

# INTRODUCTION

## Understanding climate change impacts on Indigenous Peoples and local communities: A global perspective from local studies

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### **Why a book on climate change impacts on Indigenous Peoples and local communities?**

There is overwhelming evidence that the climate of the Earth is changing (IPCC, 2021), although our understanding of the myriad of ways in which these changes affect local social-ecological systems across the globe is patchier (IPCC, 2022). This is particularly the case in remote and/or marginalized areas of the world, where the scarcity of instrumental data challenges scientists' ability to detect change (Maraun & Widmann, 2017; Rosenzweig & Neofotis, 2013). Moreover, there is also growing evidence that changes in weather patterns have and will continue to have far-reaching and disproportionate impacts upon Indigenous Peoples and local communities (Bardsley & Wiseman, 2016; Galloway-McLean, 2017), including impacts on livelihood activities and health, as well as social and cultural impacts (e.g., Green & Minchin, 2014; Maikhuri et al., 2018; Race et al., 2016). This is largely the case because climate change impacts are socially mediated: those already in social disadvantage, and particularly ethnic and political disadvantages, are likely to find themselves disproportionately affected by climate change impacts.

However, Indigenous Peoples and local communities with a long history of interaction with the environment are not mere victims of climate change impacts; they are also legitimate custodians of knowledge regarding climate change and its impacts and rights-holders to participate in and contribute to climate change decision-making at both local and international levels. Indigenous Peoples and local communities have complex knowledge systems that allow them to detect changes in the local climate and the impacts of such changes in the biophysical systems on which they depend (Reyes-García et al., 2016; Savo et al., 2016), as well as the interactions of climate-driven changes with other drivers of local environmental change (Merten et al., 2020; Smith et al., 2017). Moreover, insights from Indigenous and local knowledge systems can also improve our understanding

of how climate change affects local socioeconomic systems, livelihoods, and cultures, focusing on what matters to local people (Crate & Nuttall, 2016; Sillitoe, 2021). Therefore, Indigenous and local knowledge systems have the untapped potential to contribute to a deeper and more detailed understanding of the myriad effects of climate change on local social-ecological systems around the world, including in very remote areas.

Indigenous Peoples and local communities directly experience climate change impacts, but each group experiences impacts in a different way, not only because such impacts are place-specific but also because climate change impacts on social-ecological systems and responses to those impacts are mediated by local socioeconomic systems and cultural aspects. For example, while sea-level rise is a climate-related phenomenon with potential effects on the millions of people living close to sea level, specific biophysical (e.g., magnitude of tidal influences, geologic subsidence, overall island size, and relief) and socioeconomic conditions (e.g., resources to cope with sea-level rise, livelihood strategy) mediate how different people perceive this change and the extent to which they feel affected by it. In that context, Indigenous peoples and local communities often rely on their knowledge systems to respond to the socially mediated climate change impacts (Schlingmann et al., 2021).

Chapters in this book examine the diverse ways in which climate change -alone or in interaction with other drivers of environmental change- affects Indigenous Peoples and local communities (Part 1) and how Indigenous Peoples and local communities are locally adapting their responses to these impacts (Part 2). Cases featured draw on first-hand information collected from field research in diverse areas of the world and cover different climatic zones and livelihood activities. We argue that the approach is important in three ways. First, examining local perceptions of climate change impacts and local responses to them contributes to return to a human scale a discussion often focused on ‘mega-trends’ and ‘mega-drivers’ of change. Second, in generating human-scale data on the impacts of and responses to climate change, the chapters in this book help reframe scholarship on the human impacts of climate change, drawing its social, economic, and political dimensions, thus contributing to a line of scholarship that proposes that the global understanding of climate change impacts means recognizing their historical and political origins. Finally, by focusing on Indigenous Peoples and local communities, we hope to contribute to make climate injustices more visible and to emphasize the need to recognize Indigenous Peoples and local communities’ rights in climate research and decision-making.

The next section of this introduction addresses issues referring to authors’ common ground and yet diverging positionalities. The following two sections bring together the main findings from chapters in this book and associated research to give a global perspective of the lessons learned from multiple case studies across (1) climate change impacts on Indigenous Peoples and local communities and (2) responses to climate change impacts by Indigenous Peoples and local communities. The next section then presents lessons learned from working with different knowledge systems on the topic of climate change impacts. This general introduction ends with a general policy recommendation derived from our work accompanied by concrete steps for researchers and decision makers to put the general recommendation into action.

