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Bridging Western and Indigenous epistemologies in an opaque world: Food security and food sovereignty as climate adaptation

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Abstract

Food security and food sovereignty represent two similar but distinct pathways for community-led climate adaptation. This study examines how two North American organizations—The Kake Tribal Heritage Foundation (Alaska) and La Organización Boricuá de Agricultura Ecológica (Puerto Rico)—integrate Indigenous Knowledge (IK) and Western Science (WS) to strengthen food systems against climate-related challenges such as extreme weather, supply chain disruptions, and socio-economic inequities. Kake focuses on food security, while Organización Boricuá focuses on food sovereignty. We explore how these community organizations leverage sustainable practices, culturally rooted knowledge, and community engagement to build resilience by integrating IK and WS through these differing approaches. While both groups integrate IK and WS, tensions persist between IK's emphasis on relational, long-term stewardship and WS's empirical, replicable methods. However, these case studies illustrate how food systems initiatives serve as adaptable climate strategies through integrating local and Indigenous knowledge with broader Western scientific environmental frameworks.

Keywords

Indigenous Knowledge, Western Science, food security, food sovereignty, knowledge systems, climate adaptation, community-led initiatives, agroecology, resilience

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Introduction

Climate change continues to accelerate worldwide, affecting 3.3 to 3.6 billion people in increasingly acute ways through extreme heat, unpredictable drought and rain patterns, coastal and inland flooding, wildfires, and vector-borne diseases (Intergovernmental Panel on Climate Change [IPCC], 2023). These changes are especially impactful in rural communities and among socially vulnerable groups. This confluence of factors creates widespread disruptions to food systems, including agriculture, fisheries, and global supply chains that many communities rely on (Bindoff et al., 2019; Ding et al., 2017; Gregory et al., 2005; Tchonkouang et al., 2024). These environmental and logistical disruptions lead to significant economic instability and heighten the risk of food insecurity. While communities dependent on rain-fed agriculture, such as Indigenous communities relying on local sustenance, are at particular risk (Culas, 2012; Sheffield et al., 2014), the cascading effects of climate change are a global challenge. This broad disruption has led to a focus on adapting community food systems to increase resilience to these conditions (Campbell et al., 2022; Worstell & Green, 2017), as well as a growing emphasis on food sovereignty among Indigenous communities (Sowerwine et al., 2019; VanWinkle & Friedman, 2019).

Two food systems frameworks are represented here: food security and food sovereignty. The *food security* framework is rooted in the Food and Agriculture Organization of the United Nations [FAO]'s (2006) four pillars of availability, accessibility, utilization, and stability. It focuses on ensuring adequate supply and economic access to food (FAO, 2006; Food and Agriculture Organization [FAO], 1997). Gunaratne et al. (2021) argue that this model reflects a technocratic and market-oriented logic that prioritizes productivity and trade, often reinforcing structural inequalities and environmental degradation. By contrast, the *food sovereignty* framework emphasizes the rights of communities to define and control their own food systems, linking ecological sustainability, cultural appropriateness, and self-determination (Gunaratne et al., 2021; Nyéléni, 2007). This paradigm thus reframes climate adaptation not as efficiency optimization, but as social and ecological transformation grounded in justice and local autonomy.

Bridging these two food systems frameworks offers a useful lens for understanding how differing epistemologies—Western scientific (WS) and Indigenous Knowledge (IK)—shape responses to climate vulnerability in food systems. While food security frameworks often align with Western scientific approaches, such as emphasizing technical efficiency, measurement, and global governance, food sovereignty aligns more closely with Indigenous Knowledge systems that center relationality, reciprocity, and ecological stewardship. Integrating these perspectives reveals that effective climate adaptation may depend not on privileging one framework over the other, but on creating pathways for co-production of knowledge that combine the empirical rigor of WS with the place-based wisdom of IK (Gunaratne et al., 2021; Nyéléni, 2007).

This research contributes to the conversation about the tensions and synergies between WS and IK as communities seek to adapt to climate change, build resilience, and strengthen food sovereignty and security. We conducted case studies of two community-based organizations that have either begun or increased their food systems work to increase resilience to local impacts of climate change. The village of Kake is experimenting with hydroponic farming techniques, while Organización Boricuá focuses on regenerative agriculture in Puerto Rico. Through our interviews and site visits, we focused on two research questions: What tensions between WS and IK have emerged in addressing food system challenges as part of building climate resilience? What strategies or approaches have helped navigate these tensions? Each has approached this tension in context-specific ways, highlighting the complexity of climate change adaptation strategies and the contributions that multiple ways of knowing can bring to community adaptation efforts.

Ultimately, we found that these communities do not operate within the binary ways the WS and IK frameworks are often theorized about, or about food security and food sovereignty. Both cases demonstrate how local community members selectively weave these frameworks together to meet their specific ecological, political, and cultural needs. In Kake, hydroponic infrastructure is integrated with stewardship ethics and subsistence practices, resulting in a hybrid WS–IK approach that advances food security while reinforcing cultural continuity. In Puerto Rico, agroecological organizing draws from both ancestral farming knowledge and ecological science, illustrating how food sovereignty can be co-produced through reciprocal relationships between communities and institutions. Together, these examples show how some adaptation strategies emerge in the grey spaces where epistemologies intersect, challenging colonial binaries and demonstrating how food security and sovereignty can complement one another, rather than act in opposition. Our contribution lies in conceptualizing these bridging processes and explicating frameworks for understanding how communities actively negotiate WS and IK to build resilient, culturally grounded food systems.

