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Art and Argument: Indigitization of a Kiowa Historical Map for Teaching and Research

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Abstract: How might we teach undergraduate students about Indigenous geographies using historical maps? This paper describes processes associated with the bridging of a historical Kiowa map with computerized geographic information systems (GIS) and undergraduate geography curriculum. The authors applied an indigital framework as an approach for melding Indigenous and Western knowledge systems into a third kind of construct for teaching undergraduate students about historical/contemporary spatial issues. Indigital is the blending of Indigenous knowledge systems, such as storytelling, language, calendar keeping, dance, and songs, with computerized systems. We present an origin story about the indigitization of a historical Kiowa pictorial map, known as the Chál-k<u>o</u>-gái map, at the University of Missouri, USA. Undergraduate student engagement with the map resulted in new questions about Indigenous geographies, particularly map projections, place names, and the meaning of Kiowa symbols.

Keywords: Indigenous maps; GIS; indigital; undergraduate education; native science

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1. Introduction

"Entering the knowledge economy is undoubtedly a high-risk strategy, but if, as suggested, the commons are conceived as a complex adaptive system where each constitutive element has autonomy, then there may be one last chance for survival [1]."

The digital knowledge and information economy is well underway. If you have a cell phone, use a computer, or post on Instagram, you are a full-fledged participant within what Manual Castells called the Network Society [2]. By now, many of us are aware that digital technologies are simultaneously transformative and disruptive, and geospatial technologies, such as geographic information systems (GIS) and digital mapping, can both empower and marginalize society [3]. We are also aware that digital technologies can assist human beings in unleashing creativity, diffuse information quickly, and strengthen new teaching/learning approaches. GIS are commonplace in geography departments and classrooms in the United States. Several scholars, including the first author of this article, warned of the transformative capabilities of GIS and how the technologies could disassociate Indigenous geographic knowledge from its parent context as well as deskill elder knowledge [4–6]. However, over the last couple of decades, GIS became prevalent within Indian Country. However, this paper is neither about tribal communities nor government agencies. Rather, we explore how antiquated, forgotten Indigenous materials, such as historical maps, can be brought back to life and reimagined in university classrooms using digital devices.

How might we teach undergraduate students about Indigenous geographies using historical maps? For many scholars, maps are a good option. The difficulty arises when trying to find physical maps made by or for Indigenous peoples [7]. A wealth of secondary sources about the history of cartography are available including research by Warhus [8] and

Lewis [9]. Additional source materials are found in critical map and GIS studies [10–14]. The best resource for finding the location of potential Indigenous maps within American archives is Lewis [9]. Lewis' book entitled Cartographic Encounters is particularly important because it identifies archives that have yet to be studied thoroughly by scholars. As the title suggests, there have been 400 plus years of encounters and exchanges between indigenous peoples and Europeans. Especially important is Chapter 2, "Encounters in Government Bureaus, Archives, Museums, and Libraries". Much of the important information regarding the sources or where to find Indigenous maps in North American is found in the chapter's extensive notes. We are primarily interested in North American Plains Indian maps and representations. Warhus provides an outstanding account of North American Plains Indian Maps [8]. Another important work is "Maps, Mapmaking, and Map Use by Native North Americans" found in the History of Cartography series, Volume 2, Book 3, Chapter 4. Plains Indian maps contain rich pictorial images, similar to ledger drawings, painted on animal hides or paper using pencils and paint. Many of the historical maps present spatial stories of war and hunting. In addition, government officials, surveyors, and explorers requested maps showing geographic features such as rivers, mountains, and trails [15].

A historical Kiowa map, estimated to have been created around 1895 [16] on the Great Plains of what is now known as southwestern Oklahoma and the Kiowa, Comanche, and Apache (KCA) reservation area, is archived at the Smithsonian Institution in Washington, DC. The map was created by Chál-ko̲-gái, (Black Goose) born in 1844 to an influential Kiowa family in the KCA Reservation (p. 269). Meadows mentioned that Chál-ko̲-gái was the last generation of pre-reservation Kiowas. He served as a judge for the Court of Indian Offenses [16] (pp. 268–269). Approached in the 1890s by US attorneys involved in the boundary disputes of US vs Texas, Chál-ko̲-gái created his map to provide information about the KCA Reservation's boundaries [16] (p. 270). The map, however, is a Kiowa male representation of geography. A study of the gendering of Kiowa geographies or Plains Indian cartography has yet to emerge in the literature. What the map embodies are key aspects of European–Indigenous relationships conveyed through Kiowa art and oral traditions. Meadows studied the map and published his findings in the *Great Plains Journal* and in his book Ethnogeography of the Kiowas [16,17]. Through Meadows' work, map readers are now able to identify features and compare them with place names found in Mooney [18] and landscape features of Kiowa country. What map readers now have is a systematic inventory of some Kiowa place names and associated mapped features to work with and think about in both historical and contemporary contexts.

This paper describes processes associated with the bridging of a historical Kiowa map with computerized geographic information systems (GIS) and undergraduate geography curriculum. Of course, the merging of old and new technologies is not a new process. Currently, universities are transforming archival materials into digital constructs that are more readily accessible to students, faculty, and the public. Some digital constructs include manuscripts, books, photographs, and maps. Furthermore, what is interesting about our case study is the opportunities for archived Indigenous representations, such as maps, to bridge and decolonize using current technoscience such as GIS, geography curriculum, dome planetariums, or virtual reality environments. It is our hope that this paper will shed some light on the Indigenous knowledge and digital technology debate. Artists, technicians, and academics are experimenting with Indigenous representations in various forms to revitalize language, to understand changing environmental conditions, and spatially represent stories [19]. In what follows, we first present indigital frameworks as a heuristic for engaging with and combining Indigenous and Western knowledge systems. Our focus is on GIS and mapping. Next, we describe the origin of the indigital Kiowa map used in the undergraduate curriculum in the Department of Geography at the University of Missouri by a professor who is a member of the Kiowa Tribe of Oklahoma. Finally, we present some brief conclusions and ideas for future inquiry.

2. Indigital Framework

Indigital describes the creative merging of Indigenous knowledge systems with digital technologies [19–22]. Here, we are talking about the merging of Indigenous knowledge systems within the realm of geospatial sciences or GIScience. Indigenous scholars are in the position to "bring separate fields of inquiry together by merging ideas and concepts and in effect create new sciences that weld together bodies of knowledge" [23]. The key ideas present in Vine Deloria, Jr.'s statement are "separation" and "merging". On the one hand, Deloria is making a statement about the way the world is organized and ideas are separated. Separation does not imply equality. Rather, some ideas are given priority over the ideas of others. Separation can denote that there is a right way and a wrong way of doing things. Separation explicitly denotes real or imaginary boundaries too. Boundaries clearly separate two or more things from coming together. In other words, we have the creation of binary opposites. Merging denotes the coming together of two or more things. If boundaries are permeable between ideas and concepts, they may come together and form something new, changing as ideas and concepts change. Only within such merging spaces can indigital constructs exist within the realm of relatedness. This is not an easy task. Land and human systems have been corrupted. Separation is partially the result of settler colonialism that includes the breaking up of tribalism, the dispossession of land, dismissing Indigenous knowledge systems, and resources grabs. As a result, indigitization must be sensitive to these realities; it requires some thought.

The fields of science and technology offer hope regarding the blending of ideas. Deloria proposed:

> *"It is my hope that the present generation of Indian students will adopt some version of this [relatedness] methodology as they are studying Western science, particularly social and biological science, and leapfrog into prominence in their fields by writing and teaching from an Indian perspective. In this way science will move very quickly into a more intelligent understanding of the natural world."* [23] (pp. 34–35).

Gregory Cajete argued that:

> *"As we enter the first decade of the millennium, Native and Western cultures and their seemingly irreconcilably different ways of knowing and relating to the natural world are finding common ground and a basis for dialogue, the integration or the lack thereof will determine the direction of contemporary society in the twenty-first century."* [24] (p. 56).

Adopting indigital forms of mapping and GIS takes up the challenges presented by Deloria and Cajete.

The first author has presented cases and experimented with Indigital constructs in past research, specifically digital mapping, GIS, and storytelling [19,25]. Doris Schoenhoff described the possibilities that could arise when Indigenous knowledge and computer interfaces collide [26]. Her study was broad and opened the door for future work to describe the Indigenous knowledge system/technoscience interface within a global context. To our dismay, Indigenous peoples and their systems are often left out or marginalized within global conversations on the environment, space, time, place, and technoscience in general. The indigital framework strives to remedy and bridge the gap between these important conversations [22]. How might we think about indigital constructs?

First, indigital constructs emerge locally as individuals or groups experiment with native languages, symbols, song, dance, or other representations within digital computer environments. For instance, an elder's stories could be recorded and georeferenced to create a new indigital native language network GIS [19]. Typically, network GIS is used to find the shortest, most economic paths between points A and B. Any stop or disruption in the highway network creates an impedance. Indigitization subverts the notion of impedances and reimages those stops as storytelling places. A native language network GIS is not built for efficiency, but rather it is loaded with cultural information and knowledge of kinship relations and land allotments. The stories and travel routes reveal a local richness that captures and reimagines gridded GIS spaces of exchange. Within spaces of exchange, cultural systems, such as language and technology, do not stand alone as dichotomous entities. Rather, they merge together and can present the stories, views, ideas, and dreams of native peoples.

There is evidence that Indigenous knowledge systems and digital technologies are combinable. Combinability relies on the convergent capabilities of digital technologies and the creativity of individuals or groups of people and their intent. Universities are places of innovation, including language revitalization programs arising at Northern Arizona University [27,28], Cherokee digital storytelling and keyboard design, Kiowa language network mapping, Indigenous virtual realities at the University of Missouri [19,22], and the publication of the Kiowa "Rabbit" songs on compact discs at the University of Oklahoma, Sam Noble Museum [29]. Ideally, developing projects that incorporate the knowledge and experience of elders creates a virtual environment for sharing knowledge and information that might otherwise simply die off with the holders.

Combining leads to indigital constructions that are hybrid new spaces for engagement globally [30]. Indigitization requires acceptance of multiplicity. Fundamentally, knowledge systems, such as storytelling, are open to change. When systems are nurtured locally, it could be argued that a certain level of stability might emerge, and the local community would have some sense of control over the shaping of their knowledge systems. Community language teachers, word processors, orthographies, computer hardware and software, and smart phones might stabilize systems such as the Kiowa language, Otomi calendars, or the Cherokee syllabary. Things change when they travel across space and time. All knowledge and information systems change when they become mobile and encounter other people, materials, and ideas [31].

Perpetuation of indigital constructs is determined by reciprocity between systems. In other words, indigitization relies on bridges constructed between indigenous and scientific knowledge systems. If a one-way flow occurs, the bridge may collapse, and work will cease.

For example, one-way flows of knowledge are revealed when Cherokee or other Indigenous informants who provide place names to Apple, Microsoft, or Google realize that their own geographies are not represented. They are erased from the maps. Indigenous geographies are often trivialized as being local, vernacular, and particular to a culture which goes against the grain of technoscience standardization and universalization. The trick of indigital reciprocity is shared power, networking [32], assemblages [33], decentralization, trust, and collective responsibility. If all these relations are in place, community problems have a chance of success [22].

Indigital constructions are simultaneously everywhere and nowhere. We have already mentioned a few examples above. Many of these indigital places are universities and native communities that have access to computer hardware and software. Likewise, the indigital, as a concept and idea, can be very distant. At present, there is no way around this contradiction. It is the reality of a digital divide that is still very present in the world today. One modest remedy is to continue providing examples of how indigitization might emerge at universities and native communities in general. On the other hand, native communities may not be interested at all in indigital constructs, frameworks, or philosophy. They may approach their knowledge and information far beyond the webs of digital technologies and the information economy.

Indigital frameworks can assist students and scholars in taking a leap into unknown territories (spaces of encounters and exchanges) that blend Indigenous knowledge with Western knowledge systems. In essence, we are continuing the 400 plus year encounter and exchange because good and important ideas can emerge. Our approach is modest, using maps and GIS to teach undergraduates about Indigenous knowledge systems, how they are different, and how they are related to Western systems. The example we provide is an engagement with a historic Kiowa map, that as canvas material lies way in the archives of the Smithsonian Institution but also has a life of its own as an indigital construct.

3. Indigitizing a Historical Kiowa Map

The paragraphs below describe several different ways the Chál-ko̲-gái map (Figure 1) informed undergraduate students and was used as a spatial surface for analysis and asking questions. Classroom indigitization creates an origin story of transformation and cross-cultural dialogues. The method, here, is inquiry based and student driven. As students continued to engage with the Kiowa map, more ideas emerged and new approaches to understanding the world influenced students' thinking as they pondered geographies, both historical and contemporary. The Kiowa map is currently applied to upper-division GIS and human geography courses at the University of Missouri. It is in this place that canvas, paper, pencils, pixels, software, hardware, art, science, and human skills intermingle.

Figure 1. A portion of the Chál-ko̲-gái map showing rivers, creeks, mountains, and associated pictographs. Source: National Museum of Natural History.

Indigenous maps communicate geographic information differently than scientific maps. One remarkable feature of the map is that it contains what are known as name glyphs [17] or pictographic/pictorial images. Kiowa pictographic images are associated with their calendar system and ledger art. Kiowa pictorial images hold information about geography and seasonality. Kiowa calendars marked significant summer and winter events using pictorial images that held information about the Kiowas. James Mooney documented a Kiowa calendar and its corresponding information during the 1890s [18]. More recently, Smithsonian Anthropologist Candace Greene recorded and studied the Silver Horn calendar [34,35]. The pictorials complimented Kiowa oral traditions, representing history and geography for the tribe [35]. Other plains tribes kept similar calendar records. Greene explained that it is likely that the Kiowas adopted the calendars through encounters and exchanges with other plains tribes such as Lakota, Blackfoot, Mandan, Hidatsa, Cheyenne, and Plains Apaches. This is not surprising considering the Kiowa were a migratory group and encountered and exchanged with others along their long journey from the Yellowstone River to southwestern Oklahoma. Presently, the Chál-ko̲-gái map is held in the archives at the Museum of Natural History in Washington, DC. Until very recently, the map was only represented in its original canvas form, accessible only to scholars who had permission to view and research the item.

The first author of this paper encountered the digitized Chál-ko̲-gái map through a series of intended and unintended exchanges with colleagues. He first heard of the Kiowa map in 2007 and the map's possible temporary residence at the Fort Sill Museum outside of Lawton, OK. Initial phone calls to the museum revealed that the map came and went, and the museum director was unsure of its whereabouts. Only later it was discovered as Meadows was researching the map. Apparently, staff at the Smithsonian had digitized the map, presumably for Meadows so he could research off-site. The first author secured a very low-resolution black and white copy of the map. He used the map to discuss Kiowa representations and geographies at a conference in Hamilton, New Zealand. A Smithsonian geographer and cartographer attending the presentation was surprised at the low quality of the map. In so many words, "a Kiowa geographer should have access to a higher resolution copy of the map". The Smithsonian cartographer approached the first author and revealed that a high-resolution digital copy of the map existed on his computer in Washington, DC. He offered to send a copy of the map. It traveled through email and now exists as a 79 megabyte image on a computer at the University of Missouri in Columbia.

Making connections with the Smithsonian cartographer and the digitized map was simply an act of luck. Indigenous scholars and community members should not anticipate that other scholars or archivists will share their materials. Of course, this has always been a problem in Indian Country, and it is one of the primary reasons for distrust and lack of support for academic research in communities. Native community members who are interested in historical maps will most likely have to dig through archives and make many phone calls/emails. Digitization of historical maps by archivists is a good start regarding increased mobility and opens up the potential for innovation in education or community projects. Digital computers are rich environments for innovation and converging virtual ideas. Combing two different systems or materials often leads to the creation of a new third thing.

Historical maps exist within transforming social contexts. Originally, the canvas Chál-ko̲-gái map informed late 19th century readers (government officials, attorneys, rail companies, settlers) on the location of Kiowa land [16]. As the University of Missouri geography students found out, these dates are important because they represent a period of land dispossession or the transition from a continuous reservation to individually owned land allotments among the Kiowa, Comanche, and Apache peoples. Chál-ko̲-gái used available technologies to create the map including canvas, pencils, and Kiowa calendar images. Mixing these systems created a unique map. Antiquated canvas material had limited mobility. It could be carried by hand or perhaps mailed to distant locations. However, the speed at which canvas material traveled was slow, and archival bureaucracy further limited mobility and access. Furthermore, it is assumed that in the past only a limited number of people had access to the map, much less understood the pictorial content. One hundred years later, the canvas map encountered digital scanners, computer hardware, and software. The map was transformed into a digital construct. Digital constructs flow more freely through fiber-optic lines or from digital cloud to cloud. Mobility was increased and more eyes and ideas made contact with the historical map.

When the first author received a copy of the digital map, it was transformed into a geography-teaching tool. The 79 megabyte image sprang to life, revealing a palate of 256 potential block colors (Figure 2). The first author is a Kiowa man who currently lives approximately 10 miles east of the Missouri River in Columbia. He is a college professor at the University of Missouri (MU) and teaches several courses on Indigenous geographies, GIS, and mapping. In addition to being a global researcher, he teaches a diverse group of students at the university. The original use of the map, land dispossession through allotment, came and went. Those days are long gone. What remains is a digital map with extremely important geographic information pertaining to Kiowa geography, pictorials, and stories. He combined his knowledge of Kiowa stories, language, art, kinship relations, and lived experience within the mapped region to teach undergraduate students geographic concepts and introduce them to the language of maps. None of the students are Kiowa; they have no kinship relations. However, they are intellectually curious and eager to interpret what they see on the old map. What occurred was a hybridization of the map and its geographic information that Chál-ko̲-gái and other Kiowa ancestors never imagined would occur. This kind of system mixing is occurring at other places like the University of Oklahoma, where native languages are taught, yet most students enrolled are not native. This means that non-native students who take the native language sequence (three or four Cherokee, Kiowa, and Choctaw courses) potentially know more about the language than many of the students' native counterparts living square within their own communities. This real contradiction exists and leads to important questions. Should we put native languages and stories into practice, no matter the context? At least the culture is sustained whether one agrees or not. Arguing strongly against this position at least keeps the ideas alive and shows that people still care about their culture. How about maps? What is more important, putting the Indigenous maps into practice or storing the items away as an old artifact?

Figure 2. The complete Kiowa map. Source: National Museum of Natural History.

At the University of Missouri, Department of Geography, the Chál-ko̲-gái map melded with a couple of different Western approaches used to explore and understand geography. The first Western system was cartography and GIS. GIS can represent (with or without maps) features on the landscape and are powerful tools for analyzing spatial relationships. The second approach is associated with cultural geography and the naming of places. Historical place names can tell us much about former environmental conditions, social contexts, and landforms. Both of these traditional geography subtopics or systems transform knowledge and information. The map's unique information, design, space, and place can transform the way people understand the world as well. In fact, the Chál-ko̲-gái map does not integrate perfectly with either system, requiring some level of adjustment and rethinking on the part of the instructor, reader, or map designer. For instance, undergraduate students are unfamiliar with the meaning of pictorial images. These features must be studied and interpreted using the knowledge at hand. However, students soon learn that the colorful pictures are associated with place names and stories about Kiowa geography. Likewise, the map is an uneasy fit using GIS. The map projection systems that are the foundation of GIS are not compatible with the projection system created by Chál-ko̲-gái. On the other hand, the place name information can be turned into attribute data and the historical features can be digitized as a vector model. There is much to think about.

Bridging two systems revealed information about projections and coordinate systems that students were unaware of before encountering the digital Chál-ko̲-gái map. Late nineteenth century surveyors and cartographers created gridded spaces to map out the southern Plains. They only mapped what was inside the grid, nothing more. If territory existed outside the grid, it was mapped on another page or an inset might have been placed somewhere on the map. Black Goose broke these rules. As a map drawn on canvas, the Chál-ko̲-gái map is not projected using a mathematically shaped coordinate system. Yet, the space that makes up what is now southwest Oklahoma and northwest Texas is presented. The entire area is important when trying to understand the territorial extent of the tribe. However, there was not enough room to draw important aspects of the Washita River that extends to the northwest and into the Texas Panhandle. As a result, Chál-ko̲-gái manipulated and bent space. What an interesting problem for GIS students. Non-experts can create their own projection systems?

The digitized Chál-ko̲-gái map is a gateway into the theories and ideas of critical GIS. As Crampton and Krygier (2006) stated about Indigenous maps:

> *"These map events question the commensurability of Euclidean space, a basic assumption of much GIS. Euclidean space is a key component of the scientization and regularization of space, for example it is assumed in 'interoperability' where one dataset is commensurable with another. Critiques of Euclidean space which point to its idiosyncrasies, localness or its contingent nature show that not all knowledge can be 'scientized'."* [36] (p. 18).

The challenge for GIS students is to determine what kinds of information on the map can be used to create a database or analyzed using computers. The indigenity of the mapped information and the intellectual challenges posed by Indigenous perspectives is what makes the map construct indigital.

The digital copy of the map shows rivers, creeks, mountains, land parcels, and vegetation. Students zoomed in and out while analyzing the dendritic stream patterns and studied how they grip and hold the mapped space together. Meadows [17] inventoried hundreds of Kiowa place names. Nearly 80% of the names are associated with rivers, creeks, and springs. Technically oriented GIS students can easily cut place names found in e-copies of Meadow's book and paste them into a GIS database. Adding the Kiowa names to a GIS database and labeling features in Kiowa on a map is a form of indigitization. Figure 3 shows the work of a graduate student who digitized the features on the map. The rivers and streams are digitized exactly as they appear on the map, but other features, such as maps and the pictographs, are digitized as points (Figure 3). What is the point? By converting the map features to points, students can analyze the density of the features to determine where, on the KCA, Chál-ko̲-gái placed most of his attention. A cross-cultural dialogue emerges (Figure 4). Why are rivers and creeks so important to Kiowas? Did Chál-ko̲-gái have more knowledge about places containing a higher density of name glyphs? Did Chál-ko̲-gái come from a politically influential family? Are the name-glyphs associated with kinship relations or family stories? Why are women's views not recorded on the map?

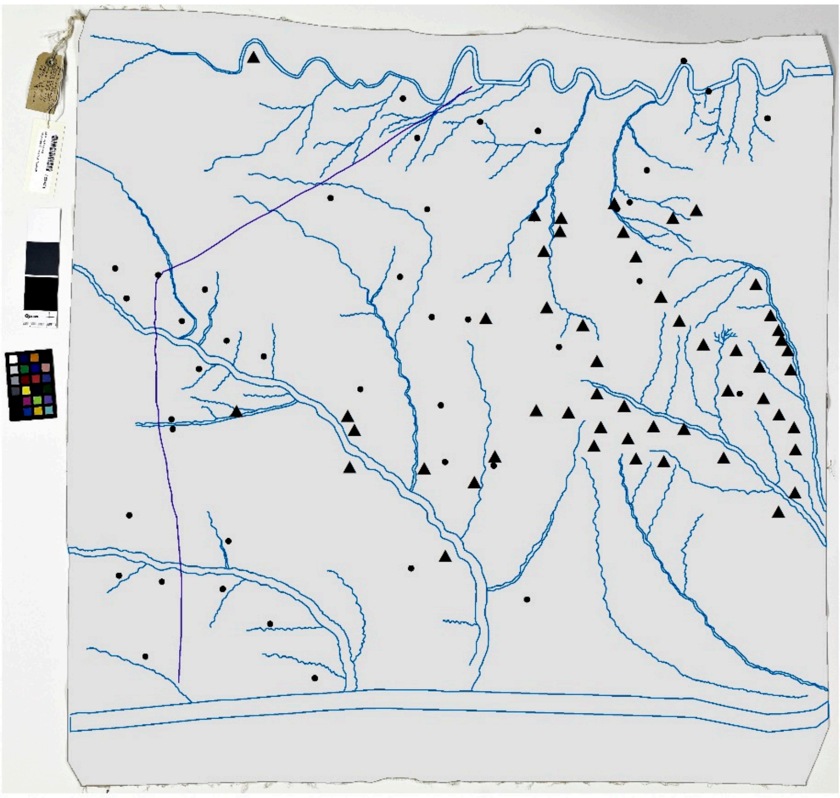

Figure 3. Digitized version of the Kiowa map. Source: Mark Palmer, University of Missouri, Department of Geography. Digitization by Lasya Venigalla.

