Bridging Power and Knowledge

Addressing Global Imbalances in Knowledge Systems for Sustainable Futures

Volume 3, Issue 1 (2025)

Edited by

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2024 Humboldt Residency Programme

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Front Matter

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Special thanks go to the members of the **Scientific Advisory Board** for their scholarly guidance, and to the global networks that continue to challenge and inspire the reimagining of knowledge, justice, and sustainability.

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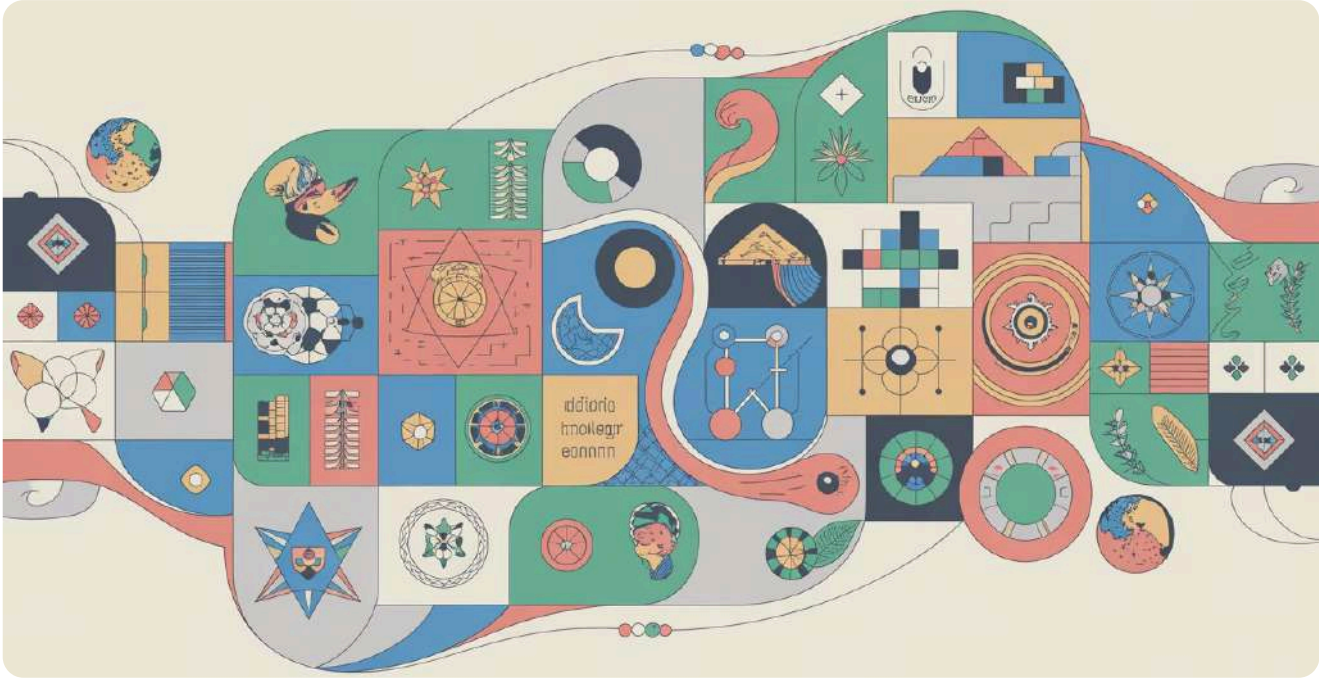

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Reflections & Emerging Pathways

This concluding reflection gathers insights from across the issue – tracing how the Humboldt Residency journey redefined collaboration across continents and disciplines. It calls for humility in knowledge exchange, empathy in research practice, and solidarity in shaping sustainable futures that honour both scientific innovation and ancestral wisdom.

About the Special Issue

This special issue of *SustainE*, *"Bridging Power and Knowledge,"* is a culmination of the **2024 Humboldt Residency Programme**, supported by the **Alexander von Humboldt Foundation**. The issue convenes diverse voices from across the world to explore how rebalancing global knowledge systems can advance sustainability, inclusion, and justice.

Through case studies, theoretical contributions, and community-led research, the authors illuminate how multiple epistemologies – scientific, indigenous, local, and spiritual – can coexist, interact, and co-create solutions for our shared future. Collectively, the works reaffirm that sustainable development is not only a technical challenge, but a profound cultural and ethical project that must reconcile **power and knowledge** through equity and dialogue.

Thematic Overview

(Summarised across four sections: Conceptual & Theoretical Foundations • Climate Change, Governance & Intersectionality • Case Studies of Local Knowledge & Sustainability Practices • Technology, Innovation & Future Pathways)

Each section contributes a critical dimension to the conversation – from rethinking epistemic hierarchies to showcasing grassroots innovation and youth-led climate action – all united by a vision of shared responsibility and global solidarity.

Preface

The idea for this special issue emerged just over a year ago during the Humboldt Residency Programme during which we as editors spent the summer of 2024 together. We reflected on how to organise an exchange of knowledge between the Global North and the Global South- both within the academic system and beyond. Our discussions centred on how to create research collaborations that are genuinely fair, given the stark power imbalances that remain. Too often, knowledge from the Global South is extracted, while collaborations disproportionately benefit scientists from the Global North, who advance their careers through prestigious publications and favourable authorship positions.

It was against this backdrop that the theme of this issue took shape: **"Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures."**

One of the themes that emerged was what is considered knowledge and who produces it. Within the academic framework, this is quite clear. Any new information that goes through peer reviewed scrutiny is considered new knowledge once it has been published and the authors are considered knowledge producers.

Yet, alongside this, there exist a multitude of other knowledge systems. Indigenous peoples hold generations-old wisdom about their environments. Activists develop specialised and localised knowledge, along with practical skills to achieve social change. Local communities are producing new forms of knowledge to confront climate change. There are countless individuals working independently in their homes or small workshops, driven by curiosity and the desire to improve society. And, of course, there are many other "knowledge generators" that we may not yet have fully recognised.

> To create space for diverse forms of knowledge and to ensure that these alternative forms are widely acknowledged and celebrated we conceptualised a different approach. Our idea was to take the model of "peer review or quality control" and experiment with extending it to other forms of knowledge that are too often excluded.

The goal behind this special issue was not only to showcase diverse knowledge systems, but to create an experimental publishing space where these voices could be placed on equal footing with academic science. By doing so, we wanted to test whether academic publishing itself could evolve into something more inclusive and representative of the world's knowledge. In SustainE, we found a partner willing to engage in this bold experiment, and in the Alexander von Humboldt Foundation, a funder prepared to support it, without knowing what the outcome would be. Our hope is that this issue will serve as a blueprint for future initiatives that seek to challenge the narrow boundaries of academic publishing, and as a step towards systemic change in how knowledge is valued and disseminated.

One of our greatest challenges was reaching those who could contribute. In the end, we received an extraordinary number of submissions–over 15 contributions in total. Still, we asked ourselves: did we reach everyone we hoped to? Our intention was to provide a platform for people who may not even realise their knowledge is valuable, who may never have thought of publishing in a journal, and for whom a conventional "call for submissions" might mean very little. We wanted to open a space where such knowledge could be recognised, preserved, and shared alongside more formal academic contributions. With strong support from the Humboldt Residency Programme and the Alexander von Humboldt Foundation, we relied on social media as well as our own networks to reach potential contributors. Yet, we also recognised the limitations: on such platforms, communication often remains within bubbles of like-minded peers.

Even so, we succeeded in gathering a diverse range of voices and perspectives, and the results are remarkable. This issue features, among others: an article on how Kazakhstan's volunteer movement is reshaping perceptions of social innovation; an exploration of whether the cultural heritage of an island nation, soon to be lost to rising sea levels, can be preserved in the metaverse; and an account from Rwanda, where traditional signs of rain have become unreliable due to climate change, and an agricultural scientist works to make official weather forecasts more usable for farmers. These are just three of the eleven contributions included here, each one equally compelling, each one building bridges, and each one adding to our shared pool of knowledge.

Finally, we extend our sincere thanks to the Humboldt Residency Programme and the Alexander von Humboldt Foundation for their support, encouragement, and trust in this experiment, and to all contributors for sharing their diverse knowledge and perspectives.

We hope you enjoy reading this issue.

Adenike Akinsemolu · Annick Eimer · Sarah Iqbal

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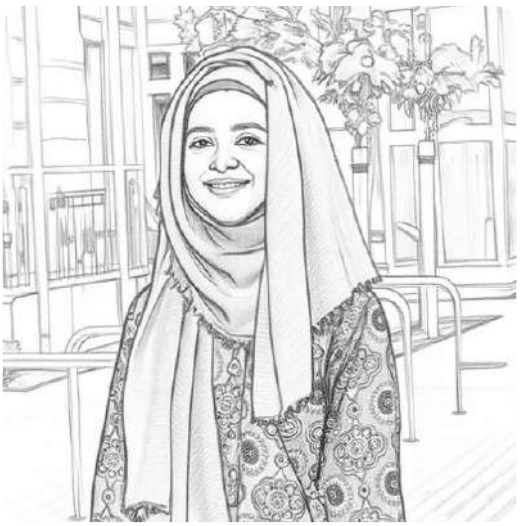

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Fostering Equitable Sustainability: Integrating Indigenous Wisdom and Scientific Knowledge for Global Solutions

PERSPECTIVE

Vaishnavi Bhagat
Viara Foundation

This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Indigenous Knowledge Systems

Traditional, local, and indigenous knowledge systems offer invaluable insights rooted in centuries of harmony with the land, providing sustainable solutions to environmental challenges.

Equitable Partnerships

The Viara Foundation demonstrates how to integrate indigenous knowledge with scientific research through community-driven solutions that empower local communities while preserving cultural heritage.

Bridging Knowledge Worlds

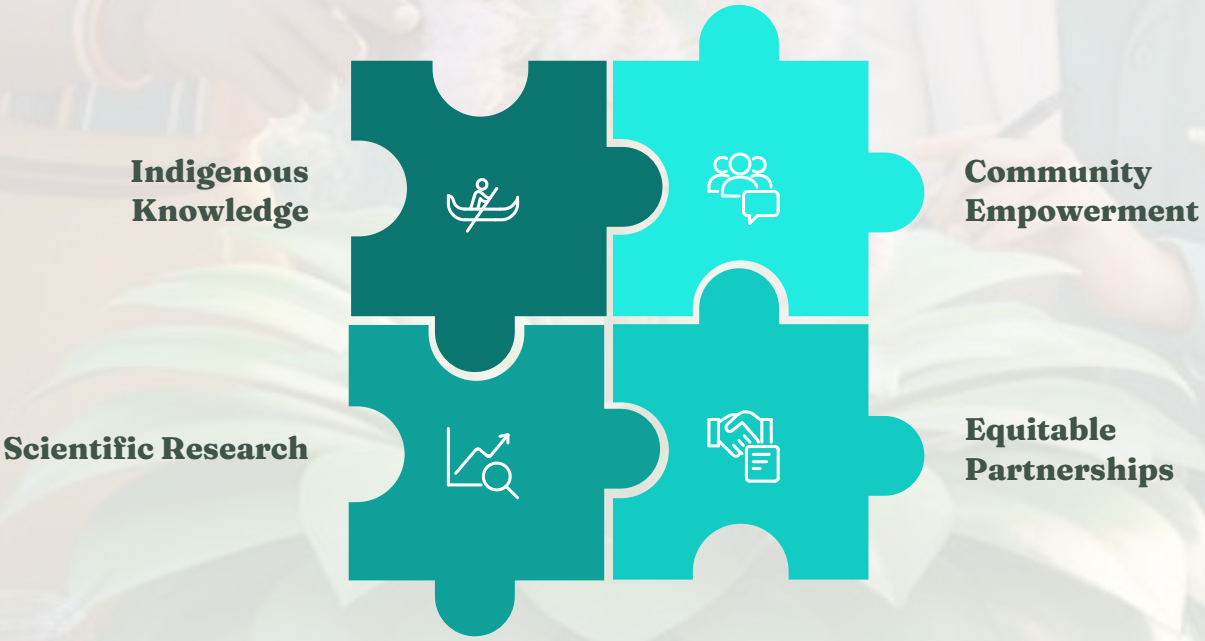
Creating partnerships that bridge traditional and scientific knowledge systems requires addressing historical marginalization, building trust, and fostering cross-cultural collaboration.

Global Implications

This approach offers a model for achieving global sustainability through inclusive knowledge systems that respect indigenous wisdom while leveraging scientific research for climate action.

ABSTRACT

In the face of unprecedented global environmental challenges, there is a growing recognition that sustainability cannot be achieved through a one-size-fits-all approach. Traditional, local, and indigenous knowledge systems–deeply rooted in the wisdom of communities who have lived in harmony with the land for centuries–offer invaluable insights that complement scientific research and technological solutions. These knowledge systems, however, have often been sidelined in global conversations on climate change and sustainability. As we move toward more inclusive and effective climate action, it is essential to bridge these knowledge worlds and create partnerships that empower local and indigenous communities. The Viara Foundation, with its commitment to community-driven solutions, offers a model for integrating indigenous knowledge with scientific research in a way that fosters empowerment and equity. This essay explores the integration of traditional knowledge with academic and scientific research, emphasizing the importance of equitable partnerships, cross-cultural collaboration, and inclusive knowledge systems. It draws from case studies and reflections to illustrate the impact of these partnerships on local communities and the environment, highlighting the lessons learned and challenges faced in creating sustainable futures through collaborative approaches to knowledge integration.



Keywords: indigenous knowledge, sustainability, equitable partnerships, cross-cultural collaboration, community-driven solutions, knowledge systems integration.

INTRODUCTION

Can integrating traditional, local, and indigenous knowledge systems with scientific research create more effective and equitable sustainability solutions? Yes. This analysis explores how the Viara Foundation's approach to community-driven development demonstrates the transformative potential of bridging knowledge worlds. In the face of unprecedented global environmental challenges, there is a growing recognition that sustainability cannot be achieved through a one-size-fits-all approach. Traditional knowledge systems offer invaluable insights that complement scientific research (Acharya & Prakash, 2025; Jessen et al., 2022), yet they have often been sidelined in global conversations on climate change and sustainability (Gómez-Baggethun & Corbera, 2013; Yanou & Ros-Tonen, 2023).

The Viara Foundation's commitment to community-driven solutions provides a model for fostering empowerment and equity while preserving cultural heritage and promoting environmental sustainability (See Figure 1).

Figure 1: Participatory framework for integrating indigenous knowledge and scientific methodologies.

THE ROLE OF INDIGENOUS AND LOCAL KNOWLEDGE

This section synthesizes the fundamental importance of indigenous and local knowledge systems in achieving global sustainability. It examines how these holistic frameworks for understanding and interacting with the environment have been shaped through generations of sustainable practices.

Holistic Understanding of Ecosystems

Indigenous and local knowledge systems are often seen as holistic frameworks for understanding and interacting with the environment (Sinthumule, 2023). These systems, passed down through generations, are grounded in a deep understanding of ecosystems, resource management, agriculture, and social organization. This knowledge is inherently sustainable, as it has been shaped by the long-term interaction between people and their environment, evolving to maintain ecological balance and ensure the survival of future generations.

Proven Sustainable Practices

For instance, indigenous agricultural practices, such as agroforestry, crop diversification, and soil regeneration techniques, have been proven to increase biodiversity, improve soil fertility, and reduce the impacts of climate change (Zougmoré et al., 2023; Acharya & Prakash, 2025). These practices are often localized, adapted to specific ecosystems, and flexible enough to adjust to changes in the environment (Escobedo et al., 2025). When applied at a global scale, they can contribute to sustainable food systems and climate resilience.