Literature Review

For decades, scholars have called for the integration of Indigenous Knowledge into the management of land, natural resources, water systems, food systems, and more (Aikenhead & Ogawa, 2007; Ijatuyi et al., 2025; Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2019; Souther et al., 2023). These calls have been heeded in projects throughout the world, whether led by community-based organizations, Indigenous tribes, or national governments. However, certain tensions arise when seeking to integrate WS and IK, which are exacerbated in the context of climate change. This review relies on other systematic reviews and key articles to clarify the tensions, identify opportunities for integration, and articulate the challenges posed by climate change to projects seeking to address food security and food sovereignty.

The tensions between IK and WS are rooted in epistemological differences. IK is context-specific, developed over generations of interaction with local environments, and deeply embedded within cultural and spiritual practices (Bohensky & Maru, 2011; Brondizio et al., 2021; Dorji et al., 2024; Mardero et al., 2023). It is passed down through oral traditions and emphasizes long-term observation, relationality with the environment, and adaptive processes that respond to local ecological dynamics (Berkes, 1999; Cajete, 2020; Ford et al., 2020). In contrast, WS privileges quantitative data, hypothesis testing, and the search for replicable and generalizable knowledge, often disregarding place-based observations as subjective or anecdotal (Dentzau, 2019). These differences create a significant divide in how each knowledge system is perceived and valued, with WS historically marginalizing IK by framing it as imprecise or irrelevant (Moller et al., 2004).

Many scholars have long seen the potential value of bringing IK into management and decision-making across sectors such as land stewardship, natural resources, wildfire management, water governance, and food systems, given that all of these domains are grounded in place-based ecological knowledge that is central to Indigenous ways of knowing (Bohensky & Maru, 2011; Dorji et al., 2024). In the realm of food systems, IK plays a foundational role by sustaining traditional foodways that are locally adapted, biodiverse, and ecologically reciprocal. These systems are informed by generations of lived experience and observation, and they rely on seasonal indicators, soil knowledge, seed saving, and intercropping practices (Knorr & Augustin, 2025; Mardero et al., 2023). For over 9,000 years, the milpa system, an Indigenous polycultural agriculture system in Mesoamerica, has continued to provide an adaptive food production model under changing climatic conditions, demonstrating how IK contributes to both resilience and sustainability (Mardero et al., 2023). Reviews emphasize that these foodways are not static; they are evolving hybrid systems that incorporate both Indigenous and scientific insights while resisting the extractive tendencies of industrial agriculture (Brondizio et al., 2021; Dorji et al., 2024). Recognizing the centrality of IK to food system transformation not only offers ecologically viable alternatives to dominant models but also safeguards the cultural heritage and biocultural diversity essential for climate adaptation.

Climate change challenges both knowledge systems. From the perspective of WS, climate models and predictions have become ubiquitous (IPCC, 2023). However, the uncertainty of climate futures is not easily resolved by WS methods, and the bandwidths of uncertainty widen over time. Climate change is unfolding in ways that challenge assumptions about climate stability, unsettle forecasting methods drawing on past trends, and force the scientific community to adhere to high confidence standards, potentially under accounting for future risks (Herrando-Pérez et al., 2019). Moreover, WS approaches tend to generalize across large scales in the global climate system. Traditionally, this data has tended to struggle to downscale results to local and regional geographies where meaningful adaptation takes place (Colley, 2024).

Meanwhile, climate change inherently challenges local and traditional ecological knowledge systems by destabilizing the long-standing relationships and feedback systems that communities have relied upon for generations. As climate variability introduces new ecological patterns, such as altered precipitation cycles and temperature patterns, the established understanding of local ecosystems can become unsettled, obsolete, or even counterproductive (Dorji et al., 2024; Mardero et al., 2023). These disruptions threaten not only food production systems but also the ontologies and cosmologies through which knowledge is transmitted and legitimized (Brondizio et al., 2021). While IK systems are inherently adaptive and dynamic, scholars have noted that the unprecedented pace and scale of climate change can exceed the capacity of traditional practices alone, necessitating both innovation and selective incorporation of scientific tools (Bohensky & Maru, 2011; Knorr & Augustin, 2025). In this context, communities are increasingly engaged in creating hybrid knowledge systems that blend traditional knowledge with contemporary observations and technologies, such as agroecological forecasting, digital seed exchanges, and participatory scenario planning, to address the uncertainty of emergent climatic regimes (Brondizio et al., 2021; Dorji et al., 2024). However, this evolution of knowledge also raises critical concerns about notions of justice, cultural erosion, and the terms under which integration with WS occurs, especially when these processes are mediated through extractive or externally driven research paradigms (Averett, 2022; Brondizio et al., 2021).

Both IK and WS systems provide valuable insights in the context of climate change, but their differences complicate their potential integration. Observations from IK, such as differences in sea ice distribution, fish abundance, and permafrost thaw, are often based on centuries of lived experience, providing localized data on environmental changes (Belfer et al., 2017; Ford et al., 2016; Kuptana, 1996; Riedlinger & Berkes, 2001). In contrast, WS examines these phenomena through empirical studies that may miss the depth of long-term interaction provided by IK. Daniel Pauly's (1995) concept of the shifting baseline syndrome posits that WS often misjudges ecological baselines by resetting them with each generation of scientists, not taking into account the gradual process of environmental degradation. Scholars like Berkes (1999) and Usher (2000) argue that IK provides localized expertise, enabling communities to detect subtle changes in the environment that WS often overlooks (Belfer et al., 2017). This long-term observational knowledge, embedded in cultural practices and oral histories, offers a temporal depth that complements WS. Oral histories can provide vital ecological data, helping to track climate shifts that extend beyond the temporal scope of WS (Bielawski, 1996). These critiques highlight WS's shortcomings, particularly in ecological sustainability, and support the integration of IK to foster a more ethical and comprehensive environmental stewardship approach.