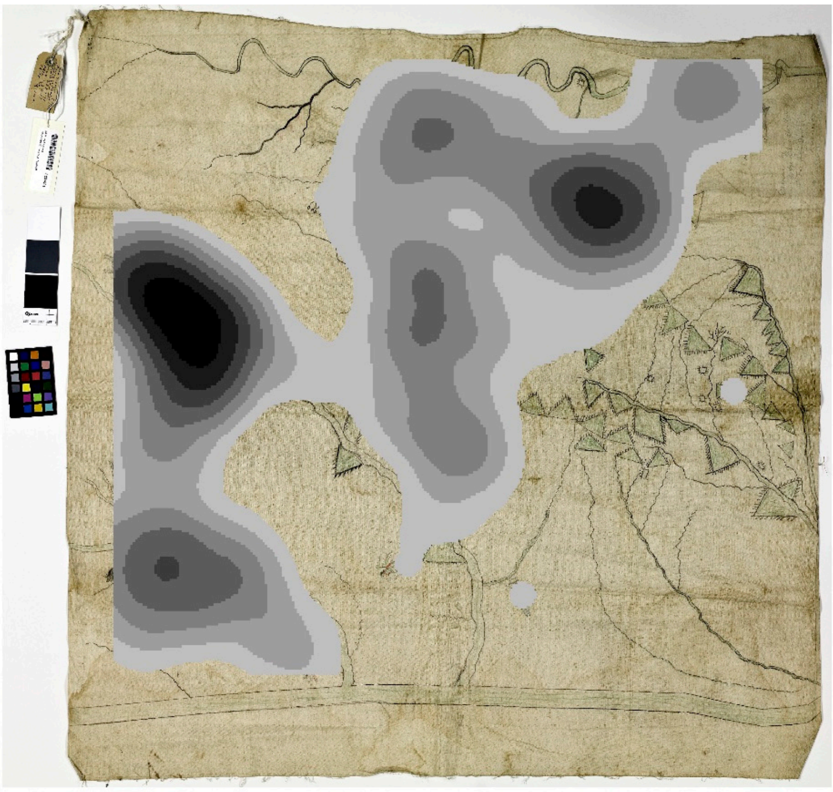

Figure 4. Map showing the density of pictorial image locations on the Kiowa map. Source: Mark Palmer, University of Missouri, Department of Geography.

Cultural geography students study the language of maps. The indigital map prompts students to ask questions about semiotics or the language of the map. Symbols on a map can refer to one thing or many things. Students read topographic maps and the meaning is often abstract, presenting contour lines or blue meandering lines that they presume represent rivers. Previous students asked, are there other ways of representing features on maps? The Chál-ko-gái map is different in that not only are symbols present for physical features but also attached to those physical features are pictorial images that are associated with stories and information. Triangular mountains are smeared across the map. Some mountains are small while others are larger. On purpose or inadvertently, Chál-ko-gái developed a visual classification of the mountains or a local ontology. Those with lines or trees are associated with the granite Wichita Mountains. Other mountains to the north are smooth and represent the limestone Slick Hills. On Chál-ko-gái's map specifically, the mountain icons are represented visually as green triangles, some crowned with vertical lines and some without lines. These vertical lines represent the blackjack oak vegetation type that grows almost exclusively on and at the base of the granite Wichita Mountain formations in the area. Similar to the projection system, Chál-ko-gái created a personal ontology or way of representing mountains on his map (granite vs limestone).

On the map, typical linguistic information is absent, aside from an outlier group of written place names and one cartographic credit. Kiowa language codes, however, are abundant. Instead of being extracted from and layered atop the map's features, they remain embedded within the pictorials and, as such, become part of the landscape itself, rather than descriptors for it. Consider the pictorial of a prairie dog near the Washita River. The drawing functions as both an iconic symbol, signifying a feature on the landscape and as a linguistic label, denoting the name of the location: Prairie-Dog-Eating-Creek. But, critically, it also functions as a mnemonic device: as we process what we are looking at, the symbol invokes the name, which, happening in the present (Prairie-Dog-Eating), invokes the story of how the name came about. For the Kiowas, it is a story of survival. The name and the experience cannot occur separately. In the map, pictorials prompt viewers to ask not only "what is there?" but "what has happened there?". Chál-ko-gái drew attention to the sprawling, widespread nature of the KCA landscape. There is so much there, it takes up the entire map space, extending to all corners, and yet still goes on—he even had to bend space to fit some of it on the map. The Chál-ko-gái map argues that no map can fully represent his landscape. Western overtones of cartographic license are not present. Rather, by showing a portion of the landscape, he attests to its immensity and to its entirety, "creating a sense of geographical meaning" [36] (p. 17). Chál-ko-gái firmly established the map showing Kiowa land. In exploring these topics, students soon learn that maps are political.

Is the Chál-ko-gái map an early form of counter-mapping? Of course, the term counter-mapping did not emerge until the mid-1990s. Nancy Peluso defined counter-mapping as an alternative strategy for defending territorial and/or resource claims [37]. Counter-mapping is an important concept regarding Indigenous geographies and cartographies on a global scale. The concept gained traction early on as a way of countering the impacts of economic globalization. How long have Indigenous peoples used maps to counter colonial and imperialistic narratives? University of Missouri students were introduced to the idea that the Chál-ko-gái map exists within the spirit of counter-mapping and just might be one of the earliest examples of a Plains Indian counter-map. The relatedness associated with land dispossession, resource grabs, and Indigenous removals is an eye-opening example that the tyrannies of capitalism, today, are not new. Seasoned scholars are well aware of this condition. However, the indigital map introduced this, in tangible form, to students, who now view the map as having something important to say within intense conversations on economic globalization. Nevertheless, theoretical perspectives and methods associated with decolonial geographies would further inform students and strengthen future work on indigital constructs.

4. Conclusions

Indigenous knowledge and representations are emerging in academic research and classroom teaching. Vine Deloria, Jr. envisioned this happening among academics and students at colleges and universities. Increasingly, there is evidence that Indigenous perspectives are making their way into university classrooms and academic research methods. Referred journals are paying attention and publishing research on Indigenous philosophies, methodologies, and geographies. Funding agencies are taking note and funding projects that bridge Indigenous and Western knowledge systems. The United Nations is attempting to bridge Indigenous and Western knowledge systems. More and more written forms of Indigenous languages are being developed in North America. Perhaps the most important first step in relating ideas is asking questions. Good questions are the foundation of research designs, research proposals, and class discussions. Questioning is the initial step enabling students and scholars to begin uncovering the reasons why Indigenous and Western philosophies have come to be separated in the first place. In fact, there should be multiple ways to go about bridging Indigenous and Western ideas. Similarities and differences between philosophies, ideas, concepts, theories, and practices can become bridges. In our minds, we can use bridges to walk freely between what some scholars deem purely Indigenous or purely Western. For students and scholars, bridging can be a liberating, decolonizing process leading to new ways of thinking about the Earth.

In our account, we showed that the Chál-ko̲-gái map is an amalgamation of sketching, artistry, land tenure, salvage anthropology, national museums, large scanners, computers, software, email, classrooms, and communities. One system does not dominate the others and there is no one-way flow of information. As soon as the students, cultural geography or GIS, think they have answers provided by their academic frameworks, the pictorial images and embedded stories take back the power and make the map rigorous to understand and use. A reciprocal give and take emerges, where students and the maps talk with each other, not at each other. Reciprocal theories or applications can eventually open up dialogues with native communities and help shape learning opportunities in both the academy and community. The process may happen quickly, it may be a slow process, or the process of dialogue may never arise. This is because the theories, applications, materials, hardware, software, skills, and motivations have to contend with a still present digital divide or other human constructed divides.

Future research should focus on the process of bridging Indigenous and Western knowledge systems. It is within processes that opportunities emerge, whether in the classroom, laboratory, or community. How successful has the blending of knowledge systems become over the past 20 or so years? What are other examples of bridging projects in North America and globally? What does culturally appropriate technology mean within the context of the knowledge and information economy? Many similar questions can help shed light on the next cycle of Indigenous thought.

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Article

The Importance of Indigenous Cartography and Toponymy to Historical Land Tenure and Contributions to Euro/American/Canadian Cartography

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Abstract: Indigenous maps are critical in understanding the historic and current land tenure of Indigenous groups. Furthermore, Indigenous claims to land can be seen in their connections via toponymy. European concepts of territory and political boundaries did not coincide with First Nation/American Indian views, resulting in the mistaken view that Natives did not have formal concepts of their territories. And Tribes/First Nations with cross-border territory have special jurisdictional problems. This paper illustrates how many Native residents were very spatially aware of their own lands, as well as neighboring nations' lands, overlaps between groups, hunting territories, populations, and trade networks. Finally, the Sinixt First Nation serve as a perfect example of a case study on how an Aboriginal people are currently inputting and using a GIS representation of their territory with proper toponymy and use areas.

Keywords: Native Americans; first nations; historic cartography; toponymy

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1. Introduction

Although Native Americans/American Indians/First Nations did not originally have access to paper for their map creation, many of them nonetheless had excellent cognitive cartography concerning their environment, settlements, populations, territories, trails and trade routes. They were often able to communicate this spatial knowledge to Euro-Americans who were mapping said lands by drafting maps (on paper, deerskin, or on the ground in dirt and snow) and providing place-names. These maps and toponymy essentially describe how well Indigenous peoples understood the geography of their lands. In recent years, many libraries and archives have started digitizing their collections, thus making maps by Indigenous peoples more easily available for scholars to study. Although a number of these maps were discussed by G. Malcolm Lewis in the *History of Cartography* series (volume 2, book 3, Chapter 4: 1984), more have since been found and disseminated. Before continuing, it must be noted that in historical cartography, G. Malcolm Lewis is the standard-bearer for scholarship in this arena [1–4].

Additionally, many Euro-American explorers would get lost without Indigenous help while traversing the North American landscape. Alternatively, sometimes Native guides intentionally led Europeans astray. This paper will illustrate the fact many Native residents were very spatially cognizant of their own lands, as well as neighboring nations' lands, overlaps between groups, hunting territories, populations, and trade networks.

2. Materials and Methods

Throughout the course of this research, we have gathered numerous historic and contemporary maps and map-related materials from various archives, libraries and other holdings. From these compiled maps and archival files, as shown below, we have built extensive evidence of Indigenous cognitive cartographic knowledge and physical cartographic abilities. For sources, we made use of digitized maps and explorers' logs that were downloaded from numerous First Nation, tribal, state, provincial, national, university and museum archives and libraries. Derived from these digital records, we have collected mapped examples of Native toponymy and territories as well. Regarding the example of the Sinixt for the current state of Indigenous knowledge, we relied on their traditional ecological knowledge of the surrounding rivers, lakes, mountains, and hunting and fishing locations.

In order to create their place-names map, the Sinixt identified historic sources that documented Sinixt toponymy. Latitude and longitude coordinates for the locations were carefully recorded, and were sometimes more general than specific, depending on the cultural importance of the location (burials were not included). Orthography of the place names was standardized and information about each place was discussed to determine what information could be made public.

3. Colonial Period

From the start, European mapmakers relied on Native informants, as can be seen in Samuel de Champlain's map of New France (1612) [5] and John Smith's map (1624) [6] of the Virginia and Chesapeake region, which contain spatial data beyond their explorations. Hermann and Pearce (2008) mapped out Champlain's travels from the Gulf of St Lawrence to Georgian Bay with notes from Champlain, imagined notes from Native voices, and the cartographers' notes. The title, *They Would Not Take Me There*, is indicative of Champlain's desire to find a route to James Bay [7]. On Smith's map, crosses are placed to indicate the limits of his travels, and beyond those crosses were named Indian territories and towns provided by his Native informants.

One of the earliest surviving Native maps in North America was in the Southeast—the Catawba Deerskin Map (ca. 1720), which abstractly encompassed the social and trade network of the Catawba, along with those of their Native and English neighbors [8]. In the Plains, as noted by Cole (2021), "in 1752, Philippe Buache compiled two maps on one sheet including a possible water route from the Lake Superior to the Pacific from Ochagach (Cree) (Figure 1) and a second map of the northern Plains from two unpublished maps by French fur traders. These two maps illustrated territories of the Assiniboils (Assiniboine), Cristinaux or Cristinots (Cree), the Monsoni (Ojibwe) and the Sioux. This map is the first printed record from the Plains of an Indigenous map" [9–11].

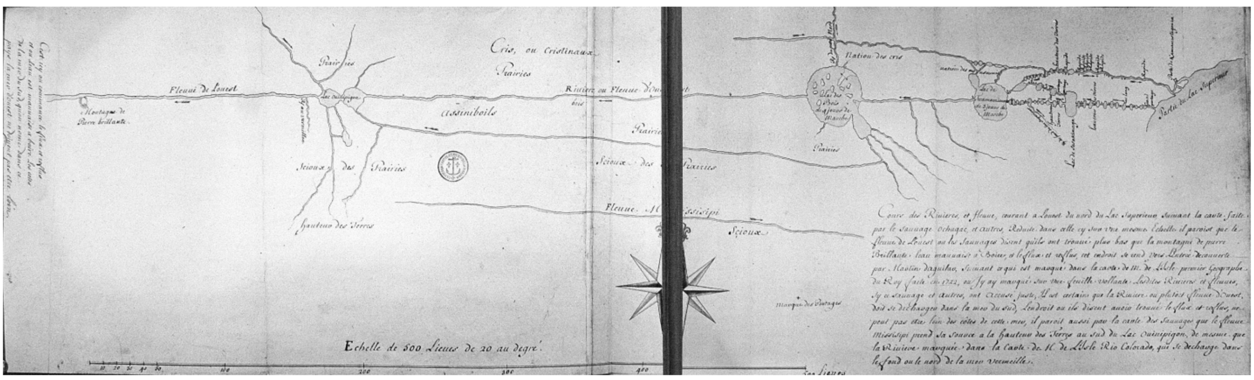

Figure 1. Map by Ochagach (Cree), traced by Philipp Bauche, of a water-bound route between Lake Superior and the unknown distant west. Downloaded and cropped from the Research Laboratories of Archaeology at the University of North Carolina.

Chegeree (unknown tribe) drafted a map of the Ohio River valley from his travels from Lake Erie to the Mississippi River (ca. 1755), which was created for the British as intelligence information at the start of the French and Indian War with locations of a French fort (Fort Duquesne), Indian settlements and distances [12]. During the same war, an unidentified Indian scout provided help to John Montrésor, creating a sketch map of the battlefield at the Monongahela [13]. Red Head (Onondaga) created a sketch map in 1759 of the area from Lake Ontario to Montreal [14]. As Lewis (2004: 15) notes, the map provided "valuable intelligence not the least for its relatively detailed representation of Chaumont and Black River Bays at the eastern extremity of Lake Ontario and possible routes from there to La Galette (Oswegatchie on the "draft") that avoided the treacherous Thousands Islands reach of the main river." The strategic intelligence on the map included the locations of Indian settlements, French forts, carrying places (portages) around rapids and Indian footpaths.

Most Euro-American maps seem to either ignore the presence of Indigenous peoples or treated them as an addendum. One particular exception was created by John Gerar William De Brahm, who mapped the Indian Nations of the Southern Department in 1766. Although the underlying base map is more of a sketch than many of its contemporaries, this map contains a wealth of information on the Native toponymy of Indian towns and territories, although the latter has the anglicized versions of the tribal names [15].

In 1767, two Native cartographers, Matonabbee and Idotlyazee (Chipewyan or Denesuline) mapped a very large area in Canada for the Hudson's Bay Company (HBC) from the Churchill River north to Coronation Gulf, and from Hudson Bay to the Great Slave Lake. June Helm spatially analyzed this map, taking note of the extensive distortion (east–west distances are greatly shortened) on the map. Nonetheless, she marveled at how knowledgeable the two men were of their extensive travels across the landscape, encompassing hydrology and other physical markers [16].

An unknown Comanche drafted a large-scale map, illustrating "an engagement in the Spanish frontier province of New Mexico between the Comanche and their traditional enemy, the Mescalero Apache. According to an accompanying document signed by then Governor Juan Bautista de Anza, the pictographic map documents illustrate the Battle of Sierra Blanca, 30 July 1787" [17,18]. This map exemplifies a depiction of a battle, which commemorates a special event that the victors wanted to remember, including deaths and injuries of people and horses, along with the number of prisoners taken.

4. 19th Century–Early 20th Century

In 1801 and 1802, Ac Ko Mok Ki (a Blackfoot chief) drew two maps (at least one of which was told orally and drawn in the snow) for the HBC staff that were redrawn and annotated by Peter Fidler (Figure 2). Although the HBC was concerned with tribal territories and hunting areas for purposes of trade/profit, Fidler was nonetheless very impressed by the geographic knowledge of Ac Ko Mok Ki concerning the drainage network of rivers connecting the Rocky Mountains to the Missouri River. The rivers and 11 mountain peaks were all assigned names by Ac ko mok ki using traditional knowledge, and included descriptions of the adjacent plains, covering a distance of over 500 miles [19,20].

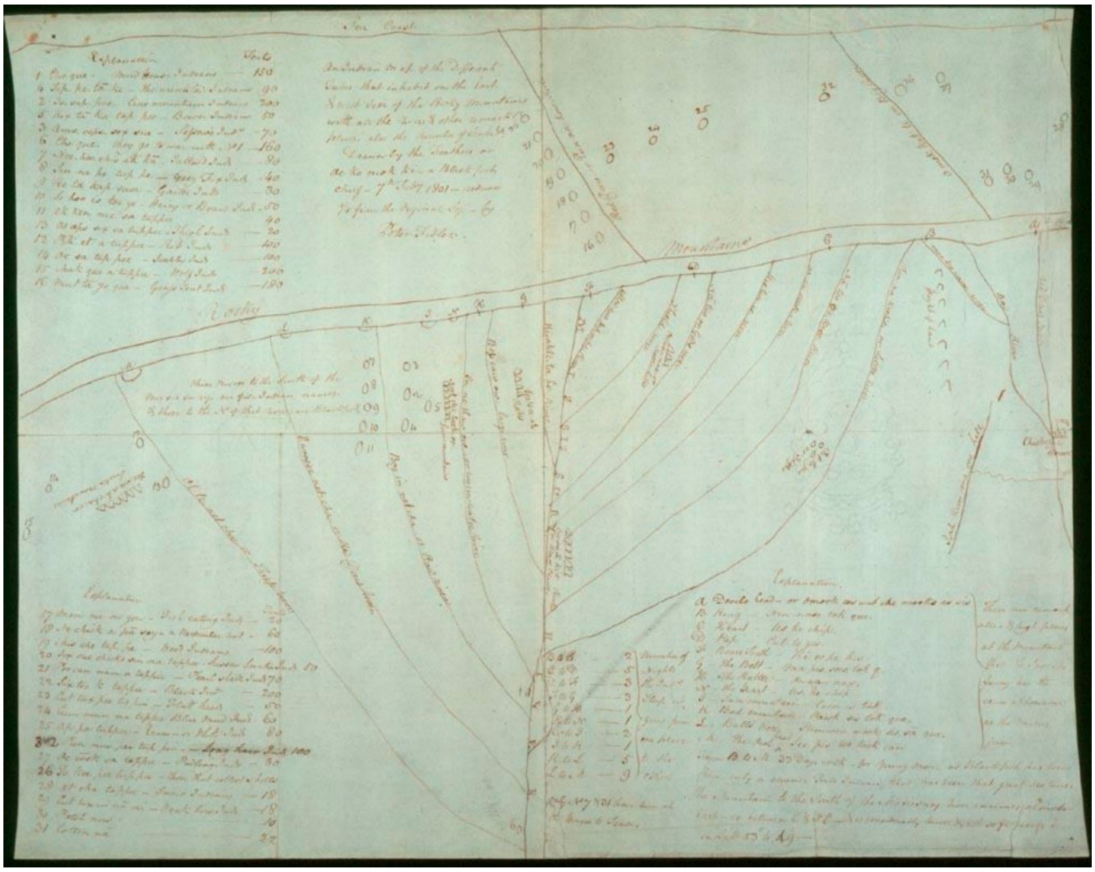

Figure 2. Map by Ac ko mok ki of the drainage network from the Missouri River to the Rocky Mountains, with annotations by Peter Fidler. Downloaded from the Hudson's Bay Company Archives.

Christopher Steinke found a map made by Too-Né, an Arikara chief, while pursuing his doctoral research in the French National Library. Steinke notes that it "captures some of the Arikara history that William Clark left unrecorded. Drawn sometime in 1805 or early 1806, it shows the course of the Missouri River, Lewis and Clark in council at the Arikara and Mandan villages, the locations of more than thirty different Indian groups, and significant places in the history of the Arikara people" [21].

The Lewis and Clark expedition produced two notable maps in 1805 and 1814 from their exploration. Both maps had extensive demographic data related to Native settlements, a large portion of which was far from the expedition's outbound and return routes. The earlier map merely identified the numbers of warriors or men, but on the latter map, the numbers of souls were noted, which probably included women and children. Neither the locations of the settlements nor the numbers of inhabitants could have been shown without the input of Indigenous informants [22,23]. Gribb and Cole (2014) spatially analyzed these data sets and found that:

"The positional accuracy of the Lewis and Clark maps was measured using the RMSE method and providing a standard for the maps of 276.3 km. The error increases as the tribal groups have less contact with Lewis and Clark along their route, thus the speculative nature of their placement identifies the problems they encountered by using secondary source information … The population counts listed for the different tribal groups, either on the maps or in the table, have some of the same shortcomings, however, with this attribute were two sources upon which to compare and analyze the population values—the Mooney values of 1928 and the *Handbook* values from a number of historical demographers/ethnographers. In the four comparisons, between the Lewis and Clark statistics for the Great Plains and the Pacific Northwest to Mooney and the *Handbooks*, we found that statistically there is no difference. Overall, the Lewis and Clark population values are a reliable source of population statistics for 1804–1806" [24–26].

In 1822, William Edward Parry, together with two Inuit, Iligliuk and Ewerat, mapped Inuit place names around Melville Peninsula in the Canadian Arctic. On one map, settlements included notations on Ookotook's Country, an 'Inhabited' area and Eskimaux (Inuit) Huts with notes from Iligliuk, e.g., "The Ships seen from here by Ookotook". The other map had Indigenous place names acknowledging Ewerat, including a note about the limits of Ewerat's geographic knowledge. Additionally, Lewis noted that "Parry was explicit in his opinion that better-quality maps could be obtained from the Inuit by providing a chart of land already known and asking for it to be extended," and presented a map drawn by Illigliak (an Inuit woman) and Parry of the northern Melville Peninsula and nearby portions of Baffin Island [27,28].

Two significant Indigenous maps were discussed by Lewis (1984): in 1825, Gero-Schunu-Wy-Ha (Oto) drafted a map that "traces the route of an Oto war party that attacked the Arapahos in the area between the upper Arkansas and upper Cimarron rivers. The events are depicted in typical Indian pictographic style against a network of rivers. The gross distortion of the network reflects the constraints imposed on the Indian by the rectangular sheet of paper. Even so, it is a remarkable map, covering about a third of a million square miles of the northern and Central American plains." (pp. 98–100). In addition, Non-Chi-Ning-Ga (Iowa) created a map in 1837 of tribal migrations in the Upper Mississippi and Missouri river basins. For both maps, Lewis redrew the maps and manually geo-referenced them against modern maps of the same areas, showing how well the two Native cartographers fared in their depiction of rather large drainage networks [29].

Joseph Nicollet published a hydrological map in 1843 of the Upper Mississippi drainage basin as part of the Fremont expedition of the War Department in the 1830s. What is important with this map is that, in addition to identifying more than a dozen Indian nations occupying the landscape, plus notations on their hunting and fishing grounds, he included both Indigenous and English names for many of the rivers, lakes, and buttes. Although these Indigenous names did not appear out of Nicollet's imagination, the source(s) of the place names is not given [30–32].

From the 1830s to the 1850s, Father Pierre-Jean De Smet drafted numerous maps dealing with the Native peoples of Canada and the U.S. from the Great Plains and Rocky Mountains west to the coasts of Oregon and British Columbia. A number of these maps incorporated help from Indigenous informants and cartographers. His most well-known map illustrates Native territories across the Plains to the Columbian Plateau and was drafted for the U.S. government in 1851. Other maps of his include numerous watersheds extending east and west of the Rockies, Native villages, and mission activities. On two of his maps, Station (sub-mission) St Pierre des Lacs along the upper Columbia River and Ft. Colville are cited, which both served the Sinixt. In addition, two Indigenous-made maps in the Pierre-Jean De Smet Map Collection at the Jesuit Archives and Research Center include one titled, *Indian Map of the Two Coeur d'Alene Upper Forks* by an unknown person, and another by Victor, chief of the Salish Indians, both of which were likely used by De Smet when he compiled the spatial data for his maps [33,34].

Another example of the good spatial cognition held by Native Americans is on a map drawn by an anonymous Assiniboine warrior in 1853 of the northern Missouri River from North Dakota to north central Montana. On the map are notations by Edwin Denig that read, "Map of the north side of the Missouri river from Fort Union, mouth of the Yellow Stone, to Fort Benton, mouth of the Maria, drawn by an Assiniboine warrior at Fort Union 27 December 1853. The artist was not acquainted with the country on the south side of the Mo. The dotted line is their usual war path to the Blackfeet. Names of rivers & c. written under his direction and explanation." Warhus (1997) added "that the Assiniboine's map was not made to give a western oriented picture of the landscape; like much of the Plains picture writing it was made to record the warpath of the anonymous brave making a raid on the Blackfeet in Montana" [35,36].

The Smithsonian's National Anthropological Archives has a collection of maps by Inuit cartographers with annotations by Franz Boas of the Baffin Island area, created in 1883 (Figure 3). As noted by the Archives, "Most of the maps are not identified as to the precise area they represent except by Eskimo [*Inuit*] place names. Other notes on the maps include a short text in Eskimo and some notes in German and English; most of these notes are illegible, because Boas used a shorthand system of his own in writing many of them, and his handwriting is very difficult to read even when not abbreviated" [37]. Nonetheless, given time, a cartographic researcher could probably match up a number of these maps by researching the Boas journal and by overlaying the maps on current high-resolution imagery or maps of Baffin Island.