### **The context of the book**

Most chapters in this book result from a community of practice organized around LICCI – *Local Indicators of Climate Change Impacts: The contribution of local knowledge to climate change research*, a project funded by the European Research Council designed to bring contextualized information from Indigenous Peoples and local communities to climate change research and policy

(Reyes-García et al., 2019). The editors of the book are the Principal Investigator of the project (ICREA Research Prof. Victoria Reyes-García) and all the core members of the LICCI team (post-doctoral scholars, PhD students, and technicians) who, over the five years of the project, have coordinated the network. Most contributions to this book are from members of the LICCI network, although a few chapters have been written by authors working on related topics who were purposely invited to enlarge the coverage of some regions or topics underrepresented in the LICCI network.

The LICCI network includes about 50 Indigenous and non-Indigenous researchers working with and affiliated with institutions around the world. The common ground of this network is a shared interest in exploring the diverse ways in which climate change affects Indigenous Peoples and local communities and how they respond to it. Members of the network recognize the acute need to increase the transferability, integration, and scalability of Indigenous and local knowledge into climate change research through the creation of a community of practice that uses standardized methods for the collection and coding of locally relevant but cross-culturally comparable data (Reyes-García et al., 2019). All members of the network also gratefully acknowledge and deeply respect the invaluable contributions of the Indigenous Peoples and local communities, whose traditional knowledge and practices have formed the foundation of this research.

Despite this common ground, there are also differences and particularities among network members, which are reflected in the content of the book. Thus, contributions to this book come from authors from different nationalities, disciplinary backgrounds, and positionalities, a diversity that inevitably affects authors' own experiences and engagement with local communities and the way information is analyzed and interpreted. This has resulted in different epistemological stances on the treatment of Indigenous and local knowledge systems across chapters. Importantly, while maintaining a diversity of theoretical approaches, authors have agreed on a common set of concepts that bring some internal coherence to this edited volume (see Glossary).

Chapters in this book also draw from a diversity of methodological tools used to collect and analyze observations of and responses to climate change impacts. Data collection tools range from ethnography and qualitative data collection methods (e.g., semi-structured interviews, focus groups, participant observation) to more systematic forms of data collection (e.g., surveys). Several authors also use secondary sources (e.g., time series of climatic data, historical sources). Data analysis varies from featuring testimonies to statistical analysis, with some chapters being more interpretative than others.

This edited volume does not intend to provide an exhaustive view of climate change impacts on Indigenous Peoples and local communities around the world nor on how people respond to such impacts. Moreover, we acknowledge some geographic biases (e.g., there is only one chapter from the South Pacific, Fiji, none from Australia or New Zealand, and some regions like the Amazon are underrepresented). However, we argue that, despite these biases, bringing together a collection of case studies allows us to identify common trends as well as idiosyncrasies – both of which are important to understand global trends and the myriad of climate change impacts across the world. In the following three sections, we aim to trespass case studies idiosyncrasies, to summarize major trends derived from the work of the LICCI network, with particular emphasis on the chapters published in this book.

### **Climate change impacts on Indigenous Peoples and local communities**

Research by the LICCI network, including chapters in this book, provides three main insights in relation to how climate change impacts Indigenous Peoples and local communities' and how they understand and report such impacts.

***Indigenous Peoples and local communities report numerous, ongoing, tangible, and widespread environmental changes***

All the contributions to this volume emphasize that Indigenous Peoples and local communities report climate change impacts as currently ongoing, locally contextualized, and affecting diverse elements of local social-ecological systems, including their physical (e.g., atmosphere, rivers, soils) and biological (e.g., trees, crops, fish) components (see also Reyes-García et al., 2024). For example, among many others, impacts recorded include changes in elements of the atmospheric system, such as changes in precipitation patterns (e.g., Babai, 2024) and fog (Mwangi et al., 2024), temperature increase (e.g., Abazeri, 2024; Mattalia et al., 2024), or weather unpredictability (e.g., Hirsch, 2024; Stratoudakis et al., 2024) including changes in seasonality (e.g., Gerkey & Sharakhmatova, 2024; Miara et al., 2022). Reports also feature changes in the physical system, including changes in freshwater availability (e.g., Izquierdo & Schlingmann, 2024) and soil humidity (Estevo et al., 2022), changes in snowfall and snow cover (e.g., García-del-Amo, Mortyn et al., 2023; Jungsberg & Wendt-Lucas, 2024), and changes in sea- and river-ice (e.g., Galappaththi, 2024; Gerkey & Sharakhmatova, 2023). Among the many reports, changes in the water cycle are particularly abundant (e.g., Estevo et al., 2022; Junqueira et al., 2021; Reyes-García et al., 2024).