Community-Driven Development Models

The Viara Foundation's work in promoting community-driven development has showcased how such knowledge can be harnessed for broader sustainability goals. In collaboration with local communities, the foundation has helped develop models that integrate traditional agricultural knowledge with modern scientific methods. These models are not only environmentally sustainable but also economically empowering, as they help communities improve their livelihoods while preserving their cultural heritage.

One striking example is the Viara Foundation's work in rainwater harvesting in rural communities. Indigenous knowledge systems have long recognized the importance of water conservation and management, using techniques such as stone wells and rainwater collection systems. By combining these traditional practices with modern technology for water purification and storage, Viara has helped improve access to clean water in areas facing water scarcity.

CHALLENGES IN BRIDGING KNOWLEDGE SYSTEMS

While the potential for integrating indigenous knowledge with scientific research is vast, several challenges hinder this process. One of the most significant barriers is the historical and ongoing marginalization of indigenous communities and their knowledge (Yanou & Ros-Tonen, 2023; Lauter, 2023). Colonial histories, power imbalances, and the dominance of Western scientific paradigms have often led to the dismissal or appropriation of indigenous knowledge systems (Gómez-Baggethun & Corbera, 2013), resulting in a lack of recognition and respect for these communities' contributions.

Historical Marginalization and Mistrust

In addition, there is often a mistrust between indigenous communities and academic/scientific researchers. This mistrust has been fueled by past experiences where indigenous knowledge was taken without consent, misrepresented, or used for exploitative purposes (Lauter, 2023; Corbett, 2025). For effective cross-cultural collaborations, it is crucial to address these concerns by fostering mutual respect, transparency, and shared ownership of knowledge.

Institutional Barriers

Another significant challenge lies in the lack of institutional support for integrating traditional knowledge into mainstream scientific research. Universities and research institutions often prioritize Western scientific methods, leaving little room for alternative ways of knowing. As a result, indigenous knowledge remains largely ignored in global sustainability discussions, even though it holds the potential to provide crucial insights into the environmental challenges we face today.

Viara Foundation's Experience

Viara Foundation's work reflects the challenges faced when bridging these knowledge systems. In many instances, the foundation has had to navigate the complex terrain of balancing community-based knowledge with scientific research methodologies. For example, in some regions, local communities were initially skeptical about collaborating with external researchers due to past experiences of exploitation. Overcoming these challenges required a long-term commitment to building trust and establishing inclusive partnerships that empowered local communities to share their knowledge on their own terms.

EQUITABLE PARTNERSHIPS AND COLLABORATION

To create effective solutions for sustainability, it is imperative to foster equitable partnerships that respect and value both traditional and scientific knowledge. This requires a shift from extractive to co-creative relationships, where indigenous communities are seen as equal partners in the knowledge production process (Acharya & Prakash, 2025; Jessen et al., 2022). The Viara Foundation's approach to partnership exemplifies this shift, prioritizing collaboration over exploitation and ensuring that local communities have a voice in shaping the solutions that affect them.

Local Leadership

Emphasizing community leaders and indigenous elders as integral partners in solution design

Shared Ownership

Treating knowledge as something to be shared, celebrated, and safeguarded rather than extracted

Biodiversity Conservation Example

A powerful example of this cross-cultural collaboration is seen in the Viara Foundation's work on biodiversity conservation in partnership with indigenous communities in the Western Ghats. These communities have a long history of protecting their local ecosystems, and their traditional knowledge of plant species, animal behavior, and ecological balance has been key in implementing conservation strategies (Sinthumule, 2023; Tarimo et al., 2025). By integrating this knowledge with scientific research on biodiversity, Viara has helped create community-led conservation programs that are both scientifically grounded and culturally resonant.

At the heart of this collaboration is a commitment to shared ownership of knowledge. In Viara's approach, knowledge is not seen as a commodity to be extracted or appropriated; it is viewed as something to be shared, celebrated, and safeguarded. This principle is especially important in Global South-North collaborations, where there is often a disparity of power between communities and researchers.

REFORMING GLOBAL KNOWLEDGE SYSTEMS

Reforming global knowledge systems to be more inclusive of indigenous and local knowledge requires a fundamental shift in how we think about knowledge production and knowledge ownership. It is essential that global sustainability frameworks recognize the value of non-Western knowledge systems and incorporate them into policy-making, research, and international climate negotiations (Corbett, 2025; Gómez-Baggethun & Corbera, 2013).

Decolonization of Knowledge Systems

One of the key ways to achieve this is through the decolonization of knowledge systems, which involves challenging the dominance of Western science and its often exclusionary practices (Yanou & Ros-Tonen, 2023). Viara Foundation advocates for the inclusion of indigenous voices in all aspects of sustainability work, from policy development to project implementation. By bringing indigenous knowledge into mainstream discourse, the foundation seeks to demonstrate that local solutions have global relevance.

Institutional Reform

Moreover, global institutions such as the United Nations and intergovernmental bodies must take steps to institutionalize the inclusion of indigenous knowledge in decision-making processes. This can be achieved by creating spaces for indigenous leaders to participate in policy discussions, recognizing traditional knowledge in environmental agreements, and ensuring that indigenous rights are protected in the context of climate action (Lauter, 2023; Jessen et al., 2022).

Climate Adaptation Framework

Viara Foundation has worked to advocate for this reform by collaborating with international organizations to create inclusive sustainability frameworks. One example is the foundation's work in climate adaptation, where it has helped shape policies that integrate traditional ecological knowledge into national climate action plans. By doing so, Viara is not only helping to address climate change but also advocating for a more just and equitable approach to environmental governance.

METHODOLOGY

This perspective analysis examines the integration of indigenous knowledge systems with scientific research through the lens of equitable partnerships and community-driven solutions. The methodology includes:

Analytical Framework

Case study analysis of community partnerships, traditional knowledge integration, & sustainable development practices

Knowledge Sources

- Community-based case studies & field experiences
- Traditional ecological knowledge documentation
- Scientific research on indigenous practices
- Policy frameworks & international agreements
- Cross-cultural collaboration models

Integration Analysis

- Equity assessment in knowledge partnerships
- Cultural preservation & empowerment evaluation
- Sustainability impact measurement
- Cross-cultural collaboration effectiveness

Considerations

- Cultural sensitivity in knowledge sharing
- Power dynamics in research partnerships
- Evolving community needs & priorities

This methodology emphasizes participatory approaches and community-led research in sustainability.

CASE STUDIES IN KNOWLEDGE INTEGRATION

The Viara Foundation's work demonstrates several successful models of knowledge integration that have created meaningful impact on both local communities and broader sustainability goals. These case studies illustrate the practical applications of bridging traditional wisdom with scientific research (Acharya & Prakash, 2025).

Rainwater Harvesting Innovation

One striking example is the Viara Foundation's work in rainwater harvesting in rural communities. Indigenous knowledge systems have long recognized the importance of water conservation and management, using techniques such as stone wells and rainwater collection systems. By combining these traditional practices with modern technology for water purification and storage, Viara has helped improve access to clean water in areas facing water scarcity. This integration not only preserved traditional knowledge but also enhanced its effectiveness through scientific innovation.

Biodiversity Conservation in Western Ghats

The foundation's biodiversity conservation work in partnership with indigenous communities in the Western Ghats exemplifies successful cross-cultural collaboration. These communities possess deep traditional knowledge of plant species, animal behavior, and ecological balance. By integrating this knowledge with scientific research on biodiversity, Viara helped create community-led conservation programs that are both scientifically grounded and culturally resonant (Sinthumule, 2023; Escobedo et al., 2025), resulting in improved ecosystem protection and community empowerment.

Community Engagement

Building trust through respectful dialogue and long-term relationship development

Knowledge Documentation

Collaborative recording of traditional practices with community consent and ownership

Scientific Integration

Combining traditional knowledge with modern research methods and technologies

Implementation

Community-led implementation ensuring cultural appropriateness and local ownership

Impact Assessment

Evaluating outcomes through both scientific metrics and community-defined success measures

GLOBAL IMPLICATIONS FOR SUSTAINABILITY

The integration of traditional, local, and indigenous knowledge systems with scientific research extends far beyond individual projects or communities. This approach offers a transformative model for addressing global environmental challenges through inclusive, culturally-responsive, and scientifically-informed solutions.

Scaling Local Solutions

Traditional ecological practices such as agroforestry, crop diversification, and soil regeneration techniques have proven effective at local scales and hold tremendous potential for global application (Zougmoré et al., 2023; Tarimo et al., 2025).

These practices, when properly documented and integrated with scientific research, can contribute to sustainable food systems and climate resilience worldwide (Acharya & Prakash, 2025; Escobedo et al., 2025).

Policy and Governance Reform

The success of community-driven approaches demonstrates the need for fundamental reforms in global sustainability frameworks. International institutions must create spaces for indigenous voices in policy discussions, recognize traditional knowledge in environmental agreements, and ensure that climate action protects indigenous rights while leveraging their expertise.

Food System Transformation

Indigenous agricultural practices offer scalable solutions for sustainable food production, biodiversity conservation, and climate adaptation.

Water Security

Traditional water management techniques, enhanced by modern technology, provide models for addressing global water scarcity challenges.

Ecosystem Conservation

Community-led conservation programs demonstrate effective approaches to protecting biodiversity and maintaining ecological balance.

DISCUSSION

This analysis of integrating indigenous wisdom with scientific knowledge reveals several critical findings that have significant implications for global sustainability, social justice, and knowledge governance. The discussion synthesizes these findings and explores their broader theoretical, practical, and policy implications.

Synthesis of Key Findings

The integration of traditional, local, and indigenous knowledge systems with scientific research represents a paradigm shift toward more equitable and effective sustainability solutions (Jessen et al., 2022; Corbett, 2025). The Viara Foundation's approach demonstrates that community-driven development, when based on respectful partnerships and shared ownership of knowledge, creates solutions that are simultaneously scientifically sound and culturally appropriate. This integration challenges traditional concepts of knowledge production and validates alternative ways of knowing that have sustained communities for generations (Gómez-Baggethun & Corbera, 2013; Yanou & Ros-Tonen, 2023).

Theoretical Implications

This approach contributes to several theoretical frameworks. First, it expands understanding of sustainability beyond technical solutions to encompass social justice, cultural preservation, and community empowerment. Second, it demonstrates how knowledge co-creation can bridge different epistemological systems without compromising the integrity of either. Third, it illustrates the emergence of "collaborative knowledge systems" that respect multiple ways of knowing while producing actionable solutions for complex environmental challenges.

Practical Implications

The success of integrated knowledge approaches provides practical models for addressing global challenges. These partnerships demonstrate that local solutions often have global relevance, offering scalable approaches to food security, water management, biodiversity conservation, and climate adaptation (Sinthumule, 2023; Zougmoré et al., 2023). However, successful implementation requires significant investment in relationship-building, cultural competency, and long-term commitment to community partnerships.

Policy and Governance Reform

The emergence of successful knowledge integration initiatives highlights the need for fundamental reforms in global governance structures. Current policy frameworks often exclude indigenous voices and traditional knowledge, despite their proven effectiveness. Reform requires creating institutional mechanisms for including diverse knowledge systems in decision-making processes and recognizing indigenous rights in environmental governance.

CONCLUSION

The integration of traditional, local, and indigenous knowledge systems with scientific research is not just an academic exercise–it is a necessary step toward achieving global sustainability (Acharya & Prakash, 2025; Escobedo et al., 2025). By embracing equitable partnerships, cross-cultural collaboration, and the empowerment of local communities, we can create solutions that are socially just, environmentally sustainable, and culturally appropriate. The Viara Foundation's approach to community-driven development provides a powerful example of how these principles can be put into practice.

In the face of the climate crisis, it is clear that traditional knowledge has a crucial role to play in shaping a sustainable future (Zougmoré et al., 2023; Jessen et al., 2022). As we continue to bridge knowledge worlds, it is essential that we do so with respect, collaboration, and a deep commitment to creating a world where all voices–especially those of indigenous communities–are heard and valued. The future of sustainability lies in our ability to listen, learn, and collaborate across cultures and knowledge systems.

The Viara Foundation's work demonstrates that when indigenous wisdom and scientific knowledge are integrated through equitable partnerships, the results benefit not only local communities but contribute to global solutions for our most pressing environmental challenges (Sinthumule, 2023; Corbett, 2025). This collaborative approach offers hope for creating a more just and sustainable world where diverse knowledge systems are recognized, respected, and leveraged for the common good.

CONFLICTS OF INTEREST

The author declares a potential conflict of interest due to prior collaboration with the organization referenced in this article. However, the author affirms that all analyses, findings, and conclusions presented in this manuscript are entirely objective and were not influenced by any past associations.

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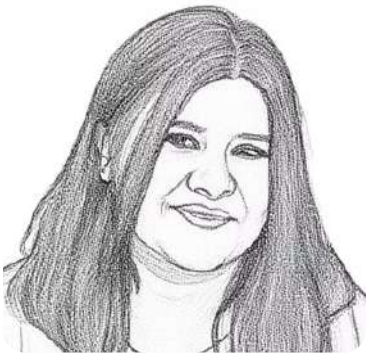

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Bridging Knowledge Systems for Inclusive Sustainability: A Cross-Cultural Perspective

PERSPECTIVE

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Cross-Cultural Collaboration

Global sustainability efforts need to integrate diverse knowledge systems, including indigenous, local, and community-based insights that have evolved over centuries alongside mainstream academic frameworks.

Power Imbalances

Current academic and policy frameworks often underutilize local perspectives, creating power imbalances that hinder comprehensive solutions to climate change and biodiversity loss.

Bridging Barriers

Structured cross-cultural collaboration can overcome resource inequities, language barriers, and systemic bias in peer review to create more equitable partnerships.

Global Solutions

Integrating multiple knowledge frameworks is not merely an ethical obligation, but a practical necessity for tackling today's global environmental and social challenges, creating more inclusive and adaptive solutions.

ABSTRACT

Global sustainability efforts increasingly acknowledge the need to integrate diverse knowledge systems, including indigenous, local, and community-based insights that have evolved over centuries. Yet, mainstream academic and policy frameworks often underutilize these perspectives, hindering the potential for comprehensive solutions to climate change, biodiversity loss, and social inequities. This perspective explores how structured cross-cultural collaboration can bridge power imbalances and enrich sustainability research and practice. Drawing from fieldwork experiences in regions such as Southern Africa and Southeast Asia, this perspective discusses barriers faced by local experts when engaging with international institutions, including resource inequities, language barriers, and systemic bias in peer review. This perspective argues that equitable partnerships require co-creation of research agendas, consensus on ethical data use, and rethinking how we define "rigor" in academic publishing. Additionally, digital platforms–while not a panacea–can facilitate more democratic forms of knowledge exchange when designed to accommodate limited connectivity and multilingual settings. This perspective also provides recommendations for policy reform, highlighting inclusive funding models, open-access publishing, and the adoption of broader evidence criteria by journals and granting agencies. By weaving together interdisciplinary research, success stories, and real-world case studies, this paper emphasizes that integrating multiple knowledge frameworks is not merely an ethical obligation, but a practical necessity for tackling today's global environmental and social challenges. Ultimately, the call is to expand epistemic horizons, recognizing that collective resilience depends on weaving together the threads of all knowledge systems into a more equitable tapestry of sustainable solutions.

