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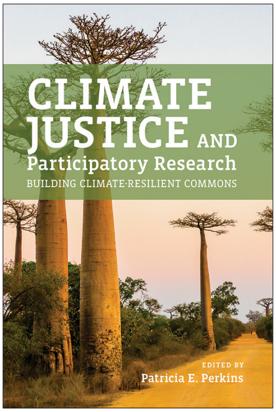

CLIMATE JUSTICE AND PARTICIPATORY RESEARCH: BUILDING CLIMATE-RESILIENT COMMONS

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Integrating Citizen Science Observations in Climate Mapping: Lessons from Coastal-Zone Geovisualization in Chilean Patagonia and the Brazilian Southeast

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Introduction

The effects of climate change have been observed on a global scale, especially in coastal areas. The Intergovernmental Panel on Climate Change (IPCC, 2022) emphasized the increase in frequency and magnitude of extreme events such as storms, floods, and heat waves, while studies have guided efforts to create climate-forecast models at different scales of analysis to identify the risks of these threats and to support mitigation and adaptation strategies.

Climate-prediction models are fundamental for representing possible impact trajectories on a regional scale. On the other hand, several studies also point to the need for climate change research to include local observations to contextualize the causes of impacts, in addition to expanding the scale of observations at the community level (David-Chavez & Gavin, 2018; Iwama et al., 2021; Reyes-García & Benyei, 2019; Savo et al., 2016).

Studies have shown that scientists are increasingly recognizing the relevance of Traditional and Local Knowledge (TLK) in providing observations for adaptation to the effects of climate change (García-del-Amo et al., 2020; Hill et al., 2020; Iwama et al., 2021; Nakashima et al., 2018; Reyes-García et al., 2019; Tengö et al., 2017) and global environmental change (Berkes, 2009; Fernández-Llamazares & Virtanen, 2020; Merçon et al., 2019). These studies identify the importance of participatory approaches in including local observations and understanding their appropriate contexts, scales, and ways to assess people's engagement in risk governance (Iwama et al., 2021); such participatory approaches can reduce impacts and risks overall.

Similarly, citizen science initiatives all over the world—understood as those scientific activities in which non-professional scientists participate (Kullenberg & Kasperowski, 2016; Bonney et al., 2014; Sauermann et al., 2020)—involve citizens and local communities in data-gathering processes for knowledge production, monitoring strategies, and cooperative governance.

Working with different knowledge systems (e.g., scientific knowledge and TLK) requires scientists and participants involved in citizen science initiatives to engage one another in more flexible, reflective, and diverse ways, because different kinds of knowledge and worldviews often clash. These efforts toward collaboration often show how the dialogue spaces created amidst such epistemological tensions can in turn create new narratives and ways of producing science that is more appropriate to the local context (Merçon et al., 2019; Tengö et al., 2021).

TLK can collaborate with scientific knowledge to co-produce new knowledge for disaster risk reduction (DRR) and climate justice. Where TLK interacts with scientific knowledge through citizen science monitoring programs or other participatory methods, local perceptions and knowledge of climate change and disaster risks can supplement poor baselines with data that scientists and communities would otherwise lack access to.

In this chapter we show how using action research—experiential, reflexive knowledge production leading to transformative change—and participatory geographic information systems (GIS) to record local observations on sea-level rise, floods, landslides, and coastal erosion produces socio-cultural responses to natural hazards and climate/environmental impacts. We held capacity-building workshops with local communities to produce their own maps using social cartography (collective mapping of socially important relationships, histories, and features based on the community's views about socio-environmental hazards, livelihoods, and natural resources), Quantum GIS, and Google Earth (for data geovisualization), and conducted interviews using mobile GPS (global positioning system) applications—e.g., Mobile Topographer, QField for QGIS, and Google Maps—to record the geographic coordinates of the information provided in the interviews.

Through our work with Mapuche Indigenous and artisanal fishers in Chiloé archipelago (Chile) (see Map 1), and with traditional communities of artisanal fishers and *Quilombolas* on Brazil's southeast coast (see Map 2), we promoted and helped build capacity to use community-based data-management tools and systems. We found that local communities had difficulty handling the geovisualization tools, even with capacity-building support. Moreover, poor access to the internet kept them from accessing the platform and using the interactive maps, which reinforces the importance of using the social cartography approach to identify critical points and using local knowledge to build escape routes in the event of a natural disaster. Based on our results, we discuss how, despite the increased use of digital platforms and social technologies to facilitate dialogue between TLK and scientific knowledge for climate change adaptation and DRR, citizen science initiatives need to move forward with a focus on long-term participation processes.