Indigenous Peoples' and local communities' reports of impacts go beyond changes in the atmospheric and physical systems and include changes in the life system, including wildlife and managed systems. Thus, research conducted by the LICCI network brings to light many reports of changes in abundance and phenology of wild plants and terrestrial and aquatic animals (e.g., Geffner-Fuenmayor, 2022; Schunko et al., 2023). But such reports also include observations of phenological changes in their agricultural calendars (Babai, 2024; Hirsch, 2024), the productivity of traditional and modern crop varieties (e.g., Attoh et al., 2024; Carmona, 2022; Chakauya et al., 2024; Labeyrie et al., 2021), including cash crops such as tea or coffee (Mwangi et al., 2024), the increase of livestock pests (e.g., Attoh et al., 2024; Junqueira et al., 2021), or the newly problematic abundance of previously present, but non-problematic, species (e.g., McConney et al., 2024). Finally, Indigenous Peoples and local communities also report on a variety of impacts on their ways of living, including reduced feasibility to practice traditional hunting and fishing livelihoods (Galappaththi, 2024; Gerkey & Sharakhmatova, 2024), mobility restrictions (e.g., Gerkey & Sharakhmatova, 2024), or damaging of houses and other infrastructure (e.g., Jungsberg & Wendt-Lucas, 2024).

***Indigenous Peoples' and local communities' report multiple and synergistic drivers of environmental change***

While the LICCI project had an original focus on climate change impacts, a consistent finding in all our study sites is that climate change impacts cannot be fully separated from other changes that are being experienced locally. In fact, this is also a finding currently featured in the scientific literature (e.g., Pörtner et al., 2021). Indeed, the research results of the LICCI network emphasize that Indigenous Peoples' and local communities' reports of environmental changes are interrelated and driven by multiple stressors (see also Li et al., 2021). In particular, our research emphasizes the importance of cascading effects across elements of the social-ecological system and of multiple drivers of change.

On the one hand, our research emphasizes that Indigenous Peoples and local communities identify many relations between elements of their social-ecological systems, pointing at many cascading effects, mainly from changes in the atmospheric and physical systems to changes in the life

system (e.g., García-del-Amo, Calvet-Mir et al., 2024; Reyes-García et al., 2024). For example, inhabitants of Sierra Nevada, Spain, report that decreasing rain and snow events diminish rivers' flow, reducing the duration and number of working natural springs, decreasing soil humidity, and increasing soil erosion. Changes in precipitation also affected wild flora, as it reduced the duration and extension of grazing areas, which in turn affected wild fauna's altitudinal distribution, with animals moving closer to the villages looking for food and water. Moreover, the shorter duration and frequency of rainfalls and snowfalls have a direct negative effect on agricultural and livestock activities (including beekeeping), decreasing their productivity and increasing the number of pests and diseases, which are aggravated by the destruction of crops by wild fauna searching for food (García-del-Amo et al., 2024).

On the other hand, our research features how Indigenous Peoples and local communities acknowledge climate change as one, but not necessarily the most important, of the multiple drivers of environmental change (e.g., Izquierdo & Schlingmann, 2024). Across case studies, we noticed that Indigenous Peoples and local communities recognize that environmental change is driven by many inter-related contextual factors, which vary from resource over-extraction (Carmona, 2024b; Estevo et al., 2022; Reyes-García et al., 2024), to development programs (Attoh et al., 2024; Porcuna-Ferrer et al., 2024), creation of new infrastructures (Izquierdo & Schlingmann, 2024; Junqueira et al., 2021), or state policies (e.g., Carmona, 2024b; Chen, 2024; Lippi & Sanfilippo, 2024). Importantly, our research also suggests that, besides these drivers, for many Indigenous Peoples and local communities, an important additional driver of environmental change is the degradation of human relation with the environment, including the loss of caring practices (e.g., Chao et al., 2024; Chen, 2024; Hirsch, 2024; Reyes-García et al., 2024).