Keywords: cross-cultural collaboration, indigenous knowledge systems, sustainability research, knowledge integration, power imbalances, equitable partnerships

INTRODUCTION

Global sustainability dialogues increasingly emphasize integrating indigenous and local knowledge systems with mainstream scientific research. The IPCC (2023) highlights that certain community-led adaptation and mitigation strategies are often more effective and culturally appropriate than top-down solutions alone. Over the past two decades, local resource management practices have demonstrated resilience in biodiversity conservation, climate adaptation, and sustainable livelihoods (Kimmerer, 2013; Nadasdy, 1999). However, power imbalances often relegate these knowledge systems to secondary status in policy arenas and academic institutions. These asymmetries risk overlooking valuable insights and marginalizing communities most affected by climate change impacts.

This commentary explores pathways to achieve more equitable cross-cultural collaboration, drawing on practical experience and established literature. By examining how research agendas are formed, funded, and disseminated, I argue that bridging knowledge systems is both ethically imperative and strategically beneficial. Successful collaborations require recognizing local expertise, allocating resources equitably, and adopting research norms accommodating different epistemological frameworks (Smith, 1999). This analysis addresses key dimensions: structural barriers, methods for creating equitable research partnerships, the role of digital tools for amplifying local voices, and necessary institutional reforms. Ultimately, understanding how diverse knowledge systems inform sustainability, such as the integration of indigenous and academic knowledge systems shown in Figure 1, not only broadens the scientific perspective but also fosters solutions that are more inclusive, adaptive, and grounded in the lived realities of local stakeholders.

Figure 1: Integration of indigenous and academic knowledge systems in collaborative field research
Karnstocks: Getty Images

THE NEED FOR CROSS-CULTURAL COLLABORATION

Contextualizing Global Sustainability Challenges

Contemporary environmental challenges–ranging from severe droughts to rising sea levels–cannot be effectively tackled through a single lens. Each region grapples with distinct socio-ecological contexts, cultural norms, and historical experiences that inform how communities perceive risks and adapt to changing conditions. Various societies have developed place-based strategies, such as seed-saving traditions or complex water-sharing agreements, which offer lessons for more generalized policy frameworks (UNESCO, 2018). Nonetheless, these local strategies often remain undocumented in mainstream literature or overlooked by policymakers due to cultural and linguistic barriers.

The Limits of a Single Epistemic Paradigm

Global North institutions, typically endowed with more resources, tend to dominate scholarly and policy-driven discourse on sustainability. This dynamic can produce a narrow focus that privileges scientific modeling and top-down policy solutions (IPCC, 2023). While scientific methods excel in quantifying impacts and forecasting global trends, they may lack the granularity needed to address localized environmental conditions. Cross-cultural collaboration thus enriches the knowledge base, integrating empirical data with context-specific insights that reflect generations of lived experience (Kimmerer, 2013).

Ethical Imperatives

Beyond practical effectiveness, ethical considerations underscore the importance of engaging local communities in decisions affecting their environments. Previous cases of resource development projects in Southeast Asia and Latin America have sparked tensions due to inadequate consultation with indigenous peoples, leading to both social conflict and ecological harm. By ensuring that local voices help shape research questions and approaches, we uphold principles of self-determination and equity, aligning with international frameworks like the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP). Such ethical alignment also fosters trust, a critical ingredient for sustained collaboration and the long-term success of sustainability initiatives.

STRUCTURAL BARRIERS AND POWER IMBALANCES

Resource Disparities

A primary obstacle to equitable collaboration is resource distribution. Local organizations and indigenous communities often lack funding and formal institutional support, leaving them reliant on external grants or sporadic project-based assistance (Lewis, 2021). Conversely, universities and NGOs based in wealthier countries can offer financial backing but may inadvertently create imbalanced power dynamics by controlling funding flows. These disparities can lead to situations where local partners are treated as informants rather than co-creators, relegated to data-gathering roles while strategic decisions remain centralized in Global North institutions.

Language and Communication Hurdles

The language used in mainstream academic circles, predominantly English, can sideline the voices of local experts. Translation of complex scientific terms into local languages–and vice versa–requires specialized skills and additional funding. Furthermore, cultural differences influence communication norms. For instance, open debates and direct criticism, common in Western academic settings, may be perceived as disrespectful in some cultures. These misalignments can hinder genuine knowledge exchange, create mistrust, and marginalize community members who cannot communicate easily in global academic languages.

Institutionalized Bias in Knowledge Validation

Peer review processes, editorial boards, and grant selection panels often prioritize frameworks and methodologies popularized in the Global North (Smith, 1999). This can invalidate research designs or findings that emerge from alternative epistemologies, such as oral histories or collective land-use practices. Meanwhile, local knowledge is sometimes dismissed as anecdotal, lacking "scientific rigor," despite often being rooted in centuries of community observation and adaptation (Nadasdy, 1999). Such systemic bias hampers the visibility and credibility of non-Western research, curtailing the broader scientific community's exposure to local innovations and ecological insights.

TOWARD EQUITABLE RESEARCH PARTNERSHIPS

Co-Creation of Research Agendas

One constructive approach is to involve local stakeholders from the very beginning of any research project. In practice, this means partnering to identify research objectives that resonate with the community's priorities–be it water management, disease control, or livelihood diversification. Co-creation not only democratizes project design but also sets a precedent for sharing intellectual property and decision-making power. Workshops and focus-group discussions can help surface local concerns and emergent ideas, fostering a sense of ownership and mutual accountability.

Holistic Ethics Protocols

Existing ethics guidelines in Western academia often prove insufficient for cross-cultural contexts. For instance, "informed consent" typically implies signing formal documents in a language that might not be well understood locally. A more robust ethical framework would include oral consent options, inclusive data governance, and community-level review processes that reflect local values (Smith, 1999). Additionally, reciprocity must be built into the project's architecture, ensuring benefits return to the community, not just to the researchers or funding agencies.

Capacity Building and Training

Providing training in data analysis, methodology, and technology adaptation is another integral step. These initiatives should be culturally responsive, delivered in local languages, and respect traditional learning practices. When communities gain skills to manage and interpret data, it facilitates more equal participation in research and policy formulation. For example, knowledge of Geographic Information System (GIS) mapping can help farmers track changes in soil fertility or rainfall patterns, aligning local observations with digital records that can be shared with external collaborators.

Equitable Funding Models

Large grant-makers, whether philanthropic foundations or government agencies, can design funding streams that prioritize partnerships with on-the-ground stakeholders. Criteria could include a formal requirement to allocate a certain percentage of funds to local training, local staff salaries, and joint leadership roles. Incorporating matching-fund obligations where feasible can help ensure local buy-in. Such arrangements mitigate the risk of extractive research and reinforce collaborative structures. Ensuring that local partners have equal representation in steering committees further cements their role in shaping research directions.

IMPLEMENTING DIGITAL PLATFORMS FOR INCLUSIVITY

Opportunities in the Digital Realm

The digitization of research methods and dissemination channels creates new avenues for engagement. Mobile phone applications and community-driven data hubs can empower local contributors to share observations–from fish migration patterns to air quality measurements–in near real-time. These tools can function as collective intelligence platforms where local knowledge merges with specialized scientific analysis (UNESCO, 2018). When communities retain control over data curation and usage, digital platforms become instruments of empowerment rather than mere data-extraction tools.

Challenges and Limitations

Nevertheless, technology's promise is constrained by infrastructure gaps and digital literacy. Many rural areas lack reliable internet connectivity, and the cost of smartphones or data plans can be prohibitive. Moreover, digital platforms may inadvertently replicate existing social inequalities–particularly if access is skewed toward younger or more affluent members of the community. Designing inclusive digital ecosystems thus requires robust needs assessments, local language support, and user-friendly interfaces that align with diverse cultural practices.

Case Example: Community Monitoring of Drought Patterns

In a semi-arid region of East Africa, local farmers collaborated with an international research team to record daily rainfall, humidity levels, and temperature using a mobile application. Over several months, the collected data was integrated with satellite imagery to create localized drought forecasts. While the initial adoption faced hurdles–limited smartphone availability and a learning curve for the app–community leaders facilitated training sessions in multiple local languages. This co-created database became a powerful advocacy tool, informing municipal water management policies and securing additional support from NGOs. The project demonstrates the potential synergy between technologically advanced methods and community-driven observational data, underscoring how both can complement each other for improved resilience.

OVERCOMING ACADEMIC BIAS AND REDEFINING RIGOR

Inclusive Peer Review Processes

Journals and academic institutions can adopt deliberate measures to diversify editorial boards and peer reviewer pools. By including scholars and practitioners from a variety of cultural and epistemic backgrounds, the peer review process becomes more inclusive. This shift would allow research grounded in oral histories, community-led research designs, or indigenous methodologies to receive fair scrutiny (Smith, 1999). Some journals now encourage multi-lingual abstracts and welcome supplementary materials–such as videos and community testimonials–that elucidate findings beyond the conventional scientific article format.

Decolonizing Research Methodologies

Calls to decolonize research underscore the need to question Western academic norms–be they strict authorship guidelines or the assumption that only particular quantitative metrics define "good science" (Kimmerer, 2013). Researchers can adopt mixed-methods approaches, weaving ethnographic observation, oral narratives, and structured surveys into a cohesive framework. By doing so, they elevate the status of local knowledge. Additionally, funders that recognize the value of local epistemologies help catalyze broader acceptance of alternative methodologies, ensuring that such research can attract critical investment and academic prestige.

Valuing Long-Term Relationships Over Extractive Outputs

A frequent critique of academic research in marginalized regions is the "parachute" model, where scholars collect data and depart, offering little in the way of tangible benefits or follow-through. Addressing this problem requires a commitment to building long-term relationships. Such commitment might entail multi-year collaborative projects, co-authorship that acknowledges local intellectual contributions, and open data policies that grant communities meaningful access to research findings. Emphasizing relational accountability over one-off publications can reshape academic incentives to align with community well-being.

Traditional Academic Model

Extract data, publish, depart with minimal community benefit

Collaborative Partnership Model

Co-create knowledge, share authorship, ensure long-term community benefits

POLICY-LEVEL INTERVENTIONS

Inclusive Funding and Policy Reforms

Governments and intergovernmental bodies, such as the United Nations Framework Convention on Climate Change (UNFCCC), can incorporate local expertise into the design of climate adaptation programs. Mechanisms like the Green Climate Fund could introduce explicit guidelines requiring evidence of local consultation and leadership in project proposals. Policy mandates of this kind not only legitimize local voices but also stimulate deeper cross-sector partnerships, ensuring that large-scale funding translates into context-responsive initiatives.

Open Access and Data Sharing

Paywalled academic journals and proprietary data sets reinforce knowledge hierarchies. Shifting toward open-access models permits communities and smaller institutions to engage with up-to-date research without prohibitive costs. In turn, such democratization fosters reciprocal data sharing, with communities more likely to make their own data publicly available when they perceive genuine benefits. For instance, the open data movement, adopted by organizations like the Global Biodiversity Information Facility, has prompted local experts to share biodiversity records in exchange for updated habitat models from international scientists.

Balancing Intellectual Property and Community Rights

In certain contexts, local knowledge may be subject to intellectual property protections, especially if it leads to the development of commercial products (e.g., pharmaceuticals or agricultural technologies). Ensuring fair compensation and acknowledgment for local experts is crucial, as is establishing protocols to safeguard sensitive cultural information. Some policy frameworks suggest adopting community license agreements that specify how data may be used, ensuring that external partners cannot exploit cultural heritage or traditional remedies for profit without returning benefits to the source communities (Lewis, 2021).

FIELD INSIGHTS

Community-Led Agroforestry Initiatives

In parts of Southeast Asia, agroforestry systems–where multiple tree and crop species are cultivated together–have sustained rural livelihoods for centuries. When global environmental NGOs introduced reforestation campaigns primarily focused on single-species plantations, local farmers contested these plans as culturally inappropriate and ecologically vulnerable to pests. Subsequent dialogues revealed that integrating traditional agroforestry knowledge could enhance biodiversity and protect against crop failure, leading to more productive and resilient landscapes. The collaborative efforts eventually shaped a hybrid model that balanced global conservation goals with community-led experimentation, demonstrating the tangible gains of inclusive research and decision-making.

Participatory Fisheries Management

Along coastal areas of South America, local fishermen's associations have long used rotational harvesting to preserve fish stocks. Scientific agencies initially dismissed these practices in favor of blanket quotas, resulting in tensions and conflicts. Over time, participatory mapping of fishing grounds and co-monitoring of catch rates validated local rotational systems. Once the data reached policymakers, they were compelled to revise national fishing regulations, blending indigenous wisdom with modern scientific oversight. This transformation process demonstrates how acknowledging local strategies can inform policy adjustments that benefit both communities and ecosystems (UNESCO, 2018).

01

Initial Conflict

Scientific agencies dismiss traditional rotational harvesting practices in favor of uniform quotas

02

Community Resistance

Local fishermen's associations contest the new regulations based on generations of experience

03

Collaborative Research

Participatory mapping and co-monitoring validate the effectiveness of local systems

04

Policy Integration

Policymakers revise regulations to blend indigenous wisdom with scientific oversight

05

Mutual Benefit

Enhanced outcomes for both communities and ecosystem conservation

RECOMMENDATIONS FOR SUSTAINABLE INTEGRATION

Embedding Local Voices in Governance

Embedding local expertise in governance bodies (such as sustainability councils or advisory panels) ensures lasting inclusion. Rotational leadership, where local representatives alternate with outside experts, promotes balanced discussion and dismantles power hierarchies. These reforms ensure local knowledge informs strategic direction, preventing it from being relegated to a mere footnote or afterthought.

Leveraging Multi-Stakeholder Alliances

Effective cross-cultural partnerships require diverse actors: universities, community groups, agencies, enterprises, and governments. These alliances deliver robust, interdisciplinary solutions by pooling distinct resources and perspectives (IPCC, 2023). They necessitate coordination, transparent communication, and dispute resolution mechanisms. Setting clear roles, timelines, and metrics mitigates conflict and strengthens mutual accountability.

Reshaping Academic Incentive Structures

Academic incentive systems often emphasize publications, grants, and citations, which can encourage exploitative collaborations that fail to genuinely empower local stakeholders. Institutions must value team-based research and co-authorship involving community partners. Promotion and tenure committees should treat public engagement, policy influence, and community impact as equally valid achievements, transforming how universities approach research in the Global South.

370M

Indigenous Peoples

Worldwide affected by climate change

50%

Biodiversity Areas

Managed by indigenous communities

80%

Global Biodiversity

Found on indigenous territories

22%

Land Area

Traditionally occupied by indigenous peoples

5000+

Distinct Cultures

Indigenous groups globally

CONCLUSION

Bridging power imbalances in sustainability research necessitates a transformative shift in how academic institutions, governments, and local communities interact. Far from undermining scientific rigor, inclusive approaches enrich our collective understanding of complex ecological and social challenges. By recognizing the validity of diverse epistemologies, co-creating research agendas, and adopting equitable funding models, we can develop more holistic and effective solutions. Digital platforms offer new avenues for knowledge exchange but must be carefully implemented to avoid reinforcing existing inequalities. Policy-level reforms, including open-access mandates and rights-based frameworks for local expertise, are pivotal for sustaining these efforts. Ultimately, the synergy of global scientific insights with local and indigenous knowledge forms a richer tapestry of possible solutions–a tapestry strong enough to address urgent planetary challenges like climate change, biodiversity loss, and social injustices. Moving forward, it is incumbent upon all stakeholders to continue fostering dialogues that are open, respectful, and collaboratively forged. Only by doing so can we build a future where environmental stewardship and community resilience advance hand-in-hand.