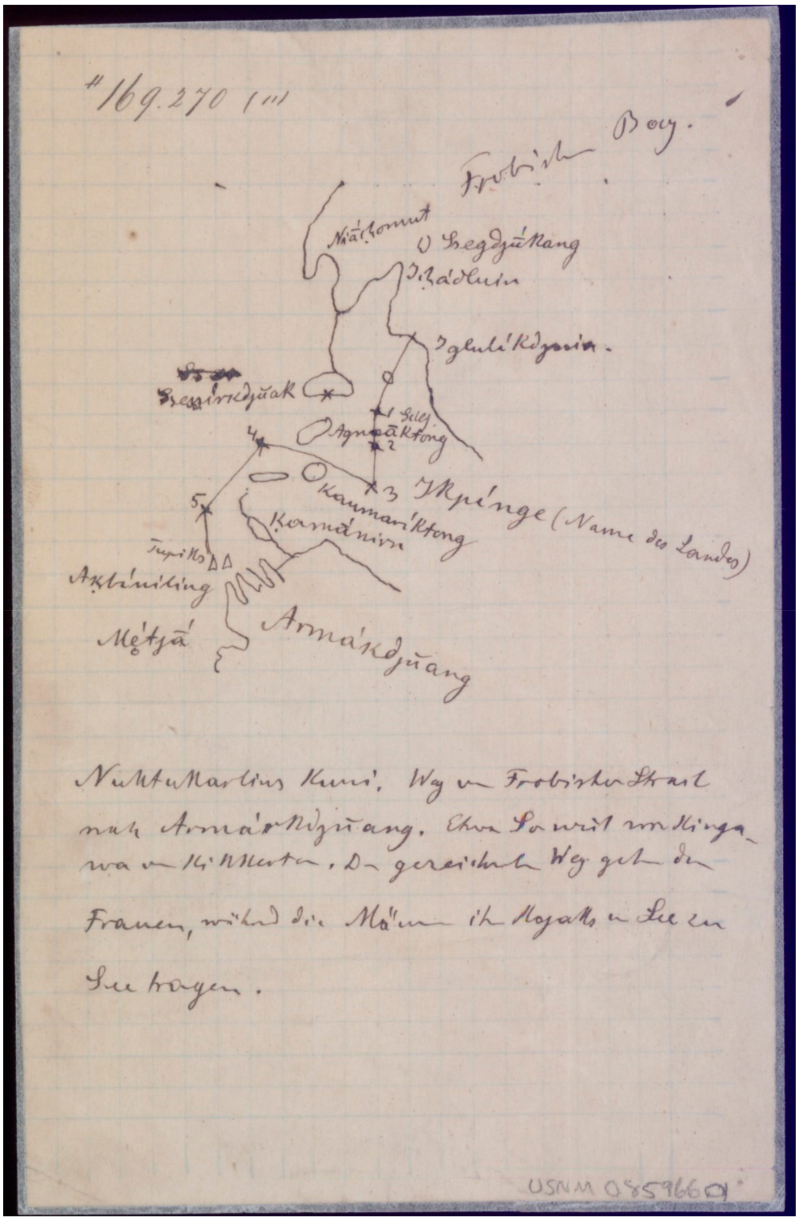

Figure 3. Map by anonymous Inuit and annotations by Franz Boas. Downloaded from the National Anthropological Archives of NMNH.

At the end of the 19th century and the beginning of the 20th century, three Indigenous cartographers, Crazy Mule (Cheyenne), Black Goose (Kiowa) and Amos Black Heart Bull (Oglala Lakota) drafted pictographic maps of events between their peoples, the U.S. government and other tribes [38–40]. These maps did not deal with toponymy, per se;

rather, they used name-glyphs to identify Indian and White settlements, military forts, battles, rivers, mountains, and other physical features; and they portrayed multiple events occurring within individual spatial frames.

An unsuccessful proposition to create the State of Sequoyah was mapped by D.W. Bolich (Muskogee) in 1905. His cartographic effort was part of an attempt by the Five Civilized Tribes (Choctaw, Chickasaw, Muscogee, Cherokee and Seminole) to prevent being admitted to the United States as a part of a joint state made of both the Indian and Oklahoma Territories. Had it been successful, the name Sequoyah as chosen was in homage to the compiler of the Cherokee syllabary [41].

Lewis (1984: 118) points out that during 1914, Ishi, who was said by Kroeber to be the last of the Yahis, "was a member of an expedition to his people's former territory between Mill Creek and Deer Creek. The expedition "led by Ishi ... covered a large part of Yahi ancestral territory, mapped it in detail, with village sites, trails, hidden brush shelters, and the smoke-lined caves ... exactly located and named. On the maps were more than two hundred native place names" (Theodora Kroeber, *Ishi in Two Worlds: A Biography of the Last Wild Indian in North America*, University of California Press: Berkeley, CA, USA, 1961, pp. 215–216). The precise nature of Ishi's mapping input is unknown. The field maps have apparently not survived. Either they or a smaller map by Ishi seem to have been the basis for the map shown here. From A. L. Kroeber, *Handbook of the Indians of California,* Bureau of American Ethnology Bulletin 78, United States Government Printing Office: Washington, DC, USA: 1925, p. 344.

5. Late 20th Century–Early 21st Century

In recent decades, many Native American tribes and nations have taken up the use of Geographic Information Systems (GIS) and mapping tools to re-establish their connections to traditional lands and waters. Esri has published four editions of the *Tribal GIS* book with a number of 1–2 page case studies on indigenous spatial activities. The Bureau of Indian Affairs, Branch of Geospatial Support provides GIS software and training to Native nations and tribes, with additional help provided by TribalGIS.com [42–47]. As a result, many Tribes/First Nations today have their own GIS offices, employing tribal members trained in GIS.

An interactive map by Village Earth made allotments openly accessible to Pine Ridge Reservation residents. According to the Village Earth website, the Pine Ridge Land Information System "makes it possible for members of the Oglala Sioux tribe to: Search for individually allotted and Tribal owned trust lands using the Tract ID; View, print and share a web link for the boundaries of specific land tracts" [48,49].

For Canada, an interactive Story Map (The Naonaiyaotit Traditional Knowledge Project Atlas) was cooperatively created by the Kitikmeot Inuit Association, Dalhousie University, Dominion Diamond Mines and Esri Canada. This website has maps of First Nation territories; Indigenous place names; heritage; travel routes and gathering places; water quality; and numerous mammal, bird and fish ranges and migration areas in the Nunavut and Northwest Territories of Canada [50]. An interactive bilingual (Inuit and English) map by Indigenous and Northern Affairs Canada delineates the four Inuit regions (Inuvialuit, Nunavut, Nunavik and Nunatsiavut) with all of the First Nation settlements in those regions, but nothing more. Hopefully, the website will contain more spatial information in the future [51]. The Gwich'in Place Names and Story Atlas allows users to interactively select towns, trails, mountains and rivers, with pop-up text discussing the stories related to each feature [52]. In addition, the Firelight Group has done some very good work with helping Indigenous communities map out the locations they and their families rely on for hunting, trapping, fishing and other important activities using traditional knowledge and use (TUS) studies, as well as Indigenous planning and ecology studies [53,54].

A poster map titled *Coming Home: Indigenous Place Names of Canada* by Margaret Wickens Pearce (2017) depicts place-names from First Nations, Métis and Inuit communities.

Indigenous toponymy, whether in Canada or in the United States, has always been part of the cognitive cartography of Native peoples. As Pearce notes on the website, "The map does not depict all of the Indigenous place names of Canada, nor are all Indigenous Nations and communities represented. Beyond the map's names are thousands upon thousands more, an ever growing and expanding atlas of intimate, geographical knowledge and experience" [55].

6. The Sinixt

The Sinixt people speak an Interior Salish language and have occupied their aboriginal homeland for centuries, along the Columbia River, from Kettle Falls in the United States to above Revelstoke in British Columbia. Like many Columbia Plateau peoples, they lost a great portion of their population in the late 18th century to smallpox and other European diseases. At the time of contact with Europeans, they had central political organization and had defended their territory against interlopers. They welcomed trade with fur companies, were regarded as great hunters and adopted the use of trade items, including guns, metal pots and pans and canvas.

The Sinixt people today are struggling with Native toponymy issues related to the Canadian government's declaration in 1956 that they were extinct. The problems of the Sinixt are compounded by the fact that their traditional aboriginal territory includes land in both Canada and the United States. In the United States, the Indian Claims Commission legally defined the Aboriginal territory of tribes, relying largely on the testimony of non-Indian anthropologists and other witnesses. In Canada, different definitions and legal rulings mean that there are special problems for Aboriginal peoples who have traditional lands on both sides of the international boundary.

One of these issues has been the development of hydroelectric power in the traditional homelands of indigenous people, including the Sinixt. In 1956, the British Columbia Natural Resources Conference published an atlas titled the *British Columbia Atlas of Resources* [56]. The British Columbia Natural Resources Conference reported that "after ten years examination and evaluation of British Columbia's natural resources...," and with the work of more than one hundred professionals, including top people in the government and industry [57], they were able to publish over forty maps covering geographical characteristics of the province and resource use in the province (contemporary and future). One of those maps showed the location of both developed and potential hydro-power, including at least eight developed sites and a number of additional sites that were not yet developed just north of the international boundary [58]. The narrative in the accompanying textual volume pointed out that British Columbia was at the time "almost wholly dependent on hydro-power" and that in the next twenty years the full potential of the Fraser and the Columbia Rivers would be necessary to meet the demands for expected power use in the province [59]. As the Canadian and British Columbian governments worked to develop hydroelectric facilities, they did not negotiate with the Sinixt or sign a treaty with them. In fact, in 1956, the Canadian government declared the Sinixt extinct.

For over a century, it had been well-known that the portion of the Columbia River which crossed the international boundary was territory of the Native people known as the Sinixt (Lakes or Arrow Lakes) Tribe. Indeed, the same 1956 British Columbia atlas included a map that showed Sinixt territory (Figure 4).

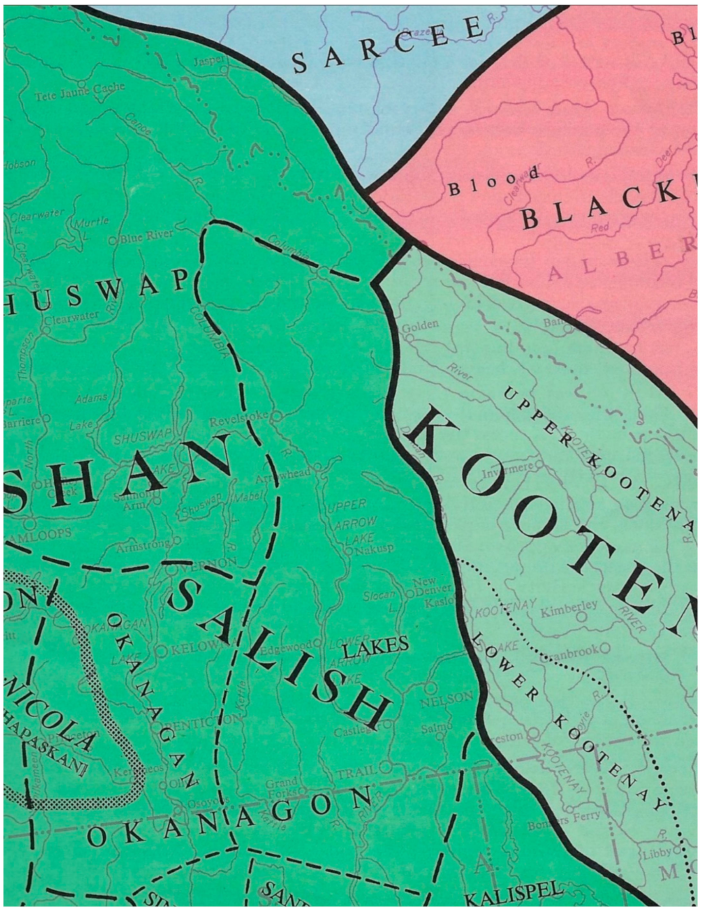

Figure 4. Sinixt (Lakes) as shown in Map 12 on pages 25–26 of the 1956 atlas created by the British Columbia Natural Resources Conference. The caption notes that the territory of the Lakes (Sinixt) is mapped as it existed in 1850.

It thus may be surprising that the federal Canadian government declared the Sinixt extinct during the same year, 1956 [60]. Late in the 19th century, Canada restricted Sinixt hunting. Between that time and 1956, the Sinixt were forced to relocate four different times, each time losing potential access to traditional lands and subsistence practices. Although it was profoundly hurtful to these people when Canada restricted their rights to hunt, declaring them extinct was not just insulting, but left a permanent scar on the communal psyche of the people. Since that time, many thousands of living Sinixt people have felt the effects of this action, and over a period of many decades, members of the Sinixt community have sought to have an audience in Canadian courts to demonstrate that they are not extinct and still have rights to their aboriginal homeland in today's British Columbia.

In 2010, Sinixt tribal member Richard Lee Desautel was cited for killing an elk in British Columbia without proper documentation. Desautel's defense was that he was hunting in his people's age-old aboriginal territory, and that as such, he was entitled to hunt there. The trial was finally held in 2016, and in 2017 the judge who presided over that trial issued a decision, ruling not only that the Sinixt were not extinct, but that Mr. Desautel did indeed have a right to hunt within his people's aboriginal territory [61]. Since 2017, two Canadian appellate courts have confirmed the lower court's decision and the ruling went before the Canadian Supreme Court. On 23 April 2021, the Supreme Court of Canada ruled that the Sinixt were not extinct and have constitutionally protected rights in their Aboriginal territory in British Columbia.

Under Canadian law, the determination of territorial rights for aboriginal people focuses on evidence from between the time of the people's first contact with Europeans to the time that the national sovereign power (in the case of the Sinixt, Great Britain) expressed sovereignty over that aboriginal territory. Thus, in the case of the Sinixt, the key dates are 1811, the date on which David Thompson first encountered the Sinixt, and 1846, the date of the Treaty of Oregon (between Great Britain and the United States).

The history of the earliest European maps of the region is very clear. The Sinixt occupied the aboriginal territory exclusively during that period [62]. A very good example of the type of cartographic evidence from the period is the map of Alexander Ross, dated 1821 (Figure 5).

Figure 5. Detail from Ross, 1821. "Sin Natch Eggs" was Ross's spelling for "Sinixt." He placed the "Sin-natch-eggs Nation" on the Columbia River in the area of what are called today Upper and Lower Arrow Lakes.

The Sinixt are a perfect example of why the study of First Nation toponymy is so important. Colonial domination of First Nations included requiring tribal members to wear European-style clothing, to live in European-style homes and to eat European-style food. Native spirituality was to be replaced by organized Christian religion and punishment was dealt out to any child that even used one word of Native language. Traditional place-names were not accepted in aboriginal territory of the people and there was systematic renaming of those places in European languages. In the case of the Sinixt, what has been termed as "cultural genocide" included declaring the people extinct, wiping them completely off the map.

Now that the Canadian courts, to date, have acknowledged that the Sinixt are not extinct, it is especially important for the people to record and make prominently public their traditional environmental knowledge of the landscape (TEK) and the original names for places in their territory in their own language. The attached Sinixt place-name map represents the first stage of the Sinixt attempt to reclaim a portion of their ancient homeland and heritage (Figure 6).

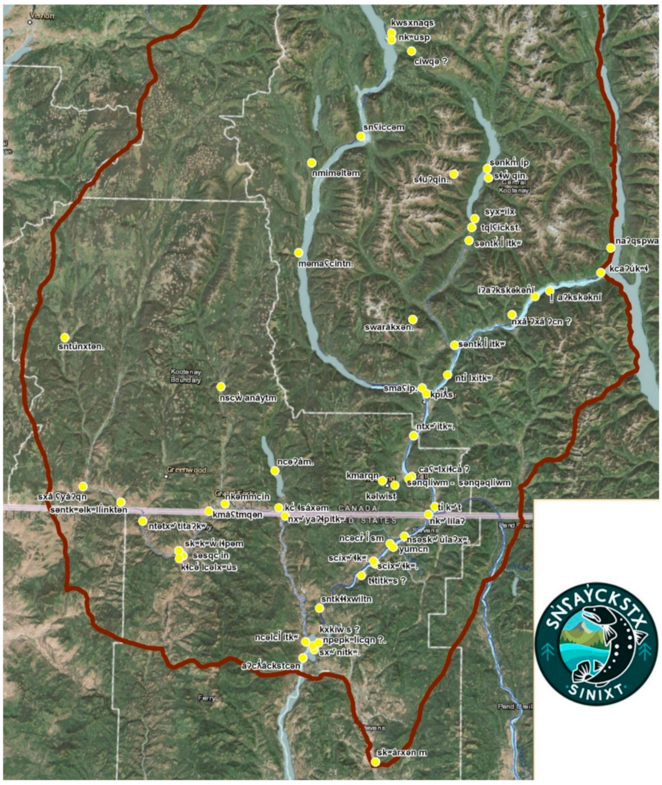

Figure 6. Detail from the sńʕaýckstx (Sinixt) place-names map, currently under construction by the Tribe in collaboration with the Colville Confederated Tribes. This detail shows the Tribe's territory and selected place names from today's Nakusp north into British Columbia, and south to Kettle Falls in Washington State [63] (also See Supplementary Materials). Reprinted with permission from The Confederated Tribes of the Colville Reservation. Colville Confederated Tribes. 2021.

7. Discussion

Regardless of whether one looks at historical maps from nearly any place in North America or at present-day mapping and GIS activities, Native Americans and First Nations have shown considerable geographic intelligence of the cultural and physical landscapes that they and their neighbors occupy. Very often, their cognitive cartographic abilities enabled them to navigate these landscapes competently, and the descriptive place names that they assign to localities demonstrate a working knowledge that has served them well.

Today, the Sinixt are applying traditional pictographic knowledge and place-names to create a map that uses modern GIS technology to address toponymy in the region of their aboriginal territory. Although this project cannot undo the colonial damage to the tribal people, it is a first step in reconciling the Sinixt with their Aboriginal territory in British Columbia. The creation of this map will be an ongoing project for the Tribe, probably for many years to come. We envision that future research, like that with the Sinixt, will assist other Indigenous Nations in their efforts for recognition, land rights and accessibility to sacred sites, hunting and fishing.

Supplementary Materials: The full Sinixt territory and place-names poster (is available online from the GIS office of the Confederated Tribes: https://drive.google.com/file/d/1cggWDHMb2x_4cIezpdEW7BARjMbIiF84/view?usp=sharing.

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Article

Mapping Inuinnaqtun: The Role of Digital Technology in the Revival of Traditional Inuit Knowledge Ecosystems

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Abstract: The term Inuinnaqtun is often used in reference to a dialect of Inuktut spoken by Inuinnait (Copper Inuit) of the Central Canadian Arctic. The broader meaning of Inuinnaqtun, however, is to speak, to create, to practice, to do, to think, to be, like an Inuinnaq (a human being). Inuinnaqtun was once its own robust ecosystem, with Inuinnait physically immersed in a landscape and way of life that nourished a fluent and full language, supported human relationships, and maintained a sophisticated body of cultural knowledge. The Inuinnait journey into the 21st century has challenged the practice of Inuinnaqtun, along with the connectivity of its ecosystem. How can an integrated Inuinnaqtun ecosystem be restored in contemporary Inuinnait society? In this paper, we outline the decade-long development of a digital mapping program to document traditional forms of engagement between Inuinnait people, language and land, and facilitate the continued circulation of knowledge that underlies these relationships. In reviewing its various successes and challenges, we critically question digital technology's ability to digitally represent Inuinnaqtun ontology, in addition to the role that digital technologies can play in facilitating the local relocation of knowledge, objects and relationships dispersed into global contexts.

Keywords: Inuinnait; Inuinnaqtun; cybercartography; digital return; toponymy; multi-media cartography; digital heritage

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1. Introduction

The transition of Inuit into the 21st century has tested the fabric of a lifeway that has long been honed through geographic isolation and cultural insularity. For centuries, Inuit throughout the North American Arctic lived according to seasonal migration within a defined, regional landscape (see [1] (pp. 33–37), [2] (pp. 410–434) for the specifics of migration and land-use among Inuinnait), and developed a high level of cultural synchronicity with a specific environment. Inuit were part of a larger ecosystem, relying on their immediate surroundings for the tools they made, the clothes they wore, and the food they ate. This close relationship went beyond physical engagement, with language, beliefs and spirituality also being finely attuned to the natural world.

The bridged cultural and environmental ecosystems of Inuit changed dramatically upon contact with Euro-American people and their traditions. While impactful cross-cultural encounters occurred at different times and to varying degrees depending on geographic location, almost all Inuit had relocated to urban settlements by the mid-1960s as a direct result of this change. The rapid transition from land to town has made it more difficult to sustain the culture, language and beliefs that are so deeply interwoven with daily engagement with the natural environment. This article will consider how one regional group of Inuit, called Inuinnait, were impacted by these changes to their lifestyle.

Inuinnait are a culturally distinct (cf. [3] (pp. 20–21)) population of Inuit who live in the Central Canadian Arctic, in the territory of Nunavut (see Figure 1). The term Inuinnait quite literally means 'the people' in the Inuinnaqtun language. Over the last two decades, the use of 'Inuinnait' has grown in popularity as a collective name to replace 'Copper

Eskimo/Inuit', a term coined by the explorer and ethnologist Vilhjalmur Stefansson in the early 20th century due to the group's distinct use of the naturally sourced copper as metal for their tools [4]. Inuinnait have long self-identified according to the names of localized family groupings dispersed across the region prior to settlement in urban communities (see Figure 2).

Figure 1. An overview of the Central Canadian Arctic indicating the positions of the four contemporary Inuinnait communities of Cambridge Bay, Ulukhaktok, Kugluktuk, and Gjoa Haven, located on and around Victoria Island and King William Island. Basemap source: Google Maps.

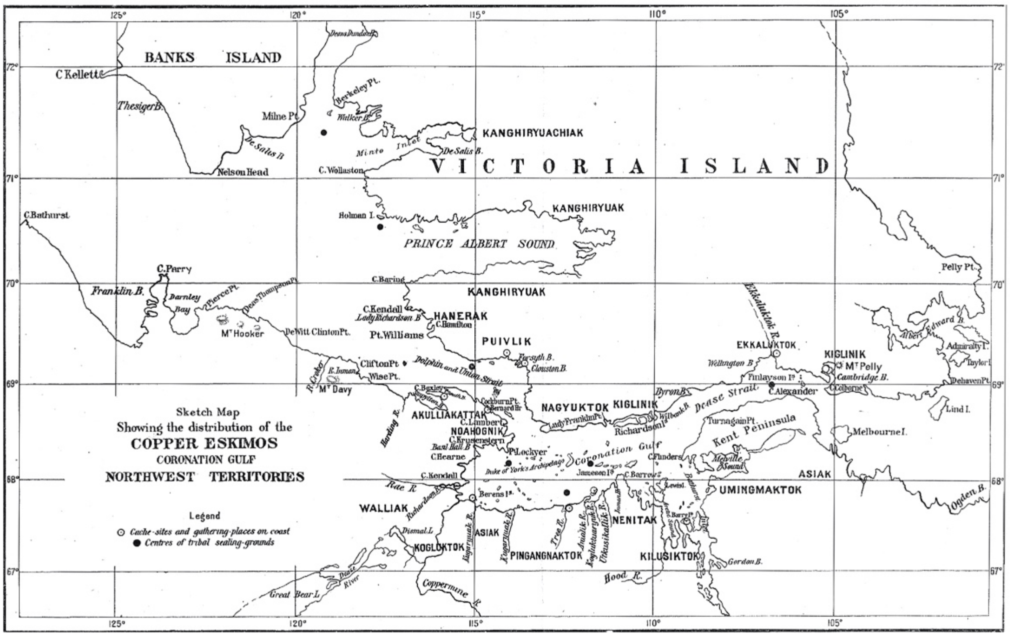

Figure 2. I A sketch map of the Inuinnait region in the Coronation Gulf surrounding Victoria Island in the Central Canada Arctic. Created by anthropologist Diamond Jenness for a 1921 ethnography [5] (287), this map provides the names of Inuinnait family groups who made up a total population of roughly 800 individuals at the time of Jenness' census work.

Located in the heart of the notoriously inaccessible Northwest Passage, Inuinnait were among the last groups of Inuit in the Canadian Arctic to engage with western culture and undergo significant lifestyle changes as a result.

A rapid transition to new materials, technologies, and worldviews has characterized the last century for many Inuit groups, and this was no different for the Inuinnait. The relative lateness of their contact with Euro-Americans, which began around 1910, was accompanied by a strong awareness of the degree of change awaiting the group as they negotiated the arrival of foreign people, ideas, and materials. In 1921, the anthropologist Diamond Jenness outlined the various impacts of western society on Inuinnait since initial contact occurred roughly a decade earlier, noting deep ramifications across all aspects of Inuinnait culture—from material possessions, diet, and hunting preferences, to migration routes and social/religious practices [6]. By 1924, Knud Rasmussen of the Danish Fifth Thule Expedition—to be discussed later in this paper—was documenting the language and lifeways of Inuinnait with an understanding that his recordings would serve to help rebuild Inuinnait culture upon its inevitable collapse [7].

Concern regarding the change in and loss of what many refer to as 'traditional' Inuinnait knowledge and practices continues into the present, particularly in relation to digital technologies. Inuit have been using digital media as tools for communication since the earliest days of the Internet [8]. The Internet's widespread arrival to northern communities in the 1990s was greeted not only as a way to bring Inuit together across the Arctic's geographic expanse, but also to amplify their voices and unique identity across the world [8] (pp. 54–56), [9] (p. 115). However, the prospect of an Internet-based future for Inuit was also tempered by anxiety about its potential impacts on their way of life, with facilitated access to global culture and resources seen as a surefire way to further unravel the Inuit social fabric [10,11]. To this day, the study of digital media use among Inuit remains split by the debate of assimilation vs. appropriation: one which asks "whether Inuit can appropriate digital media in order to preserve their culture or whether the technology will cause Inuit to be assimilated into a dominant global culture" [12] (p. 228). The question is whether the specific affordances of a technology—what it allows people to do, or prevents them from doing—has a dramatic impact on shaping the ways that Inuit culture and knowledge exist on-line.