Research results of the LICCI network clearly show that Indigenous Peoples and local communities identify numerous dynamic interactions of positive and negative feedback between climate, social, political, ecological, economic, and cultural structures. The recognition of this multifactorial and nested complexity acknowledges that climate change impacts do not come in a vacuum, but often add to situations of colonialism, inequality, and environmental injustice. Within these contexts, climate change, while recognized as having an impact, is often not considered the main topic of concern (e.g., Blanch-Ramirez et al., 2022; Hirsch, 2024; Izquierdo & Schlingmann, 2024; Levy Guillén, 2022; Porcuna-Ferrer et al., 2023). For example, for agriculturalists in the Colca Valley (Peru), climate change impacts are mediated by structures of inequality, violence, and environmental injustice rooted in a highly centralized and urbanized form of capitalism configured by Peru's colonial past (Hirsch, 2024). In the same vein, Koryak, Chukchi, and Even peoples, inhabitants of the Kamchatka Peninsula in Northeast Siberia, Russia, report that climate change impacts are exacerbated by legacies of social transformation derived from Soviet and post-Soviet policies (Gerkey & Sharakhmatova, 2024). Moreover, precisely because of political and economic inequalities, some groups -e.g., Indigenous and local women- may have more at stake in addressing climate change impacts and other sources of environmental change than others (e.g., Abazeri, 2024; Porcuna-Ferrer et al., 2024). Finally, as featured in several chapters of this book, Indigenous Peoples and local communities identify that synergistic interactions between climate change and other drivers of change can amplify (e.g., Carmona, 2023; Hirsch, 2024; Junqueira et al., 2021) or attenuate (e.g., Chen, 2024) the overall impacts of change.

Overall, Indigenous Peoples and local communities' understandings of change provide a holistic, multi-causal, and multi-scalar complex picture of the relations between humans and the environment, entangling ecological observations with socio-economic, cultural and political critiques. In doing so, they provide a political – and not a purely ecological- view of change, highlighting the need to focus on intersecting impacts.

### ***Indigenous Peoples and local communities' reports of environmental change are not uniform***

A third finding that derives from research by the LICCI network is that reports of changes vary across geographical areas and social characteristics of groups and individuals. We found variation at different levels. First, as climate-driven environmental change manifests differently across regions, so do reports of these changes (Reyes-García et al., 2024), even at local scales (García-del-amo et al., 2023). Moreover, the same indicator of change exerts different impacts, or impacts of different intensities, across livelihood strategies (e.g., Estevo et al., 2022; García-del-Amo et al., 2022; Reyes-García et al., 2024). For example, weather instability makes agricultural labour increasingly speculative and anxiety-riddled (Hirsch, 2024; Vázquez-Martínez, 2022), and sea-ice-based hunting extremely dangerous (Galappaththi, 2024).

Second, we also found variation associated with whether impacts were perceived as negative. Indeed, reports of climate-driven environmental changes are often perceived as negative, but not always. Some reports of environmental changes are presented as having a positive impact. For example, while most Kolla-Atacameños People and local communities in the Argentine Puna perceive climate change as negative, some people also perceive warmer climates in the local extremely cold weather as positive (e.g., Izquierdo & Schlingmann, 2024). Some people also report as positive changes that permit longer fishing seasons (e.g., Stratoudakis et al., 2024) or that increase the length of agricultural season (e.g., Blanch-Ramirez et al., 2022; Estevo et al., 2022; Fuchs et al., 2024).

Finally, ethnicity or cultural norms (e.g., Mwangi et al., 2024), household context (e.g., Lippi & Sanfilippo, 2024) and individual characteristics, such as gender (Abazeri, 2024), age, or level of relation with the environment (García-del-Amo et al., 2023) are also linked to variation in reports of climate-driven environmental changes. For example, in the mountains of Sierra Nevada, Spain, people whose livelihood directly depends on nature report many more changes and relations among observed changes than people who do not live in close relation with the environment (García-del-Amo et al., 2023), and Kikuyu and Meru smallholder farmers living in mountains in central Kenya report the use of different adaptation strategies, e.g., irrigation is more widespread amongst the Meru than among the Kikuyu, arguably because cultural differences between these groups shape their adaptation strategies (Mwangi et al., 2024).