Recognition

Acknowledge diverse knowledge systems as equally valid

Co-creation

Develop collaborative research agendas with local communities

Integration

Weave traditional and scientific knowledge into holistic solutions

Implementation

Transform institutional structures to support equitable partnerships

Resilience

Build sustainable futures through collaborative knowledge systems

CONFLICTS OF INTEREST

The author declares no conflict of interest

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From Spiritism to Empiricism: Bridging the Western-Traditional Knowledge Divide with the Igbo Trado-Religious Practices of Arochukwu

REVIEW

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Ancient Igbo Wisdom

The study explores how the traditional beliefs and practices of the Igbo people in Arochukwu are deeply connected to their environment. For them, protecting nature isn't just a choice; it's a spiritual responsibility passed down through generations.

Traditional Ecological Knowledge (TEK)

This refers to the vast, inherited knowledge of how nature works. It includes everything from understanding local plants and animals to sustainable farming methods and conservation strategies that have kept ecosystems healthy for thousands of years.

Spirituality & Nature

The research highlights how Igbo spiritual practices foster a profound respect for the natural world. This spiritual bond encourages careful use of resources and active protection of sacred groves, rivers, and wildlife, seeing them as vital parts of their identity and existence.

Bridging Knowledge Systems

A key finding is the importance of bringing together this traditional wisdom with Western scientific approaches. This "bridging" can lead to more holistic, effective, and culturally appropriate solutions for environmental protection and sustainable development globally.

ABSTRACT

This study examines the Igbo trado-religious practices of Arochukwu, Nigeria, intending to bridge the divide between Traditional Ecological Knowledge (TEK) and Western science in addressing environmental sustainability challenges. Employing a qualitative methodology, the research utilizes semi-structured interviews, participant observation, and literature review to analyze the ecological significance of Arochukwu's sacred market days, totemic beliefs, and herbal medicine practices. The findings reveal that Arochukwu's trado-religious practices embody sophisticated ecological knowledge systems that parallel Western scientific understanding in several aspects. The four-day market system demonstrates an acute awareness of spatial orientation, which aligns with natural cycles crucial for sustainable resource management. Totemic beliefs inadvertently contribute to biodiversity conservation, while herbal medicine practices represent a vast repository of pharmacological knowledge. The study recommends fostering collaborative research initiatives that meaningfully integrate TEK and Western science, embracing a multicultural approach that recognizes the strengths of both knowledge systems. Additionally, it advocates for establishing equitable data-sharing mechanisms, supporting Indigenous knowledge transmission, and integrating TEK into educational curricula and environmental policies.

Sacred Market DaysFour-day system guiding sustainable resource use

Totemic ConservationBeliefs that protect species and habitats

Herbal KnowledgeTraditional pharmacology and ecological uses

Knowledge IntegrationCollaborative frameworks linking TEK and science

Keywords: Traditional Ecological Knowledge, Indigenous epistemology, Environmental governance, Knowledge systems integration, Biodiversity conservation.

INTRODUCTION

Climate change is no longer a distant threat but a more immediate overarching reality across countries of the world (Aslam et al., 2024, p.1517). More than ever, extreme weather events and natural disasters like wildfires, hurricanes, flash floods, droughts, and cyclones are becoming common occurrences (Hassan, 2024, p. 423). At present, biodiversity loss is at the highest rate ever recorded in human history. This ecological crisis, encompassing pollution and land degradation, has resulted in far-reaching consequences. Reduced agricultural harvests, community distress, and an estimated annual human mortality rate of approximately 9 million globally are dreadful effects. In addition, world temperature is projected to surpass the critical threshold of 1.5°C as early as 2027, thus portending an existential threat to humans, animals and the environment (United Nations Environment Programme, 2024, p. 2).

According to the Intergovernmental Panel on Climate Change (IPCC) (2023, p.5), regions and populations already facing significant developmental limitations exhibit high vulnerability to climatic hazards. Approximately 3.3 to 3.6 billion people reside in highly vulnerable contexts, with the most substantial adverse impacts concentrated in numerous locations and communities across Africa, Asia, Central and South America, Least Developed Countries (LDCs), Small Islands, and the Arctic, as depicted in Figure 1.

Figure 1: A dramatic photograph of a landscape showing signs of environmental stress. GettyImages

Alongside Global Environmental Issues (GEI), academic and governmental bodies, international organisations, and Non-governmental Organisations (NGOs) are making concerted efforts to mitigate climate change challenges stemming from industrialization, deforestation, and other anthropogenic activities. Conversely, these endeavors face inherent and sometimes conflicting challenges within academic scholarship. This means that despite widespread efforts, distinct academic approaches and perspectives can create significant obstacles or lead to contradictory findings, complicating the path to definitive solutions.

Western Science vs. Traditional Ecological Knowledge (TEK)

A polarization exists between Western science and Traditional Ecological Knowledge (TEK), each representing a distinct epistemological framework for understanding and addressing environmental challenges. This divergence often leads to different methodologies and priorities in tackling climate change.

Anthropocentric vs. Posthumanist Worldviews

A moral dilemma arises in choosing between anthropocentric or posthumanist worldviews as a remedial pathway for ecological degradation. This fundamental philosophical divide influences proposed solutions, leading to debates over whether human-centric approaches or broader, non-human inclusive perspectives should guide environmental policy (Lertzman 2010, pp. 109-110; Kopnina, 2019, pp. 1-2).

This divergence in understanding and approach, as well as the contrasting perspectives, is visually represented in Figure 2.

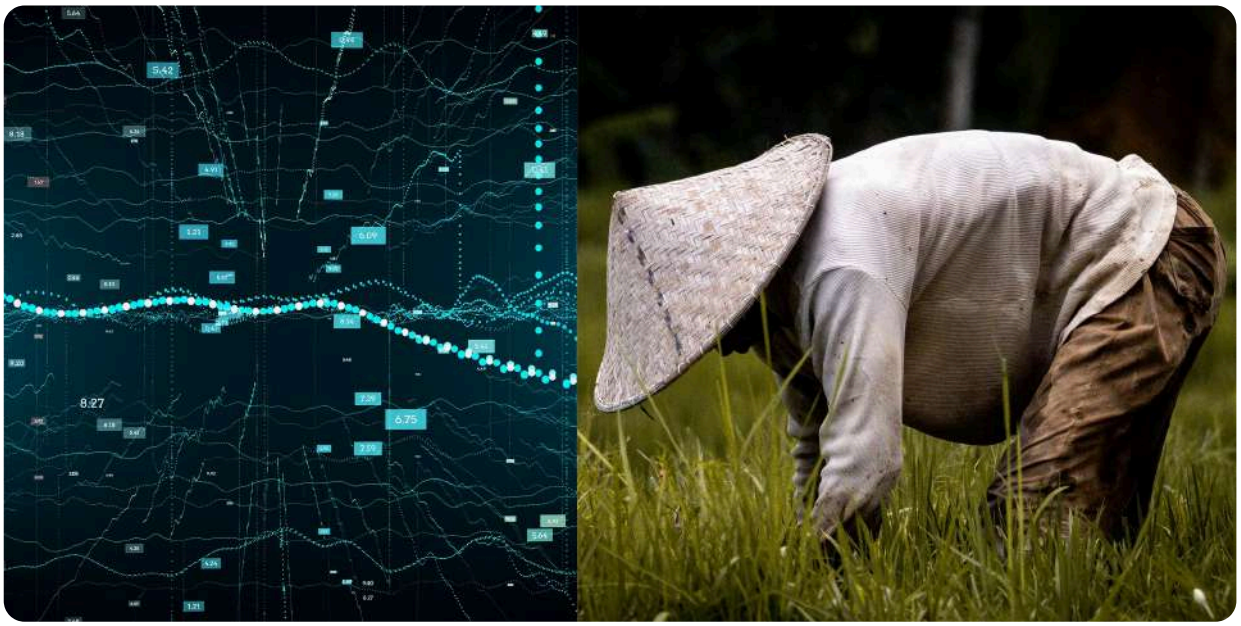


Figure 2: Western science and Traditional Ecological Knowledge approaches to environmental challenges. GettyImages

TEK, also known as tacit knowledge or Local Indigenous Knowledge Systems (LINKS) (UNESCO, 2023, p. 1), is an accumulated body of knowledge, practices, and representations explaining the relationships between living beings and their physical environment. It evolves adaptively, transmitted across generations via cultural mechanisms like oral traditions, rituals, or seasonal festivities (Mazzocchi, 2006; Berkes et al., 2000, p.1252). Despite its community and cultural specificity, TEK is a "set of knowledge [that] includes an intimate and detailed knowledge of plants, animals, and natural phenomena, the development and use of appropriate technologies for hunting, fishing, trapping, agriculture, and forestry, and a holistic knowledge, or 'world view' which parallels the scientific discipline of ecology" (Ananda, 2021, p. 57; Miraglia, 1998). However, its parallelism with scientific knowledge remains a keenly contested subject within Western science. As Berkes et al. (2000, p. 1251) note, "'tradition' was a problematic word for researchers in development and anthropology" due to 19th-century stereotypes of barbarism and primitiveness.

This stereotyping of TEK was evident in broader patterns of colonial disruption and religious imposition on Indigenous knowledge in Igboland, Nigeria. British colonialism (late 19th-mid 20th century) systematically dismantled Indigenous governance systems, including the Aro Confederacy's sophisticated ecological management practices, by forcibly enforcing cash-crop economies. This economic shift fundamentally displaced long-established, sustainable land-use traditions and undermined local resource control (Oriji, 2011). Concurrently, Christian missionary campaigns suppressed TEK by vehemently labelling Indigenous spiritual-ecological practices–such as the veneration of sacred groves (Ohia Akwu) and deity-based conservation–as "pagan" or superstitious. This aggressive evangelization effectively severed communities from ancestral knowledge intrinsically tied to their ritual landscapes, cultural identity, and sustainable resource management methods (Nweke, 2023).

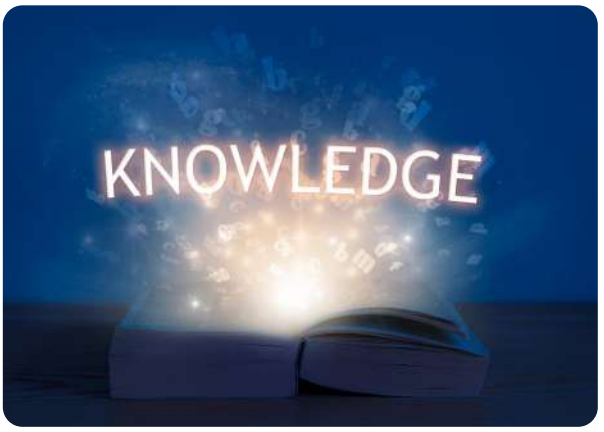
Furthermore, an extant academic corpus addresses TEK and Western Science, with many contrasting scholarly perspectives gaining traction regarding environmental sustainability and knowledge-bridging. Methodologically, Mazzocchi (2006) avers that their divergent methodologies and ontological perspectives characterize the dichotomy. Western science typically employs analytical and reductionist methods, while TEK often embraces a more holistic and context-dependent approach. Western science primarily studies measurable phenomena within time and space, relying on observable data and reproducible evidence, whereas TEK focuses on observable phenomena and their metaphysical aspects to understand the natural world. Philosophically, Lertzman (2010, p. 109)–an assistant professor at the University of Calgary, who contributed to environmental sustainability before his tragic death in 2021–argues that neither TEK nor Western science represents monolithic institutions, especially since Western science itself is an Indigenous knowledge peculiar to the West: "My teachers have been indigenous professors trained within their own cultures". He further added that colonialism's impact on TEK practitioners and their communities has left indelible philosophical, socio-economic, and institutional barriers to bridging TEK and Western science.

From a rather religious perspective, Dasgupta and Ramanathan (2014, p. 1457) submit that: "Finding ways to develop a sustainable relationship with nature requires not only engagement of scientists and political leaders but also [the] moral leadership that religious institutions are in a position to offer" This is consequent on the fact that the expected results: sustainability and ethical use of nature, are relatively achievable, especially as four out of every five persons in the world have some religious affiliations (Kanu, 2021a, p. 74). Several researchers (including Oelschlaeger, 1994; Northcott, 2013; Khalid F 2013; Izzi Dien, 2013; Halpert, 2012), religious bodies and movements (Cornwall Alliance 2009; Lausanne Movement 2012; Global Buddhist Climate Change Collective 2015; Evangelical Environmental Network, 2006; Islamic International Climate Change Symposium, 2015) have also affirmed the relationship between religion and environmental sustainability. Like the syncretism of religion and TEK in Bishnoi, Rajasthan, India and the water temple system of Bali, Indonesia. On the ill effect of religion on TEK, Kanu (2021b, p. 299) fears that the influence of Christianity and Islam, western education, and other cross-cultural influences has brought about a decline in the original way and manner people (Igbos) accorded reverence to totems in African ontology.

Premised on the need for more sustainable environmental solutions that include the full value of nature in economic and political decision-making and bridging the Western-traditional ecological knowledge divide, this essay uses a qualitative research methodology to examine the Igbo trado-religious practices of Arochukwu while establishing the scientific relevance/parallels of the traditional ecological knowledge of the natives to environmental sustainability. As a single case study, data was collated through a semi-structured interview with an octogenarian, Nwankwo Micheal Okafor and participant observation. This was through a formal request and granted consent (see Appendix 1). The fact that the Igbos are scattered across the Arochukwu community made us search for methods to build trust under the condition of not living within the community. The adopted theoretical frameworks - the African Religious-based Conservation and Decolonial and Relational Land-based Theories, guide and lend relevant correlations of our findings on the Igbo trado-religious practices to ecological conservation. More so, to help inform the discussion, the essay also leveraged published academic literature, books, reliable news articles, field photos and video, with triangulation to validate the multiple sources. By organisation, section one covers the introduction (including the essay objective and problem statement, literature review and research method), and sections one, three and four cover the theoretical framework, empirical analysis and conclusion, respectively.

AFRICAN RELIGIOUS-BASED CONSERVATION AND DECOLONIAL RELATIONAL LAND-BASED THEORIES

The study employs a robust theoretical framework given the diverse phenomena under investigation. Mueller and Urbach (2017, p. 350) emphasize theory's crucial role in research for understanding, explaining, and predicting phenomena, clarifying the 'what, how, and why.' While numerous popular theoretical frameworks address environmental sustainability (e.g., Resilience, Feminist, Ecological Modernization, and Deep Ecology Theories), few adequately capture power dynamics and knowledge-bridging related to environmental sustainability. Therefore, this essay adopts two theoretical frameworks for its analysis: African Religious-based Conservation Theory and Decolonial and Relational Land-based Theory. These theories, detailed below, encompass both the trado-religious practices of indigenous communities and their potential as a workable model for environmental sustainability, as illustrated in Figure 3.



African Religious-based Conservation Theory

Igbo-African theory connecting spiritual and physical realms through Chukwu (Supreme Being). Nature has inherent sacredness; 'Chi' (spirit beings) influence the physical world, creating ethical frameworks for human-environment interaction.

Decolonial and Relational Land-based Theory

Challenges Eurocentric research paradigms and eliminates colonial biases against Indigenous perspectives. Promotes respectful intercultural dialogue through cultural camps to unite Indigenous land-based knowledge with Western research, fostering social justice and environmental resilience.