This paper documents Pitquhirnikkut Ilihautiniq/Kitikmeot Heritage Society's (PI/KHS) ongoing research program to map and mobilize Inuinnaqtun ecosystems through an online digital platform development. PI/KHS is an Inuit-directed, non-profit organization based in Cambridge Bay, Nunavut, dedicated to the preservation and renewal of Inuinnait knowledge, language and culture across the four contemporary Inuinnait communities. Research and programming at the society are guided by an Inuinnaq Director and Board, who work closely to ensure that the organization's activities align with the cultural, linguistic, and heritage priorities in the community.

In 2005, PI/KHS began to consider a digital future for Inuinnait knowledge, collected as part of its cultural research program. This transition was motivated by multiple reasons, including the decreasing number of language experts and elders with first-hand experience of a land-based lifestyle, the relative impermanence of existing analog and textual recordings of Inuinnait knowledge, and the need for greater accessibility of these resources among Inuinnait, especially younger generations. As an organization, we were deeply involved in exploring the role that digitization could play in efforts to document and preserve Inuit language, culture and history. Over the course of developing multiple digital platforms using the Nunaliit cybercartographic framework, we have explored various ways in which the Inuinnait ecosystem could be represented in a digital environment. Throughout this process, we were often faced with the same dilemma of assimilation vs. appropriation, namely: can a customized Inuinnait digital platform support the structure and understanding of an online Inuinnaqtun ecosystem? Digital environments can depict specific objects, places and experiences—even enhance them through multimedia content—but at what cost to other valuable cultural context and information?

2. Materials and Methods

While there is a vast existing academic literature on cultural ecology in the Canadian Arctic, the concept of an Inuinnaqtun ecosystem underlying PI/KHS' work is one that stems directly from the experience and intellectual traditions of Inuinnait elders. In retelling their lives, many elders emphasize a story of change: one of being born and raised on the land, then moving into town; one going from deep familiarity and harmony with the environment to being urban-bound. Underlying all of these narratives is the understanding that Inuinnait culture was once deeply embedded and in sync with the natural environment, and that this is where the culture continues to reside, even when its people do not.

Awareness of the disconnect between contemporary Inuinnait communities and traditional culture permeates the stories Inuinnait tell about themselves. There is a common understanding that the Inuinnaqtun ecosystem is not simply a thing of the past, but an enduring cultural state that requires active engagement and maintenance. This is especially the case when living in an urban environment in which English is a dominant language and the growing reliance on technology, values, and priorities external to the culture has further widened the gap between generations. The distance between Inuinnait and their ancestral language and lifeways is not envisioned in terms of 'loss', but rather 'dormancy', with foundational cultural knowledge said to be sleeping, just waiting for new generations to revive it.

To define the Inuinnaqtun ecosystem is to reference a highly complex worldview and way of being that has evolved over centuries of Inuit engagement with their environment. As was demonstrated through Janet McGrath's conversations with Inuit scholar Mariano Aupilarjuk [13], profound theoretical and experiential foundations underlie Inuit ontology, despite the difficulties articulating them outside the cultural traditions in which they are anchored. In searching for a way to explain an Inuinnaqtun ecosystem that is both understandable and relatable to a broader audience, this article focuses on the intricate connections between three of its key components: language, land and people. Each of these concepts will be briefly explored in turn.

The Inuinnaqtun language is a key factor for understanding the broader Inuinnaqtun ecosystem. In addition to its geographic territory (see Figures 1 and 2), Inuinnait culture distinguishes itself from other regional Inuit groups through clothing styles, social practices, and material technologies and, perhaps most importantly, through language. The Inuit language family has a large geographic distribution across the Arctic, which is generally attributed to the rapid spread of common ancestors from Alaska to Greenland roughly 800 years ago. Over the centuries that followed, the common language began to differ in dialect. Inuinnait developed a unique version of the language, shaped specifically according to their lifestyle and surroundings, known as Inuinnaqtun. Like all Inuit languages, Inuinnaqtun has its roots in orality rather than writing. Roman orthography was introduced by early missionaries, but the heart of the language continues to reside in the spoken word.

While Inuinnaqtun refers to a language dialect, it has a broader meaning within the culture: Inuinnaqtun means to speak, to create, to practice, to do, to think, to be, like an Inuinnaq (Inuinnaq meaning a human being). In this sense, Inuinnaqtun refers to a larger cycle in which language not only allows people to name their world, but also to properly function within it. Understanding of the Inuinnaqtun ecosystem is deepened when the concept of language is added to that of land. Inuinnait once lived in a purely Inuinnaqtun environment. Everything in that environment was named: animals, the elements, and natural resources were all layered with rich terminology that was passed along and sustained through constant engagement. Many family groups took their names and social identity from specific geographic landmarks along their seasonal migration routes (see Figure 2). While pre-contact Inuinnait landscapes were not generally recorded through mapping (see exceptions in [14,15] (p. 5), places were intimately known through toponymy. The extensive use of place names allowed Inuinnait to craft a simultaneously personalized and deeply cultured narrative for the visually uniform tundra landscape, with travelers often reciting the names of features along the trail to track both their physical progress across the land, and deepen their sense of history and cultural belonging within it [1] (p. 11). In addition to place names, many landscapes also possess oral traditions, which include detailed explanations of a place name's meaning and origins, descriptions of the resources available at a site, or accounts of past events extending from deep history to living memory.

Relationships between people also strongly factor into this ecosystem, both through intricate kinship structures and mentorship to ensure the free-flow and continuance of Inuinnaqtun knowledge. Knowledge of language and land was acquired through observation, listening, and being physically and mentally present among cultural experts. Knowledge transfer was a social process, with each generation working together to prepare individuals for the stages of their lives in which specific skills and insights are required. As articulated by Scott Heyes [16] (pp. 45–46), Inuit knowledge of their environment was transmitted through a "process where people who are capable and knowledgeable in performing select tasks support new learners until their knowledge is sufficient for them to accomplish tasks on their own ... The practical transmission of traditional knowledge through hunting—an ongoing process of instruction and learning—allowed young Inuit to acquire knowledge about the land while on the land". Almost invariably, in such a system, the individuals dispensing culturally specific knowledge belonged to older generations.

Maintaining an ecosystem of language, land and people requires that all three elements are present: a change in one impacts them all. The introduction of Inuinnait to the western world greatly disrupted this ecosystem. The transition from land to town happened quickly. Many Inuinnait had not directly encountered non-Inuit explorers and traders until the mid to late 1910s. By the 1920s, trading posts had moved into the area, encouraging Inuit to leave traditional subsistence hunting for the pursuit of fox furs, which could be sold to posts in exchange for western luxuries. The trading posts were quickly followed by other institutions: the RCMP, Roman Catholic and Anglican churches. In 1951, the region's first residential school was built to physically remove children from their families and language to ensure an education in western ways. When these children returned to their homes, many of them unilingual in English, they found themselves in a world for which they no longer had words to engage with or describe. Leveraging the vulnerabilities of cultural transition, the Canadian Government facilitated the movement of Inuinnait populations off the land and into hastily built settlements where systems of education, health care and social welfare services could be more easily administered [17]. As Inuinnait life adjusted to the realities of settlement, practices associated with living on the land became less used. This, in turn, brought about the gradual disappearance of the highly customized technology, terminology, and social relationships that accompanied these activities. In towns, Inuinnaqtun withdrew from homes and separated from everyday use. Generational divides diverted the experience of the young and old. Sophisticated systems of oral tradition and social knowledge transfer suffered through the breakdown of these relationships.

The question of how to reverse the breakdown of traditional lifeways in a modern era has been an ongoing challenge to Inuit and non-Inuit alike. The early 2000s saw a growing academic movement towards digital technology as a means to document, preserve and revive Indigenous knowledge and language across the Arctic and beyond (see, e.g., [18–20]). While proposed applications were diverse—ranging from computer and archive databasing and GIS mapping to the digital repatriation of museum collections—they were uniformly optimistic about the translation of Indigenous knowledge into new digital media and platforms, citing the potential for more permanent records, increased accessibility within and between remote communities, economic benefits [21], and increased opportunities for marginalized groups to have their voices heard [22]. There was concern that digitized Indigenous knowledge would be corrupted when removed from its original contexts of production, dissemination or performance, but the position taken by many was that the "digital preservation of indigenous knowledge should not be seen as a means of replacing traditional forms of education in indigenous communities, but rather as something that will enhance or be used as an additional tool in this process" [20] (p. 27) (see other examples in [8,9,23,24]).

At PI/KHS, we too questioned whether an enhanced virtual environment could help rebuild connectivity between Inuinnait people, language, and land by highlighting—and even possibly recreating—the connections that daily life was struggling to sustain. From the start, we knew that any digital platform articulating the Inuinnaqtun ecosystem would have to be custom-built. Off-the-shelf databases and software are robust, but all too often have a predetermined structure for organizing and relating content. We needed a structure specific to Inuinnait. In 2006, PI/KHS partnered with the Geomatics and Cartographic Research Centre (GCRC) at Carleton University in Ottawa, Canada to develop its own solution to storing, organizing and preserving Inuinnait knowledge. GCRC was pioneering the concept of cybercartography, which sought to broaden the ways in which both spatial and non-spatial information could be visualized in digital environments. As defined D.R. Taylor Fraser, who coined the word, cybercartography entails "the organization, presentation, analysis and communication of spatially referenced information on a wide range of topics of interest and use to society in an interactive, dynamic, multimedia and multisensory format" [25] (p. 406). The interactive digital atlases produced by GCRC use a framework called Nunaliit, an open-source software package created to facilitate mapping input by community members with limited knowledge of geographic information processing [26]. The resulting platforms are capable of mapping connections and relationships between quantitative and qualitative information in a manner that can better mirror the sensory realities of various individuals and communities.

There were several qualities of the Nunaliit framework that immediately struck a chord with our organization:

(1) Nunaliit is open-source. All its code is publicly available and non-proprietary. Nobody owns it; nobody profits from it. This level of openness grants the possibility to push development into new, case-specific directions.
(2) Nunaliit is what is referred to as a distributed network, meaning that it connects multiple users through the same underlying database system. A benefit of this is that users can shape and visualize data according to their specific needs. Any new functions, features, or upgrades developed by one user, are then available to anyone else using the framework. The costs of maintaining the system over time are also distributed, making it more sustainable.
(3) Nunaliit is a relational database. In the simplest terms, this means that each piece of information entered into a Nunaliit database is a discrete document. A museum record of an Inuinnait parka, for example, would be its own document. A photo of that parka is a separate document. A photo of someone wearing the parka would be a separate document, a comment that someone makes about the person wearing the parka would be a separate document, and so on. This allows for a system in which data are not tied together in a conscripted way. They are a cloud of free-floating documents. These can be related to one another in different ways, forming ever-changing pathways of interconnection and association.

The ultimate benefit of the Nunaliit framework regarding our objectives of mapping both individual and collective cultural connections lies in its flexibility in terms of knowledge access. Nunaliit is capable of ingesting almost any form of digital media or information, and stores individual records in their own flexible documents that can, but are not required to, conform to an expected structure or schema. These schemas might organize documents with similar attributes such as map features, video interviews with elders, PDF scans of book pages, people, or photographs. This support for the flexible organization of data leaves users free to design and redesign as they go without being stuck with the original data design. This effectively results in large, non-linear webs of knowledge that can be organized, navigated, and presented in multiple ways according to specific needs and priorities. This unique design became particularly important in terms of the desire to create a database of Inuit knowledge that is actually amenable to Inuit structures of storing, teaching, and using the information it contains.

3. Results

Inuit traditions of mapping also informed our efforts to digitally chart an Inuinnaqtun ecosystem. The Inuinnaqtun term for maps is 'nunaujaq', which can be translated as being 'of the land'. No permanent maps have been recorded among pre-contact Inuit in the Canadian Arctic, although their presence has been theorized from a scattering of early three-dimensional relief maps carved from driftwood [16] (p. 6), and landscapes incised in ivory [27] (p. 47), [28]. The earliest Inuit maps were ephemeral in nature and took physical shape from the very landscape they sought to describe: charts etched in snow and sand, and intricate topographies assembled from sticks and stones ([14], [16] (p. 5)). These maps were not objective documents, in the sense of their orientation, scale, and representation of landscape being uniform and universally readable, but required an additional layer of communication and narration to complete the transfer of environmental knowledge. Material charts began to emerge only with the first encounters between Inuit and the western world. Close to 200 maps drawn by Inuit for explorers and ethnographers between 1818 and 1924 are known to exist, mainly from the contexts of non-Inuit expeditions requiring elaborate geographical information to navigate unknown surroundings. In line with ephemeral traditions of mapping, notes Renee Fossett [14] (p. 75), Inuit produced these graphic representations as "nothing more than incidental by-products of the oral teaching and learning process". Contrary to the standardized increments of miles employed in western-style maps, the units used by Inuit to estimate and represent distance resulted from the fusion of physical range and the (highly individualized) amount of time taken to travel that distance [16] (pp. 12–13). According to Peter Whitridge [28] (p. 226), this sophisticated form of cartographic representation—a hybridization of the ideal, real, natural and cultural—might even be seen as an improvement on western mapping, in which manipulation of scale: "represents a correction of the deficiencies of a two (or three) dimensional representation of a four-dimensional object (a journey)".

Like the traditional Inuit maps, our use of the Nunaliit framework to situate knowledge within an Inuinnaqtun ecosystem would have to be less about communicating a universal description of an environment than about allowing a series of highly personalized and hybridized stories to be retold. While the succession of digital tools we created over the next 15 years could never replace first-hand Inuinnaqtun experiences, they could serve as a way to document, organize and continue telling them, not as a single event, place name, or unique object, but as a larger atmospheric cloud of conversation and association that more closely mirrored the workings of an ecosystem. In detailing our resulting efforts, this article will specifically focus on describing the role of cultural compatibility in our design of digital platforms, with more detailed explanations of their methodology and functionality already available through other publications about the projects [29,30].

3.1. The Kitikmeot Place Name Atlas: Mapping Inuinnaqtun Connections to Land

In 2006, the development of PI/KHS' first digital platform, called the Kitikmeot Place Name Atlas, began [31]. As its name suggests, this mapping tool was created to inventory and communicate Inuinnaqtun toponyms. Since 2000, PI/KHS researchers meticulously documented toponyms through community-engaged programming, elders' meetings and field research, with the goal of reviving their usage through increased local awareness and official recognition on territorial and national topographic maps. We looked to Nunaliit's framework to further support and visualize the relationships and language underlying this sense of place.

The Place Name Atlas was designed as scrollable digital map of the Inuinnait region with all named places geolocated (see Figure 3). In collecting toponyms for the dataset during land and map-based interviews with elders, close attention was paid to recording knowledge peripheral to the actual names—a methodology adapted from

Ludger Muller-Wille's place name surveys in Nunavik [32]. As more thoroughly detailed in a 2014 publication [29], this included the recording of multiple components for each landscape feature:

1. The location and extent of geographical features covered by each place name.
2. The Innuinaqtun geographical entity or entities represented by the place name.
3. The pronunciation of each place name.
4. The proper representation of each place name in the orthographies used by speakers of the Inuinnaqtun dialects who use the place name.
5. The meaning of each place name.
6. The oral traditions associated with the name, including stories, legends, and songs.

Figure 3. A video of elder Frank Analok is linked to the Tikiraaryuk site and describes its history of use for seal hunting and iglu building. Each yellow dot on the map represents a unique place name and associated data.

More than 1300 places were recorded using this methodology and incorporated into the Atlas.

Language plays an important role in this platform. The use of spoken Inuinnaqtun was prioritized to help preserve the integrity of the primarily oral language and its pronunciations. Inuinnaqtun orthography is still largely unstandardized, with different generations accustomed to different variations in spelling. Reliance on spoken versions of place names by language experts ensures that authoritative versions are in place. Audio files of each name being spoken by a language expert were embedded in each mapped place, and are activated when hovered over or selected.

The platform was also designed to integrate human relationships into its mapping of place names. As previously mentioned in this article, landscape knowledge is traditionally transferred through mentorship by elder members of a community, who instruct younger individuals in the physical navigation of sites, the activities that take place there, and the body of oral tradition that surrounds the place. While this form of interactive, 'on-site' education is not possible in a virtual environment, we focused on introducing additional interview and media content from local elders and land users into named places. Interviews and video recordings of individuals engaging with the landscape, or narrating the mythology and history of specific sites, were made accessible for many locations, lending a much-needed human element to its interpretation (see Figure 3).

Through mapped place names, integrating interviews and spoken translations, the Kitikmeot Place Name Atlas was able to digitally bridge the Inuinnaqtun language, people and place. A distinct challenge for the Atlas was negotiating the element of physical experience that is so critical to Inuit traditions of learning about the land. While virtually engaging with a landscape can relay many educational details, it is very different from being physically present on the land. PI/KHS navigates this gap using parallel non-digital programs such as land-based cultural camps, hunting, and harvesting excursions. We continue to look for ways in which the experience of being 'on the land' can be incorporated into our digital site. One attempt to heighten the virtual experience of named places was to introduce photospheres of individual sites that allow users to visually pan around the environment being described (see Figure 4). As other Arctic digital heritage projects have demonstrated [33,34], the use of panospheres and 3D modeling have strong potential to connect people to remote environments that they cannot otherwise visit in person.

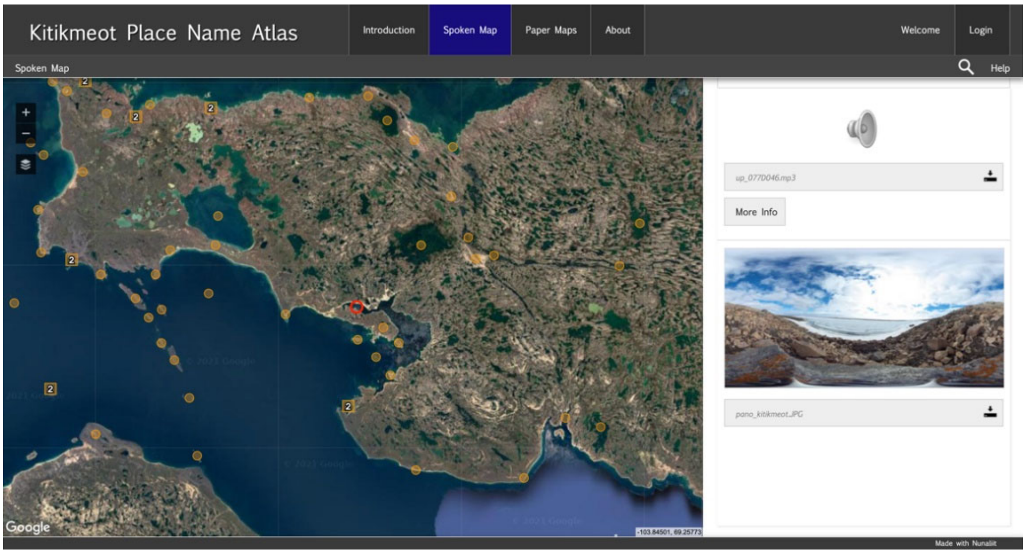

Figure 4. A photosphere of the Kangiqhuk area allows individuals to see the areas being described. This functionality was designed to facilitate visual engagement with remote sites that few people can travel to.

3.2. The Fifth Thule Expedition Atlas: Mapping Inuinnaqtun Connections to the Past

While the Kitikmeot Place Names Atlas spoke to Inuinnait connections with natural landscape, we also wanted to accentuate the historical topography of the Inuinnait region. For many Inuinnait, the physical landscape is deeply layered in experience and narrative. The act of travelling through, and engaging with, this storied landscape is an important way for Inuinnait to re-affirm their contemporary connections to the land and the ancestors who once lived there. As Béatrice Collignon notes [1] (p. 90), the land occupied by Inunnait cannot be expressed through a simple map, "with nothing more than axes of travel, points that mark camps and hunting areas. Through human experience and storytelling, the landscape becomes a memoryscape, a humanized environment. The territory becomes a world filled not merely with its living people (who are not numerous), but also of their ancestors, their adventures and misadventures, their bones and their spirits".

In line with the goal of digitally representing an Inuinnaqtun landscape, we were interested in re-establishing connections between current Inuinnait populations and the rich ecosystem of knowledge, beliefs and relationships that informed Inuinnait culture in the past. The focus of this work was ultimately found in the Fifth Thule Expedition. Between 1921 and 1924, Danish–Greenlandic ethnographer Knud Rasmussen led a research team across the whole of the North American Arctic—from Greenland to Siberia—acquiring detailed observations, collections and documentation about the Inuit cultures they encountered (see, e.g., [7,35–38]). The linguistic and cultural fluency of Knud Rasmussen—who was of mixed European and Greenlandic Inuit heritage—allowed him to speak with Inuit in their own tongue and compile detailed information about their cultural and social environments. Rasmussen spent a total of three months specifically working among the Inuinnait [39,40].

In anticipation of the centennial anniversary for this important expedition, PI/KHS wanted to ensure that the rich cultural ecosystem it documented was both defined and made available to contemporary Inuinnait communities [30]. In 2014, the organization partnered with the National Museum of Denmark—the recipient of many of Rasmussen's collections—on a project to bring Inuinnait elders and staff to Denmark to reunite them with material collections, photographs and textual recordings from the expedition so as to interpret the ongoing importance of historical materials to the culture [41]. The methodology for this research was not dissimilar to that of collecting placenames. Elders visiting the collections provided rich cultural information, including Inuinnaqtun terminology for the items and their composite parts. They also told stories about their personal experience with the objects, and often talked about seeing them used in their childhood by their parents and grandparents. All proceedings were video-recorded. These interviews were part of our larger endeavour to isolate and extract Inuinnait knowledge—in the form of oral traditions, songs, traditional place names, linguistic information, genealogical information, Inuit-drawn maps, photographs, and ethnographic objects—from the non-Inuit narrative and theories that originally guided the expedition.

Working alongside GCRC's developers, we used the Nunaliit framework as a foundation to map the intricate worldview of Inuinnait, as held both at the time of Rasmussen's visit 100 years ago, and in the present day. The platform was called the Fifth Thule Expedition Atlas [42], and was developed with four key functions in mind:

1. Providing digital access to Inuit knowledge gathered on the expedition;
2. Providing opportunities for Inuit to verify and enhance he tknowledge collected by the expedition;
3. Linking the results of contemporary research and Inuit experiences to expedition findings;
4. Creating opportunities for Nunavummiut to interact with the expedition objects and environments in augmented reality environments.

As a first approach to situating Inuinnait knowledge in a digital environment, our project gravitated back to using a spatial, map-based interface similar to the Place Name Atlas (see Figure 5).

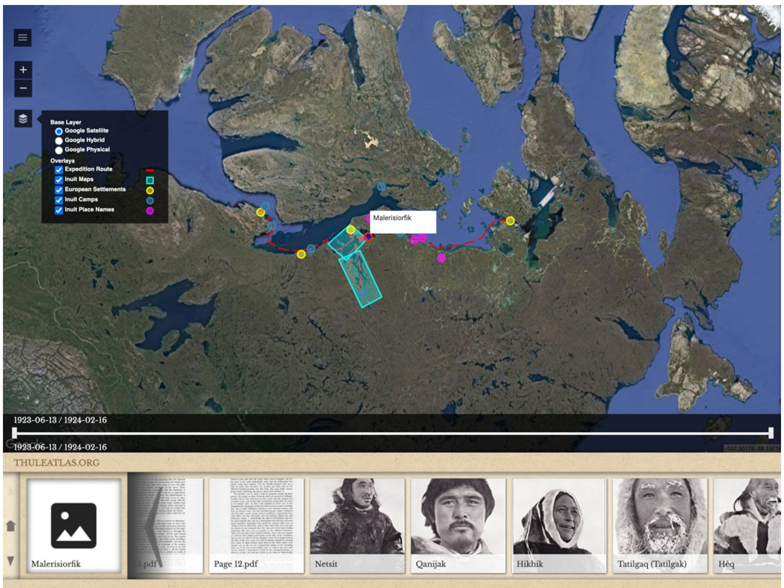

Figure 5. A geospatial map of the Fifth Thule Expedition's course through the Inuinnait region. Clicking on a specific location summons the people, knowledge and collections sourced from that location.

This interface allows users to cartographically access information through an area map that visualizes locations such as the expedition routes, culturally significant places, and Inuit camps encountered by the expedition. Clicking on locations in the map will summon cultural documentation related to that place, whether these are photos of Inuit who once occupied the area, records of the knowledge they imparted, or transcribed songs and stories. This reliance on a more conventional cartographic methodology facilitates its use by Inuit elders and land users [43], and increases the potential to link the knowledge to additional geographic applications such as the Place Names Atlas.