### ***Indigenous Peoples and local communities' responses to impacts from climate change and associated stressors***

Research by the LICCI network also provides main insights on how Indigenous Peoples and local communities respond to the compounded impacts originating from climate change and other stressors.

### ***Indigenous Peoples and local communities respond to climate change impacts in plural ways***

The analysis of different case studies clearly shows that Indigenous Peoples and local communities respond to current impacts in diverse ways (see also Schlingmann et al., 2021). Among cases featured by the LICCI network, most documented responses include coping with change (e.g., Carmona, 2022; Porcuna-Ferrer et al., 2024) or the adoption of incremental adaptations, i.e., modifying livelihood strategies (e.g., Ávila et al., 2021; Hirsch, 2024; Labeyrie et al., 2021; Vázquez-Martínez, 2022).

For example, farmers in the Carpathians have changed their mowing, sowing, and harvesting practices to respond to weather unpredictability (Babai, 2024). Transformational adaptations, including migration to cities and changing to non-nature-related jobs, are widespread across geographical areas and livelihood activities, but they are not dominant (Zant et al., in press). Results call for caution when inferring that response options adopted are “adaptive” or “sustainable”, as the long-term consequences of responses adopted are often unknown (e.g., Ferrara & Lindberg, 2024). Moreover, some responses, while allowing for immediate coping with climate change impacts, can be detrimental in the long-term, increasing pressure on Indigenous Peoples and local communities to discontinue adaptive practices or to adopt unsustainable relationships with the territory (Zant et al., in press). For example, a review of the literature suggests that switching to off-farm work, while helping to cope with short term climate change impacts, also results in a decline in traditional activities, reduction in food production and self-sufficiency, and higher market dependency, potentially decreasing households’ resilience (Galappaththi & Schlingmann, 2023).

### ***Social, political, and cultural barriers hamper Indigenous Peoples’ and local communities’ adoption of response options***

A second finding reflected in research by the LICCI network is that structural social, political, cultural, and other types of barriers hamper Indigenous Peoples’ and local communities’ adoption of some response options to climate change impacts. For example, Tyrol farmers in Austria are constrained to adopt transformational adaptation options as such responses require community work, which is in shortage because of social barriers (e.g., rural depopulation) (Fuchs et al., 2024). Likewise, farmers in Northern Ghana face financial barriers to adopt technical improvements proposed by government officials to enhance adaptation (Attoh et al., 2024).

Structural barriers are symptomatic of Indigenous Peoples’ and local communities’ histories of colonialism (Fayazi et al., 2020; Piggott-McKellar et al., 2019), for which they cannot be successfully addressed through technical means, as featured in several chapters of this book. For example, the Mapuche-Pehuenche in Southern Chile are considered vulnerable to climate change, but they express that what has made them vulnerable is the violation of their rights to their territory and way of life through the progressive degradation of their land by logging extraction and their structural marginalization from the decision-making processes (Carmona, 2023). Similarly, Quechua descendant farmers in the Colca Valley, Peru, shifted to market-oriented agriculture under the promise of economic development and the promise of a stable climate. The decrease of agricultural productivity under current market-dependence and unpredictable weather conditions is at the root of their vulnerability (Hirsch, 2024). In that understanding, chapters in this book also highlight how people suffering additional layers of marginalization (e.g., Indigenous women in patriarchal structures) face even further barriers to adaptation options (e.g., Ayanlade et al., 2024; Porcuna-Ferrer et al., 2024).

The adoption of response options might result in trade-offs and unequal distribution of costs and benefits across actors with different roles in society. For example, among Bassari farmers’ (Senegal), gender and access to financial, physical, and natural capital define who can implement and benefit from new agricultural technologies. In this case, the introduction of cotton as cash crop has increased men’s income but has also resulted in the abandonment of drought-tolerant native crops, increasing women’s work burden and the overall household’s vulnerability to market uncertainties (Porcuna-Ferrer et al., 2024).