Integrating IK into WS frameworks remains challenging due to gaps in validation criteria. While WS relies on empirical data and reproducibility, IK is grounded in relational knowledge and lived experience (Bohensky & Maru, 2011; Dentzau, 2019; Dorji et al., 2024). These differences often result in WS marginalizing IK as anecdotal, reinforcing the dominant narratives of scientific objectivity, generalizability, and reproducibility (Bohensky & Maru, 2011; Brondizio et al., 2021). Nadasdy (1999) and Cruikshank (1998) point out that IK is often decontextualized when integrated into WS frameworks, reducing it to isolated facts rather than acknowledging its holistic worldview (Cajete, 2020). This process diminishes the cultural and spiritual dimensions of IK, reinforcing colonial structures that marginalize Indigenous voices in environmental governance (Berkes & Folke, 1998).

Furthermore, as Makondo and Thomas (2018) discussed, institutional barriers prevent IK from being meaningfully included in global climate adaptation strategies. These barriers reflect the dominance of WS in shaping adaptation policies, often sidelining Indigenous contributions (Makondo & Thomas, 2018).

Several frameworks have been proposed to address the enduring epistemic imbalance between IK and WS, as shown in Table 1 below, each offering different pathways to knowledge integration. Among the most community-oriented is the Two-Eyed Seeing framework (Bartlett et al., 2007), which emphasizes mutual respect and relational accountability in bringing together Indigenous and Western knowledge systems. Rather than synthesizing them into a singular epistemology, Two-Eyed Seeing promotes viewing the world through both lenses simultaneously, retaining the integrity of each.

Expanding on this, Knowledge Co-Production processes, such as that developed by Yua et al. (2022), provide a structure for multistakeholder collaboration grounded in inclusivity, power-sharing, and mutual learning. These approaches are particularly relevant in climate adaptation and food systems research, where knowledge must be both locally grounded and scientifically credible. Similarly, Tsosie et al.'s (2022) Six Rs framework—respect, relationship, representation, relevance, responsibility, and reciprocity—offers ethical guidelines for research with Indigenous communities, helping to prevent extractive partnerships and to center Indigenous agency.

Relational Approaches, as outlined by Chan et al. (2016), prioritize reciprocity, trust, and long-term relationship-building, foundational components for legitimizing IK within climate adaptation processes. Adaptive Co-Management (Armitage et al., 2008) focuses on iterative, decentralized gov-

Table 1. Frameworks to Integrate Indigenous Knowledge (IK) and Western Science (WS)

Framework	Description
Two-Eyed Seeing	Emphasizes learning to see from one eye with the strengths of Indigenous Knowledge and from the other with the strengths of Western Science, fostering mutual respect and relational understanding as the foundation for collaboration.
Knowledge Co-Production	A dynamic and inclusive process that brings together diverse knowledge holders to collaboratively define problems, methods, and outcomes, enabling context-specific and equitable solutions across scales.
Six Rs	A normative framework rooted in Indigenous scholarship that centers respect, relationship, representation, relevance, responsibility, and reciprocity as guiding ethics for research and engagement.
Relational Approaches	Grounded in the idea that knowledge and adaptation emerge through sustained relationships and trust, emphasizing human-environment interdependence and local capacity-building.
Adaptive Co-Management	Integrates learning-by-doing with decentralized governance, enabling communities and institutions to iteratively respond to ecological and social change through shared authority.
Weaving Knowledge Systems	Intentionally connects Indigenous and Western epistemologies through relational processes that honor cultural protocols and uphold Indigenous agency in decision-making.
Social-Ecological Systems (SES)	Examines the interconnectedness of human and natural systems, emphasizing resilience, feedback loops, and cross-scale governance for adaptive sustainability.
Multiple Evidence Base	Recognizes multiple, equally valid forms of evidence, from scientific data to experiential and Indigenous knowledge, and seeks their complementarity in policy and practice.
Post-Normal Science (PNS)	Addresses complex, high-uncertainty problems by expanding who counts as an expert and incorporating diverse values and perspectives into the scientific process.

ernance that is well-suited to complex, dynamic systems such as food systems and water networks. Weaving Knowledge Systems (Martin & Mirraboopa, 2003) builds on this by explicitly privileging Indigenous voices and cultural protocols in the co-creation of knowledge, reinforcing sovereignty and ontological pluralism. All these frameworks have some level of epistemological overlap, focused on synthesizing two methods of analysis.

At broader scales, a set of more macro-oriented frameworks offer complementary tools. The Social-Ecological Systems (SES) framework (Ostrom, 2009) provides a diagnostic approach for understanding interactions between ecological and institutional systems. The Multiple Evidence Base (MEB) approach (Tengö et al., 2014) facilitates cross-scale dialogue by treating diverse knowledge systems as equally valid forms of evidence. Finally, Post-Normal Science (PNS) (Funtowicz & Ravetz, 1993) promotes inclusive, participatory research under conditions of uncertainty, opening space for Indigenous perspectives in global climate governance. Together, these frameworks reflect a maturing recognition that bridging IK and WS requires more than technical inclusion; it demands relational, institutional, and ethical commitments to co-production, sovereignty, and justice.

While barriers remain in integrating WS and IK, particularly in knowledge creation and power dynamics, the literature increasingly recognizes the benefits of utilizing both systems for effective climate change adaptation and for addressing failures of the industrialized food system to improve food security or food sovereignty. As the global community continues to confront the realities of climate change, integrating IK and WS may be essential in crafting adaptive strategies that are both locally relevant and globally informed. Multiple frameworks have been proposed to foster respectful and complementary integration, ensuring that both knowledge systems contribute meaningfully to climate resilience strategies. However, what is less well understood is whether these models are equally applicable or practical to people working to address food security and sovereignty in the context of climate adaptation responses. Our research aims to add to this dialogue on the challenges and opportunities of integrating WS and IK in developing climate adaptation strategies for food security and food sovereignty.