Currently, in both Brazil and Chile and throughout the countries of Latin America and the Caribbean, initiatives such as spatial data infrastructures (SDIs) are being developed at the national level.[1] The SDIs are available for data visualization by local communities, but our research shows that these infrastructures have been little—if ever—used at the local community level, and usually their use is limited to researchers and managers. Taking a prototype of such global platforms from the Local Indicators of Climate Change Impacts Observation Network (LICCION), and initiatives to improve government programs at the national level, such as the Cemaden-Educação[2] programme in Brazil, we consider how centralized SDIs might support local initiatives. In this sense, we discuss how and why it is necessary to expand the discussion of the barriers and opportunities for integrating traditional and scientific knowledge in long-term citizen science initiatives on climate change and DRR.

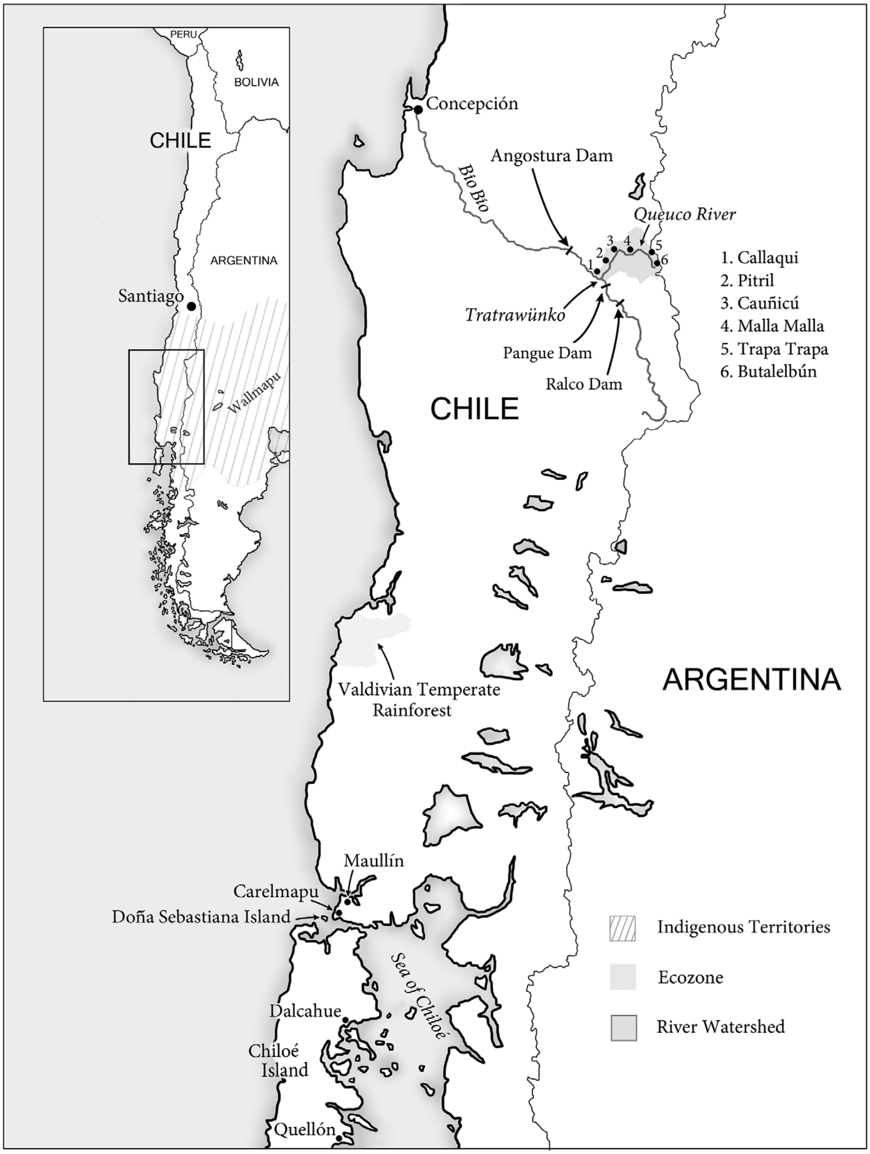
This chapter presents two case studies, one in Brazil and the other in Chile, where citizen science approaches were developed with participatory methodologies such as action research and social cartography. Community work groups were formed at the Federal University of Rio de Janeiro in Brazil and at the University of Los Lagos in Osorno, Chile.[3] Our initiative proposed to develop a quantitative and qualitative approach for vulnerability analysis and adaptation to climate change, focusing on communities living with elevated climate-related disaster risks. The research seeks to advance scientific knowledge production based on citizen science, integrated with technical-scientific risk mapping in coastal zones in the south of Chile and the southeast of Brazil.