***Indigenous and local knowledge systems provide contextualized and suitable response options***

Our third important finding in relation to Indigenous Peoples' and local communities' responses to change is that Indigenous and local knowledge systems provide contextualized and suitable options to respond to the simultaneous impacts of climate change and other drivers of global change. Indigenous and local knowledge systems have contributed to climate change response mechanisms that reflect local ontologies and governance systems (Galappaththi, 2024; Reyes-García & Junqueira, 2023). They are contextualized in local livelihoods (Schlingmann et al., 2021) and cultural preferences (Mwangi et al., 2024), rely on local resources and means (e.g., Chakauya et al., 2023), and address the synergistic effects of simultaneous drivers of change (e.g., Abazeri, 2024). For example, Sereer farmers in Senegal shift between crop varieties depending both on climate trends and agricultural extension policies, showing their ability to cope with simultaneous drivers of change (Ruggieri et al., 2021). As Indigenous and local knowledge systems allow the adoption of autonomous responses (e.g., Jungsberg & Wendt-Lucas, 2024), these knowledge systems can be considered as enabling factors in the context of climate change adaptation. Chapters in this book suggest that such bottom-up responses can help manage multiple stressors and minimize vulnerabilities (e.g., Abazeri, 2024; Galappaththi, 2024). For example, among Inuit, the use of co-management to respond to climate change impacts supports community resilience by improving food security, fostering social learning, and co-producing knowledge (Galappaththi, 2024).

Research by the LICCI network also shows that Indigenous and local knowledge can be effective to shape response options in interaction with other bodies of knowledge. For example, using online systems to integrate local and scientific knowledge of communities in coastal areas can serve to assess risk and vulnerability situations and shape adaptation or mitigation strategies to face environmental change and climate risks (Iwama et al., 2023). Also, interacting information from autonomous responses to climate change impacts and national adaptation policies can improve the fit between responses at different scales (Singh et al., 2024) and improve all phases of the policy cycle that generate response options (e.g., Carmona, 2024b; McConney et al., 2024).

**Working with different knowledge systems to contribute to climate change research and policy**

Beyond research findings, work undertaken by the LICCI network also provides important insights from the research process, in particular, in relation to conducting research with Indigenous Peoples and local communities about climate change impacts. In this section, we outline three main lessons learned regarding our research process.

***Indigenous Peoples' and local communities' conceptualizations of climate change are not fully transferable to scientific categories***

Indigenous knowledge and local knowledge systems are holistic systems encompassing knowledge (e.g., monitoring changes), practices (e.g., water management), and value systems (e.g., relational values of nature) that do not always have equivalents in scientific categories (see also Orlove et al., 2023). Different members of the LICCI network worked with aspects of Indigenous and local knowledge systems referring to climate change impacts that were encoded in different cultural manifestations, including proverbs (Garteizgogeoasca et al., 2020), agricultural calendars (Miara et al., 2022), rituals and beliefs (Chao et al., 2024), or ways of managing landscapes, ecosystems,



or species (Abazeri, 2024; Reyes-García et al., 2023). Some of these elements cannot be fully transferred to scientific categories.

However, in many cases, members of the LICCI network were able to weave elements of different knowledge systems to generate a more enriched view of climate change impacts (Reyes-García et al., 2024) and potential responses (McConney et al., 2024; Singh et al., 2024). For example, weather-related proverbs provide long-term observations of many elements of the atmospheric system and their impact on the biophysical world. In Sierra Nevada, Spain, the reported inaccuracy of weather-related proverbs provides a richer understanding of environmental changes than the limited number of indicators that scientists can locally measure (Garteizgogeoasca et al., 2020). Similarly, regarding response options, the contrast between autonomous and planned responses can guide more comprehensive and less redundant adaptation policies, as shown by the analysis contrasting of local adaptation in iTaukei communities and national adaptation plans in Fiji (Singh et al., 2024).

### ***Understandings of climate change impacts derived from different knowledge systems often, but not always, overlap***

A second finding brought from our research process is that, across case studies, reports from different knowledge systems often, but not always, overlap. For example, the Tuareg of Illizi (Algeria) reported changes and irregularities in their ecological calendar, which have impacted their pastoral and semi-pastoral livelihoods. These reports are aligned with scientifically measured climate observations. Paradoxically, although participants recall with detail the climatic disasters that happened in the region over the last century, they do not explicitly report changes in the frequency of extreme events (Miara et al., 2022).