Methods

Our research seeks to understand how practitioners working for food security or food sovereignty as a climate adaptation strategy navigate tensions and seek integration of IK and WS. We approached this work by identifying our cases from a larger research project (Holmes et al., 2025) where community-based organizations were working to address food insecurity and food sovereignty in a diversity of contexts using a range of approaches. The cases, the Kake Tribal Heritage Foundation in Alaska and Organización Boricuá, allow for comparison of different programmatic approaches and contexts for addressing food insecurity and sovereignty issues. For data collection, we reviewed program websites and publicly available program documents, including grant applications and reporting documents. We conducted one-to-two-hour interviews with 14 respondents (three from Kake, 11 from Boricuá) from the cases to delve more deeply into specific programs. Finally, we conducted a three-day site visit to Puerto Rico to meet with Organización Boricuá staff members, travel to program sites, conduct interviews with staff and community members, and engage in informal conversations in context.

Our interviews covered the program's operational mechanisms, funding, governance, policy impediments, successes and challenges, and scaling. The tensions and integration of IK and WS emerged in different ways in both cases and became a central theme of our ongoing data collection efforts. Our data analysis involved reviewing program documentation of all programs, as well as interview transcripts and notes from observations and informal conversations. The project team met, on average, 1.5 times per month throughout the data collection and analysis process, which consisted of two years of working together. Team members independently reviewed transcripts and project documents to identify emerging themes across cases. In our review, co-authors independently identified knowledge systems as a core challenge facing these projects. As a team, we began having cross-case discussions among those involved directly in data collection for each case to compare and contrast alignment with our emergent analysis. We focused our analysis on data pertaining to how these different groups navigated tensions between different knowledge systems as they arose. We continued monthly group discussions to cross-reference our respective reviews of the data, where we began to draw out key themes related to knowledge systems and their use in developing and implementing climate adaptation projects to build food security and sovereignty. Through these team meetings, we developed our cross-cutting themes, which we elaborate on in our discussion section.

Case Studies

To explore how community-based organizations navigate the complexities of climate adaptation and knowledge integration, this section presents two distinct case studies: the Kake Tribal Heritage Foundation in Alaska and La Organización Boricuá de Agricultura Ecológica in Puerto Rico. While Kake primarily utilizes a food security framework and Organización Boricuá that of food sovereignty, both cases illustrate how local practitioners negotiate the tensions between Western Science and Indigenous Knowledge. Through a review of these diverse contexts, we examine the context-specific strategies used to build local resilience, the "grey spaces" where these differing epistemologies intersect, and how contrasting strategies were ultimately selected.

The Village of Kake

The village of Kake, one of the homes of the Tlingit people in Southeast Alaska, is a small community of approximately 470 residents on Kupreanof Island. The island is dominated by the Tongass National Forest and makes up part of the archipelago composing the Alaskan panhandle (U.S. Census Bureau, 2025). Historically, Kake's food system has been deeply rooted in the community's traditional knowledge, which revolves around the sustainable use of local resources such as fish (salmon, halibut, herring), shellfish (gumboots and clams), land mammals (deer, moose, and grouse), and berries (Personal interview, anonymous member of the Kake Tribal Heritage Foundation Interview, October 27, 2023). This Tlingit geographic and cultural knowledge is passed down through generations, where places are not purely physical locations, but hold historical, spiritual, and social importance. They are deeply connected to the Tlingit cultural identity and spiritual relationship with the land (Thornton, 2008, p. 36). IK systems, like those in Kake, are based on long-term lived experiences, oral traditions, and practices adapted to the local environment over centuries. They offer a nuanced understanding of ecological balance, ensuring sustainable harvesting practices and careful stewardship of resources (Personal interview, anonymous member of the Kake Tribal Heritage Foundation Interview, October 27, 2023).

As climate change accelerates and disrupts local ecosystems, Kake faces new challenges that strain this traditional knowledge. Increasingly unpredictable weather patterns, warmer water temperatures, and shifts in seasonal cycles affect the availability and quality of the natural resources upon which the Tlingit have traditionally relied (Personal interview, anonymous member of the Kake Tribal Heritage Foundation Interview, October 27, 2023). For example, salmon, a cornerstone of the community's diet, face barriers to spawning as stream temperatures rise (Crozier et al., 2021), while clams and gumboots can become toxic in warmer waters (van der Fels-Klerx, 2012). The people of Kake have experienced these impacts directly: "As the waters get warmer and warmer, the level of toxicity has been rising at a high rate lately" (Personal interview, anonymous member of the Kake Tribal Heritage Foundation Interview, October 27, 2023), leading to restrictions on clam consumption to protect health. Various berry crops, including blueberries, salmonberries, and blackberries, are impacted by drought and excessive rainfall, resulting in reduced harvests in drought years and moldy crops in overly wet years (Mucioki, 2024; personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023).

Due to these disruptions, imported foods have played an increasingly significant role in the Kake food system. Imported foods are brought into Kake through two avenues: through a seaplane and a barge. While the seaplane has maintained consistent schedules, the cost of transporting goods is exceptionally high at around US$1.00 per pound. This fee turns a US$10 case of water into a US$35 financial hardship (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). While far more affordable, the barge has faced repeated interruptions, sometimes leading to fresh produce arriving spoiled (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023).