We recommend strengthening trust with local communities for citizen science initiatives. We also recommend raising funds to guarantee adequate infrastructure and continuous training for monitoring climate change at the local level for those communities eager for intra- and inter-institutional partnerships (Alonso-Yanez et al., 2019; David-Chavez & Gavin, 2018; Reyes-García et al., 2019). Several studies have pointed out that the question of sustainability is one of the biggest continuity challenges for citizen science initiatives—along with different perspectives/epistemologies, data sovereignty, and citizen engagement (Arriagada et al., 2018; Iwama et al., 2021; Lam et al., 2020; Reyes-García et al., 2022).

Study Areas

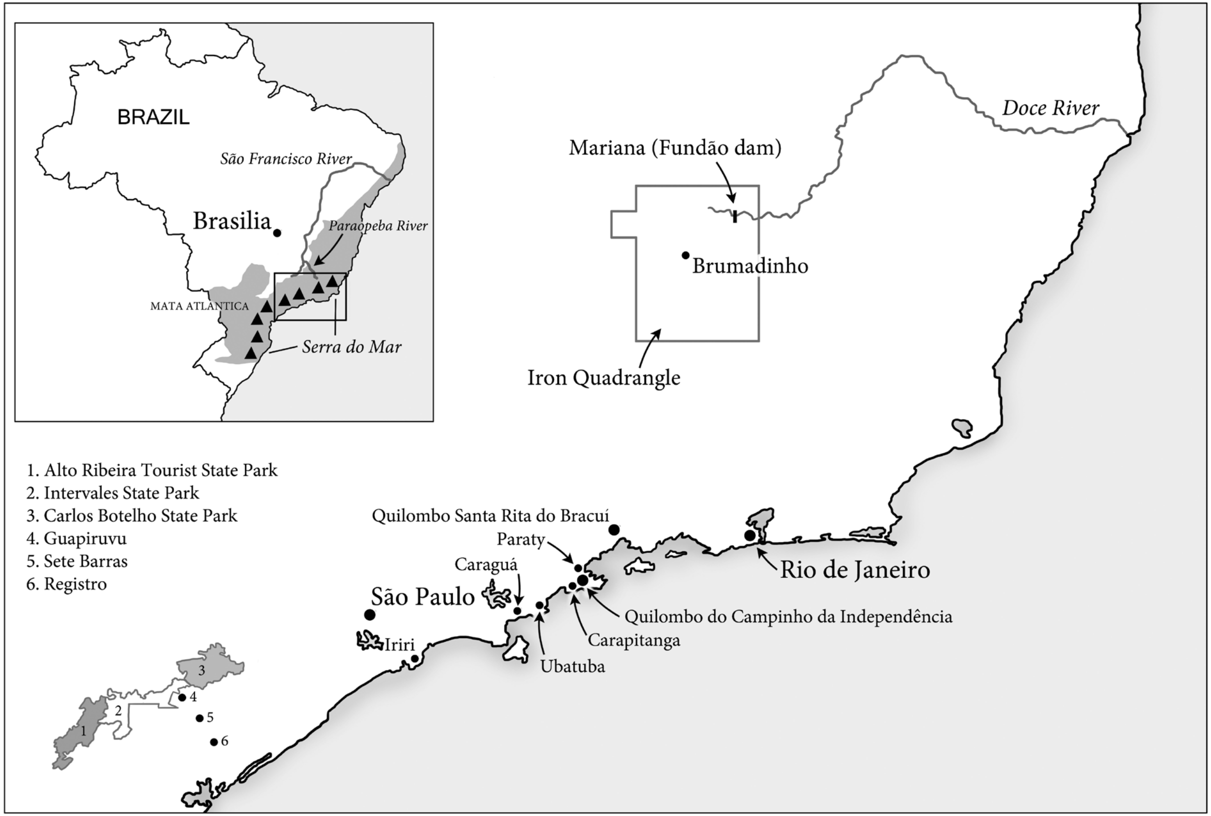
The geographical areas where we worked were in Chiloé Province (Chile) and the northern coast of São Paulo State (Brazil) (see Map 1, Map 2). The action research was carried out at two different times and places: 2017–2018 for the Brazilian case study (the cities of Caraguatatuba (often shortened to just Caraguá), Ubatuba in Sao Paulo State, and Paraty in Rio de Janeiro State; and 2019–2020 for the Chilean case study in the cities of Maullín in Llanquihue province and Dalcahue and Quellón on Chiloé Island (Map 2)).