The challenge of representing Rasmussen's rich glimpse into the interconnected lives of Inuinnait, language and land required us to do more than physically plot the information on a map. A second interface for the Fifth Thule Atlas was created to provide direct access to interactive and searchable PDF versions of Rasmussen and his colleagues' expedition reports. All Inuit knowledge featured throughout the text—whether in the form of songs, photos, place or person names, etc.—was isolated as discrete documents, which could be selected and explored in greater detail. These documents could be manually connected to other pieces of contextual information—a kayak gathered by the expedition, for example, linked with both the museum records and an elder interview about the same kayak recorded during our Denmark travels 100 years later—forming long chains of associated information that provide a fuller understanding of how the information is associated with Inuinnait lives. Every knowledge document entered into the Atlas is also accompanied by a community-driven report that allows users to add information, edit content, or contribute additional metadata (see Figure 6).

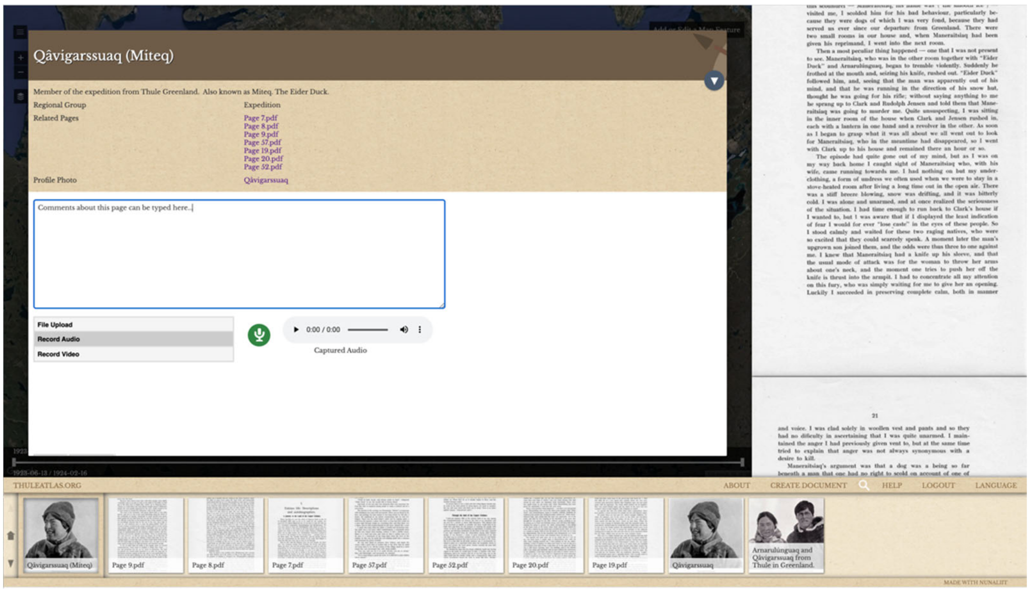

Figure 6. Functionality allows for users to link their own text, audio and video commentaries to specific expedition report pages or extracted Inuit knowledge documents.

The format of these contributions encompasses written text, audio and video recordings through the computer browser, or as additional files uploaded directly by a user. This parallel version of the Fifth Thule reports helps Inuinnait voice their own connections to this historical content and enhance/qualify its meaning in a more contemporary context. To date, this application has been used for purposes as diverse as community video uploads detailing the making and use of tools reconstructed from details and images in the expedition reports, to versions of Inuinnaqtun songs translated from the reports into contemporary Inuinnaqtun orthography [44].

The Atlas' third form of interface allows users to engage directly with subject categories of interest such as place names, people, oral traditions, photographs, maps, routes, and report pages. This interface exists as a series of visual 'tiles', which can be navigated according to the user's specific interests. As exemplified in Figure 7, a user interested in people encountered by the expedition can select the 'people' tile from the list of categories, and the tile row will re-populate to show all the individuals encountered on the expedition. When the desired person is selected, the tiles further re-populate with all documented information related to that particular person, including the place in which they were encountered, tools they made, and songs, stories and maps that they created.

Figure 7. This sequence of three tile selections illustrates how users can navigate various categories of knowledge according to their specific interests, and how each choice of tile will cause the row to repopulate with all documents related to the selection.

The Fifth Thule Atlas facilitates Inuinnait connections with historical knowledge by providing various access points to the information. It allows users to navigate documents in a spatialized manner for the easy location of relevant information. Most Inuinnait are aware of the areas occupied by their families prior to settlement and can locate them along the mapped expedition route to delve deeper into the knowledge these ancestors. It also encourages users to more critically navigate Inuinnait knowledge, as contained in expedition reports, gauging for themselves how the information may have been influenced by the motivations, agendas, and anthropological theories of the researchers that collected them. The functionality of commenting allows Inuinnait to begin redressing perceived distortions of cultural information by added to existing records, further shaping the ways in which they are accessed and navigated. This dialogue between the past and present ensures that the Inuinnaqtun knowledge being represented is not static or fixed, but an ever-changing landscape of association, learning and transfer.

3.3. The Inuinnait Knowledge Bank: Mapping Inuinnaqtun Connections in a Local and Global Context

A critical part of mapping the connections between contemporary populations and a broader Inuinnaqtun ecosystem is ensuring that the Inuit knowledge detailing those connections is accessible to as many Inuinnait as possible. As generations of Inuinnait grow more distant from traditional lifeways, there is an increasing reliance on secondary sources for the recovery of cultural knowledge that eludes collective memory, and even the Arctic itself, through storage in museums, archives and memory institutions around the world. As demonstrated by the Fifth Thule Expedition, this includes images, material collections, and information sourced directly from Inuinnait and recorded in the relative permanence of fieldnotes and photographs. Based on the success of the Fifth Thule Atlas, we began to more deeply consider how the recovered collections can strengthen an Inuinnait ecosystem.

In 2019, we began re-developing the Nunaliit framework to fashion a customized collections management system to broaden engagement between Inuinnait and the dispersed records of their cultural knowledge. Called the Inuinnait Knowledge Bank [45], this platform was designed to compile records from a vast number of museums and archives—

including PI/KHS' own digitized archives and donated private collections— with the ultimate goal of a centralized and searchable record existing for every digitally available Inuinnait object, photo and archives document around the world. The consolidation of geographically distributed knowledge and collections into a single digital portal that can be managed by Inuit supports local control of that knowledge and increases the possibilities to apply it according to Inuinnaqtun priorities. While still a work in progress, the Inuinnait Knowledge Bank is currently populated with roughly 3000 records and continues to grow in interesting new directions (see Figure 8).

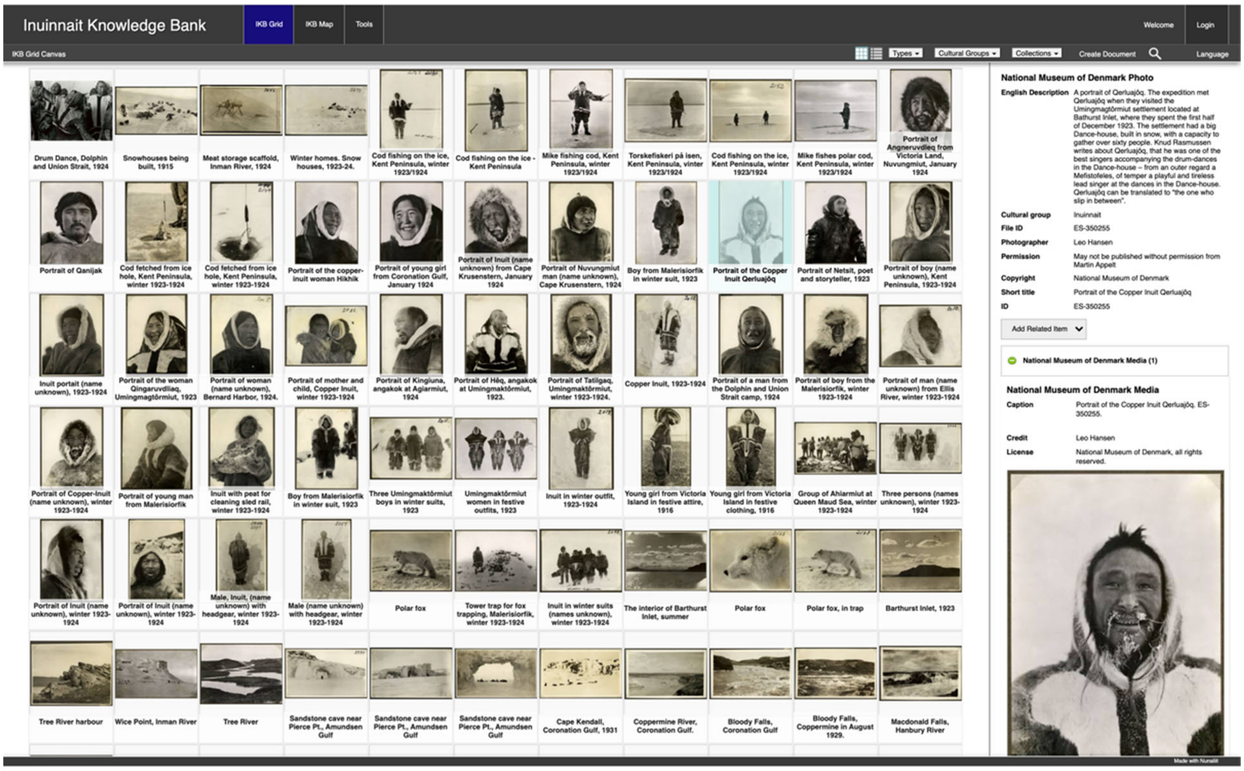

Figure 8. An overview of the records contained in the Inuinnait Knowledge Bank's collection management system. Institutional metadata for each record are displayed verbatim on the right-hand side of the screen.

The Knowledge Bank seeks to restore traditional pathways and priorities for collective knowledge management, leveraging the expertise of community members by providing them with three essential ingredients for knowledge-sharing: a way to access geographically dispersed records; a repository to store and manage local knowledge; and a digital framework to support traditional networks and relationships for knowledge sharing and transmission. These functions will be explored in turn.

Traditional content management systems follow a similar approach to western mapping in that each record is granted a fixed position in an overall collection. These records are defined through key attributes, and take their place alongside similar item categories, time periods or creations by specific artists or makers. In drawing together a vast number of different institutions' collections—each with their own key attributes—the Knowledge Bank seeks a more a emic cultural approach to organization and display. To begin, each record in the Inuinnait Knowledge Bank is populated with its holding institution's original language and metadata to ensure that the integrity of its existing documentation is maintained (see Figure 8). To build on this record, we applied the Fifth Thule Atlas' functionality for user-submitted text, audio and video comments, allowing the records to be further layered with Inuinnaqtun terminology and cultural content to broaden their context. This might entail uploading Inuinnaqtun language descriptions, metadata attributes deemed to be missing from the original record, or entirely novel material that a user feels should be referenced alongside the document or object (see Figure 9).

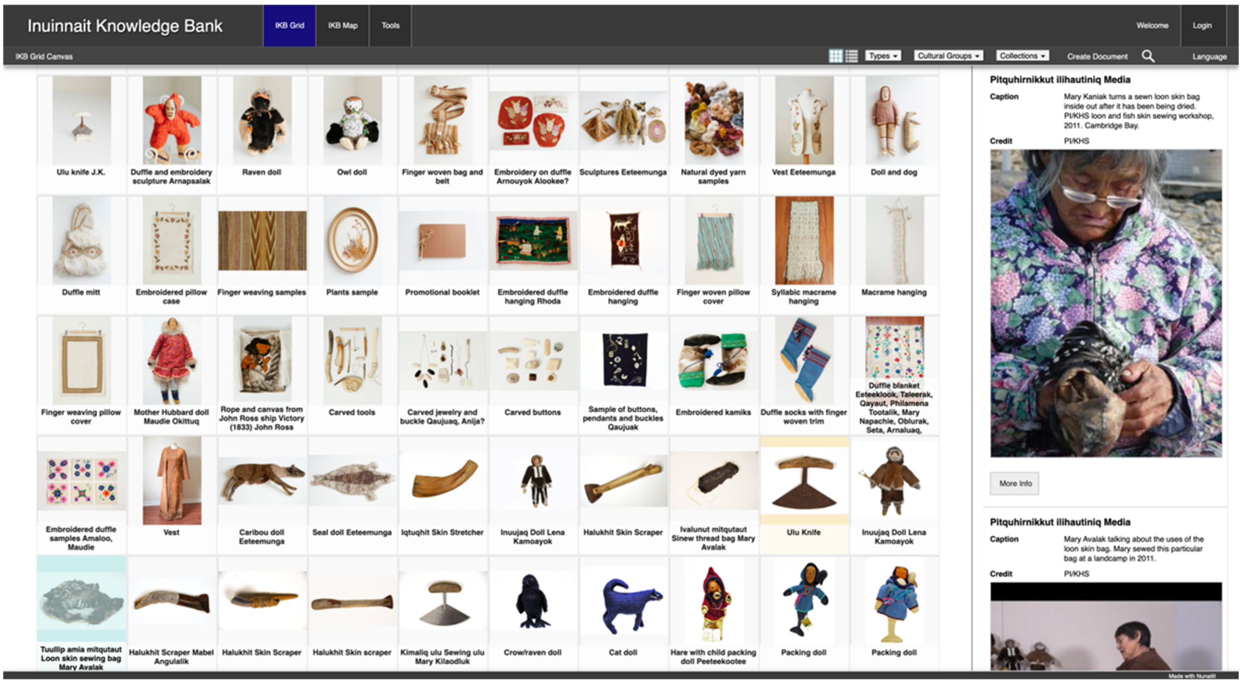

Figure 9. Community submitted records about a loon skin bag help to better position collections within a cultural context. The multiple videos seen to the right of the screen demonstrate a loon bag's manufacture techniques, Inuinnaqtun terminology, and a host of related information regarding everything from harvesting techniques for loons to cultural prescriptions for materials that should be carried within such a bag.

We are currently implementing improvements such as content tagging to allow an even broader audience to describe, categorize and highlight specific records, and share new language and information with one another. With this functionality, users can create and apply existing and unique categories to organize and search the content, highlight various relationships between individual digital records, and easily identify which collections/records are priorities for research or programming through sentiment tagging (i.e., liking). Through tagging, we hope to eventually implement a unique Inuit content licensing system, in which users can layer objects with descriptions of cultural protocols to engage with the collections in both digital and physical form.

It is our hope that the Inuinnait Knowledge Bank is adopted by northern communities as a central tool to access and contribute to the knowledge about Inuinnait lifeways both past and present. Despite this being a virtual and, in many ways, global endeavour through its reliance on the Internet and foreign collections, we have tried to ensure that the knowledge continues to reside in the Inuinnait region. The Inuinnait Knowledge Bank is currently housed in a dedicated server at the May Hakongak Cultural Centre in Cambridge Bay, as an early priority for our digital work was the ability to identify a specific location when asked by community members where the accumulated knowledge is being stored. Controlling the physical location of digital knowledge comes with additional benefits. A server linked to a wifi network can give local people faster and easier access to its contents. It also serves as a gateway for knowledge, allowing community members to decide whether information should remain exclusively within their community, be shared with neighbouring Inuinnait communities, or be available to everyone using the Internet. This tiered approach is key to fostering the development of local data ownership and sovereignty.

4. Discussion

Over the last 15 years, our Inuinnaqtun mapping program has introduced a novel language for information-sharing and storytelling among Inuinnait. This language draws from the age-old contexts of Inuit culture, but also lies squarely in newness and the digital realm. A major question underlying this work is whether or not this form of hybrid platform serves as an effective form of communication, in the sense that it can connect a once thriving cultural ecosystem with new generations of Inuit without first-hand experience of its full richness, sophistication and fluency. This question recalls the same conundrum of digital adaptation vs. assimilation brought up earlier in this paper.

The major strength of our digital mapping platforms lies in their ability to document and preserve the stories and cultural knowledge held by Inuinnait elders. The perspectives of individuals who spent their formative years on the land—immersed in the fluency of the Inuinnaqtun language and ecosystem—are both an increasingly limited resource and essential for carrying forward the intricate network of connections that once threaded the Inuinnait world into a coherent whole. These contemporary voices are further magnified through the addition of temporally deeper and geographically dispersed records, in the form of historical recordings, place names, photos, and material collections. Our platforms serve to define these remembrances and fragments of information, anchoring them in space and time so that the richness and depth of the Inuinnait presence in their region can be visualized and, in many cases, directly heard. When considered as maps, they illustrate the coverage of Inuinnait knowledge: a topography of convergences between people, land, and language.

A return to Inuinnait conventions of mapping, however, highlights the need for a very different form of cartography. Traditionally, Inuit maps were guided by first-hand experience, encounter, and the stories that these create. They detailed a personal journey from the vantage of that individual. It is a very different feeling to be physically present in an Arctic landscape than to engage with it on a screen; the same is true for the handling of material objects and collections [46]. As much of the world has discovered during COVID-19 and the shift to virtual meetings, a similar rule applies to our relationships with other people. Something is always lost with remove. To re-quote Renee Fossett on the performative nature of Inuit maps [14] (p. 75), is it possible to also think about the platforms we have produced as "nothing more than incidental by-products of the oral teaching and learning process"? If so, what does this process entail?

This final section of our paper briefly considers the activities surrounding the creation and usage of our mapping platforms by Inuinnait as the key ingredient for their proposed purpose of knowledge transfer and mending the Inuinnaqtun ecosystem. We will begin with the land. As discussed, landscape knowledge is traditionally passed on through mentorship by the elder members of a society through activities and the recounting of oral tradition. The mentee accordingly builds their own landscape ontology by integrating this knowledge while practicing/gaining their own experience in that environment. For a digital platform to accurately reflect this relationship, the encounters it provides with the land must be as real as possible. While we have used photospheres to augment landscape visualization, they do little to capture the full sensory and physical immersion that would traditionally accompany learning in, and from, a place. The critical element of communicating connectivity between places is also missing—of understanding an area not as an individual location, but as one part of larger network of places. To better align our platforms with these cultural understandings of place, we ultimately need to move them offline. We continue to look at the ways in which land knowledge within the Atlases could be integrated with GPS and inReach technologies as a way for users to access and contribute to digital content about locations while being physically present.

Fluency of language is a similar issue. Like land, language does not exist as a series of isolated points or words. It is dynamic, highly fluid and context-specific. Our platforms have targeted the accuracy of language through spoken-word functionality, and the ability of users to build upon historical fieldnotes, collection records and institutional metadata with Inuinnaqtun equivalents. We have introduced videos and audio transcripts created in the Inuinnaqtun language as supporting documentation for digital records. However, in order to thrive, the Inuinnaqtun language needs to transcend the screen and enter daily use and application. This has become our new focus for the platform. In 2018, PI/KHS began a pilot program in conjunction with its Fifth Thule Expedition Atlas to translate the Inuinnaqtun recorded in Knud Rasmussen's 'Intellectual Culture of the Copper Eskimos' [7] into a more accessible script. Ramussen employed a personalized orthography based on Western Greenlandic, which made the Inuinnaqtun terms he recorded all but unreadable to Inuinnait. A team of language experts across the Inuinnait communities was organized to begin extracting and translating Rasmussen's script, transcribing Inuinnaqtun songs and stories [44], and create terminology for entry into a separate Nunaliit-based platform designed as virtual Inuinnaqtun lexicon [47]. The importance of this translation work for the Inuinnaqtun ecosystem lies in the fact that it put language back into circulation; old songs were re-sung during drum dances, past stories were made new through their retelling, and terminology was mined for technical nuance to enhance the accuracy and scope of current conversations. This provides a strong example of how our mapping platforms can serve as a resource to connect speakers and resituate language in the real world rather than in digital space.

Last, but not least, we would like to consider if and how our platforms contribute to the strengthening of Inuinnaqtun relationships. In a fully functional Inuinnaqtun ecosystem, cultural skills and language are acquired through observation, listening and general proximity to experts: a highly social process of knowledge transfer. With the breakdown of intergenerational knowledge relationships and oral transmission, social interactions of this nature are harder to maintain. The mapping platforms we have developed excel in facilitating connections with individuals from the past. Through the Fifth Thule Atlas, users can gain access to stories, worldview and collections gathered from their ancestors 100 years ago. Video content enhancing the digital records in the Kitikmeot Place Names Atlas and Inuinnait Knowledge Bank also provide an element of social sharing and storytelling featuring more contemporary populations. Despite this, the interactive element of direct person-to-person engagement is still missing from the platform. Until this functionality develops, we capitalize on the mapping platforms as a common focus to bridge the interests and skillsets of different generations. This primarily occurs through data entry workshops partnering tech-saavy youth with local elders, a strengths-based approach which allows all participants to share and learn (see Figure 10).

Figure 10. A Cambridge Bay student is partnered with Mabel Etegik to assist with navigation and content entry in the Kitikmeot Place Names Atlas.

5. Conclusions

In seeking out new approaches for mapping and reconnecting the Inuinnaqtun ecosystem, it is important to recognize that our ambitions do not lie in revolutionizing the ways that Inunnait tell their stories, engage with one another, or learn from the land. These practices have been honed for centuries and have no room for improvement. The ultimate aim of this work is to widen the pool of content for future listeners and learners; to broaden the perspective of new generations with the stories of the old. While real-world experience and engagement remain the best ways for Inuinnait to understand and repair the intricate connections of their culture's ecosystem, should these mechanisms fail due to the widening gaps between generations, the pressures accompanying urban settlement, and the balance of local and global identities, we believe that a carefully designed cartographic application can provide both a beneficial repository for Inuinnait knowledge and the common focus required to renew its circulation in daily life.

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Article

Mapping for Awareness of Indigenous Stories

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Abstract: Joseph Kerski has identified five converging global trends—geo-awareness, geo-enablement, geotechnologies, citizen science, and storytelling—which contribute to the increased relevance of geography for education and society. While these trends are discussed by Kerski in the context of the proliferating significance of geography in teaching and education, they also provide a useful lens for considering the increasing ubiquity of critical approaches to cartography both in general and in the context of teaching and education, where mapping can include participatory collaborations with individuals from a variety of knowledge communities and extend to the mapping of experiences, emotions, and Indigenous perspectives. In this paper, we consider these trends and related ideas such as Kerski's "geoliteracy" and metaliteracy in light of some relatively current examples and in light of the evolution of research and teaching linked with a series of interrelated map-based projects and courses that take a multidimensional approach to teaching and learning about the Residential Schools Legacy in Canada.

Keywords: mapping; reconciliation; indigenous; art; digital pedagogy; reflexivity; Cybercartography; GIAMedia; FOSS; intercultural literacy

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1. Introduction

Joseph Kerski has identified "five converging global trends—geo-awareness, geo-enablement, geotechnologies, citizen science, and storytelling—[which] have the potential to offer geography a world audience—attention from education and society that may be unprecedented in the history of the discipline" (2015, 14). While these trends are discussed by Kerski in the context of the proliferating significance of geography to teaching and education, they also provide a useful lens for considering the increasing ubiquity of critical approaches to cartography both in general and in the context of teaching and education. As a result of works in critical cartography, instead of being used solely as a tool for exerting authority over territory and people's understanding of it, mapping is increasingly being thought of in terms of contributing to human flourishing [1,2] through the enhancement of agency and the inclusion of multiple—often previously silenced or underattended to—perspectives and ways [3]. Characterized as a clan comprised of a multitude of interrelated families (for example, critical GIS; participatory mapping; and VGI or thematic areas such as art, journalism, and crisis mapping), critical cartography is correspondingly relevant in an increasing range of educational settings, with online approaches to cartography facing similar challenges and possibilities as other digital endeavors [4]. In this paper, we first present some examples from the literature that reflect the trends identified by Kerski in order to situate our discussion of the research and teaching linked to sketch mapping of Residential School survivor interviews, which occurred over a series of interrelated map-based projects in the context of an experience-based Master's course that involved a multidimensional approach to learning about the

Residential Schools Legacy in Canada, and to provide a basis for the discussion of related ideas such as "geoliteracy" and "metaliteracy" [5].

1.1. Education, Mapping, and the Five Converging Global Trends: Examples from the Literature

Kerski discusses geo-awareness in the context of increasing complexity, with global issues having local and individual impacts and public consciousness being consequently raised, where "[t]here is a heightened awareness that these issues affect individuals' everyday lives, that they are serious, and that they need to be solved [and] growing realization that they all occur somewhere, at multiple scales, with specific spatial distributions, patterns, and linkages; and with temporal and spatial components" (2015, p. 15). The need to understand complex issues and phenomena in terms of these aspects intimates the appropriateness of critical approaches to cartography as agents of not only geo-awareness but carto-awareness as well, where integrating geospatial technologies into geography lessons can enhance geographical and relational thinking in students in comparison with conventional lessons [6,7].

While cartography has conventionally been the language of geography and geographical education, the emergence of phenomena such as digital and web 2 mapping have expanded the cartography's relevance to education and research in other fields. In this regard, cartographic and place-based approaches to pedagogy are being used increasingly to broaden the previous approaches, including by adding an ethical dimension. For example, Laurie Rubel and Cynthia Nicol emphasized the benefits of mapping and placed-based approaches with their teaching math for the spatial justice approach [8], which included previous collaborations with teachers on Haida Gwaii in Canada's Pacific northwest coast to engage high school youths in exploring "themes of tree logging and food harvesting, emphasizing local and Indigenous perspectives" (p. 174), where math instructions were given important context and learning was given new purpose in terms of "considering socio-ecological issues around sustainability as it pertains to food production" (p. 174).