These disruptions have created uncertainty and stress in the food systems that the people of Kake rely on, with one resident noting, "We've noticed a dramatic change over the past 15 years—it's definitely a lot different than when I was my kids' age" (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). While traditional knowledge offers insight into managing these resources, the scale and rapid pace of these changes present unprecedented challenges that traditional methods alone may struggle to address. In response to these challenges, an external consultant to the tribe recommended applying for grant funding to add capacity to their adaptation efforts, thus leading to a US$100,000 grant, the largest the foundation had ever procured (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). This was funded through the Climate Resiliency program of the First Nations Development Institute, an American Indian nonprofit that has funded over US$100 million in grants since 1993, covering a range of thematic areas, including climate change, language, and agriculture. This funding helped facilitate the foundation's acquisition of a hydroponic system, a controlled environment system for growing plants in a nutrient-rich water solution, instead of growing crops in soil exposed to the elements (U.S. Department of Agriculture [USDA], 2025). This allowed foundation leaders and volunteers to grow green leafy vegetables year-round for distribution directly to community members who face challenges in regularly obtaining healthy foods.

The hydroponics system represents a Western, technology-driven approach to food security and was initially met with skepticism from some members of the community. It took months to receive the equipment and weeks to obtain training and install the system; then, a few short weeks later, the results of growing lettuce in the system began to become apparent. The system was installed in a community facility and overseen by staff and volunteers of the Tribal Foundation. It served primarily as a demonstration project that could be expanded for more substantial production in the future. Some community members viewed the technology as "too artificial" (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). It was a stark departure from their experience relying on their natural ecosystems. In a community where "everything's completely natural, we eat what grows out of the ground or what we fish or pick the berries or [hunt] deer or moose," the introduction of a system that produces vegetables in a matter of weeks seemed unnatural and disorienting to some (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). Despite this initial community consternation, the project began gaining acceptance as lettuces began to grow. According to our interviewees, as community members witnessed the practical benefits of the hydroponic system, such as the ability to grow fresh vegetables across all seasons, they began to reconcile the traditional with the new.

The project's leaders are keenly aware that they must balance maintaining the cultural integrity of the community's traditional food system while slowly integrating new Western technologies (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). The hydroponic system is not intended to be or seen as a replacement for Kake's traditional food system. It is seen as a complementary tool that can help mitigate the risks posed by climate change (Mucioki, 2024). This is evident in a traditional agricultural training project at the local school, where students are learning how to establish and manage local farms tied to the growing season of the island (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). These simultaneous efforts by different organizations on the island align behind the shared goal of decoupling dependencies on industrial food systems supply chains and strengthening capacity for self-reliance.

As the project progressed, the Kake Tribal Heritage Foundation continued educating the community regarding the risks of climate change and the benefits of adopting new adaptive strategies (Personal interview, anonymous member of the Kake Tribal Heritage Foundation, October 27, 2023). The hydroponic system is not solely about growing vegetables; it is also about preparing for a future where climate disruptions severely impact traditional food sources. The foundation's leaders see the project as part of a broader strategy to improve self-reliance and resilience in the face of climate change. The hydroponics project fosters greater food security, even while deviating from a more traditional food system. However, the leaders recognize the need to involve community members as they introduce new elements into their food system. In this way, Kake's hydroponic system represents a critical step into the intersection of WS and IK, aiming to offer a pathway toward climate resiliency while respecting the community's cultural heritage.

La Organización Boricuá de Agricultura Ecológica de Puerto Rico

The colonial history of Puerto Rico, from Spanish rule in the 16th century to a U.S. territory over the last century, has laid the groundwork for a dependency on external resources, particularly in food production (Garriga-Lopez & Ginzburg, 2023). Prior to this colonial shift, Puerto Rico's agricultural practices were largely self-sustaining, with Indigenous (Taíno) and later Afro-Caribbean communities developing agricultural systems that were in harmony with the island's natural environment (Taíno Society, 2018). However, as industrialization took hold through initiatives like Operation Bootstrap in 1947, the island shifted to a model prioritizing export-driven, industrialized agriculture (Ayala & Kennedy, 2021). This, in turn, left Puerto Rico heavily reliant on food imports, which made up 85% of its food supply by the 1980s (Caban, 1989). This shift not only disrupted traditional agricultural knowledge but also increased the island's vulnerability to external shocks, as demonstrated during the COVID-19 pandemic when the number of families experiencing food insecurity on the island increased by 16,000 (Ostolaza et al., 2021).

In this context, Organización Boricuá, founded in 1989, has worked to reclaim food sovereignty through agroecology, a framework that intertwines WS with IK. In contrast to industrial farming, agroecology emphasizes biodiversity, sustainability, and the integration of local knowledge systems with ecological science (Wezel et al., 2020). According to one of the project organizers, their methods, which draw on ancestral agricultural practices such as diversified cropping and soil health management, are proving more resilient in the face of climate change. He points out that after Hurricanes Irma and Maria made landfall in 2017 as category-five storms, conventional monoculture farms using chemical inputs and monocropping were devastated, while agroecological farms sustained minimal damage:

> In the communities that we are at, where we've put into practice these systems, we didn't have any damage to the topsoil. … We saw conventional farms that are heavy on external inputs, like chemical inputs, chemical fertilizers, and herbicides, and they do monocropping. They lost everything because they didn't have a diverse nature; it doesn't work. (Personal interview, anonymous member of Organización Boricuá, July 6, 2023)

Farmers within Organización Boricuá note that tensions exist between the approaches to technology and ecological practices. Indigenous farming methodologies used by the farmers often emphasize traditional ecological knowledge and practices developed over millennia. In contrast, Western methodologies frequently rely on modern technologies and practices that may not consider ecological ramifications. One example is the use of herbicides and pesticides by larger global farming companies in Puerto Rico to eradicate weeds and pests. These chemicals, the farmers explained, always seep into fertile land and water systems, negatively affecting crops and water filtration for months (Personal interview, anonymous member of Organización Boricuá, July 6, 2023). Indigenous, holistic approaches supporting biodiversity include organic composition, crop diversification, or the introduction of beneficial insects that naturally prey on the pests in contrast to the toxic chemical approach.