Off Chile's Pacific coast lies the Sea of Chiloé, with coastal plains from Chiloé Island (41ºS) to the extreme south of Chile; the coast is made up of fjords, estuaries, channels, and gulfs (Fariña et al., 2008; Avaria & Barra, 2009). The marine currents (such as the cold Humboldt Current) that bathe Chile's coastal zone largely define its ecological characteristics and high biological productivity, essential for the country's fishing industry. The occurrence of periodic weather fluctuations and climatic phenomena such as El Niño and La Niña temporarily modify some of these conditions, complicating



Map 1 Chile—South-Central Coast and BioBío Watershed

Map 2 Brazil—Areas of Minas Gerais, São Paulo, and Rio de Janeiro States



the ecological dynamics in Chilean seas (Camus, 2001). In Brazil, the Serra do Mar along the coastline intensifies atmospheric flows coming from the sea to produce high rainfall (Nunes & Calbete 2000; Scofield et al., 2014). In periods of intense and prolonged rains, landslides and floods are frequent (Tavares & Mendonça 2017; Koga-Vicente & Nunes, 2011).

The communities in both study areas have developed important productive activities associated with exploitation of natural resources (for example, in Brazil with the oil and gas industry, and in Chile with salmon farming and artisanal fishing). They are also both tourist areas, with strong pressure on infrastructure services in the summer months. The study areas, Chiloé and the north coast of São Paulo State, were selected because residents in both territories experience problems related to disasters, almost daily. The social and cultural contexts are different, however, and this may demonstrate different climate change adaptation strategies.

Both areas have recurring problems, such as disaster risks related to tidal waves and floods. In Chile, in particular, the threat of earthquakes and tsunamis is added. The history of Chile records dozens of destructive tsunamis, with earthquakes named Huara (2005), Aysén (2007), Tocopilla (2007), Cobquecura (2010–event 27F), Iquique (2014), and Illapel (2015) being especially important. Earthquakes accompanied by tsunamis have caused national catastrophes with hundreds of victims and great economic damage. In addition, the effects of the El Niño phenomenon, associated with other threats such as floods and droughts, affect ecosystem dynamics, enhancing the effects of red tides (harmful algal blooms), and causing immeasurable economic, environmental, and social impacts for fishing communities.

Methods

Using social cartography, this work engaged six local community groups in the collective production of their own maps of social risk, evacuation routes, and adaptation strategies at the local level––maps of flooding, sea-level rise, coastal erosion, tsunamis, and droughts. The maps drawn up in participatory processes were digitalized using open-source QGIS mapping software, and compared to data produced by scientific and technical institutions. In addition, interviews were conducted with long-time residents. Figure 2.1 outlines the CoAdapta methodology adapted from previous work in Brazil (Albagli & Iwama, 2022).

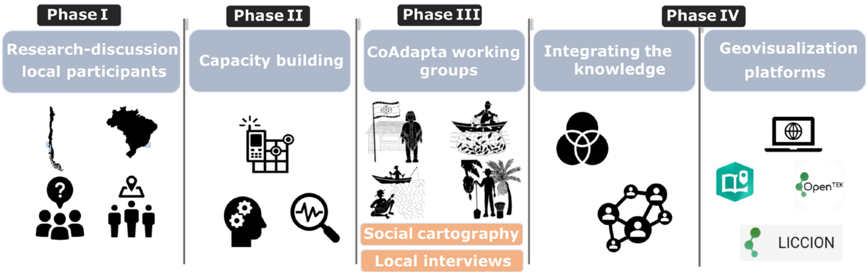


Fig. 2.1 The CoAdapta approach, using participatory citizen science.

We built on a methodology developed earlier in the CoAdapta | Litoral project for linking citizen science with GIS and SDI mapping (Figure 2.1). In each country, three local CoAdapta groups were created: in Brazil, groups from Iriri/Onça (Ubatuba), Juqueriquere (Caraguatatuba), and from Carapitanga (Paraty); and in Chile, groups from Maullín (Llanquihue), Dalcahue, and Quellón (Chiloé Island).

Following discussions about the purpose and value of this research for local participants (Phase I), the groups were trained in global positioning systems (GPS), and GPS devices coupled to phone applications allowed participants to collect local observations on climate change impacts (Phase II). Each group co-constructed semi-structured questionnaires with questions on how climate change is perceived to be happening, what impacts people observe, and how they respond with adaptation strategies based on local knowledge. Using social cartography, the groups carried out participatory mapping, showing the places where impacts occur and the responding local adaptation strategies, which include escape routes in case of disasters (Phase III).