Kerski's "geo-enablement" is used to refer to the increasing trend of enabling digital technologies with geospatial characteristics and functionalities and contributing to areas such as "the internet of things" and "smart cities", while, at the same time, reflecting spatial inequities in terms of both geo-enablement rates and access to digital technologies in general [9]. With reference to increasing the public consciousness of the relevance of geotechnologies, Kerski notes the proliferating accessibility to "satellite imagery, digital maps, aerial photographs, 3D profiles, geodatabases, spatial statistics, and related tools, methods, and data [where today] millions of maps and satellite images are viewed hourly", as "digital maps are used in newscasts, web pages, videos, and news feeds [are] becoming among the most common type of 21st Century media" [9] (p. 16). This growing awareness of the relevance of spatial perspectives and geotechnologies to society in general is particularly relevant to education. For example, Huang and Liu's exploratory work in teaching history involved students visiting relevant sites and engaging with a mobile map learning environment to visualize historical events. This approach further explores the educational potential of the emerging world of geotechnology, enhances student learning experiences, and contributes to the further development of the mobile map learning environment [10].

Digital awareness and enablement are closely related to Kerski's geo-awareness and geo-enablement, as illustrated by Francis Harvey and Jennifer Kotting [11] with their combined "active learning" and a "scaffolding strategy" approach to digital pedagogy, which better enables digitally savvy undergraduate students who are not focused on becoming cartographic or GIS specialists to understand and engage meaningfully with cartography. Described as "digital natives", these students are equipped with skill sets that are readily adapted to new technologies and, in some cases, are already familiar to these learners who thrive in an "active learning" environment (Harvey and Kotting, 2011, p. 271). Instead of the traditional lecture followed by applied learning, which is consistent with the information acquisition view, a knowledge construction view sees "multimedia learning [as] a sense- making activity in which the learner seeks to build a coherent mental representation from the presented material. Unlike information—which is an objective commodity that can be moved from one mind to another—knowledge is personally constructed by the learner and cannot be delivered in exact form from one mind to another" [12] (p. 12). In line with this view, the scaffolding strategy employed by Harvey and Kotting is sensitive to diverse learning approaches and involves "organizing curricula and syllabi using concrete elements of support, such as surveys experiences, and assignments with intentional references to students' preconceptions and diverse knowledges" (Harvey and Kotting 2011, p. 272). Related features of their hybrid approach include a flexible approach to teaching, especially since technology is constantly changing.

O. Ripeka Mercier and Arama Rata (2017) discussed a similar approach in relation to place-based education in Indigenous contexts with their use of place-based assignments that included student engagement with a digital mapping tool and that aimed at enabling students to reconcile a Māori studies perspective with Western technology [13]. Seeking to put "our faces in our places" (Mercier and Rata 2017, p. 76), the authors describe digital mapping as a complementary tool for learning for both Māori and non-Māori students and identified four unique learning outcomes: diversifying learning, skills acquisition, peer sharing, and learning aspects of place, which, in turn, "[draw] out cultural and historical attitudes towards land" (Mercier and Rata 2017, p. 92).

According to Angelica Carvalho Di Maio [14], web-based digital cartography is important "for the construction of spatial reasoning, which leads to the understanding of power relations, [where] spatial thinking helps to structure problems, find answers and express solutions" (322). Di Maio (2015) acknowledges and makes room in her pedagogy for the prior digital knowledge and tools that students may have and bring to the classroom. Her approach uses digital technologies involving "the Internet, satellite imagery, and mapping" as tools for students and educators to "think spatially" and develop problem-solving skills through critically thinking about the "whys of "where" (p. 322). In addition to teaching skills for cartographic literacy, access to digital mapping tools and projects provide opportunities for situating learners in the places they live, connecting them through different scales to their communities, counties, states, nations, and the rest of the world by participating, informing, and contributing as map readers and then as map mapmakers (Di Maio 2015). At the same time, as Di Maio cautions, it is important to note that geotechnologies (GIS, GNSS, remote sensing techniques, etc.) are not in themselves solutions to problems. Instead, they are important aspects of processes related to mobilizing "new forms of knowledge and actions, especially in favor of citizenship" (2015, p. 323).

Kerski's discussion of citizen science centers on the general public or "sensor network" as the most significant component of the "internet of things" [9]. In addition to the people having increasing accessibility to geotechnologies, they are also becoming knowledge creators in geo-technological environments, providing ways to "ground truth" scientific, policy, and other forms of knowledge [15] and include "connecting with others through fitness apps, recommending products matching a person's purchasing history, and feeding individuals' current speed and location to a regional real-time traffic map so that motorists can avoid snarls [. . .] providing information about the planet as has never been gathered before" (Kerski, 2015, p. 16).

In educational contexts, many cases involving the integration of geotechnologies in a curriculum involve students cocreating knowledge as part of their learning process. For example, Dan Klooster, Nathan Strout, and David Smith [16] had students gather original data with unmanned aerial vehicles (UAV) in a trail mapping exercise for "GIS in the Jungle", a University of Redlands travel course in environmental education to Panama, in addition to interacting with "local guides and support staff, school kids and their families, indigenous leaders, and indigenous forest guards [to] learn about the history of deforestation in the valley" (Klooster et al., 2021, p. 4). According to the authors, the direct rainforest experiences and GIS projects "help[ed] students develop an understanding of nature's interlocking systems and the interdependence of life on Earth" in addition to providing "a platform for interacting with indigenous peoples struggling to defend their rainforest territory from colonist deforestation" (Klooster et al., 2021, p. 1).

Rachel Olson, Jeffrey Hackett, and Steven De Roy [17] discussed the representation of Indigenous knowledge (IK) through the mapping of spatial information, which has been taking place in Canada since the early 1970s (Olson et al., 2016, p. 348), where "[t]hese mapping initiatives continue to be primarily associated with traditional land-use (TLU) studies and have deep roots in participatory methods that include aspects of participatory geographic information systems (PGIS)" (Olson et al., 2016, p. 348). They recommend critical academic attention to TLU studies, which will impact how research is conducted, developed, and presented and is required in order to better resolve significant discrepancies between Indigenous knowledge and Western scientific knowledge. In this regard, the authors presented a methodological expansion of traditional land use data collection and documentation processes that incorporate digital tools to increase "the spatial data set in efficient and accessible ways that were previously unavailable in more traditional paper mapping processes" (Olson et al., 2016, p. 351). As the authors suggested, "a direct-to-digital methodology has the potential to address some of the tensions inherent in the integration of IK in geospatial technologies [. . .] in terms of how [they are] able to meet both Western Scientific quality indicators for spatial data, as well as address the proposed Indigenous indicators [which can] be viewed as a first step in the development of a critical cartographic literacy in relation to TLU studies" (Olson et al., 2016, p. 354).

While maps and mapping figure prominently in Kerski's [9] discussions of all trends, they are perhaps most prominent in his discussion of the trend toward storytelling, which notes the map's capacity to tell a story and the potential for "geographic tools, data, and multimedia on the web [to] expand the ability and audience for storytelling through maps [where any] person with a smartphone or computer can use maps to tell his or her story [. . .]. From Napoleon's march to this year's hurricanes, from China's new highways to where food originates, educators, students, researchers, and the public can create their own story maps, through the use of live web maps with text, video, audio, sketches, and photographs" (Kerski 2015, p. 16). Reflecting on the student perspective, Teresa Iturrioz et al. [18] reported on the nature and benefits of their end-of-degree project in Geomatics Engineering to create the Black Death Atlas, which includes a series of eight interactive story maps telling stories of "the causes and consequences of the Black Death spreading across Europe" (2016, p. 225). An important motivation for the choice to engage students in researching this phenomenon was the gap in the existing resources for teaching in a multidimensional manner about the consequences of the Black Death for medieval European society, where extant digital maps did not accurately represent the expansion of the epidemic. Story mapping was selected as the approach that could best present the quantitative data with qualitative narrative elements (for example, representing the chronology of events with a timeline slider). Using CartoDB and Odyssey, they created a total of "eight interactive maps, considering the animation, symbology and data planes, providing each map the features and controls needed from proper exploration" (Iturrioz et al., 2016, p. 229). Their findings supported this kind of interactive atlas as an effective pedagogical tool, especially insofar as it involved students in the critical cocreation of knowledge.

In addition to their usefulness *for* telling stories, digital mapping approaches and technologies are also beneficial for teaching and learning *about* stories. Describing his work as "literary cartography", Daniel Leisawitz described the Orlando Furioso Atlas, a digital humanities project that involved research assistants in the creation of interactive maps to "translate cartographically" Ludovico Ariosto's sixteenth century narrative poem, the Orlando Furioso [19]. The Atlas is "based on two interactive carte, one literary [the poem's text] and one cartographic [a high-resolution digital scan of the famous 1507 world map by Martin Waldseemüller]" (Leisawitz, 2019, p. 146), and where "the characters' travels are traced onto [the] contemporaneous world map that portrays a worldview in flux, facilitating an understanding of the interaction of the real and the fantastic in the poetic text, in the cartographic text, and in readers' imaginations" (p. 144).

With a special focus on Indigenous perspectives, ways, and cartographies in a post-colonial context, Stephanie Pyne and Tilley Laskey [20] discussed the evolution of digital and participatory approaches to mapping with students around the story of Giacomo C. Beltrami, an atypical figure from the colonial period who travelled up the Mississippi River in 1823, met and engaged with Ojibwe and Dakota peoples, and acquired a series of gifts and other material artefacts, some of which are housed at the Museo Civico di Scienze Naturale in Bergamo, Italy. Over five years, in a Master's course in Intercultural Geography in the Management of Tourism Systems (PMTS) program at the University of Bergamo (Italy), Pyne and Laskey collaborated with Professor Federica Burini to integrate cybercartographic maps into the course curriculum, which included field trips to the museum near the university to "map" its North American (Beltrami) collection, engaging students in multimedia documentation at the museum from their own perspectives, and the collaborative creation of the pilot cybercartographic Beltrami Exhibition Map, which was actually the first cybercartographic map produced under the Residential Schools Land Memory Mapping Project (discussed below).

With its attention to different learning approaches and focus on collaborative approaches to digital atlas development, the cybercartographic approach pioneered by D. R. Fraser Taylor [21] reflects all of Kerski's [9] trends, where a "cybercartographic atlas is quite different from a conventional atlas, and is a metaphor for all kinds of qualitative and quantitative information linked by location" (Taylor, 2021, p. 93), where the "story" informed by collaborative relationships drives the map design and development and where the process is considered to be of equal significance to the product [21,22]. The evolution of Cybercartography has been written about extensively (see https://gcrc.carleton.ca/index.html?module=module.gcrcatlas_publications, (accessed on 1 April 2022)), as has its roots in Fraser Taylor's early development geography work in Kenya [3,4,23], where Taylor mobilized the community for the ground mapping exercises to better inform development policies and provide alternatives to top-down approaches. Since the introduction of the concept of Cybercartography in 1997, both the theory and practice of Cybercartography have evolved as the result of interactions with Indigenous communities, researchers, students, and others [21,24,25]. Reflecting on the nature of cybercartographic atlas projects since 2003, Taylor emphasized the importance of viewing the capacity to map as a basic human instinct and means of telling stories [26] and redefined Cybercartography as

> *"a complex, holistic, user-centered process which applies location-based technologies to the analysis of topics of interest to society, and the presentation of the results in innovative ways through cybercartographic atlases [where a] cybercartographic atlas is a metaphor for all kinds of qualitative and quantitative information linked by location and displayed in innovative, interactive, multimodal and multisensory formats. Cybercartographic atlases permit user communities to tell their own stories. Both mapping and storytelling are basic human instincts and are a central part of the holistic nature of Cybercartography. The process of creating these atlases is as equally important as the atlas as product"* (Taylor, 2019, pp. 20–21).

Cybercartographic atlases have been developed and used in a variety of educational contexts, including formal classroom settings, and are geared toward a broad audience that includes a wide range of users [27]. In addition, Cybercartography focuses on atlas development, which includes attention to individual maps, yet in a broader narrative framework that reflects multidimensional understanding [3], in addition to a commitment to FOSS, with the ongoing development of the Nunaliit software framework [28] (https://nunaliit.org/, (accessed on 1 April 2022)).

Highlighting important issues related to storytelling and digital mapping with Indigenous peoples, Mark Palmer [29] observed that mapmaking in North America has been characterized by encounters, exchanges, and translations between Indigenous and Euro-

Americans and that despite the dichotomies that have been constructed between Western scientific and Indigenous traditional in academic fields, "the boundaries between geographic knowledge systems have always been fuzzy and crossable, like ethno-cartography and counter-mapping in Alaska and Canada and GIS processes controlled more by government institutions in the 'lower 48' US states" (2012, p. 81). Bearing this observation in mind, Palmer proposed a new model, indigital geographic information networks (iGIN), "to describe the heterogeneous processes of encounters, exchanges, and translations—merging Indigenous, scientific, and digital technologies in inclusive forms of technoscience" (2012, p. 81).

In collaboration with his father, a professor of linguistics anthropology and fluent speaker of Kiowa, Palmer explored "the ways in which GIS can be incorporated into the study of Kiowa geography and storyscapes" (2012, p. 85). Acknowledging that additional research is necessary, Palmer is nevertheless optimistic about the significant potential for the digital technologies that he incorporates into his research to support multiple applications, including language revitalization, and geographic knowledge networks (Palmer 2012, p. 87). Building on this work, Palmer et al. [30] reintroduced indigital frameworks as "the creative merging of Indigenous knowledge systems with digital technologies" (Palmer et al., 2021, p. 3) and discussed the importance of digital devices and tools as means to engage with historical maps in undergraduate geography curriculum through "processes associated with the bridging of a historical Kiowa map with computerized geographic information systems (GIS)" (Palmer et al., 2021, p. 2). Digitized historical maps provide a starting point for [indigital] conversations, encouraging the development of reciprocal theories and applications that support dialogue between various groups. The process of making analog materials available for educational purposes is happening in many different contexts; however, in relation to Indigenous materials, the authors propose that indigital frameworks can function as "a heuristic for engaging with and combining Indigenous and Western knowledge systems" (Palmer et al., 2021, p. 2), which have historically been separated but could instead be brought together through active comparisons between the two.

1.2. Context and Background: The Canadian Residential Schools Legacy, Reconciliation, and Mapping

Although intercultural reconciliation with respect to the Residential Schools Legacy in Canada is the main context for the interrelated research and teaching discussed below, this context and the legacy itself are linked to broader reconciliation contexts, where there is a need for reconciliation not only between peoples but also between people and the land. Perhaps we will know when intercultural reconciliation has been achieved when incommensurabilities in cultural perspectives and knowledge are overcome and mutual understanding is the norm. Avoiding misappropriation and misrepresentation of Indigenous and other knowledges, perspectives, and ways is a significant reconciliation process, in addition to critical approaches to cartography that engage in activities such as (i) acknowledging the ongoing effects of a "colonial past" rife with Western rationalism and (ii) respecting and incorporating Indigenous approaches to knowledge, knowledge gathering, and interpretation [3,31].

The Canadian Residential Schools Legacy is a significant issue that can also be better understood through attention to various literacies, including geo-, carto-, digital, and cultural literacies. The momentum to raise awareness about many dimensions of this legacy has increased at least since 2015, when the Truth and Reconciliation Commission of Canada (2008–2015) released its Final Report [32], which contained 94 Calls to Action, with many focused on educational reform. According to the Commission, more than 150,000 First Nations, Métis, and Inuit children in Canada were forcibly taken to residential schools and denied many freedoms, including their right to speak their language, practice their culture, and communicate with family. Many former students have reported being victims of physical and/or sexual abuse, and several generations of survivors' descendants have been plagued with the negative intergenerational effects of their residential school experiences. Recently, new international attention was drawn to the issue of unmarked burial sites of children who attended Indian Residential Schools in Canada. Given the many dimensions of this legacy over time, reconciliation is a process that also takes time; involves many actors; and includes a shift toward decolonizing education policies to foster critical thinking skills, reflexivity, and ethical awareness [27].

Mapping Residential Schools themes using a cybercartographic approach first emerged in May 2011 during work on the Social Sciences and Humanities Research Council of Canada (SSHRC)-funded cybercartographic Lake Huron Treaty Atlas [3,31] as a function of emerging research partnerships and the idea that the Residential Schools' legacy represents an important dimension of ongoing treaty-based relationships. Further interest in and use of the map spurred some improvements and led to a further SSHRC grant for a 2015–2020 project to develop the cybercartographic Residential Schools Land Memory Atlas in addition to other project outputs—for example, the book *Cybercartography in a Reconciliation Community: Engaging Intersecting Perspectives* [22], which was written before project completion and reflects the reflexive and emergent nature of the project. The Residential Schools Land Memory Mapping Project (RSLMMP) provided an opportunity to build on previous works in several significant areas, including the involvement of a broader range of collaborators in both online and "on the ground" cybercartographic mapping and map enrichment reflecting a diverse range of contributors.

The project's relationship-focused approach involved reciprocity, engaging people in the production of cybercartographic maps, giving these maps back to communities for education and further input, and intersecting with community and academic partners by building on already established relationships and developing new research relationships—all aspects that are consistent with the cybercartographic atlas making approach. The project welcomed a broad base of contributors with distinct tasks and functions in collaborative processes related to cybercartographic map and atlas development and built on theoretical and methodological developments in critical cartography and Cybercartography, including taking a holistic approach that is consistent with Indigenous worldviews. Contributing to an enriched awareness of Residential Schools, their sites, and survivors' perspectives, the project has expanded the research, education, and community networks and increased awareness of the broad relevance of critical approaches to cartography. The work to develop this atlas incorporated both archival and experience-based knowledge of the schools, their sites, and survivors' stories. Individual map modules included the I Have a Right to Be Heard Map Module and the In the News Map Module, and significant new content is reflected in the Sketch Mapping component of the Residential Schools Map, which existed previously in the Lake Huron Treaty Atlas. The Residential Schools Land Memory Atlas (RSLMA; see https://residentialschoolsatlas.org/, (accessed on 1 April 2022)), which is the central output of the project, was launched on 21 June 2020, Canada's National Indigenous Peoples Day.

Since 2014, students and others have been involved in various collaborations in the development of various maps in the cybercartographic Residential Schools Land Memory Atlas [22,27,31]. In addition to engaging at least 10 graduate and undergraduate research assistants in a teaching and learning research environment [33], mapping exercises were incorporated into a variety of courses in ways that were linked to ongoing collaborative map research: first, in Cybercartography (which involves the Nunaliit software framework) and second, under the MEME (Multimedia Emergent mapping for Education) Project (which involves the GIAMedia software framework; see https://ggrmaps.utsc.utoronto.ca/giamedia_demo/, (accessed on 1 April 2022)). This included student contributions to ongoing research in a variety of ways, which added a new dimension of purpose for students, especially given the social and spatial justice aims of the research.

2. Methods

Research and teaching linked first to the Residential Schools Land Memory Mapping Project and second to the MEME (Multimedia Emergent Mapping for Education) Project have primarily employed critical cartographic, emergent, reflexive, and Indigenous methods to better understand the Canadian Residential Schools Legacy and contribute to intercultural reconciliation through collaborative and deep mapping processes aimed at "building awareness to bridge relationships" [3,22]. The emphasis on emergence and reflexivity at the research project and curriculum levels has, in turn, provided the basis for students to develop their own specific methods for geo-transcribing [3] survivor stories in their sketch mapping exercises. Although each project relies on a unique and developing software framework, they share common roots and reflect the trends of geo-awareness, geo-enablement, geotechnologies, citizen science, and storytelling described by Kerski [9], in addition to aiming for enhancements in geo-, meta-, and carto-literacies through reflexive and emergent approaches that aim to be consistent with Indigenous ways in the manner described by Palmer [29,30]. The following two subsections provide an overview of the reflexive and holistic ways that research and teaching intersect in mutually reinforcing ways to enhance student learning and the cocreation of knowledge in their reflective, broadly construed sketch mapping of Residential School survivor stories.

2.1. Integrating Research and Teaching in the Survivor Stories Sketch Mapping Exercise

Between January and April 2019, the first group of students engaged with sketch mapping exercises linked to the developing Residential Schools Land Memory Atlas in a Master's level experienced-based workshop course, INF1005H/1006H, at the Faculty of Information, University of Toronto, Canada, that focused on reconciliation initiatives by museums, archives, and heritage centers in relation to the Residential Schools Legacy [27,34]. With its focus on transdisciplinary collaborations with the Galleries, Libraries, Archives, and Museums (GLAM) sector, the Residential Schools Land Memory Mapping Project (RSLMMP) reflected various case studies in GLAM and introduced a complementary critical cartographic perspective. As such, it provided an ideal case study focus for the course, which also included a series of guest speakers and students engaging in written reflections on both the speakers' presentations and workshops and their individual work progress.

The student reflections for all class meetings were insightful and reflected an appreciation for the learning processes they were engaging in while also representing a valuable contribution to the RSLMMP. Between January and April 2020, the second group of students participated in the same course and sketch mapping exercise, both of which evolved in several ways, partly as a result of the lessons learned from the 2019 class. This course was completed several months before the June 2020 launch of the Residential Schools Land Memory Atlas and included student sketch mapping contributions. In addition, 85 students in a fourth year undergraduate Social Work and Indigenous Peoples course (SOWK 4000) at Carleton University engaged in sketch mapping and contributed content to the Residential Schools Land Memory Atlas.

Following the launch of the Atlas, between January 2021 and April 2021, the third group of students participated remotely in the same course, which included the same sketch mapping exercise, this time linked to the MEME Project, a new collaborative mapping project, which began to emerge in July 2020. While teaching continued to involve references to the Residential Schools Land Memory Atlas (for example, using it as a presentation tool in conjunction with visits from guest speakers who had been collaborators on the project), there was a shift in the map-based platform from Nunaliit to GIAMedia. The first map created under this project, "On the Land", emerged through work with and by students in INF1501H (Fall 2020) creating and mapping multimedia and written reflections in response to their surroundings [11,35,36]. Adapting lessons and mapping infrastructure established during this course and carrying forward a sketch mapping activity previously undertaken in conjunction with the Residential Schools Land Memory Mapping Project (based on the series of stories from the Legacy of Hope's "Where Are the Children Website"), GIAMedia was used to create the new "Mapping Survivors Stories" content management website, which also continued to develop through work with and by students in INF1005H and 1006H (Winter 2021) in consultation with Jane Hubbard (Education Director, Legacy of Hope Foundation (LHF; see https://legacyofhope.ca/, (accessed on 1 April 2022)). With reference primarily to the LHF's Survivor Stories page (see Figure 1), students were asked to review the interviews at their own pace until they had selected or adopted a story to focus their mapping exercise on. Each video is approximately one hour in duration and includes a soft interview approach with the same prompting questions posed to the participating survivors together with a written transcript.

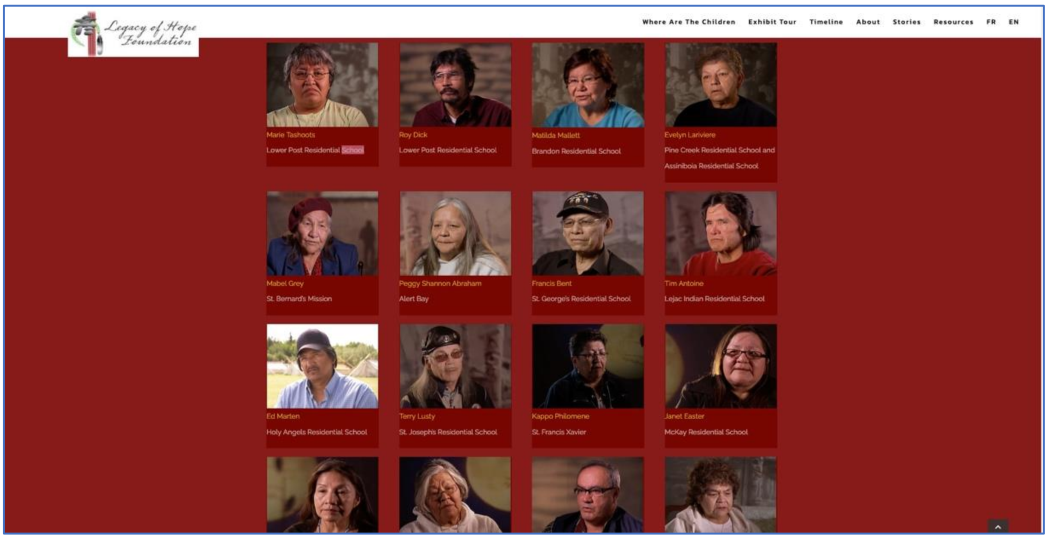


Figure 1. Screenshot of the Survivor Stories page of the Legacy of Hope's Where Are the Children Website showing thumbnail views of Residential Schools Survivors (The Survivor interviews are available on the stories page at: https://legacyofhope.ca/wherearethechildren/, (accessed on 1 April 2022)).

2.2. Zooming in on Some Details of the Sketch Mapping Exercise

Taking an iterative and holistic approach to research and teaching which methods can provide context for the results and vice versa makes it challenging to discuss methods in isolation. In addition, a full appreciation of sketch mapping exercise methods can only be attained with lived knowledge of the details presented and discussed in the classes involving sketch mapping exercises. This section is thus a mid-level discussion of the methods employed at the intersection of research and teaching with respect to student sketch mapping of survivor stories.