There are many reasons that can explain mismatches between information from different knowledge systems. For example, mismatches might come from tensions between different understandings of the term “climate change.” Research among the Bassari of south-eastern Senegal shows how the local interpretation of changing climatic conditions has ontological foundations. The Bassari do not understand ‘climate’ as something separated, but rather as a phenomenon inextricably linked with socio-economic dynamics and immaterial aspects, such as supernatural forces (e.g., Porcuna-Ferrer et al., 2023). Mismatches between information from different knowledge systems can also come from divergent perceptions of reality due to other changes, such as changes in lifestyle (e.g., houses are now isolated, people wear warmer clothing, or use more efficient technology) (e.g., Ferrara & Lindberg, 2024; Stratoudakis et al., 2024). For example, fishers in Portugal argued that people perceive environmental conditions as milder now than in the past because now they have more robust fishing gears and vessels that allow more secure navigation (Stratoudakis et al., 2024). Moreover, mismatches can also come from a focus on different spatial or temporal scales (e.g., Ferrara & Lindberg, 2024; Mattalia et al., 2024; Reyes-García & Junqueira, 2023). Science often focuses on planetary changes and long (geological) time, whereas Indigenous and local knowledge systems often focus on changes that happen at the local geographical scale and in short (historical) time (e.g., Ferrara & Lindberg, 2024; Reyes-García & Junqueira, 2023). The scale at which information is aggregated (e.g., global vs. local, short-term vs. long-term) might also lead to different conclusions.

Even when reports from different knowledge systems match, Indigenous and local knowledge systems signal new complexities and nuances that might have been previously invisible, often emphasizing aspects that matter to local people. For example, in the Juruá river (Brazil), while climatic models show inconclusive or contradictory precipitation trends, there is a clear local

understanding that summers have become wetter (Estevo et al., 2022), thus complementing scientific understandings. Complementarities between knowledge systems can help define research priorities. For example, Meru farmers in Mt. Kenya (Kenya) reported changing rainfall patterns and increased temperatures (matching with weather stations data), which are increasing pests and diseases in the banana fields, their preferred staple food. However, farmers also explained that the impacts are aggravated given the lack of research and access to improved banana varieties, which together reduces banana productivity (Mwangi et al., 2024).

Overall, exploring mismatches and complementarities between knowledge systems, rather than validating information from one or another knowledge system, should lead to an enriched picture of reality and more contextualized research priorities (Tengö et al., 2014).

### ***Current scientific research practices do not uphold Indigenous and local knowledge systems and ignore environmental impacts of research***

Our last lesson learned from examining our research process refers to several mismatches noted between the goals of our project and the use of current research practices. In executing this project, several members of the LICCI network signaled that current scientific research practices largely privilege norms and standards that do not encourage the co-construction of new knowledge based on evidence from different knowledge systems (see also Orlove et al. 2024). Moreover, such practices reproduce structural barriers that do not encourage citizen's participation in science (Iwama et al., 2023) and do not acknowledge the power dynamics set by professional researchers, often in privileged positions in the production of knowledge (Reyes-García et al., 2024).

Even more, members of the network also acknowledged that research projects framed under current research “best practices” are often not obliged – and sometimes not even aware- of the need to respect Indigenous Peoples’ rights to their knowledge – as enshrined in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) – and consequently to their data, nor are scientific institutions equipped to do so (Reyes-García et al., 2022a).

Finally, members of the network also acknowledged that under current frameworks, researchers are not incentivized to acknowledge and reduce the environmental impact of their research activities, thus -ironically- contributing to aggravate the carbon impact of research activities, which ultimately perpetuates the paradox of aggravating climate change impacts among Indigenous Peoples and local communities. For example, during its initial phase, the LICCI project emitted an estimate of 161 tons CO<sub>2</sub>-eq, which could have been largely reduced to 92 tons CO<sub>2</sub>-eq (or 53% of the emissions) by applying a standard set of measures already proposed by scholars aiming to decarbonize research or even to 4 tons CO<sub>2</sub>-eq (or 2.4% of the estimated emissions) by applying more strict measures aiming to reach carbon neutrality. Most emissions reductions come from reducing travel, which is not likely to happen unless the research sector develops normative standards of scientific research practice that encourage, value or even impose the reduction of carbon emissions (Reyes-García et al., 2022b).