The results on impact sites and adaptation strategies were organized into a prototype CoAdapta platform to design custom maps using the Story Map tool, an application from the ESRI company that uses ArcGIS software (a common GIS computer program). These maps enhance digital storytelling about observations on climate change and adaptation. Other tools used were OpenTEK and Oblo, digital platforms implemented by the LICCI[4] (local indicators of climate change impacts) and LICCI(ON)[5] (LICCI observation network) projects. LICCI is a project aimed at bringing Indigenous and local knowledge into climate change research, funded by the European

Research Council. Through cutting-edge science, the LICCI project strives to deepen understanding of perceived climate change impacts, include TLK in policy-making processes, and influence international climate change negotiations. LICCION was created to help share the climate research of the LICCI project. CoAdapta data were adapted to the LICCI climate impact classification protocol to geovisualize data on both platforms. Both LICCI and LICCION projects were coordinated by the Institute of Environmental Science and Technology of the Autonomous University of Barcelona, in collaboration with the CoAdapta | Litoral project. As shown by all these connections, global networks, and partnerships among research institutes and universities, there is no shortage of funding or academic interest in expanding sources of data on climate change to address its risks and impacts.

This chapter explains our participatory research process and presents preliminary results on how the local coastal communities in Brazil and Chile are responding to the impacts of climate change (Figure 2.1, Phase IV). We also discuss the potential roles, opportunities, and challenges for co-building a geovisualization platform in appropriate, culturally sensitive language accessible to traditional communities that do not frequently use such technologies or the internet.

Between Phase III and Phase IV, there are possibilities of combining high-tech methods with participatory, lower-tech methods and testing the efficacy, effectiveness, and value of this approach. We experimented with several high-tech mapping platforms to explore this.

Story Map Platform

The CoAdapta platform used the Story Map tool, a web-based application linked to ArcGIS, to build stories with custom maps that inform and inspire local observations about climate change impacts and adaptation. Storytelling helps people comprehend and navigate the climate crisis together, building agency through shared understandings (Ellis & Gladwin, 2022). Maps are an integral part of storytelling about climate change impacts, offering narratives a stronger sense of place, illustrating spatial relationships, and adding visualizations of local data.

With a map-maker, we created custom maps to enhance the participants' digital storytelling. We added text, photos, and videos to their existing web maps built in ArcGIS, and web scenes to create an interactive narrative that is easy to publish and share.

OpenTEK and Oblo Platforms

LICCION is based on LICCI research methodology (Reyes-García et al., 2020), which proposes a classification of climate change impacts through indicators, built from qualitative place-based observation of climate change impacts. The indicators are grouped into four main systems: climatological, physical, biological, and socio-cultural/economic. LICCION is grounded in a co-production process where local actors have access to first-draft LICCI indicators that are transformed according to their local realities, interests, and concerns, and are able to modify the classification to develop surveys that best meet their needs and can be integrated into the Oblo platform.

Oblo is a free and open-source technology designed by the Institute of Environmental Science and Technology of the Autonomous University of Barcelona. It allows anyone to create online platforms to document and visualize geolocalized data. The first platform the LICCI research team built with Oblo is OpenTEK, a citizen science tool designed to encourage participation in climate change research by allowing anyone in the world to document and classify observations on local climate change impacts. This tool is currently being extended in collaboration with non-governmental organizations (NGOs) and researchers to provide more relevant biocultural options and functionalities for community-based data collection.[6]

The adaptability of the Oblo technology and LICCI methodology allows communities and organisations to determine what dataset can be included and to develop multiple local-level platforms for collecting policy-relevant or context-specific data.

In this research, we aimed to test the flexibility of the Oblo platform and LICCI using qualitative and quantitative data collected through the CoAdapta process. This process provided qualitative data from surveys, and spatial data collected and created through Phases I, II, III, IV of the process (Figure 2.1). To organise data, firstly we compared the LICCI indicators with CoAdapta survey questions and participatory mapping, in order to recognize common elements and classify CoAdapta information according to the LICCI indicators. The data were organised under the natural disaster umbrella selecting different LICCI indicators of each system and creating new ones.