With a focus on relationships, including student relationship to the storyteller and working together to identify students' interests, visions, and commitments, the workshop approach to learning in these classes employed the same talk–templates–tradition approach taken in a previous work [4], which was consistent with the oral transmission of the knowledge methods advocated by Indigenous peoples and involved reflexivity and the emergence of new knowledge, understanding, and relationships. For example, the sketch mapping of survivors' stories assignment evolved in relation to adapting the course content developed by a previous instructor and continued to evolve in an iterative fashion as a function of the collaborative relationships and the creative output of research assistant Annita Parish and all students who participated in the exercise, in addition to research relationships that emerged in the collaborative writing and mapping processes for Chapter 3 in *Cybercartography in a Reconciliation Community*, "Mapping Jeff Thomas Mapping" ([27,34]).

As background for the mapping approach to Residential Schools reconciliation, students were taught about the social and spatial justice aims of the project, especially in terms of intercultural reconciliation in a transitional justice framework, in addition to being exposed to aspects of critical cartography and transdisciplinary research and other contextual information regarding the Residential Schools Legacy and Indigenous perspectives (via readings, videos, and links to map-based and other websites; this was also part of the orientation phases for the project research assistants). Students were encouraged to learn about this legacy through direct and reflective engagement with the storytellers, stories, and additional rich information provided by guest speakers who were also collaborators on various aspects of the RSLMMP and the MEME Project. This encouragement was reflected in the course curriculum, which included a choice between exercises linked to stories told by individual survivors in the sketch mapping exercise, and the news story summary and reflection mapping exercise, which revolved around stories reflecting the many dimensions of the Residential Schools Legacy (years two and three), while, in year one, students who did not choose the sketch mapping exercise conducted online research and mapped information related to the many truth and reconciliation projects funded under the Indian Residential Schools Settlement Agreement, which was conducted only in the 2019 class [27].

The collaborative approach to the research focused on the design and development of digital map-based interactive websites with partners and research assistants both informed and was informed by teaching and learning in a university classroom context, where teaching from a collaborative education mapping perspective emphasizes inclusivity and reciprocity and aims to create a welcoming teaching environment for students that is attentive to the differences in learning styles [27]. Moreover, the teaching method evolved in conjunction with the evolution of the research projects and involved the same two-pronged approach to integrating critical academic and Indigenous perspectives that was developed in the projects to develop the cybercartographic Lake Huron Treaty Atlas [3,31], in addition to an arational talk–templates–tradition approach to iterative processes in the method development [3,4,37], combined with emergence and reflexivity, where "reflexivity" can be considered "a philosophy, a research method or a technique" [38] (p. 984). Reflexive methods, including a focus on positionality and personal reflections, are of particular significance in both the atlas and map development research and related teaching, especially given the inclusivity of reconciliation with respect to the Residential Schools Legacy, which can be seen from institutional to personal spheres [27].

A modeling approach to sketch mapping was employed in an effort to provide gentle guidance while leaving room for individual expression and creativity. It is in this regard that methods can also be viewed as results and that the notion of taking an iterative approach is relevant. For example, for the first group of students who participated in the exercise (2019 class), the initial models included those provided by RSLMMP research assistant Annita Parish and a paper by Brenda Wastasecoot [39], "Nikis Memory Map: A Cree Girl Speaks from the Past" (which was an item in the previous instructor's resources) that includes a sketched memory map of her childhood home. As the course continued over the following two years, students had progressively more sketch mapping examples from previous students to consider, and the output was generally categorized in the following three categories: analog drawing, digital drawing, and mixed media. Additionally, given the short six-class duration of the course, students were reminded that they were doing a sample exploratory exercise that should involve witnessing their survivor's entire interview yet only producing a sample of reflections and salient survivor memories in their sketch map output. In this regard, instruction combined the idea of learning from models with advice for students to retain their positionality and their empathy for the storytellers. In addition, a broad approach to both "sketch" and "mapping" was emphasized, such that each student had plenty of scope to develop their own customized approach and understood that the exercise was more about establishing a relationship with the storyteller through their work rather than being about creating a finished product or telling someone else's story.

In general, the following ideas or aspects were important to the sketch mapping methods:

1. Taking time to review and choose/adopt a story;
2. Tracking sketch mapping process, including working notes;
3. Selecting memories that resonate;
4. Portraying geography of story;
5. Written map interpretation/reflection;
6. Witnessing, yet going beyond and involving reciprocity in terms of giving back by sharing impressions, lessons learned, aspects of process;
7. Reflecting courage and respect, among other Seven Grandfathers Teachings.

Although reflexivity was prominent in many ways during the workshop course, it was especially prominent in the sketch mapping exercise for which the sketch mapping processes described above comprised part one. Part two involved students either providing permission to upload digitized sketch mapping output to the Residential Schools Land Memory Atlas (for years one and two) or students directly uploading their sketch mapping output to their class GIAMedia map-based site (for year three). While both platforms can be used as teaching tools for both knowledge dissemination and knowledge creation, there are some important differences that influenced some of the methodological specifics. In all classes, guest speakers talked about their involvement in Residential Schools reconciliation initiatives, and teaching included talk of reflexivity, with emphasis on the process. It is also important to note that individual discussions and consultations between teacher and students took place in both in-person and remote contexts in relation to sketch mapping approaches and ideas.

3. Results: Student Output as a Function of Research and Teaching

The following two subsections present a small subset of results from the new awareness-building digital pedagogical mapping methods that are developing with the sketch mapping of the stories of the residential school survivors from the Legacy of Hope's Where Are the Children website. These results comprise a sketch of the iterative, emergent, and flexible nature of the reflexive mapping exercises that have been developing at the intersection of research and teaching over two projects: The RSLLMP and the MEME Project. Focusing on the output of several authors of this paper (Annita, Peter, and Shawn) provides an alternative venue to present their work in addition to their presence in the map-based content management websites discussed in this paper.

3.1. Sketch Mapping Survivor Stories for a Cybercartographic Atlas

As stated above, there is a holistic relationship between the methods and results in this work, such that the results feed back into the methods, becoming models for the creation of future results. In this regard, all of the sketch maps produced by previous students who consented to publishing their works in the Residential Schools Land Memory Atlas reflect their unique positionalities while providing models for subsequent students to inform their approaches. While the students followed the same general method, each student inevitably generated unique approaches as a function of their individual characteristics and the characters of the survivors whose stories they were mapping.

Work with Annita Parish on the sketch mapping involved much devotion and time in terms of the discussion and review of Annita's initial sketch maps, which were, in turn, used as the initial models for the students to refer to in the development of their own unique approaches. Annita spent months reflectively and reflexively sketch mapping the stories of the survivors who attended Lejac Residential School while in continual dialogue with Stephanie (as both lead researcher and course instructor). This work progressed in an iterative fashion, explored a variety of approaches, and requires a dedicated paper to present in sufficient detail. The sketch mapping by Annita in Figure 2 shows thumbnail views of some of her work on the sketch mapping of her salient and geographical impressions of the story of Alfred Solonas, a survivor who went to Lejac Indian Residential

School in British Columbia, while Figure 3 illustrates a full view of the thumbnail for a photo of the portions of Annita's sketch mapping book, which presents both the results and exploratory processes.

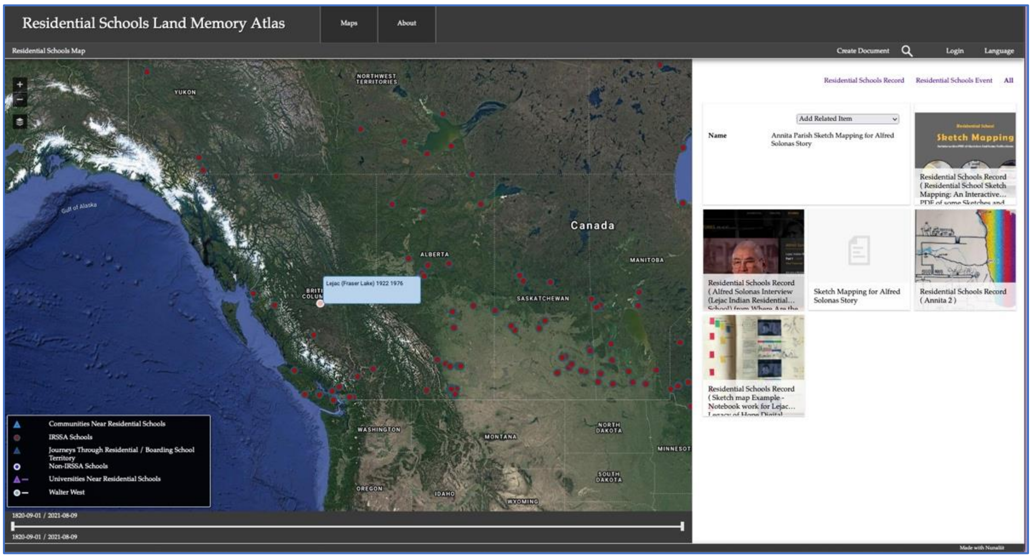


Figure 2. Screenshot of the Residential Schools Map of the Residential Schools Land Memory Atlas, showing thumbnail views of the sketch mapping by Annita Parish in relation to the story of Alfred Solonas in the side panel and the location for Lejac (Fraser Lake) Residential School in the center map panel (Available online: https://residentialschoolsatlas.org/index.html?module=module.residential_schools#eyJ0IjoieCIsImkiOiJiMzBkMjVkMTg2MDdjM2ZmNWJmOTcwZTQzNDNjODBkNSIsInMiOjE2NDQ3Njc2NDYzOTZ9, (accessed on 1 April 2022)).

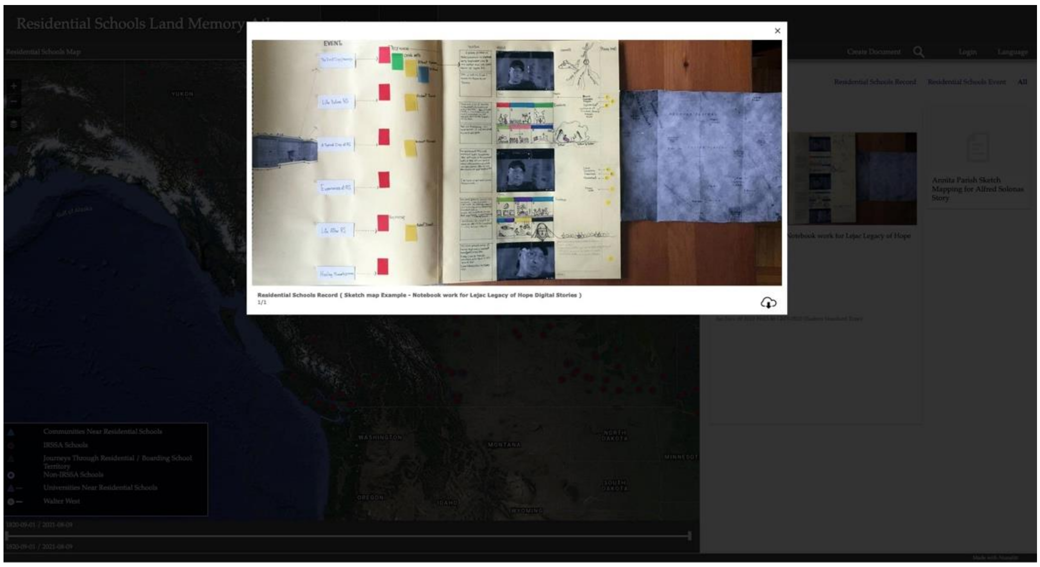


Figure 3. Screenshot of the Residential Schools Map of the Residential Schools Land Memory Atlas, showing a full view of the sketch mapping work by Annita Parish (Available online: https://residentialschoolsatlas.org/index.html?module=module.residential_schools#eyJ0IjoieCIsImkiOiJkZGQ4NjM1NDJjZjExMDE5YzM2MDRhNzc2NzYzNTA2MSIsInMiOjE2NDQ4NjQ2OTA5MzV9, (accessed on 1 April 2022)).

Most of the sketch mapping—especially in year one—involved analog drawing that was later digitized and added to the Atlas to display on the Residential Schools Map. However, with an emphasis on positionality and encouraging students to "come into a relationship" with the storytelling through their sketch mapping, digital and mixed media approaches also began to emerge over the three years of classes. The incredible degree of variation while maintaining common themes makes each student example worthy of presentation, and consequently, we decided to present some examples created by several authors of this paper. The Residential Schools Map is the best place to review the years one and two sketch mapping results, which can be accessed in a variety of ways, one simple way being to search "sketch" to produce a series of thumbnail results in the map's side panel (see Figure 4) (Since the Atlas organizes documents via relations, it is necessary to click on the related documents to a selected document, one of which is the place document. This document includes a "find on map" feature, which, if clicked on, will identify a point on the Residential Schools Map for the residential school attended by the survivor whose story is being sketch mapped. In addition, it is easier to view results on the map if the overlay for IRSSA schools is the only overlay being viewed).

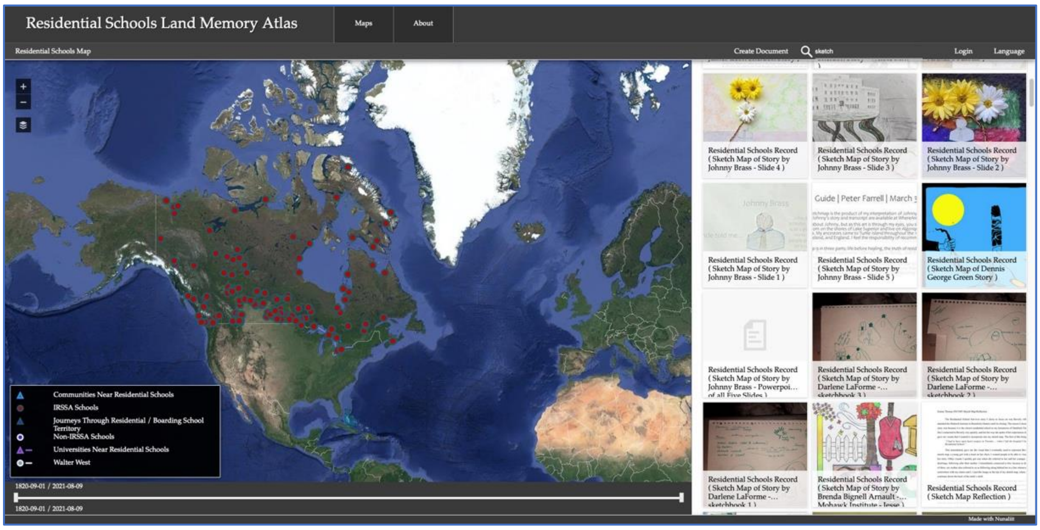


Figure 4. Screenshot of Residential Schools Map of the Residential Schools Land Memory Atlas, showing thumbnail views of the student sketch mapping output in the side panel and the locations for the schools identified in the Indian Residential Schools Settlement Agreement (IRSSA; see https://www.rcaanc-cirnac.gc.ca/eng/1100100015576/1571581687074, (accessed on 27 April 2022)) in the center map panel.

Although most examples are primarily analog drawing, sketching, or painting, there has nevertheless been plenty of diversity in the approaches, including mixed media, performative examples, and digital examples of many varieties. This diversity reflects an emphasis on positionality, which—in a positive light—includes a focus on the awareness of our own individual perspectives, gifts, and abilities. Sketch maps included a variety of features, with many profiling quotes from the survivor stories that resonated with them and/or reflected certain iconic memories of experiences, for example, journey to school for the first time, a typical day at school, life after residential school, and memories of home, with part of this consistency being due to a similar soft interview approach taken by the LHF in the survivor interviews. In addition, many students included excellent comments on their positionality and mapping processes. For example, Peter Farrell, a student from the second year of this class, chose a mixed media approach for his sketch mapping of Johnny Brass's story and included an interpretative guide (see Figures 5 and 6).

Peter's mapping approach reflects a concern with positionality and his awareness of the sacredness of Johnny's story. A closer examination of Peter's mapping work beyond the thumbnail view in Figure 5 is more apt in the online environment; yet, for the purposes of this paper, it is worth drawing attention here to the reflexive relationship between the written narrative and "graphic" expression in the sketch mapping exercise.

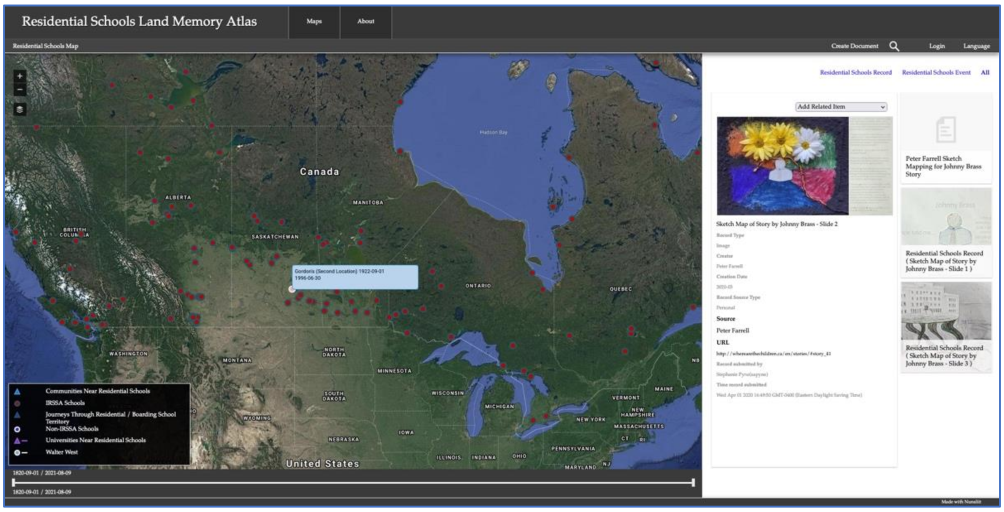


Figure 5. Screenshot of Residential Schools Map of the Residential Schools Land Memory Atlas, showing a document view and thumbnails of the sketch mapping by Peter Farrell for Johnny Brass's story in the side panel and the location for Gordon's Residential School in the center map panel (The media depicted in Figures 5 and 6 are available at: https://residentialschoolsatlas.org/index.html?module=module.residential_schools#eyJ0IjoieCIsImkiOiIxMzE4NGNkZTdjODViZGZkODA5MzdmZDkzZjU3M2M5ZCIsInMiOjE2NDQ4NjQ5MzgyODR9, (accessed on 1 April 2022)).

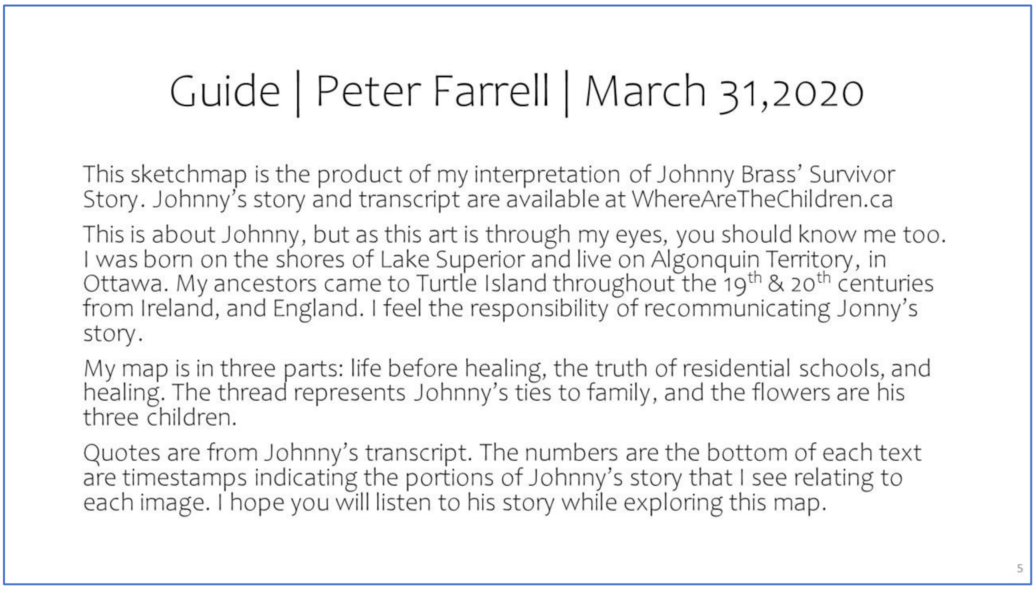


Figure 6. Interpretative map guide to Peter Farrell's sketch mapping of Johnny Brass's story.

In a weekly class reflection, Peter acknowledged the depth of the sketch mapping exercise that is no doubt linked to the power that maps and mapping processes have when it comes to engaging with stories, in addition to the sacredness of the stories themselves:

> *The sketch map assignment pushed me to engage more deeply with the stories of residential school survivors. This is the content at the core of the Truth and Reconciliation Commission process. While I am familiar with the TRC Calls to Action, have read novels, listened to stories of survivors, and facilitated learning experiences for others around residential schools, I have never attempted to interact so deeply with a story so as to interpret and recommunicate it to others. This was scary for me, and, despite my Grade 3 level art skills, I am proud of what I made. Thank you for setting a goal and encouraging me along the way.*

Several other students across all the years of the class took a mixed media (including mixing analog and digital) approach to their sketch mapping of a survivor's story, producing an array of interesting and thought- and feeling-provoking examples. Some of these are included in the RSLMA and others are in the class-specific Sketch Mapping Survivors Map discussed below. An excellent example of blending analog and digital modes and creating an artwork that can be read like a map is the sketch map of Dennis George Greene's story by Shawn Johnston, also a student from the second year of the class who was, at the same time, a practicing artist and a returning guest speaker to subsequent classes (see Figures 7 and 8).

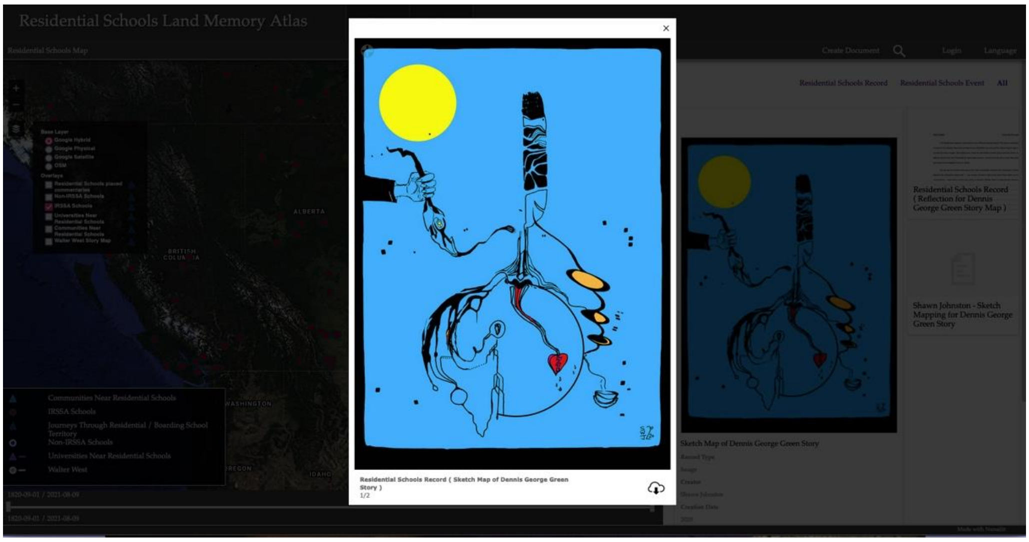


Figure 7. Screenshot of the Residential Schools Map of the Residential Schools Land Memory Atlas, showing a full view of Shawn Johnston's sketch mapping for the story of Dennis George Greene.

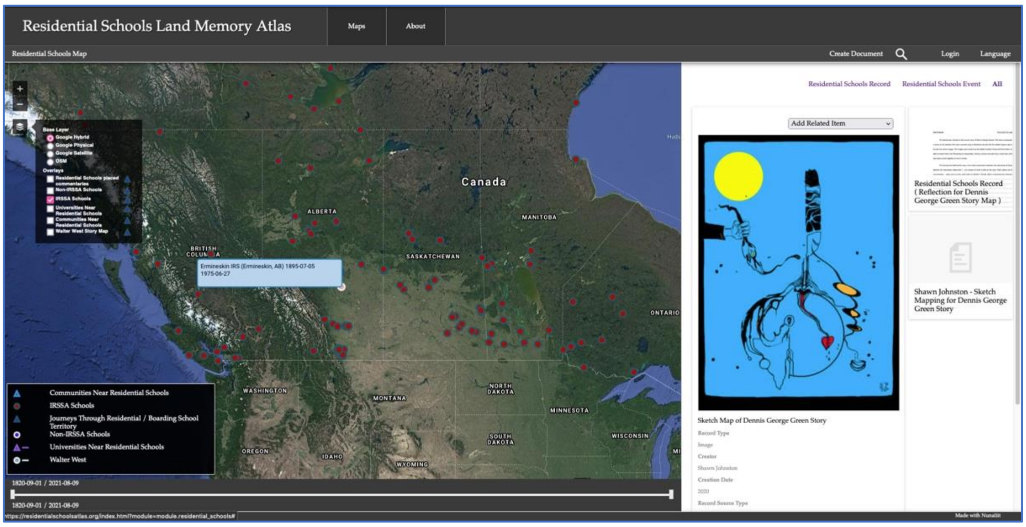


Figure 8. Screenshot of the Residential Schools Map of the Residential Schools Land Memory Atlas, showing document view and thumbnails of the sketch mapping by Shawn Johnston in the side panel and the location for the Ermineskin Residential School in the center map panel (Available online: https://residentialschoolsatlas.org/index.html?module=module.residential_schools#eyJ0IjoieCIsImkiOiIxMzE4NGNkZTdjODViZGZkODA5MzdmZDkzZjVhNTM4OCIsInMiOjE2NDQ4NjUwMzE0MDN9, (accessed on 1 April 2022)).