### **Looking forward: policy recommendations**

A growing body of research suggests that Indigenous Peoples and local communities are systematically marginalized in climate research and policy, a status that is linked to their general marginalization in society, current political power structures, and histories of colonization (e.g., Chakraborty & Sherpa, 2021; Conway et al., 2019; Ford et al., 2016; Yap & Watene, 2019). This realization has given rise to several recommendations on how to work with Indigenous Peoples

and local communities in climate research and policy (e.g., McElwee et al., 2020; Roue & Nakashima, 2018). Following this trend, in this last section, we provide a main recommendation for partnering with Indigenous and local knowledge holders to engage them and their knowledge systems in climate research and policy. We then present some concrete steps for researchers, research institutions, and decision makers to put the aforementioned recommendation into action. Given the diversity of context in which Indigenous Peoples and local communities are found and the different focus of our research, we also emphasize that the application of any policy recommendation will need to be contextualized.

**Policy recommendation:** *Recognize Indigenous Peoples and local communities as legitimate custodians of knowledge regarding climate change and its impacts and as key rights-holders to participate in and contribute to climate change decision-making at both local and international levels.*

Concrete steps for **researchers and research institutions** to put the aforementioned recommendation into action include

Include representatives from Indigenous Peoples and local communities in scientific committees, national delegations, or advisory/technical bodies dealing with climate and environmental change research.

Establish protocols for validating and endorsing data and information when working with Indigenous knowledge systems in research institutions, to ensure these align with Indigenous Data Sovereignty principles. This should involve including representatives from Indigenous Peoples and local communities in research, ethics, and data regulating bodies and setting up mechanisms and infrastructure that facilitate the respect of these rights.

Recognize and uphold Indigenous Peoples' rights (as enshrined in UNDRIP, 2007) in climate and environmental research, especially in projects that involve Indigenous Peoples' and local communities' knowledge to address climate change impacts. Such rights include, among others, collective rights to resources, land, knowledge and, consequently, data.

Evaluate research that involves Indigenous and local knowledge based on criteria that go beyond academic metrics, including evaluation criteria such as formal recognition of Indigenous Peoples and local communities as knowledge holders, type of engagement with the community, and research benefits to the community.

Create specific research opportunities that allow for the extra time required to prepare proposals for collaborative research.

Provide support, and particularly funding, for Indigenous researchers and Indigenous research institutions.

Foster national and international networks and exchanges of experiences (e.g., via workshops) among Indigenous Peoples and local communities around climate change impacts to ensure a safe space for exchanging and valuing their knowledge and worldviews, without necessarily seeking to transfer it to scientific terms.

Implement a zero-carbon emission policy on climate change research projects (and beyond) to minimize the emissions generated by research activities, which ultimately perpetuate the paradox of aggravating climate change impacts among Indigenous Peoples and local communities.

Concrete steps for **decision makers** to put the aforementioned recommendation into action include:

Enhance decision makers' competencies and capacities to receive, comprehend, and value insights from Indigenous peoples and local communities, both at the individual and institutional levels.

- Include representatives of Indigenous Peoples and local communities at all levels of climate decision-making. Given their existing management of territories, at the local level, Indigenous Peoples and local communities should be actively included in local climate policy and planning. At the global level, Indigenous Peoples and local communities should be guaranteed permanent, effective, and meaningful participation in intergovernmental processes and bodies.
- Incorporate Indigenous and local knowledge into all stages of climate decision-making, from defining climate change impacts, vulnerabilities, and adaptations to designing climate policies and making decisions about climate finance. Specifically, as Indigenous Peoples and local communities must adapt to changes they are not responsible for, and as responding to these changes incurs high costs, governments must cover the increased costs associated with dealing with climate change and its impacts. This includes both economic and non-economic costs associated with loss and damage from climate change impacts.
- Uphold Indigenous Peoples' Rights (as enshrined in UNDRIP, 2007) in climate policy, which involves undergoing proper and continuous consultation and Free, Prior Informed Consent (FPIC) before establishing any policies for climate mitigation, adaptation, and reparation.
- Ensure *multifoci* and inclusive adaptation policies that consider potential synergies between climatic and socioeconomic factors, which prioritize contextualized and locally implemented solutions, and avoid technological lock-in.
- Improve policies based on contextualized intersectional vulnerability assessments that consider the specific vulnerabilities of certain groups (e.g., Indigenous Peoples, ethnic minorities, women, children, landless people) and integrate those factors in climate action plans at all governance levels.
- Improve horizontal and vertical coherence in climate adaptation policies to integrate the multiple and simultaneous challenges faced by Indigenous Peoples and local communities across different sectors and geographic scales.

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