Figures 3: Theoretical frameworks bridging Indigenous knowledge and Western science. GettyImages

The African Religious-based Conservation Theory is an African indigenous theory developed by Ikechukwu Kanu Anthony (PhD). The theoretical framework is based on the nature of the Igbo-African universe. A universe that consists of the spiritual and physical realms, and created by one and the same Supreme Being called Chukwu, who controls, sustains and upholds the universe. This also explains why he is called Osebuluwa (the sustainer of the universe). It is this connection of the physical and spiritual realms of reality through Chukwu, the Igbo-African perceives the world around him in terms of religion (Kanu, 2021a). Central to this worldview is the belief that 'Chi,' or spirit beings, exert significant influence over the physical world. The physical realm is perceived as a stage upon which these spiritual forces manifest their power. Consequently, successful human endeavours in the Igbo community are contingent upon acknowledging and appeasing the spiritual world. This metaphysical understanding and attribution of vitality and sentience to the environment underpin the ethical framework guiding Igbo interactions with nature. Therefore, despite the submission of the African Religious-Based Conservation Theory that nature possesses inherent sacredness and deserves respect rather than exploitation, it lays the basis for the augmentation of what counts as legitimate ecological knowledge (Kanu, 2021a, pp. 43-44).

Decolonial and Conversational Land-based theory is not typically attributed to single founders but rather emerged from diverse intellectual contributions within Indigenous knowledge systems, postcolonial studies, and critical social theory. However, alluding to Datta and Starlight (2024, pp. 1-2), the decolonial and conversational land-based theory emphasizes the importance of eliminating colonial asymmetric biases towards Indigenous perspectives. This approach challenges Eurocentric research paradigms that have often marginalized Indigenous knowledge and perpetuated colonial power dynamics. The theory advocates for creating spaces where Indigenous and Western worldviews can intersect and foster intercultural and respectful dialogue through cultural camps (Teena and Datta, 2024, p. 1). At the core of the theory are the conversational components of openness, sensitivity, acknowledgement of the sacredness of culture, deep respect and sincerity to learn. These conversational ethics unite Indigenous land-based knowledge, community members, and Western researchers, facilitating collaboration and dispelling stereotypes (Datta and Starlight, 2024, pp.2-3). Additionally, Teena and Datta (2024, pp.10-12) submit: “Our decolonial conversation critically discusses why bridging Indigenous and Western knowledge systems is essential to foster mutual respect, promote social justice, and address pressing global challenges. Through traditional cultural camps, we centred Indigenous land-based knowledge as a wealth of traditional ecological knowledge and sustainable resource”. Therefore, recognizing and valuing Indigenous knowledge empowers Indigenous communities and strengthens cultural diversity, which is crucial for social cohesion and environmental resilience.

EMPIRICAL ANALYSIS

Overview of the case study area

The term Igbo refers to both the Ndigbo people and their language (Onumajuru, 2016, p.308). As one of Nigeria's three major ethnic groups (Yoruba, Hausa, Igbo), the Igbo people are also among Africa's largest, with a population of about sixty million (60) million. Ndigbo occupy Nigeria's Southeast, with Igbo-land culturally spanning Northern (Enugu State), Southern (Imo State), North Eastern (Ebonyi State), Eastern (Abia State, with Arochukwu in the East), and Western Igbo (Anambra State) regions (see Figure 4). Igbo-land's closest neighbors are the Ijaw and Ogoni in the South, the Yako, Ekoi, and Ibibio in the East, the Tiv, Idoma, and Igala in the North, and the Edo and Urhobo in the West (Chukwu, 2024; Duru, 2024; Njoga et al., 2021, p.3).

Figure 4: Map of case study area showing its position in the region, Nigeria
Source: Njoga et al. (2021, p.4)

Arochukwu, the case study area, is an ancient home to approximately 169,339 people (50.60% men, 49.40% women, per a 2022 City Population projection for 2025). It covers approximately 524 square kilometers, characterized by diverse topography, prominent settlements, and various natural resources. Arochukwu's elevation varies, with some areas reaching around 152 meters (approximately 500 feet) above sea level, influencing its landscape, climate, agricultural practices, and settlement patterns. The region is rich in water bodies crucial to its ecosystem and livelihoods, including the Imo River, a major river in southeastern Nigeria that provides water for domestic and agricultural use, transportation, and fishing. Numerous streams and smaller rivers further enhance the area's biodiversity and agricultural potential (Odumodu et al., 2015, p.48; Odoh et al., 2024, pp.107-108). Despite these features, Arochukwu was chosen for study due to its location in Africa's most populous nation and its significance within Nigeria's major ethnic groups (the Igbos), offering rich cultural and traditional ecological knowledge for academic inquiry.

Research design and validation of data collection method

This research employs a single case study methodology to examine the unique approach to environmental sustainability embedded within TEK. Data collection primarily relied on a semi-structured interview conducted with an elder from the Arochukwu community. The interview was recorded using an iPad, transcribed using a human transcription service, edited using CapCut and uploaded to Dropbox as a visual appendix. This semi-interview approach was deemed most suitable given the community's known reticence and discernment. Chukwu (2024, p.6) observes that extracting critical information from this community can be challenging, as they tend to selectively share information deemed beneficial to their interests. Consequently, a semi-structured interview was deemed the most appropriate method to foster open dialogue and elicit in-depth insights. The interviewee, Mazi Nwankwo Michael Okafor - a respected member of the Arochukwu community with extensive knowledge of trado-religious practices and experience that corroborates existing academic literature on the region - granted an interview following his close connection to one of the researchers.

As visualized in Figure 5, the research design of this essay is predicated upon a two-pronged approach. Firstly, it elucidates several areas where Arochukwu TEK demonstrates significant relevance for ecological preservation, thereby establishing a rationale for bridging the divide between Western scientific knowledge and traditional knowledge systems. This analysis was predicated on the African religious-based theory, which provides an interpretive ground for the trado-religious practices and their parallels to Western science. Secondly, it explores potential ways for integrating Western science and TEK to foster a more inclusive and concerted effort in mitigating climate change. These highlighted ways, in bridging the divide, are guided by the decolonial and relational land-based theoretical framework earlier expounded on in section 2.

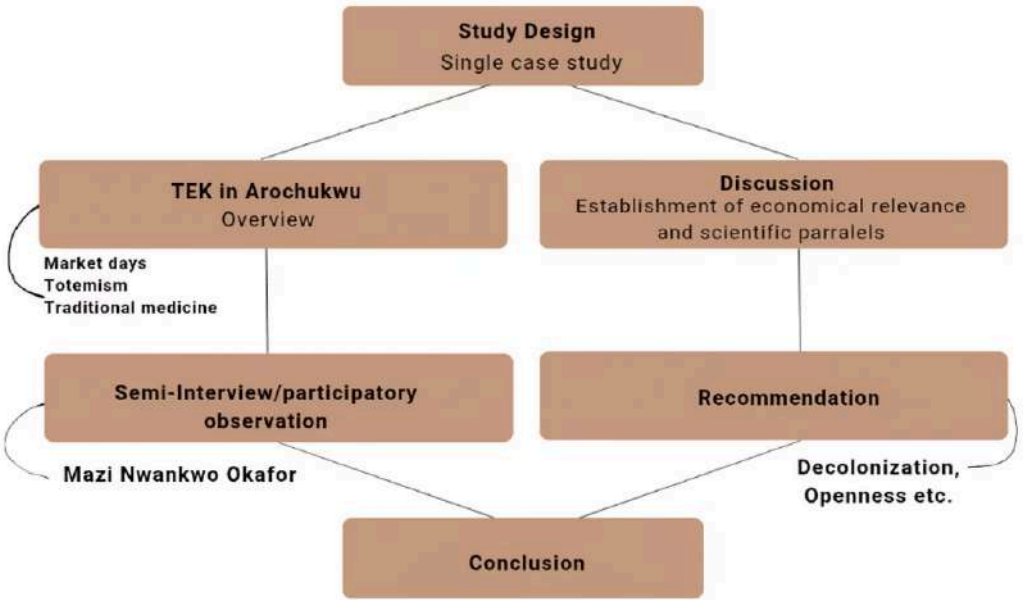


Figure 5: Schematic overview of the study design

The Arochukwu sacred market days and their ecological relevance

Before colonization and Western calendars, Igbo cosmology marked time using unique market days, central to Igbo trado-religious practices, history, and culture. These days were tied to annual religious and cultural festivals (e.g., the New Yam Festival, the Ofala Festival, and masquerade festivals), forming part of the Igbo traditional calendar. For example, the New Yam festival marks the end of one agricultural season and the rainy season (Esther and Uchechukwu, 2022, p.1). The Igbo calendar (4-day week, 7-week month, 28-day month, 13-month year, 91-week year, 364 days) significantly differs from the Western Gregorian calendar (7-day week, 30-day month, 52-week year, 365/6 days) (Kanu, 2021a, p. 41). Mazi Nwankwo Okafor elucidated that the Eke, Orie, Afo, and Nkwo market days hold significant cultural and social importance in Arochukwu and broader Igbo land (see Appendix 1), underscored by customary laws regulating activities. Specific days are traditionally allocated for farming, water and wood collection, hunting, fishing, agricultural trade, and matrimonial celebrations–a practice enabling the land use cycle and 'co-becoming'. Deviation from these prescribed ethos constitutes a taboo with potential social and spiritual consequences within Arochukwu.

Kanu (2021b), in “Igbo- African Market Days and the Conservation of the Ecosystem”, further details the market days, corroborating interview data (See Figure 5):

1. Eke day

The beginning of the market days (Isi Mbido Ahia) and the first son of the week (Diokpara Ubosi). A sacred day where burials and marriage introductions are forbidden. It is a day for oath-taking, and associated with the sacred python (Eke).

2. Orie day

The first daughter of the week (Ada Ubosi). It marks the opening of the farming season and is a day of rest from farm work. Major celebrations like the New Yam Festival are held, but traditional marriages and divorces are forbidden.

3. Afo day

The second son of the week (Osote Diokpara). A day for merriment, masquerade displays, commerce, and socializing. Meetings of all kinds are held on this day.

4. Nkwo day

The second daughter of the week (Isote Ada Ubosi). It is considered a day for the righteous, and many celebrations begin. It is a major market day, and in some communities, women do not attend burials to ensure the market is full.

Figure 5: Overview of Arochukwu Sacred Market Days and their Cultural Significance

This highlights the market days' multifaceted significance, blending economic, spiritual, and social dimensions to foster community cohesion and cultural continuity. Consistent with the African Religious-based theoretical framework, these days illustrate how Arochukwu natives view physical and spiritual realms as interconnected, rejecting a rigid material-metaphysical dichotomy (Kanu, 2021a, pp.43-44).

Totemism and Sacred Plants in Arochukwu and their environmental significance

Totemism, a complex system of belief and practice, establishes a profound connection between a human group and a specific animal, plant, or natural object (Onyagholo, 2025, p.58). This practice is deeply rooted in traditional African societies, characterized by reverence for sacred entities like animals, trees, and places. According to Ndubisi (2021, p.134), this totemic reverence stems from the belief that these sacred entities are inhabited by spirits, underscoring the interconnectedness between physical and spiritual realms within the African cosmology. Mazi Nwankwo Okafor, speaking on Arochukwu's totemic beliefs, adds that its streams are considered sacred abodes of deities: "[...] we have streams, big streams, for example, where our spirit is living, that is the Long Juju of Arochukwu [...] of which, a day that that spirit will come out, nobody can near that place or the rivers [sic]". He further states that some trees, bushes, and animals in Arochukwu are totemic, exemplified by the python: "A strong animal like Agwo, in the English language we call it python [...] is a very very big animal in that environment guiding the community day and night in Arochukwu [...] (as seen in Figure 6). it will come and keep watch in your house. [...] Like my own compound now, I have Oha leaf, I plant it [...] it is a very important tree. Some plant it to prevent evil in the compound" While these beliefs might appear farfetched, they are integral to Igbo trado-religious practices, enforced by strict adherence due to perceived dire consequences for desecration. This totemic belief also substantiates the theorized intersection between the material and immaterial worlds within the African religious-based conversational theoretical framework. Below are some other totemic beliefs of Arochukwu and the Igbo land (see Table 1):

*Figure 6: Py*thon in natural Nigerian forest setting.

Table 1: Totemic objects and beliefs in Arochukwu and Igbo land

S/N	Totemic entities	Totemic beliefs
1	Python (Agwo or Eke)	Referred to as 'Our Mother' (Nne anyi). It is taboo to kill it, as it is an abode for ancestral spirits. Killing one requires performing burial rites.
2	Owl (Ikwikwi)	A symbol of vigilance, believed to be a messenger from the ancestors. Killing it means cutting off communication with the gods.
3	Ram (Ebuna)	A symbol of greatness and the choice animal for sacrifices to the deity Amadioha. Used in important ceremonies and burial rites for strong men.
4	Tiger (Agụ)	A sacred animal in Umulelu, Abia state. It is not eaten or killed, with oral history suggesting community members could transform into tigers.
5	Tortoise (Mbekwu)	A mystical symbol of wisdom and discernment. Its shell is used by diviners in religious rituals.
6	Iroko, Ngwu, Ofo, Ogirisi, Oha	Sacred plant species to which sacrifices are offered. They are sometimes used as offerings to the gods of the land.

Source: Kanu (2021a, pp. 6-8) and Ndubisi (2021, pp. 137-138)

Arochukwu Trado-Herbal Medicine

Herbal medicine also known as indigenous or traditional medicine is a type of medicine or therapy found among aboriginal inhabitants of a particular community. It makes use of spirituality, herbs, animals and mineral components either combined or used singly to bring about healing and protection to both humans and animals (Obika and Eke, 2019, p.1678). Accordingly, because survival within the natural environment necessitates a degree of environmental manipulation and adaptation, traditional healthcare systems played a pivotal role in ensuring human survival in pre-colonial African societies (Tunde, 2021, pp.109-110). At present, notwithstanding the several critiques of traditional medicine, about 80% of the African population still relies on traditional medicine for their basic health needs with about 45 herbal medicines adopted on national essential medicines lists (World Health Organization, 2022, p.1), as illustrated in Figure 7.

Figure 7: Traditional herbal medicine, showing a collection of herbs and medicinal plants prepared for use, illustrating a key aspect of Arochukwu's traditional healthcare practices.

DISCUSSION

Arochukwu trado-religious practices: Ecological significance and scientific parallels

The close similarity between the market days, totemic beliefs and herbal medicine as regards tradition and religion by the Igbos in Arochukwu evidentially captures TEK in its unique and natural form. As earlier established, these traditional knowledge systems are strongly contested within Western academia and by mainstream medical practitioners, especially for their lack of objectivity, measurability and adherence to scientific methods. Despite the associated lack of empiricism with TEK, these Indigenous knowledge systems consist of several parallels with Western knowledge and ecological significance in understanding and preserving our natural world. The United Nations Development Programmes (UNDP) (2020, p. 3), on social and environmental standards, affirms that indigenous peoples' holistic approach to well-being often emphasizes harmony with nature, self-governance, priority of community interests over individual ones, security of land, resource rights, cultural identity and dignity

Specifically, the cyclical nature of the Igbo market days in Arochukwu embodies a sophisticated system of resource management that aligns with contemporary principles of sustainability, including ethical sharing, shifting cultivation, and permaculture. The traditional allocation of specific days for activities such as farming, water and wood fetching and hunting demonstrates a deep understanding of ecological respect and the importance of allowing for periods of rest and regeneration. Hence, ensuring the sustainable utilization of natural resources and fostering a sense of community and shared responsibility. All these, amid the evolution and erosion of several traditional practices by modern pressures, buttress the pertinence of the trado-religious practices of Arochukwu. Additionally, at the core of the observation of these days are the taboos - an institution with spiritual and ecological implications - that compel obedience. By adhering to the market days, the Igbos have demonstrated a remarkable capacity for living in harmony with their environment for generations. Therefore, this traditional knowledge system offers valuable insights to societies and key sector actors grappling with environmental challenges by emphasizing the importance of respecting ecological limits, fostering sustainable resource use, and cultivating a harmonious relationship with the natural world.