As a vital component of their sketch mapping output, Shawn included the following useful reflective interpretation of their map art in their contributions to the Residential Schools Land Memory Atlas:

> *This sketch map is based on the survivor story of Dennis George Greene. The map is composed of a series of ink sketches that were scanned using a Moleskine Journal and the Adobe Capture app and turned into vector images. The images were saved into the Adobe Creative Cloud and from there I was able to import them into Photoshop to reassemble, colorize, connect and edit into a visual story where each piece comes together to form a whole.*
>
> *The driving force behind this map is the initial conversation between the interviewer and Greene wherein the interviewer states " ... our version of truth is told on the land. That's where we find reconciliation ... when we're on the earth with our Mother" (00:38). When considering this statement, and after visiting and revisiting Greene's own discussions around fear of the unknown, silence, and the benefits of breaking the cycle, I imagined Greene's face imprinted upon or embedded within the ground of the earth. I saw him as one of the misdirected warriors he talked about. One that is arising from a slumber, moving toward or readying for battle, but not yet in battle. I visualized Greene's truth as a tree growing out of the opening of his mouth; telling the story of an individual who on one side is strong and resilient yet disconnected on the other; dislodged from the self. An individual who was unplugged from their community and their 'essence' by the Residential School system at an early age. The right side of the tree is half of a feather representing the strength that resides within Greene. It encompasses Greene's journey; his self-evolution and actualization and represents the strength revealed in the telling of his survivor story. The left side represents Greene as a 'seedling' being unplugged by the hand of the priests and nuns of the Ermineskin Residential School. The broken tree retains its prongs, suggesting that a re-connection is possible.*
>
> *The broken heart has multiple meanings. I felt there was a lot of sadness in this story. Greene references instances where he and the other children were deprived of love, touch (and trust in others), praise and approval from those in charge of the schools. Greene addresses the generational effects that have trickled down to the children and grandchildren as a result, perpetuating pre-existing patterns of loveless, broken and chaotic relationships.*
>
> *The seed attached to the mind behind the eye is a new growth that it is being cultivated by the subconscious and is developing upside down. The lines that stem from it suggest that it takes longer to break the surface as they are reaching towards (to break through) the other side of the earth. Hope exists in a small piece that has broken through the ground. This new growth must seek the sustenance of the sage bowl on the right. The smoke that comes from the sage bowl will then carry the new growth through the 3 moon phases and back into the feather (I realized afterwards that this is representative of episodes from season 3 of the Chilling Adventures of Sabrina where the Spellman family call to Hecate, invoking the power of the triple moon (maiden, mother, crone). This moon phase represents path of life cycle, as well as a cycle of the phases of Greene's self-reflection and realization.*
>
> *Finally, the tears from the broken heart send water to the bottom of the earth. The seed senses this and grows in that direction so that it can flourish. The black dots are the memory traces, the frequencies that hang in the air around us and the earth. It is unclear whether they are guides, or just various paths that lead back to the self.*

The emphasis on reflection and self-expression in the class was aided by a weekly brief reflection exercise, which, in the case of Shawn's final class reflection, included further reflections on their experiences sketch mapping the story of Dennis George Greene, including thoughts on the importance of a meta-literacy linking education to daily life and comments on how the course provided a reflexive context for the sketch mapping exercise:

> *I really enjoyed this workshop and have had such a rewarding experience hearing the guest speakers; watching videos related to Indigenous culture and customs; reading about the mapping process and exploring oral/visual storytelling. I enjoyed how you gave the class the ability to reflect on the information that we were receiving each week and felt that reflecting helped me to look within myself to establish meaningful connections with the course materials that could be carried forward into my education, artistic practice and everyday life. I have experienced a full range of emotions over the past six weeks, especially while hearing the various survivor stories on the Where are the children website. I am so thankful that I found the story that I ended up choosing. The experiences Greene recounted, the truths I heard him reveal and the wisdom that he has cultivated within himself has touched me very deeply.*

Another important aspect of the sketch mapping assignment was adding the students' work to the Residential Schools Map of the Residential Schools Land Memory Atlas, which was the most apt home for this body of work. Given the abundance of student work, and in light of previous challenges with a large number of people uploading content at the same time [20], the choice was made to involve a small team of RSLMMP research assistants and student volunteers for the task of adding this content to the atlas, in addition to other related tasks. More than 100 students participated in the sketch mapping exercise and gave permission for their work to be added to the Atlas.

3.2. A Class Map Website Approach to Residential Schools Reconciliation Education

Year three of the class followed the launch of the Residential Schools Land Memory Atlas and involved the use of a new GIAMedia framework and the creation of a map-based content management website devoted solely to the sketch mapping exercise. At the same time, this class-based website development was part of the open-ended digital pedagogies research project, the MEME (Multimedia Emergent Mapping for Education) Project, which is focused on the research and development of small group and class maps that are viewable only by the participants—in this case, the participating students. With attention to issues such as privacy and information ownership considerations, student contents in the Mapping Survivor Stories map are not currently available to the public, although consultations with student contributors are underway regarding the future of the map work. With this said, Annita Parish has given permission to share examples of her sketch mapping content in the Mapping Survivor Stories Map. Figures 9–11 show three different views of Annita's sketch mapping output for the story of Robert Tomah, with Figure 9 showing a thumbnail pop-up for Robert's memory of flying from home to begin his attendance at Lejac Residential School. The orange dot on the map signifies both the school's location and the existence of a document containing the sketch mapping content related to Robert's school-based memories.

Figure 10 shows a full document view of this school-based memory document, which includes a written reflection and multiple multimedia files, where the written reflection includes comments related to salient points of Roy's story and a summary of Annita's unique sketch mapping methods.

Figure 11 shows a full-screen view of one multimedia item from the school-based memory document and illustrates another possible view in the GIAMedia website.

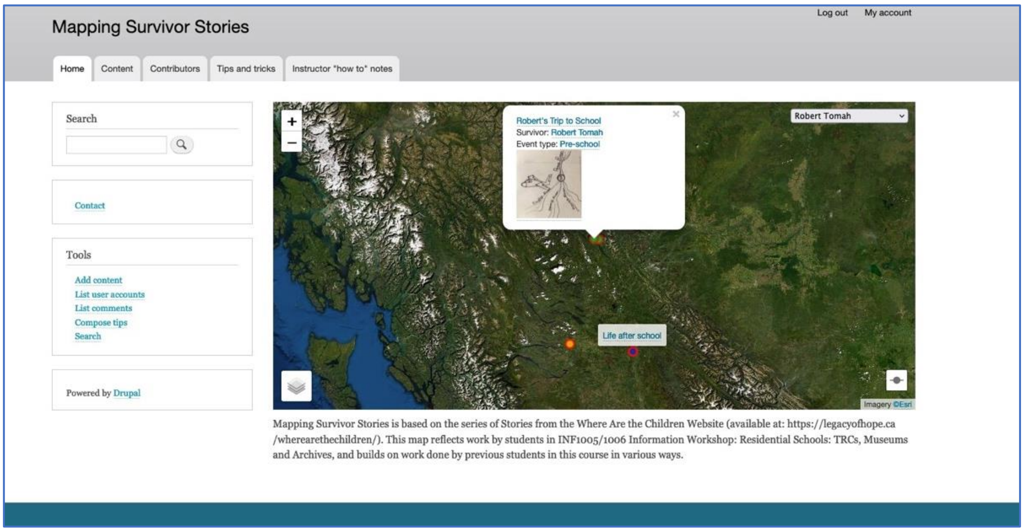
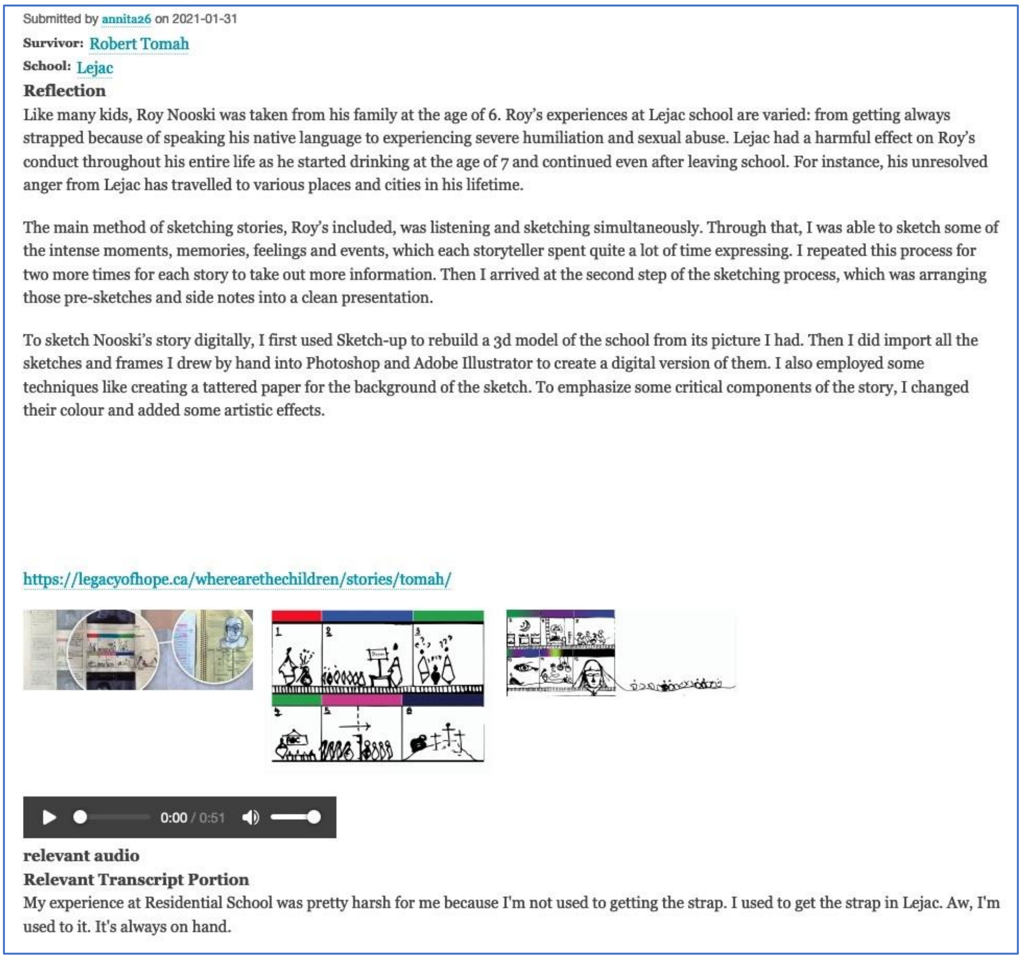


Figure 9. Screenshot of the Mapping Survivor Stories Map home page showing a thumbnail pop-up for Robert's memory of flying from home to begin attendance at Lejac Residential School.


Submitted by annita26 on 2021-01-31

Survivor: Robert Tomah

School: Lejac

Reflection

Like many kids, Roy Nooski was taken from his family at the age of 6. Roy's experiences at Lejac school are varied: from getting always strapped because of speaking his native language to experiencing severe humiliation and sexual abuse. Lejac had a harmful effect on Roy's conduct throughout his entire life as he started drinking at the age of 7 and continued even after leaving school. For instance, his unresolved anger from Lejac has travelled to various places and cities in his lifetime.

The main method of sketching stories, Roy's included, was listening and sketching simultaneously. Through that, I was able to sketch some of the intense moments, memories, feelings and events, which each storyteller spent quite a lot of time expressing. I repeated this process for two more times for each story to take out more information. Then I arrived at the second step of the sketching process, which was arranging those pre-sketches and side notes into a clean presentation.

To sketch Nooski's story digitally, I first used Sketch-up to rebuild a 3d model of the school from its picture I had. Then I did import all the sketches and frames I drew by hand into Photoshop and Adobe Illustrator to create a digital version of them. I also employed some techniques like creating a tattered paper for the background of the sketch. To emphasize some critical components of the story, I changed their colour and added some artistic effects.

https://legacyofhope.ca/wherearethechildren/stories/tomah/

0:00 / 0:51

relevant audio

Relevant Transcript Portion

My experience at Residential School was pretty harsh for me because I'm not used to getting the strap. I used to get the strap in Lejac. Aw, I'm used to it. It's always on hand.

Figure 10. Screenshot of the Mapping Survivor Stories Map showing a full document view.

Figure 11. Screenshot of the Mapping Survivor Stories Map showing a full-screen view.

4. Discussion

Concomitant with the five converging trends of geo-awareness, geo-enablement, geotechnologies, citizen science, and storytelling is the emergence of a "geoliterate population", which can increasingly make appropriate decisions through the assessment and use of geographic information [9]. Going beyond narrow views of "geoliteracy" that are based on a foundation of "spatial, area studies, man-land, and earth science [in addition to] movement, region, human-environment interaction, location, and place" (2015, p. 17), Kerski linked "geoliteracy" with the idea of an interconnected and multidimensional world and suggested that "geoliteracy" should refer more broadly to knowledge relating to "how our world works, is connected, how to make effective decisions, or interactions, interconnections, and implications" (2015, p. 17). A linked and perhaps broader concept that could be seen to incorporate "geoliteracy" is "metaliteracy" [5], a concept referring to the knowledge capacity across disciplinary and other domains.

Kerski described what he calls the three legs that form the stool of geoliteracy: (i) the core content (i.e., systems thinking); (ii) building skills to use geographic tools (with a focus on the geographic inquiry model, tackling difficult problems); and (iii) the geographic perspective (including spatial thinking and critical thinking), which no doubt interacts in a mutually reinforcing, holistic, and reflexive fashion. Appreciation for geoliteracy is reflected in the funding of various projects in the United States, and Kerski advocates for a push from educators, many of whom have readily incorporated geospatial tools to support student engagement and learning [9].

As is intimated by the variety of relatively recent examples from the literature provided in the introduction, digital cartography has been incorporated into the curriculum of a diverse array of disciplines (and inter-disciplines?), each with its own literacy. In this regard, Andrzej Rutkowski and Stacy Williams [5] discussed the importance of metaliteracy in the context of their work with students during an undergraduate writing course at USC Libraries, University of Southern California, Los Angeles, which aimed to nurture spatial thinking and metaliteracy by enhancing pedagogical resources beyond the library resources and by developing better search terms and research strategies [5]. Their strategy was to intentionally apply the existing Association of College and Research Libraries (ACRL) Framework for Information Literacy for Higher Education and to introduce multiple literacies by framing their assignments and final project around a spatial ethnography of a neighborhood (engaging with archival/primary source documents, in addition to adding their own secondary and tertiary source materials through research and compiling photographs and textual documents that were then mapped and shared on a digital platform). Going beyond educating students with respect to technical knowledge, they "wanted students to think more critically about data at the geographic level of a neighborhood and how it impacts people and communities" (Rutkowski and Williams, 2019, p. 222). They also “wanted a way to synthesize a set of writing assignments that would use archival material and lead to student published essays online that would be accessible through an interactive map” (Rutkowski and Williams, 2019, p. 222).

The concept of “metaliteracy”, as it appears in the ACRL Framework, was incorporated as a means of thinking about how the course was designed (using original digital materials, resulting in a collaborative digital project) and how the students would interact with a variety of technologies as producers, collaborators, and distributors. Students were encouraged to incorporate “self-awareness of place and how it impacts and creates knowledge” (Rutkowski and Williams, 2019, p. 222). This emphasis reflected an awareness of the spatial turn described by Edward Ayers [40], who proposed that, as we struggle to convey temporal and spatial data with text alone, digital mapping tools might actually be the most effective way to demonstrate certain kinds of large-scale changes (deep contingency) and complex patterns as they transform in space over time and explore the ways in which digital mapping tools can incorporate movements to convey time (and space), thus providing an engaging visualization to which the human brain responds favorably.

While the five emerging trends identified by Kerski may support the development of geo- and meta-literacies in the general population, incorporating critical approaches to digital cartographic pedagogies can only serve to enhance and push the boundaries of the possibilities in this regard through the complementary support of critical cartographic (or carto-) literacy, where carto-literacy can be seen to require a broad view of mapping that reflects the main trends in critical cartography, including challenging the conventional status quo assumptions about space by emphasizing deconstruction, reconstruction, or both [31,41–44] and favoring approaches that can be consistent with Indigenous perspectives and understanding. Examples of this are the rejection of binary distinctions and the preference for a performative approach to cartography advocated by Vincent Del Casino Jr and Stephen Hanna [45] and the emergent approach to mapping described by David Turnbull [37] and Robert Kitchin and Martin Dodge [46], in addition to emphasis on the reflexivity and reflexive methods [3,47]. As Margaret Pearce and Renee Pualani Louis [48] emphasized, when it comes to engaging with mapping in a way that involves Indigenous peoples, “[t]he problem that faces Indigenous peoples worldwide is to find a way to incorporate Western [geospatial technologies] and cartographic multimedia while minimizing the mistranslations, recolonizations, and assimilations of conventional technoscience” (Pearce and Louis, 2008, p. 123).

Critical cartographic literacy has been recommended, especially in cases involving Indigenous mapping and education, where it is important to be aware of the ways in which Western cartography is rooted in the same Cartesian–Newtonian epistemology that underpins the colonial worldview. Advocating a two-pronged approach, Jay Johnson, Renee Pualani Louis, and Albertus Pramono [49] discussed some related tensions and challenges: “To engage the technologies of Western cartography is to involve our communities and their knowledge systems with a science implicated in the European colonial endeavour and is a decision which should be made only after examining not only our past experiences of colonial mapping/surveying but also the long history of Western cartographic traditions” (Johnson et al., 2006, p. 82).

Engaging Free and Open-Source Software (FOSS) platforms in digital pedagogies involving mapping could provide a fruitful path forward in developing two-pronged approaches to curricula involving Indigenous Peoples and knowledge. In this regard, the sketch mapping exercises with university students that have been evolving over the past three years have been doing so in conjunction with two distinct but interrelated research projects, each involving the design and development of distinct FOSS platforms. Regardless of the platform and research project, all courses reflected a reconciliation context and involved the development of an environment for safe sharing and the fostering of initiative, in addition to involving much talk with students (especially in remote teaching). Additional shared aspects can be appreciated in terms of Kerski’s [9] pedagogical recommendations for promoting and supporting geoliteracy, which include the following: help students engage with the tools, engage the research community, promote civic engagement, tell stories with maps, and focus on change (2015, pp. 20–21). According to Kerski, "students who are well grounded in the spatial perspective through geography may be better able to use data on a variety of scales, in a variety of contexts, think systematically and holistically, and use quantitative and qualitative approaches to solve problems" (2015, p. 22), where engagement with spatial thinking, inquiry, and problem-based learning also aligns with education for activism (2015, p. 25). Both approaches include these aspects, each in different, yet related, ways.

While Kerski [9] made a series of relevant and useful recommendations for "[seizing] the opportunity [. . .] to actively promote the inclusion of geographic content knowledge, skills, and perspectives throughout education and society" (2015, p. 19), the example he provided made use of proprietary software. If we were to add to his well-considered recommendations, we would include a recommendation to employ FOSS in the map-based website design and development for pedagogical purposes. Referring to a variation of FOSS, Yu-Wei Lin and Matthijs den Besten [50] were particularly concerned with gender-based exclusions and barriers in FLOSS (free/libre open-source software) environments, where they understood FLOSS as "the result of many incremental innovations contributed by people located in different places around the world [. . .], which include[s] the freedoms to study, change, distribute and redistribute source code" (2019, p. 1018). They are part of a larger field of FOSS community engagement in justice-related thought, including issues related to responsibility, identity, inclusion, and motivation [51–54]. With FOSS as a central foundation for both RSLMMP and MEME, this means an enhanced awareness and engagement of students with "mapping platforms", which have intrinsic, in addition to instrumental, value; map-based pedagogical projects that use proprietary software tend to lean more towards a solely instrumental valuing of mapping platforms.

When it comes to recommendations for digital map-incorporating approaches into educational contexts involving Indigenous contents and themes, we further recommend reflexive and emergent approaches where increasing the skepticism of the neutral, objective "scientific gaze" has led an increasing number of social science practitioners and other scholars to adopt "a reflexive stance in which we recognize all social activity, including research itself, as an ongoing endogenous accomplishment" (Cunliffe, 2003, 983). Reflexivity is a dynamic and multidimensional concept that invites holistic, pan-disciplinary interpretation, and resisting reduction and binary opposition, "reflexivity" has a broad application at multiple scales. Perhaps at its most general level of applicability, "reflexivity" means 'to bend back upon oneself'" (Finlay and Gough, 2003, p. ix), which indicates a cyclical, as opposed to a linear, perspective. Linda Finlay and Brendan Gough [55] identified some of the main strands of the investigation involving reflexivity, including "the humanistic-phenomenological and psychoanalytic emphasis on self-knowledge, 'critical' traditions such as feminism, which prioritize socio-political positions, and social constructionist and 'postmodern' approaches, which attend to discourse and rhetoric in the production of research texts" (Finlay and Gough, 2003, p. 1). Although discourse on reflexivity may not be identical to Indigenous approaches, the concept is consistent with their holistic aspects.

According to Ruth Nicholls [56], "researchers need to engage with reflexive evaluation of collective and negotiated design, data collection and data analysis to consider inter-personal and collective dynamics during the research process" (2009, p. 117). Nicholls further recommended participatory and collaborative methodologies for research involving Indigenous peoples, a recommendation that could be extended to educational contexts, and advocated applying multiple layers of reflexivity in research involving Indigenous people, where "[a]dditional political and relational layers of reflexivity are essential to critically evaluate empowerment and participation by working 'the spaces between' through reflection about collaboration" (2009, p. 117) and where "[t]his reflexive work entails resisting essentialist positions while also recognising difference within a collective" (2009, p. 117). Linda Finlay and Brendan Gough [55] similarly grouped "reflexivity" into the three categories of personal reflexivity, reflexivity within relationships, and reflexivity through collaboration. Indeed, personal reflexivity, sometimes referred to in terms of positionality, is the most common meaning of reflexivity reflected in the theory and practice of everything from education and health studies to planning studies and virtually every form of ethnographic inquiry. This form of reflexivity is considered by some to be "a defining feature of human consciousness in a post-modern world" (Finlay and Gough 2003, p. 1). While Adital Ben-Ari and Guy Enosh [57] considered reflective processes in terms of both the "state of mind" and "active engagement" and identified four levels of reflection: "observation; informants' accounts; text deliberation; and contextualization and reconstruction", where "reflective processes may refer to deliberate awareness involving both a contemplative stance (state of mind) and intentional activity aimed at recognizing differentness and generating knowledge (active engagement)" (2009, p. 152).

New knowledge has emerged from reflexive practices, especially those that involve multiple modes, media, or formats [46,58]. Reflexive relationships abound: between theory and practice (e.g., relational space concepts), between mapping and GLAM, between analog and digital, and between students and survivors—going beyond witnessing and bringing themselves respectfully into the survivor's stories—via a critical cartographic and approach to sketch mapping that involves both reflection and reflexion. Focusing on a deep mapping approach provides a buffer and allows students to spend more time with interviews and to give back, to honor, and to learn from the survivors. The opportunity for students who were able to map their sketch mapping further in the GIAMedia Mapping Survivor Stories Map provided a good example of reflexivity, wherein students were able to actively further "map" their sketch mapping in a map-based website tailored to the exercise. Moreover, the emphasis on place—combined with the case study approach to Indigenous knowledge and stories taken in a course attended by students from many cultural backgrounds—hearkens to similar approaches referred to in this paper that bridge various forms of literacy through unifying and complementary mapping process and exercises (e.g., 13 and 14).

5. Conclusions

This paper has provided a glimpse into what has been cast as the methods and results for the purpose of complying with publication guidelines. It is worthy of note that earlier drafts of this article were structured quite differently, in more of a narrative storytelling format. With this said, the process of "reformatting" the paper has led to a new way of reflecting on the sketch mapping exercise in the context of digital pedagogies, two different map-based content management systems, and more. In relation to the various geo-trends and literacies that are emerging with increasing significance in this day and age, the sketch mapping exercise is helping to draw attention to the importance of intercultural literacy as both an end of geo-, carto-, and metaliteracy, in addition to being an important means toward reaching intercultural reconciliation. In this regard, there remain many additional details related to the research and teaching under both the Residential Schools Land Memory Mapping Project and the MEME Project, including other mapping exercises, comparisons between projects, and details related to individual student contributions.

It is admittedly a challenge to present the results of this evolving research in article format and even in map format, because of the complexity and volume of the outputs associated with the student contributions, which were all excellent, irrespective of artistic capacity. For this reason, many examples of student sketch mapping have been presented either in the Residential Schools Map of the Residential Schools Land Memory Atlas or in the Mapping Survivor Stories Map associated with the MEME Project, each of which involves unique navigation and view strategies, and both of which are perpetually in development and represent individual outputs that would involve a burdensome number of images and explanations in a single paper. Both the methods and the results reflect student geo-transcriptions [3] of survivor stories in a way that involves witnessing, honoring, learning from survivors, and paying attention to the place, in addition to exploring individual creativity and other aspects linked to the overall reconciliation objective: building awareness to bridge relationships. The examples presented in this paper give an indication of the depth of connection that is possible between students and Residential School survivors via the sketch mapping exercise.

Finally, it is worth noting that the production of this paper reflects many hours of distributed conversations on various themes, which underscores the significance of the process comprising the product with talk as the substance underlying the written word.

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