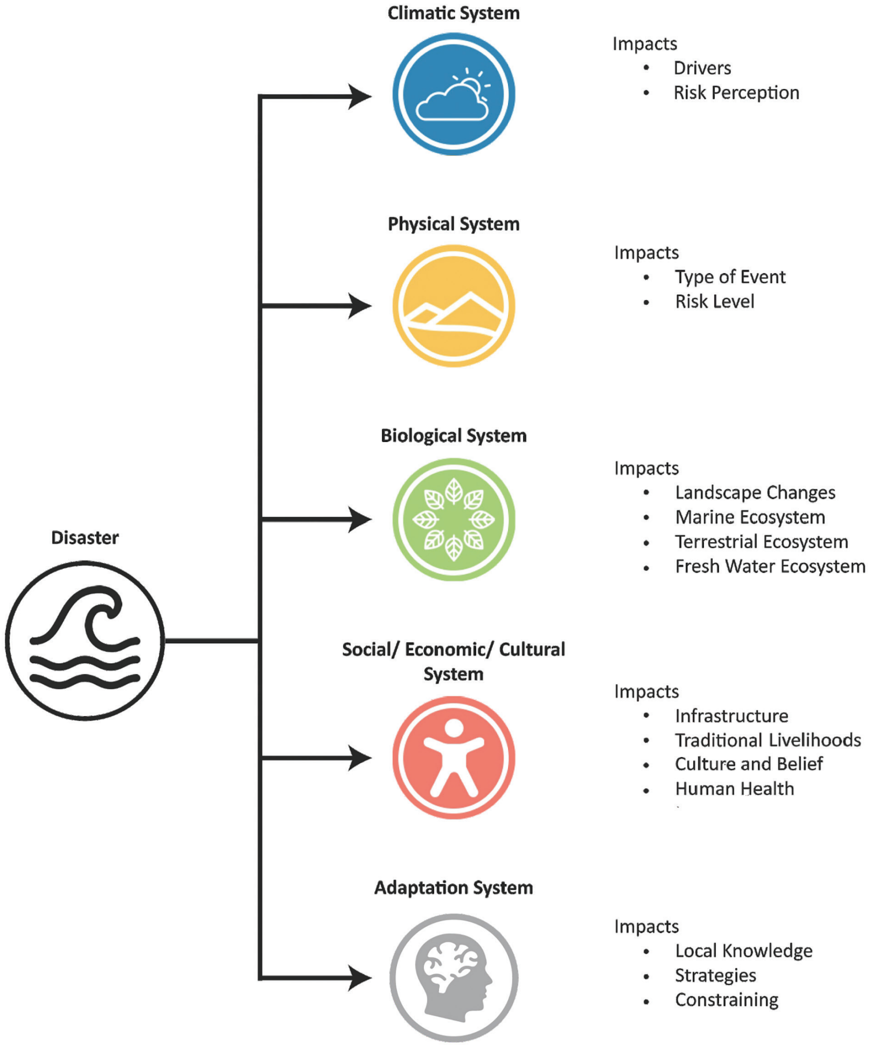


Fig. 2.2 CoAdapta data organization, adapted from LICCI tree.

Each CoAdapta interview represented a data-entry point in the platform, complemented with qualitative spatial information; some indicators had georeferenced points, for example flooding areas, security areas, etc. The data was organized into five systems, followed by their indicators (see Figure 2.2).

Geovisualization of Local Observation Data on Climate Change Impacts and Adaptation in Different Platforms

We are working with data collected from the CoAdapta | Litoral project from 2017 to 2020 using three digital platforms: Story Map, OpenTEK, and Oblo.

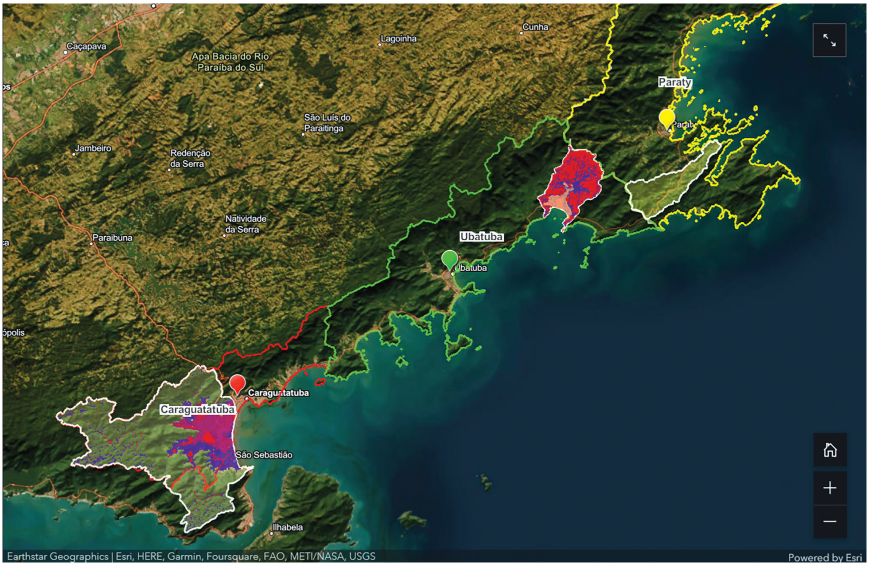
In Story Map, data collected from interviews, social cartography data, and audiovisual materials are made available on the platform in an interactive system.[7] It is an intuitive platform, easy to use and easy to interact with. However, it is also a paid platform, sold by the ESRI company, limiting access to those who can pay for the use and design of the maps created (Figure 2.3 and 2.4).