Furthermore, totemic beliefs within Arochukwu society demonstrate a remarkable congruence with modern ecological principles. By identifying certain animals and plants with sacred significance, these beliefs inadvertently contribute to biodiversity conservation. The reverence accorded to totemic species, such as the Eke/Agwo (python) - exemplified by the avoidance of harm (see Appendix 2) and the performance of respectful rituals in cases of accidental harm - fosters an environment conducive to their survival and well-being. This reverence, indicating co-becoming - highlights the inherent value embedded within traditional ecological knowledge systems. The protection and reverence of totemic species not only ensures their continued existence but also contributes to the overall health and stability of the ecosystem.

In conclusion, as what is deemed rudimentary or traditional is not inherently inefficient or unimpactful, traditional medicine parallels Western medicine in source, result and side-effect. Herbal medicine, just like Western medicine, involves, inter alia, the use of plants and other resources from the environment, which have been verified over the years by generations to treat sicknesses. While the side effects of taking herbal medicine remain a profound subject of deliberation, Western medicine is also condemned for its side effects. A qualitative study conducted among 28 diabetic patients in four government clinics under the jurisdiction of the state of Negeri Sembilan, Malaysia, found that most of the patients perceived the negative side effects of Western medicine, which led them to consider incorporating herbal medicine in treating diabetes (Ithnain et al., 2024, p.125). Similarly, because practitioners of traditional medicine believe in multiple ontological sides of sicknesses - natural and spiritual, with recorded results, this, to some extent, parallels the results of Western medicine (Tunde, 2021, p. 167).

These diverse ecological and philosophical parallels between Arochukwu TEK practices and Western ecological models are further illustrated in the comparative analysis shown in Table 2.

Table 2: TEK and Western Ecological Models Parallels

Arochukwu TEK Practices	Western Ecological Model	Key Similarities
Seasonal Rotational Farming (Mgbanwe ala)	Agroecology	They both emphasize crop diversity, soil fertility cycles, and reduced chemical dependency.
Market Days and Seasonal Calendars for Planting/Harvest	Phenology	Both track biological cycles for optimal resource use.
Community-Based Wildlife Hunting Quotas	Sustainable Yield Model (MSY)	Both impose limits to prevent overharvesting.
Spiritual Sanctions for Overexploitation	Tragedy of the Commons Theory	Both address resource overuse through governance.
Sacred Groves (Ohia Akwu) & Species Taboos	Island Biogeography Theory	They both recognize habitat patches as critical for biodiversity conservation.
Herbal Medicine	Pharmacology	They both are geared to improve health

Source: Informed from interview and Berkes (2012).

RECOMMENDATIONS ON BRIDGING TEK AND WESTERN SCIENCE

Humanity's broken relationship with the natural world underlies our current environmental reality (United Nations Environment Programme, 2024, p. 2). Bridging the perceived gap between Traditional Ecological Knowledge (TEK) and Western science is crucial for addressing escalating environmental challenges from anthropogenic activities. While Western science emphasizes empirical data and quantitative analysis, TEK, embedded in indigenous cultures, offers a profound understanding of local ecosystems, developed over generations through observation and lived experiences. This understanding entails intricate knowledge of plant and animal behavior, seasonal patterns, and the interconnectedness of all living beings within an ecosystem. Recognizing the limitations of a purely Western scientific approach and the invaluable insights from TEK enables more holistic and effective solutions for environmental conservation and sustainable development.

Appealing to the Decolonial Relational Land-based Theory's components–openness, sensitivity, acknowledgement of cultural sacredness, deep respect, and sincerity to learn–the following recommendations are submitted:

01

Rectifying colonial biases

Recognize and address historical power asymmetries marginalizing Indigenous knowledge, challenging Western epistemic violence through institutional and policy shifts.

02

Equitable knowledge exchange through cultural camps

Institute fair protocols for reciprocal data sharing, ensuring proper acknowledgement and benefit distribution. Encourage cultural camps (e.g., Two-Eyed Seeing) to integrate knowledge systems.

03

Mainstreaming TEK in education

Systematically incorporate TEK into all education levels to raise awareness and cultivate deeper understanding of diverse knowledge systems for sustainable living.

04

Policy Integration

Advocate for explicit TEK integration into environmental policies and decision-making, creating formal mechanisms for TEK holders' active participation.

05

Culturally sensitive research paradigms

Develop research methodologies consonant with Indigenous cultural protocols, values, and worldviews, including culturally appropriate consent and finding presentation.

06

Harmonious research initiatives

Establish research collaborations that authentically merge TEK with Western science, ensuring Indigenous wisdom is respected and integrated into research and policy.

07

Preservation of Indigenous knowledge

Allocate resources to initiatives facilitating TEK transmission and revitalization, including language preservation, documentation, and intergenerational knowledge transfer.

CONCLUSION

This study endeavours to bridge the conceptual and practical divides between Traditional Ecological Knowledge (TEK) and Western science, fostering a more integrated approach to environmental challenges. By meticulously analyzing extant academic literature, relevant reports, and theorizing with the African Religious-based Conservation and the Decolonial Relational Land-based theories, this essay argues that the trado-religious practices of Arochukwu is parallel to Western science in several ways and thus, should be recognized and adopted in mainstream environmental sustainability policies and practices, especially as what may be termed traditional or indigenous may not entirely be ineffective. The sacred and intricate aspects of Eke, Orie, Afo and Nkwo market days, coupled with the unfeigned reverence of certain animals, plants and places, are identified through the prism of the African Religious-based Conversation theory as unique ways in which the Igbos respect and co-exist with their environment and ensure sustainability. This resonates with the concept of care-as-country that implies an effectiveness in caring for the environment when seen "as" a part of us. The study also submitted some parallels between TEK and Western science in terms of source, result and side-effects. Furthermore, given the establishment of ecological significance and parallels, the study transcended towards establishing ways TEK and Western science, two methodologically distinct systems of knowledge, can be bridged. Therefore, it submits that bridging the gap between TEK and Western science requires a commitment to respectful dialogue, equitable partnerships, and a genuine desire to learn from diverse knowledge systems. By fostering collaborative research, supporting Indigenous knowledge keepers, and integrating TEK into education and policy, we can create a more just and sustainable future where both Indigenous and Western knowledge systems are valued and respected. This collaborative endeavour will not only enhance our understanding of the natural world but also contribute to the sustainable well-being of both humans and our environment.

CONFLICTS OF INTEREST

The author declares no conflict of interest

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APPENDIX

Appendix 1: Video of Interview.

The link below contains a video of the authors'semi-structured interview with Mazi Nwankwo Okafor:

Interview with Mazi Nwankwo Okafor Michael.mp4

Dropbox

Interview with Mazi Nwankwo Okafor Michael.mp4

Shared with Dropbox

Appendix 2

An online video of Eke moving in Igbo land with the accorded respect:

A video of Eke in Igbo land..mp4

Dropbox

A video of Eke in Igbo land..mp4

Shared with Dropbox

Source: Sylvia Egbuji **https://www.facebook.com/share/r/1Xst12Ks3r/**

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Shezhire as a Code of Sustainability: Traditional Kazakh Wisdom for Sustainable Futures

REVIEW

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures

PLAIN-LANGUAGE SUMMARY

Shezhire: Ancient Wisdom

Shezhire is a Kazakh system merging family trees with environmental and cultural knowledge. It guided communities for centuries to live sustainably and understand their heritage. This study explores how this traditional wisdom addresses modern challenges.

Key Research Findings

Our study of 1,000 Kazakh people reveals shezhire's continued relevance and value. It holds vital information on climate adaptation, resource management, and social organization, offering insights for global sustainable development efforts.

Bridging Past & Present

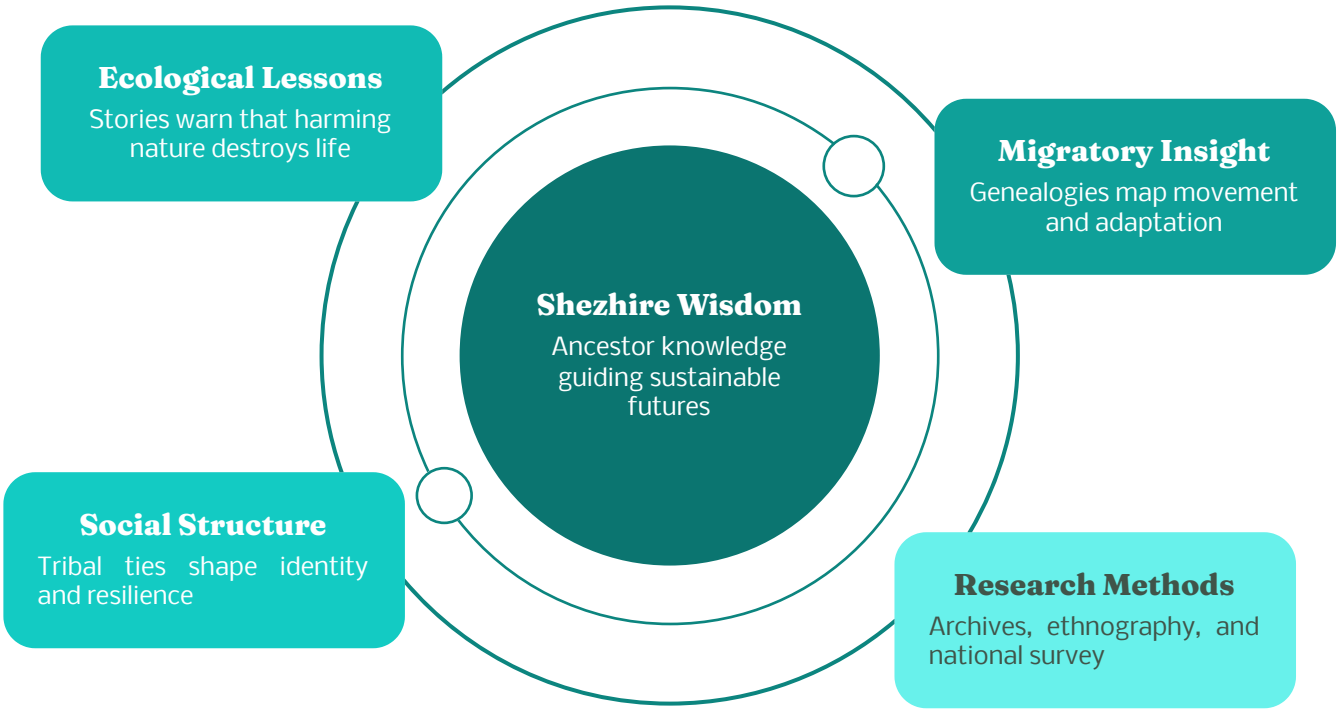
Facing environmental and social crises, traditional systems like shezhire provide proven solutions developed over generations. Indigenous wisdom isn't just history; it's a practical resource for building resilient communities and managing nature responsibly.

Pathway to Sustainability

Shezhire demonstrates how traditional knowledge can bridge ancient wisdom with modern sustainability needs. It offers valuable insights for educators, policymakers, and communities striving for a more sustainable future worldwide.

ABSTRACT

Shezhire is the voice of our ancestors, a reflection of their wisdom honed over centuries. Today, in an era of change, it can become key to fostering harmony between humanity and nature. Every story in the shezhire teaches us that if we destroy nature, our lives will be destroyed. This knowledge remains relevant today, as global resources face increasing threats. Shezhire (genealogies) of the Kazakh people are not only a system of tribal ties but also a unique cultural, social, and historical phenomenon that has shaped the identity and structure of Kazakh society for centuries. In this article, Shezhire is viewed not only as a family history but also as a critical source of ecological, migratory, and anthropological data relevant to contemporary discourse on sustainable development. The study substantiates this claim using a combined approach that integrates archival analysis, ethnographic fieldwork, and a nationwide sociological survey involving 1,000 respondents across five regions of Kazakhstan. These methods provide a comprehensive understanding of how Shezhire records reflect ecological adaptation, migratory processes, and genetic diversity, which together contribute to the resilience of communities in changing conditions. Thus, Shezhire is not only a chronicle of the past but also a cultural bridge to the future. By preserving and reinterpreting the legacies of our ancestors through interdisciplinary research, we contribute to building a sustainable world for future generations.



Keywords: shezhire, Kazakh genealogies, traditional ecological knowledge, sustainable development, migration, cultural heritage.

INTRODUCTION

Shezhire, or genealogies, are one of the most important traditions in the culture and self-awareness of the Kazakh people. This is not merely a list of ancestors, but a holistic system of knowledge that combines historical, ecological, and social aspects (Jessen et al., 2022). Knowing one's genealogy up to the seventh generation was considered a sacred duty for every Kazakh and played a key role in regulating social ties, preserving ancestral memory, forming cultural identity, and adapting to natural conditions (Guirkinger & Aldashev, 2016). Within local society, shezhire served as a living archive, recording not only names and dates but also migration routes, territorial features, and ecological knowledge of the landscape and its resources (Shakirova et al., 2023).

Today, in the context of globalization and the erosion of traditional knowledge (Tezekbay & Tolessin, 2024), shezhire is acquiring new meaning as a cultural and ecological archive. It can be considered a valuable source of information on migrations and the adaptation strategies of the Kazakh people over centuries. To this day, references to ancestral movements, choices of nomadic lands, and marriages represent relevant environmental and social lessons, reflecting sustainable practices of natural resource management and the maintenance of biodiversity.

In this article, shezhire is considered not only as a historical phenomenon but also as a model for studying sustainable development. For this purpose, an analysis of the historical and cultural origins of shezhire was conducted, revealing its functions within the social structure of Kazakh society and its role in the formation of cultural identity. The structure and geography of shezhire are also analyzed, including the system of division into zhuzes and clans (Olzhbaekova, 2025), territorial distribution, and migration routes. Based on a review of ethnographic and genetic studies, as well as data obtained during a sociological survey conducted among 1,000 respondents from five regions of Kazakhstan, anthropological and genetic features of some Kazakh clans are highlighted. This allows us to discuss how the combination of these characteristics has historically shaped the genetic diversity of Kazakh society and can be used in modern scientific and educational contexts of sustainable development. It also allows us to analyze the potential of shezhire as a tool for the formation of educational and scientific programs aimed at preserving traditional knowledge and integrating it into modern strategies for sustainable development (Corbett, 2025). Thus, the article aims to comprehensively understand shezhire as a multifunctional cultural and ecological archive that combines traditional knowledge and modern scientific approaches, making it a relevant resource for shaping a sustainable future.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Origins and Functions of Shezhire

Origin of the Concept of "Shezhire"

Shezhire (Kazakh for genealogy/history, from Arabic "shajara" meaning tree) is a unique Kazakh system of oral and written knowledge, functioning as a comprehensive archive of historical, cultural, and environmental wisdom passed through generations (see Figure 1). It covers family ties, natural resource management, survival in extreme conditions, environmental harmony, and social norms. This aligns with UNESCO's recognition of practices like traditional yurt-making (one of Kazakhstan's 14 Intangible Cultural Heritage elements as of 2024), highlighting sustainable resource management using 'natural and renewable raw materials' (UNESCO, 2024).

Research demonstrates Central Asian nomadic pastoralists successfully use traditional forecasting for climate change adaptation (Herrera, 2023) and precipitation management. Their centuries-old sophisticated ecological ideologies, rooted in human-nature coexistence, exemplify advanced environmental management (Jessen et al., 2022).