The introduction of genetically modified organisms (GMOs) and other experimental practices by Western farmers, subsidized and incentivized by the government to farm on large, fertile land, is another recognized conflict. Agribusinesses are allowed to experiment with various crops, using GMOs, without the consent of local farmers. Farmers who value traditional methods and sustainable practices often resist these practices (Personal interview, anonymous member of Organización Boricuá, July 6, 2023; Martínez Mercado, 2017). These policies enacted by the government have not only conflicted with IK but have also caused concerns about health consequences and long-term environmental impacts (Ramos, 2019; Personal interview, anonymous member of Organización Boricuá, July 6, 2023).

Beyond these technology tensions, farmers perceive that government policies have historically displaced rural and farming communities. The farmers indicated that multinational agricultural agrochemical corporations (such as Bayer, Syngenta, and DuPont), along with government policies, perpetuate dependency on specific types of seeds and agricultural practices. Foods produced on the island are bound for export while processed foods fill island stores. Local farmers try to resist this corporate dominance, contesting the role of multinationals in prolonging unsustainable food practices. Organización Boricuá engages in policy advocacy, builds community networks, promotes education and awareness-building, and seeks to resist land grabs and resolve land tenure and access conflicts.

Despite these tensions, there are synergies between Indigenous Knowledge and Western Science that incorporate both traditional ecological knowledge and modern techniques in agricultural practices. Agroecology itself represents a Western, scientifically validated approach grounded in Indigenous farming practices. While this form of agricultural practice can be seen as a form of resistance to mainstream Western industrialized monoculture, Western Science and technology provide insight and support to the Indigenous techniques. Farmers participating in Organización Boricuá use traditional agricultural practices and collaborative approaches such as resource sharing, partnerships with local organizations, and the continuous exploration of refined techniques in farming. However, these techniques are intertwined with other techniques that have helped the Indigenous systems to become climate resilient. One farmer mentioned using plastic structures to create small greenhouses, which helps protect crops from adverse weather conditions. Others use cistern water catchment systems to better manage water resources and adapt to weather variability, such as addressing water shortages during summer months, which have recently begun to plague farms more often (Personal interview, anonymous member of Organización Boricuá, July 6, 2023). The union of Western methodologies with their current practices provided technological and practical solutions.

Ultimately, the work of Organización Boricuá exemplifies how IK and WS can complement each other, particularly in the realm of climate adaptation. By blending traditional practices informed by IK with technologies and practices informed by WS, the organization is helping to create a more resilient and self-reliant Puerto Rico. However, this process is not without challenges, as it requires constant negotiation between competing worldviews and knowledge systems, all in a context of ongoing colonial dynamics and environmental crises.

Discussion

The case studies of the village of Kake and Organización Boricuá reveal that, while food security and food sovereignty are often theorized as distinct or even oppositional paths, in practice, they function as complementary strategies for climate adaptation. This section moves beyond the individual narratives of these organizations to analyze how they collectively navigate the epistemological tensions between Western Science and Indigenous Knowledge. By examining the context-dependency of these efforts and the frameworks that support knowledge integration, we illustrate that resilient food systems are built not by prioritizing one knowledge system, but through relational processes that integrate both empirical rigor and place-based wisdom.

Context Dependency and Climate Change

Scholars of Indigenous ways of knowing recognize that IK is context-dependent, based on the place, traditions, cultures, and stories of the Indigenous peoples who have lived in particular regions for generations (Bohensky & Maru, 2011; Dorji et al., 2024; Brondizio et al., 2021). This place-based ecological knowledge, sometimes referred to as Traditional Ecological Knowledge (TEK), is foundational to many Indigenous Knowledge systems. Our cases align with this perspective, particularly in relation to food systems. However, the context of climate change and colonial capitalist systems has led to changes that challenge this foundational knowledge and traditional foodways. The tensions that arise in our cases mirror many of those that are identified in the literature, such as conflicting epistemological assumptions and worldviews (Bohensky & Maru, 2011; Brondizio et al., 2021; Dorji et al., 2024; Tengö et al., 2014). Some of the tensions in our cases also demonstrate how climate change exacerbates challenges to both WS and IK.

For example, in Kake, IK has contributed to a rich understanding of the ecological systems that contribute to local food sources. The traditional food system was tied to knowledge of ecological systems, seasons, and cycles that allow for hunting of game and seafood, and gathering of fruits in particular. Meanwhile, the industrial food system fostered a dependency on weekly barge shipments of processed foods and produce to supply the shelves of the local grocery. Supply disruptions during the COVID-19 pandemic demonstrated to the people of Kake that their over-reliance on the industrial food system made their food security less resilient and undermined their food sovereignty. However, turning to local food sources proved challenging, as the ecological reality was shifting in the face of climate change. Seasons are changing, food sources are becoming uncertain and unpredictable, and, in the case of the clams, a traditional food source is becoming toxic as waters warm. In seeking food security in Kake, the Kake Heritage Foundation has sought new food-producing technologies and approaches to adapt to this changing context, one that blends IK and WS traditions.