Looking to provide greater accessibility and replicability in how data is visualized, the CoAdapta | Litoral and LICCION projects sought to show how the free, open-source Oblo platform could adapt to the context of previously co-designed projects at the community level. Based on revisions/adaptations of classification systems from LICCI protocols on climate change impact observations, and questions related to the development of the CoAdapta project, an initial Oblo prototype was created.[8]

Thus, data mapped from social cartography were gradually transferred to the university-built Oblo platform in order to give visibility to the data co-built with traditional and local communities in the coastal CoAdapta and LICCION project, following a co-production process (Figure 2.5 and 2.6). Both projects involved local actors and their knowledge to inform climate change impacts at local levels. Despite the similarities in process, different frameworks or lenses were used to understand climate change, creating challenges for integrating both projects.

Barriers and Opportunities of Map Visualising Platforms

Our conclusions about this effort to combine TLK and digitized scientific mapping methods for use by communities are mixed. One challenge relates to the design and purpose of the mapping software and platforms. CoAdapta has been using a risk-based approach and LICCION an impact-based approach,



Figs. 2.3 Brazilian sites and **2.4** Chilean sites. Co-Adapta data in Story Map platform for southeast Brazil (Fig 2.3) and for Chiloé Island, Chile (Fig. 2.4).

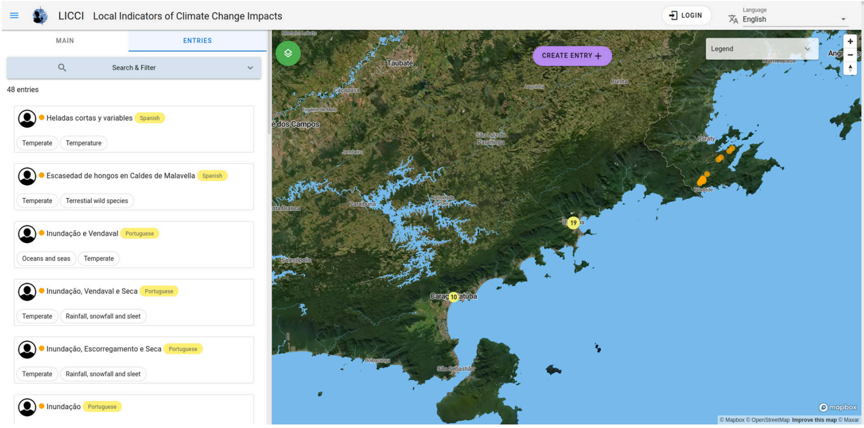


Fig. 2.5 CoAdapta data presented in the OpenTEK platfom for southeast Brazil.

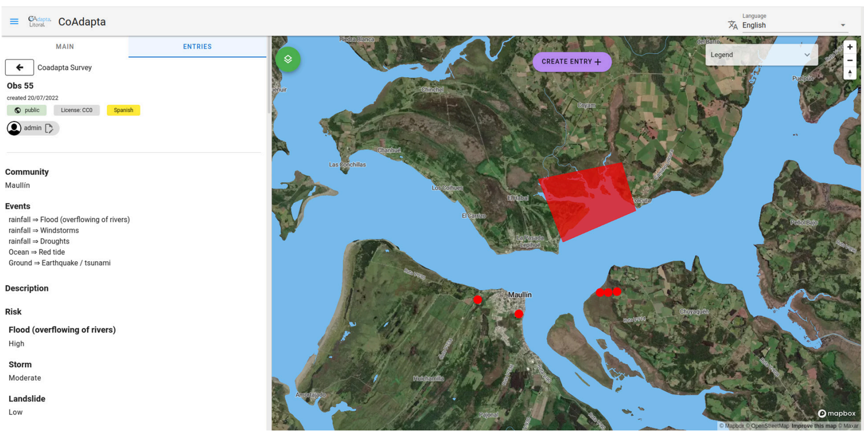


Fig. 2.6 Oblo platform for southern Chile. The Oblo and OpenTEK platforms directly share local citizen science observations, recorded in Portuguese or Spanish. All data is conveyed in the language in which it was generated use such technologies on the internet."

making it difficult to fit CoAdapta data into the Oblo platform. Converting data into the proper data format was also challenging. For instance, spatial information was in shapefiles, which is typical for geoprocessing data. Using this information as Oblo data required extra steps to transform it to meet Oblo requirements, designed initially to geospatialize data from JSON (JavaScript Object Notation), a standard text-based format for representing structured data based on JavaScript object syntax.