Shezhire was first recorded in Kazakh culture in written form during the Golden Horde era (13th-15th centuries) and gained widespread recognition (15th-18th centuries) during the Kazakh Khanate's formation, becoming integral to its political structure, social status, territorial rights, and diplomatic relations (Guirkinger & Aldashev, 2016). Kazakh zhyrau (epic poets and storytellers) like Ketbuga and Asan Kaigy orally transmitted shezhire, preserving the memory of khans, batyrs, and historical events. Written versions appeared in medieval historians' works, most notably Abulgazy Bakhodur Khan's "Shezhire of the Turks" (17th century), which described Kazakh genealogies within the broader Turkic community.

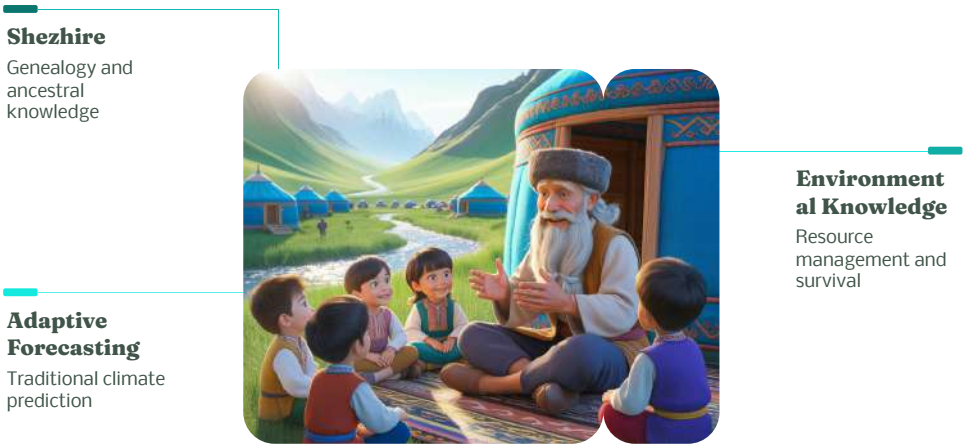


Figure 1. Shezhire as a Comprehensive Knowledge System

Academic research on traditional knowledge systems in Central Asia remains limited. A systematic review found only 52 publications on climate change adaptation in Central Asian mountains (Saidaliyeva, 2024), underscoring the urgent need for more comprehensive studies of systems like shezhire. Shezhire reflected family history alongside geographical, ecological, and social contexts. For example, each family branch linked to specific regions: the Argyns in the Middle Zhuz to the central and northern steppes, the Adai in the Younger Zhuz to Western Kazakhstan's desert regions, and most of the Senior Zhuz to Southern Kazakhstan (Olzhbaekova, 2025).

Kazakh Migrations & Ecological Adaptations Timeline

This timeline illustrates key periods in Kazakh history, highlighting significant migrations and ecological adaptations that shaped their culture and sustainability practices (see Figure 2).

1 13th-15th Century: Golden Horde Era

- Formation of early Kazakh identity
- Development of shezhire documentation system
- Adaptation to steppe environments and seasonal migrations (Ventresca Miller et al., 2020)

2 15th-16th Century: Kazakh Khanate Formation

- Unification under Janibek and Kerei (1465-1466)
- Establishment of three zhuz system (Senior, Middle, Junior)
- Territorial organization based on ecological zones

3 16th-17th Century: Territorial Expansion

- Clan migrations following seasonal pastures (Ulambayar, 2023)
- Development of water management systems
- Adaptation to diverse landscapes (steppes, deserts, mountains)

4 18th Century: Climate Adaptation

- Argyn clan migration northward due to southern desertification (Davaadalai et al., 2024)
- Documentation of drought responses in shezhire
- Development of flexible nomadic strategies (Tugjamba et al., 2023)

5 19th-20th Century: Colonial Pressures

- Adaptation to Russian settlement policies
- Preservation of traditional knowledge systems (Tegizbekova, 2018)
- Integration of new agricultural practices

6 21st Century: Modern Applications

- Revival of shezhire knowledge for sustainability (Acharya & Prakash, 2025)
- Integration with climate science and conservation (Corbett, 2025)
- UNESCO recognition of traditional practices (UNESCO, 2014)

Figure 2. Kazakh Migrations & Ecological Adaptations Timeline

Social Functions of the Shezhire

The Shezhire had many functions that went beyond simply recording genealogies. It was an important element of the social organization of Kazakh society, in which everything was built around family ties. The Shezhire was the main instrument of self-identification. Every Kazakh knew their genealogy up to the seventh generation, a knowledge considered essential for understanding their role in society. Not knowing one's origins was perceived as a lack of respect for ancestors and one's own culture. Kazakh society strictly adhered to the principle of "zheti ata" (seven ancestors). This custom prohibited marriages between descendants related within seven generations, which helped prevent undesirable genetic consequences. The tradition of zheti ata (seven ancestors) was fundamental to Kazakh society, requiring every individual to know their genealogy up to seven generations to prevent marriages within this lineage and maintain genetic health. The Shezhire recorded these lineages to avoid accidental violations of this rule.

The Shezhire system also provided clarity in matters of leadership and social status. For example, contenders for the Khan's throne had to belong to the Tore clan, which traced its origins back to Genghis Khan. Clans, such as the Naimans, Kipchaks, or Dulats, had their own territories and influence depending on their place in the Shezhire system. This complex social structure represented an open type of stratification where individuals could advance their social position despite the traditionalism of nomadic society. Shezhire served as a basis for the transmission of cultural values, heroic stories, and lessons from the past. Through stories about ancestors, children learned about virtues such as courage, hospitality, and respect for elders. Shezhire also recorded the connection of clans with certain territories, which played a key role in land ownership issues. This allowed for the avoidance of conflicts between clans and ensured harmonious coexistence in the context of a nomadic lifestyle. Even to this day, one can trace a logical connection, as most clans have retained their locations on the modern territory of Kazakhstan.

Thus, Shezhire was not only a genealogical system but also a mechanism for social regulation and the preservation of historical memory (Shakirova et al., 2023). It united the Kazakh people into a single community, creating strong cultural roots that helped nomadic communities survive and thrive. In the following sections, we will explore how Shezhire reflected the geographical and ecological aspects of Kazakh life, and trace its significance in the adaptation and development of society.

Shezhire's Multifaceted Social Functions

Beyond a mere genealogical record, the Shezhire was an indispensable tool for social organization, self-identification, and cultural preservation within Kazakh society. It provided a framework for legal, social, and cultural norms, intricately weaving personal identity with collective history.

Self-Identification

Every Kazakh knew their genealogy up to the seventh generation, understanding their lineage and societal role through Shezhire.

Marriage Regulation

The "Zheti Ata" principle, documented in Shezhire, prevented marriages within seven generations to maintain genetic diversity and respect ancestry (Guirkinger & Aldashev, 2016).

Political Hierarchy

Shezhire defined leadership eligibility; for example, only the Tore clan, direct descendants of Genghis Khan, could aspire to the Khanate.

Territorial Connections

It recorded clan affiliations with specific lands, which was crucial for land ownership, resource management, and conflict prevention among nomadic groups (Ulambayar, 2023).

Cultural Transmission

The Shezhire served as a repository for cultural values, heroic narratives, and historical lessons, passed down through generations (UNESCO, 2024).

Social Regulation

By providing a clear social structure and historical context, Shezhire mitigated conflicts and fostered harmonious coexistence within the community (Shakirova et al., 2023).

These functions demonstrate the Shezhire's profound impact on shaping Kazakh societal norms, from individual identity to collective governance, ensuring stability and continuity across centuries of nomadic life (Tezekbay & Tolessin, 2024).

Structure and Geography of Shezhire

The Three Zhuzes: Senior, Middle, and Junior

The Shezhire of the Kazakh people is structured around the system of three zhuzes: Senior (Uly Zhuz), Middle (Orta Zhuz), and Junior (Kishi Zhuz). This unique construction was formed as a result of historical, geographical, and social processes spanning thousands of years. Each zhuz is a confederation of tribes (ru) united by common origin, territory, and leadership traditions. The zhuz system organized Kazakh society into large unions based on kinship ties, providing a basis for governance, conflict resolution, and natural resource management. Within each zhuz, tribes were in turn subdivided into clans and lineages, creating a multi-level hierarchical organization that combined kinship ties with socio-political functions.

Senior Zhuz

The Senior Zhuz occupied the southern regions of modern Kazakhstan, including the territories along the Syr Darya River, Tien Shan, and Zhetysu (Semirechye). The clan groups of the Senior Zhuz, such as the Dulaty, Kanly, Suany, Albany, and Shapyrashty, played a key role in the cultural and economic life of the region. Notably, the clans of the Senior Zhuz were characterized by their proximity to the sedentary civilizations of Central Asia. Situated along key routes of the Silk Road, these territories facilitated active trade and cultural exchange.

Middle Zhuz

The Middle Zhuz occupied the central and northeastern steppes, including the regions of Saryarka, Pavlodar, and East Kazakhstan. Its main clans included Argyn, Kipchak, Naiman, Konyrat, and Kerey. The clans of the Middle Zhuz were renowned for their military and administrative traditions. They participated in key battles, such as the struggle with the Dzungars, and played an important role in the political system of the Kazakh Khanate.

Junior Zhuz

The Junior Zhuz was located in the western steppes, including the modern Atyrau, Aktobe, and Mangistau regions. Its main clans were Bayuly, Alimuly, and Zhetiru. The Junior Zhuz lived in harsh climatic conditions, where nomadism was more intense. Adapting to these challenging environments and practicing nomadic pastoralism were central to their way of life.

Intra-clan Structures

Within each zhuz, the Shezhire detailed clan ties, creating a complex network of relationships between sub-clans (ata-balasy). This structure ensured social hierarchy and organization. Each large clan was divided into smaller subdivisions. For instance, the Argyns of the Middle Zhuz included sub-clans such as Karakesek, Kanzhygaly, and Temesh. These sub-clans, in turn, could be divided into even smaller groups, each with its own leader (bi or elder). Among the Dulats of the Senior Zhuz, subdivisions like Sary, Shymyr, and Botpay secured their territories depending on natural conditions. The Shezhire was maintained and transmitted under the leadership of elders, who were the keepers of clan memory. They could detail important events and family ties, ensuring the preservation of knowledge about ancestors (Tegizbekova, 2018). Each clan had its own territory, where it lived and roamed. The Naiman clan occupied the eastern regions, rich in pastures and rivers. The Adai clan settled in the desert regions of Western Kazakhstan, developing unique methods of survival in harsh conditions. Clans often differed in cultural traditions, which can be observed, for example, in the ornamentation characteristic of each clan and in local dialects of the Kazakh language. These differences were often reflected in the Shezhire.

Shezhire as a Migration Map

Shezhire recorded the migration routes of Kazakh clans, reflecting their adaptation to natural conditions. From the 7th to the 10th centuries, the ancestors of the Kazakhs, including the Karluks and Kipchaks, migrated from Altai to the steppes along the Syr Darya. These migrations were driven by the search for new pastures and climate change (Genina, 2015). The Argyns and Kipchaks often migrated due to conflicts with neighboring tribes and deteriorating environmental conditions. Migration contributed not only to settlement but also to cultural exchange. For example, the Kipchaks brought their traditions and language, which influenced the formation of the modern Kazakh language. This process exemplifies the inherent resilience of Kazakh communities, which adapted to changing political and economic landscapes by integrating external influences and preserving core elements of their social structure, nomadic economy, and cultural identity. Shezhire also preserved the memory of nomadic routes, which were determined by the availability of water and pastures. For example, the routes of the Adai clan passed along the Caspian Sea, which provided access to water in an arid climate (Ventresca Miller et al., 2020). The structure and geography of the Shezhire reflect the complex system of organization of Kazakh society. The three zhuzes and their clan structures created a balance between local autonomy and national identity. This balance was maintained through traditional governance mechanisms such as councils of elders (biy), inter-clan gatherings, and customs (adat) governing conflict resolution, land use, and marriage alliances (Davaadalai et al., 2024). In addition, shared seasonal migration cycles and coordinated pasture management facilitated cooperation between clans, highlighting the importance of adaptation and human interaction with nature.

Ecology and Anthropology of Shezhire

Ecological Aspects of Shezhire

Shezhire as an ecological archive: integration of knowledge about nature. The Kazakh shezhire, being the foundation of the people's cultural memory, is not only a genealogical collection but also a unique ecological archive reflecting a deep understanding of the nomadic society's interaction with its environment. These genealogies included data on the most productive pastures, the seasonality of their use, and migration routes. This made shezhire a practical tool for adapting to changing natural conditions (Herrera, 2023), with migration data observable on the map in Figure 3. This information was primarily recorded and transmitted orally by clan elders, biys, and narrators, who carefully memorized and recited it during general meetings and ritual ceremonies. The continuous recitation of this knowledge from generation to generation strengthened its reliability and accuracy, acting as a living archive essential for survival in the steppe (Jessen et al., 2022).

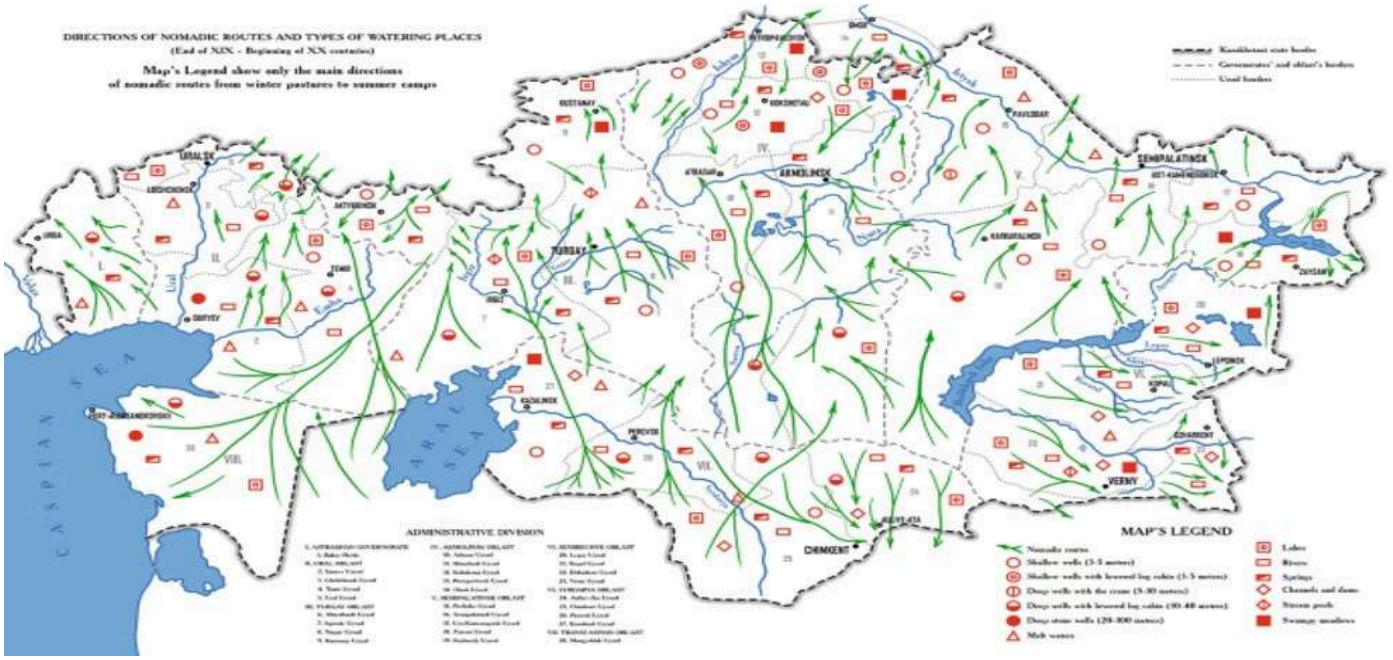


Figure 3. Directions of Nomadic Routes and Types of Watering Places

The shezhire of the Senior Zhuz mentions the territories of Zhetysu, characterized by highly productive pastures. Their use was strictly regulated to prevent land degradation, and such knowledge contributed to the maintenance of ecosystem balance. Oral legends about the Syr Darya and Balkhash, included in the shezhire, conveyed information about safe watering places for livestock. This practice reduced anthropogenic pressure on the environment. The example of the Adai clan from the Younger Zhuz demonstrates how the shezhire served as a tool for adaptation to the harsh conditions of the Mangistau deserts (Tugjamba et al., 2023).