Agroecology in Puerto Rico is not just an agricultural movement; it is also a tool for sovereignty and resilience, particularly in the aftermath of colonialism and climate disasters. After Hurricane Maria, agroecology became a lifeline for many communities, enabling them to rebuild sustainable food systems in the face of government neglect and infrastructural collapse (Gies, 2018). The failures of the industrial food system in the face of such a high-intensity disaster emphasized the value of Indigenous Knowledge to build resilience. Agroecology is rooted in ecological principles and informed by Indigenous and local practices. It emphasizes natural processes and ecosystem services over a reliance on synthetic inputs and technological advancements characteristic of industrial agriculture. These technologies, initially designed for highly mechanized industrial systems, do not intrinsically align with agroecological systems, which prioritize biodiversity, ecological balance, and social equity (Zeng et al., 2023). Still, scaling up the agroecology approach has proven challenging, both in terms of overcoming the power of corporations in shaping land tenure and agricultural inputs, and in controlling seed, and in dealing with the land and labor-intensive agroecology processes. Furthermore, other resilience responses, such as building solar farms, compete for the available land, creating tensions between different sets of needs, including energy demands in the food system.

Food Security and Food Sovereignty

Distinguishing between food security and food sovereignty is useful when examining how WS and IK epistemologies differently conceptualize adaptation, resilience, and justice in food systems. Food security has been institutionalized as the dominant global framework through government agencies, philanthropic funders, and policy metrics, by emphasizing technical solutions, market efficiency, and the quantitative assessment of supply and demand (FAO, 1997, 2006). As Gunaratne et al. (2021) argue, this framework reflects a Western technocratic worldview that prioritizes productivity, trade, and economic growth, often at the expense of local autonomy and ecological sustainability. In this model, food is treated as a commodity whose “security” depends on international markets, technological inputs, and state regulation rather than on community control or cultural integrity. In contrast, food sovereignty, as articulated in the Nyéléni Declaration (2007) and championed by La Via Campesina, reframes food as a right grounded in ecological stewardship, local knowledge, and self-determination. It is explicitly a collective and relational concept, emphasizing the ability of communities to define their own agricultural systems, protect biodiversity, and sustain culturally appropriate practices through reciprocal relations with land, water, and nonhuman life (Nyéléni, 2007; Wittman, 2011).

Rather than viewing these frameworks as oppositional, the two case studies illustrate how they can function in tandem through the bridging of WS and IK. Kake's hydroponic agriculture project, for instance, aligns with a food security approach by addressing logistical and climatic constraints on year-round food availability in a remote and rapidly shifting community. Yet its design, implementation, and monitoring processes are deeply rooted in local values of stewardship and intergenerational knowledge transfer, reflecting IK principles of relationality and adaptation to place (Lenart, 2022). By integrating hydroponic technologies with traditional ecological knowledge—such as seasonal cycles and water use ethics—Kake demonstrates that WS and IK can co-produce contextually appropriate innovations that strengthen both physical and cultural resilience.

In contrast, Organización Boricuá pursues a food sovereignty pathway grounded in agroecology and community governance. Its regenerative farming initiatives emphasize autonomy, soil regeneration, and collective seed stewardship, prioritizing local control over inputs, decision-making, and land management (Carrasco-Torrontegui et al., 2021). While less reliant on formal scientific infrastructure, Organización Boricuá's approach also engages with WS ecological research, drawing on data on soil carbon, crop diversity, and rainfall patterns to enhance sustainability. Through these collaborations, the organization exemplifies the principles of knowledge co-production and the "Two-Eyed Seeing" framework (Bartlett et al., 2007), in which scientific and Indigenous ways of knowing operate in parallel and inform each other. The result is not a rejection of WS but a reframing of it as a partner in a pluralistic epistemological landscape that centers cultural sovereignty and ecological resilience.

Both cases reveal that whether pursuing food security or food sovereignty, effective climate adaptation depends not on privileging one epistemology over the other, but on building bridges between them. Kake's success in blending hydroponic innovation with local stewardship, and Boricuá's use of agroecology to resist dependency while engaging with ecological science, both demonstrate that WS and IK can complement each other when grounded in mutual respect and shared goals. As Gunaratne et al. (2021) argue, climate adaptation must move beyond binary framings toward integrative systems of knowledge. Climate change, while challenging both WS and IK in different ways, presents an opportunity for integrating these knowledge systems to more effectively respond to climate impacts. In this light, whether pursuing food security or food sovereignty, WS and IK can be bridged through participatory governance and relational science to support more resilient, equitable, and sustainable food systems.

Relationships for Integration

What stands out in our cases is that the knowledge conflicts of IK and WS are navigated most effectively through interpersonal relationships that cut across Indigenous and Western colonizing cultures. In Kake, the tribe did not lead the charge to hydroponics. Rather, it was a Western climate scientist who identified this potential solution to a recognized need for food security. She had both the analytical skills to make the case and the technical skills to both procure and manage a grant, the largest the Kake Tribal Heritage Foundation had ever obtained. The approach was in many ways unfamiliar to the tribal members—the grants and reporting process, the technology of hydroponics, growing food throughout the year in a climate with a seasonally limited growing season, and more. But they had a prior relationship and trusted their partner, who guided the grant-making and implementation of the project. They collectively navigated the tensions due to a trusted partnership and strong relationship after years of working together on another climate change data science project. It had less to do with reconciling competing knowledge systems than navigating uncertain and conflicting terrain together with a friend.

In Puerto Rico, Indigenous farming practices are more community-oriented, as local farmers support each other through regular social interactions, such as 'La Promesa' celebration, which recognizes teachers, historical stalwarts in the farming community, and successful crop growers from the previous year. At the beginning of each year, farmers from Organización Boricuá participate in La Promesa. Through music, socialization, food, and spiritual activities, a sense of community and solidarity is concretized among the farmers. Through this process of building solidarity, farmers working with the organization recommit to the agroecology approach and find ways to navigate tensions between their approach and industrial farming systems.