A more fundamental problem relates to how the technologies were used during the process of participatory research. Researchers responsible for organizing CoAdapta information into the LICCION platform did not participate in the data collection; therefore, interpretation and the limited knowledge regarding each social-ecological system might have led to a loss of information. Consequently, we highly recommend that researchers be involved in the knowledge co-production process from the beginning of the project in order to adjust the survey and interviews to create the data following the LICCION tree, or to re-organize the data together with local participants and organizations, during the fieldwork period of engagement in the communities.

Finally, the LICCION project has several protocols related to the CARE (collective benefit, authority to control, responsibility, ethics) principles of Indigenous data governance, which were developed by the Global Indigenous Data Alliance,[9] and relate to Indigenous data sovereignty and ethical data management practices. CoAdapta also has a set of principles around protecting sensitive cultural or traditional knowledge. It is important to spend the time and resources to understand these goals, and the differences between these protocols and other similar measures, and to develop appropriate principles in each community context—perhaps in collaboration with local organizations and community members—so as to ensure that data collection and analysis meet each project's standards for ethics and community respect.

We found that some community members were less comfortable than others with the technological aspects of mapping that we tried to use, despite our efforts to familiarize everyone with the software, platforms, and methodologies of this kind of mapping. Since climate change impacts have grave implications for traditional communities who hold important and relevant knowledge and understandings, and government decision-makers usually rely on high-tech data analysis methods, we see this process of continuing to relate TLK and high-tech science as a long-term participatory priority.

With Indigenous and civil society partners, LICCION has extended Oblo and developed distinct community-centred domains and surveys to not only facilitate the documentation of observations on local climate change impacts but also to allow community-specific livelihoods, perspectives, and protocols to be considered and integrated. The purpose of these new domains and surveys is to enable customary and community-led research and evidence-building on climate change while upholding Indigenous data sovereignty principles and values.

Final Remarks

Citizen science initiatives using digital platforms have been widely used at various scales and levels in many local communities. Our chapter presented our reflections on the processes of collecting climate observations in traditional coastal communities in Chile and Brazil, which were co-designed in prototypes of digital geovisualization platforms that allowed for quick visualisation in vector data format (points, polygons, and lines), as well as the formats of photographic records, text, and videos.

The use of data from Indigenous and traditional communities has raised concerns about data sovereignty in projects such as CoAdapta, LICCI, and LICCION, underscoring the need for traditional communities to use technologies that presuppose principles of open access, easy access, and cognitive flexibility (Albagli & Iwama, 2022; Reyes-García et al., 2022; Serret et al., 2019).

Citizen science initiatives with traditional communities often have a methodological design that seeks to build bonds of trust via local working groups and establish research relationships at the level of collaboration or co-design. In this sense, it is also important to emphasize the principles of the right to research (Appadurai, 2006), guaranteeing community participants their legitimate citizens' rights.

Our results demonstrate the importance of seeking open and freely accessible methodologies for visualizing and sharing data produced at the community level, together with protocols that guarantee free decisions about what types of information the community wants to share, so that the purpose of knowledge production is situated in the local context.

NOTES

1 See, for example, SDI development in Chile at https://www.ide.cl/ and in Brazil at https://inde.gov.br/.

2 See http://www2.cemaden.gov.br/cemaden-educacao/.

3 The Brazilian team was part of the CoAdapta | Litoral project, carried out from 2017 to 2021 and funded by the Rio de Janeiro State Foundation for Research Support at the Brazilian Science and Technology Information Institute, Federal University of Rio de Janeiro. For researchers at the University of Los Lagos in Chile, funding support came through a Queen Elizabeth II Diamond Jubilee Scholarships Advanced Scholars Program (QES-AS) project based at York University (Canada).

4 LICCI project—https://licci.eu/.

5 LICCION project—https://licci.eu/liccion/.

6 See https://oblo.network/. Features and technical documentation can be found here: https://oblo-cit-sci.github.io/.

7 See https://www.coadaptalitoral.net/mapping-platform.html.

8 See https://oblo.network/domain?d=coadapta.

9 See https://www.gida-global.org/care.

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