Frameworks for Practice

In our literature search, we identified nine frameworks that aim to reconcile tensions between IK and WS. What our cases demonstrate is that among the frameworks for integrating IK and WS, those that focus on relationships, community-building, and trust-building appear to be more effective when seeking to build food security and sovereignty in the context of climate change.

The work undertaken by Kake exemplifies the relational and trust-centered frameworks of *Two-Eyed Seeing*, *Relational Approaches*, and *Knowledge Co-Production*, embodying the principle of viewing the world "through both eyes." They aim to balance the IK of ecological cycles with WS tools for sustainable food production. This process has strengthened local adaptive capacity by integrating local food production through Western scientific methods, enabling the community to produce healthy and "natural" food, as well as new technological methods of production (Riedlinger & Berkes, 2001; Ford et al., 2020). Through iterative collaboration and shared authority, Kake demonstrates *Adaptive Co-Management* in practice, where trust and relational accountability form the foundation of effective cross-epistemic food system adaptation (Armitage et al., 2008; Bartlett et al., 2007)

Organización Boricuá's work in agroecology manifests multiple knowledge-bridging frameworks, most prominently *Weaving Knowledge Systems*, *Six Rs*, and *Knowledge Co-Production*, thus integrating ancestral farming techniques with scientific methods of soil regeneration and biodiversity management. Their diversified cropping and seed preservation practices exemplify *Weaving Knowledge Systems* (Martin & Mirraboopa, 2003), prioritizing Indigenous voices and cultural protocols in the co-creation of knowledge. This collaboration has produced empirically validated approaches to soil health that also sustain cultural continuity and community autonomy. The *Six Rs* framework (Tsosie et al., 2022) is reflected in Organización Boricuá's ethical commitments to respect, reciprocity, and responsibility for the land, principles embedded in their struggle for food sovereignty and resistance to extractive agribusiness models (Altieri et al., 2015). Together, these practices embody a relational and justice-oriented model of climate adaptation grounded in ecological and cultural regeneration

Additionally, for Organización Boricuá, their work is centered on agroecology, an agricultural framework that intentionally weaves together IK and WS. The organization's methods, such as diversified cropping and soil health management, are rooted in ancestral practices while also being scientifically validated for their resilience to climate shocks. These approaches embody the *Weaving Knowledge Systems* framework and are a clear example of *Knowledge Co-Production*, where traditional methods are proven effective through empirical observation. Furthermore, their efforts to protect agricultural land and prioritize food sovereignty over technological fixes for renewable energy reflect the core principles of the *Six Rs* framework, emphasizing respect and responsibility for the land and community. Our site visit in Puerto Rico highlighted this commitment to relational approaches; we saw firsthand how the organization's work is deeply embedded in the land and culture, fostering a sense of biocultural heritage that stands in stark contrast to the extractive, capitalist models of industrial agriculture.

These overlapping and at times competing frameworks typically have strengths that work to accomplish a range of goals, from constructing new methods of participatory research and community engagement to concerns regarding multi-level governance. None of these frameworks is wholly unique or distinct, having borrowed and built upon the most effective elements of the frameworks that came before it. When utilizing these frameworks as an analytical tool in practical, community-driven work, those most applicable can lead communities toward better pathways for building knowledge systems.

We also recognize that in the context of climate change, uncertainties, emergent challenges, and changing contexts are central to the experience of people working to address longstanding challenges to food security and food sovereignty. In many ways, the improvisational and relational responses are those that gain traction in these cases. It is not necessarily a systematic analysis of many variables or the development of a strategic plan. Rather, it is well-meaning, determined, and capable people, working together with others who bring different skills, competencies, and perspectives to the table, filling gaps and making progress together that makes the difference. Thus, trusting relationships allow participants to navigate tensions and discomfort together as they work through their differences and come to depend on each other to develop understanding and make progress.

Conclusion

The long-standing binary between food security and food sovereignty—and, by extension, between WS and IK—cannot be separated from the histories of colonization and imperialism that produced it. These global systems of power institutionalized hierarchies of knowledge, positioning WS as universal, objective, and modern, while rendering IK as local, subjective, and antiquated (Shiva, 1988; Smith, 1999). This epistemic asymmetry was central to colonial expansion: it justified the displacement of Indigenous food systems, the commodification of land and seed, and the imposition of technocratic agricultural models. The global "food security" paradigm, though well-intentioned, still reflects these colonial logics of extraction and control, emphasizing productivity, efficiency, and external expertise. By contrast, "food sovereignty" has emerged as a decolonial counter framework rooted in IK systems that center reciprocity, ecological balance, and self-determination (Nyéléni, 2007; Wittman, 2011).

However, the world in practice is far more complex than this theoretical binary suggests. The dichotomy between WS and IK, so sharply drawn in theory, rarely holds in communities navigating the lived realities of climate change. The case studies of Kake and Organización Boricuá demonstrate that effective adaptation occurs not at the poles but in the spaces between. Both cases illustrate how communities historically marginalized by colonization are reclaiming agency by blending WS and IK in ways that reinforce cultural integrity while enhancing adaptive capacity.

In this light, bridging frameworks such as *Two-Eyed Seeing*, *Knowledge Co-Production*, and the *Multiple Evidence Base* take on both methodological and political importance. They are not simply tools for community collaboration, but mechanisms for unsettling the hierarchies that have long separated WS and IK. These frameworks invite an orientation that values complementarity over competition. Recognizing that the world is neither binary nor neatly ordered, but instead textured and relational, allows for a more honest engagement with how knowledge is produced, shared, and applied. By embracing the spaces where WS and IK intersect, food systems can be both scientifically robust and culturally grounded, capable of addressing not only the technical dimensions of climate adaptation but moral, historical, and relational ones as well.

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