Rational Use of Resources

The Adai people documented information about temporary reservoirs and wells. This allowed them to maintain a livestock economy despite the limited water supply. The shezhire of each clan reflects migrations along the Caspian coast, which provided access to water and food resources, thereby minimizing the risks of ecosystem depletion. The Adai people meticulously documented temporary water bodies, wells, and seasonal camps in shezhire, which allowed them to successfully conduct nomadic pastoralism even with limited water resources. These genealogies of each clan recorded migration routes along the Caspian coast, ensuring sustainable access to water and pastures, and thereby preventing ecosystem degradation. Such traditional knowledge of water use and spatial memory can serve as a valuable source for modern conservation strategies and the rational distribution of water resources in the arid regions of western Kazakhstan (Figure 4).

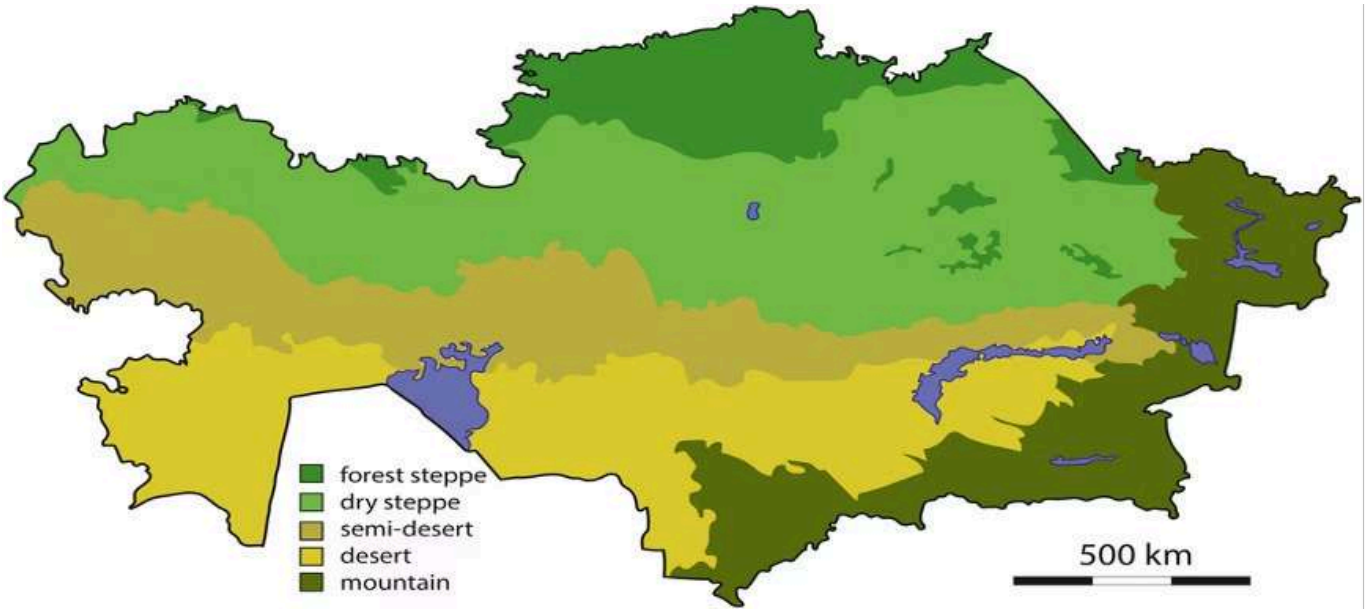


Figure 4. Ecological zones across Kazakhstan

Climate Change and Its Reflection in the Shezhire

The shezhire recorded the adaptation strategies used by clans in response to climate change (Redvers & Aubrey, 2023). For example, in the 13th-14th centuries, desertification of the southern steppes was observed, which forced the Kipchaks and Argyns from the Middle Zhuz to migrate north to the wetter regions of Saryarka. In the 18th-19th centuries, the clans of the Great Zhuz introduced irrigation methods to the fertile lands along the Syr Darya, contributing to the development of sedentary agriculture.

Environmental Consequences of Industrialization

Soviet collectivization in the 20th century led to the disruption of traditional migration routes documented in the shezhire, disrupting the ecological knowledge of pastoral communities accumulated over centuries. This disruption directly contributed to the acceleration of soil erosion and desertification.

In the Younger Zhuz area, particularly in the Aktobe region, biodiversity declined dramatically due to overgrazing and the abandonment of sustainable rotational grazing practices once institutionalized in the shezhire. Recent ecological research confirms significant declines in native plant species and soil fertility associated with these historical changes, highlighting the ecological consequences of the erasure of traditional knowledge systems. This proves once again that shezhire contains enormous potential for studying traditional practices of sustainable nature management. Analysis of genealogies helps, firstly, to restore historical data on migrations, which contributes to the study of climate change, and also to develop strategies for the rational use of pasture ecosystems, taking into account traditional knowledge (Guirkinger & Aldashev, 2016).

Anthropological and Genetic Aspects of Shezhire

Recent research in the field of molecular anthropology demonstrates a striking correlation between the genealogies documented in the Shezhire and the genetic diversity of the Kazakh population, emphasizing its complex historical and geographical origin. According to the data, the most common haplogroups in the Great Zhuz are C2 and R1a, which reflect ancient Turkic and Indo-Iranian migrations. In the Middle Zhuz, a high frequency of haplogroup G is observed, which researchers associate with the migrations of the Kipchaks and their subsequent integration into the Mongol troops. Meanwhile, in the Younger Zhuz, haplogroup J2 stands out, indicating historical contacts with populations from the Caucasus and Caspian regions. Mitochondrial DNA studies show that the maternal lines of different clans trace back to various regions of Eurasia. This genetic diversity corroborates historical evidence of inter-clan marriages and external contacts. These results illustrate how shezhire not only documents social memory but also reflects a deeper biological history.

Physical Anthropological Characteristics of the Clans

Middle Zhuz

The Argyns and Naimans exhibit pronounced Mongoloid features, including a broad skull and high cheekbones, which is associated with their genetic heritage from the nomads of Central Asia.

Great Zhuz

The Suans and Dulats display mixed features, which may be a consequence of their close interaction with sedentary peoples of Central Asia, such as the Sogdians.

Younger Zhuz

The Zhetiru and Alimuls possess Caucasoid features, including a thin nose and deep eye slits, indicating their connection with the Sarmatians and Alans.

Social Regulation and Genetic Health: The Rule of "Zheti Ata"

Shezhire played a central role in maintaining the genetic health of Kazakh communities through the "Zheti Ata" rule, which prohibited marriages between individuals with common ancestors within seven generations (Olzhbaekova, 2025). By effectively preventing consanguineous unions, this system helped to preserve genetic diversity and reduce the prevalence of hereditary diseases. Similar restrictions on kinship-based marriages have been observed in other nomadic societies; for example, the Khoton exogamy rules of Mongolian pastoralists, as well as the clan exogamy of Kyrgyz tribes. Modern research in population genetics confirms that such systems have helped to limit the spread of recessive genetic diseases in small, endogamous populations.

Ethnocultural Parallels and Global Context

The Kazakh system of shezhire has parallels in the genealogies of other nomadic peoples. For instance, the Mongols maintained "Altan tobchi," a genealogy focusing on the Genghis Khan dynasties (Genina, 2015). Among the Turkic tribes of Central Asia, shezhire recorded tribal unions and political hierarchy. The Kazakh tradition is distinguished by its comprehensive detail, covering not only the political elite but also a wide range of clans, which emphasizes its importance for anthropological and sociological analysis. UNESCO's recognition of traditional knowledge systems across cultures supports this comparative approach. For instance, traditional yurt-making knowledge shared between Kazakhstan and Kyrgyzstan was jointly inscribed on UNESCO's Representative List in 2014, demonstrating the cross-cultural value of nomadic heritage.

Despite their cultural significance, traditional knowledge systems in Central Asia face protection challenges. Research indicates that Central Asian states lack specialized regional tools to protect genetic resources and traditional knowledge, with only Kyrgyzstan developing legal frameworks for traditional knowledge protection as of 2018 (Tegizbekova, 2018). This regulatory gap underscores the vulnerability of systems like shezhire.

Shezhire as a Source of Anthropological Data

A comparative analysis of shezhire and archaeological data reveals insights into migrations and cultural contacts. Specifically, the migrations of the Kipchaks (Middle Zhuz) show an overlap with the spread of material culture, such as ceramics and weaponry (Ventresca Miller et al., 2020). Furthermore, genetic studies confirm the significant influence of Iranian and Mongolian migrations, which are also mentioned in the oral traditions of shezhire. The ecological and anthropological aspects of shezhire demonstrate the intricate interrelationship between humans and nature, genetic heritage, and cultural memory. The integration of traditional and scientific knowledge is increasingly recognized as essential for climate adaptation, supporting the relevance of shezhire in contemporary sustainability efforts.

MATERIALS AND METHODS

In preparation for this article, a sociological study was conducted to examine the perception of shezhire in modern society (Olzhbaekova, 2025), its importance for sustainable development, and possible ways of utilizing this cultural heritage in a global context. The study employed a quantitative approach. The sociological survey was administered to the population of Kazakhstan, maintaining regional and age balance. The sample comprised 1,000 respondents, proportionally distributed across regions, age categories, and gender groups based on data from the latest national census (see Figure 5). This sample design ensures the statistical representativeness of the sample relative to the adult population of Kazakhstan, thereby confirming the validity of the results obtained.

Regional Distribution

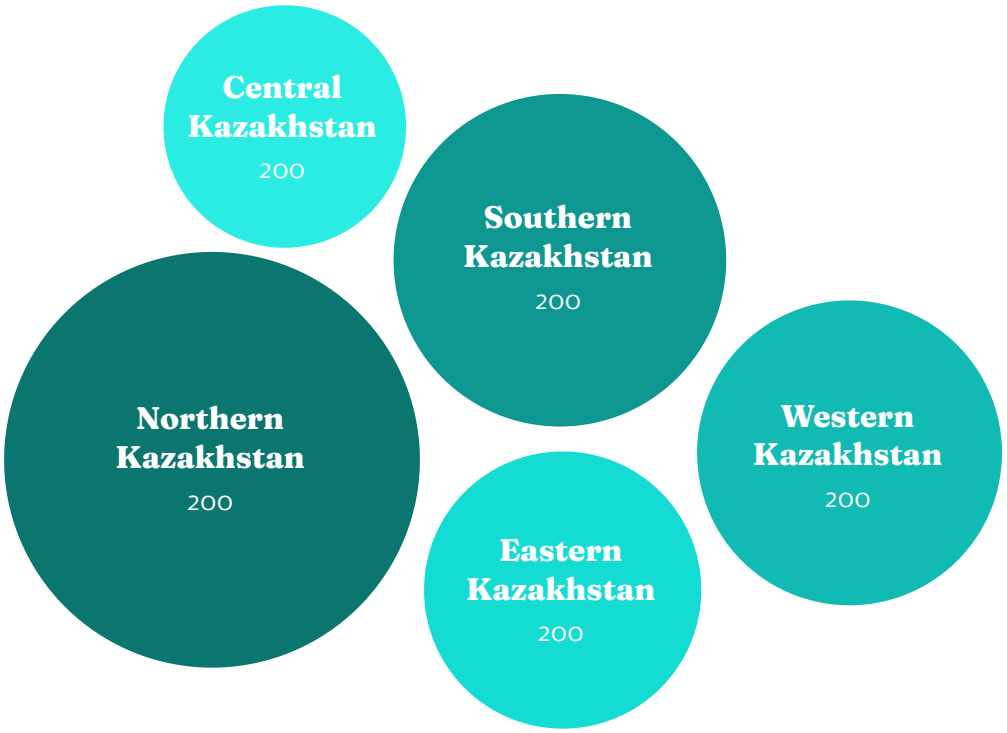


Figure 5. Regional Distribution of Survey Respondents

Each region was represented by four age categories, with 50 people in each:

- Younger group (up to 18 years old).
- Youth (18-25 years old).
- Working age (25-40 years old).
- Older generation (40 years and older).

Survey Design and Data Collection

The survey included a number of questions aimed at obtaining objective data on the perception of shezhire and its potential role in various aspects of sustainable development. For a more accurate analysis, the questions were grouped into three thematic blocks:

Cultural Heritage and Identity

- Do you know what shezhire is?
- Do you consider shezhire an important element of cultural heritage? (UNESCO, 2024)
- Do you use knowledge of your genealogy in your life (upbringing, family values, decision-making)?
- Have you ever been interested in the genetic origins of your family?

Ecological Potential and Sustainable Development Potential

- What modern problems, in your opinion, can be solved with the help of shezhire? (Redvers & Aubrey, 2023)
- Can shezhire be considered an ecological archive of traditional knowledge?
- How can shezhire contribute to sustainable development? (Select the most relevant areas: ecology, education, social justice, etc.)

Education and Integration with Modern Science

- Should the study of shezhire be included in educational programs?
- Do you think that genetics can complement the knowledge contained in shezhire? (Acharya & Prakash, 2025)
- Should genetic data be used to preserve cultural heritage?

This thematic grouping allowed us to analyze the answers not only to individual questions but also in broader cultural, environmental, and educational contexts. The survey was conducted using the Google Forms platform, which ensured the convenience of data collection and minimized geographical barriers. The link to the survey was distributed through social networks, educational institutions, and public organizations. Additionally, local surveys were conducted in rural and urban areas to account for regional characteristics. The collected data were categorized by region, age group, and thematic block. This made it possible to identify regional differences in the perception of shezhire, as well as to analyze how age and level of awareness affect attitudes toward this phenomenon.

Ethical considerations: Participation was voluntary and anonymous; consent was obtained from all respondents (and parental/guardian consent for minors). No identifying data were collected.

RESULTS

Shezhire as a Tool for Sustainable Development in the Modern World

Shezhire, as a unique genealogical and cultural tradition of the Kazakh people, is a powerful tool for preserving historical memory, environmental knowledge, and social order. This system, passed down through generations in oral and written forms, not only documents the origins and connections between clans but also contains profound information about human interaction with the natural environment, migration patterns, principles of social structure, and sustainable practices. Today, shezhire has the potential to be integrated into global sustainable development strategies, especially in the context of growing interest in traditional knowledge as a resource for adaptation to modern challenges (see Figure 6).

Figure 6. Shezhire's Role in Sustainable Development

RESULTS

Historical and Cultural Significance of Shezhire and Sustainability

Shezhire, developed from a nomadic lifestyle demanding high environmental and social adaptation, was crucial for sustainable resource management (pastures, water, migration routes). For instance, Kazakh clans like the Dulats of the Senior Zhuz used it to transmit cultural heritage detailing Zhetysu's fertile lands, seasonal availability, and acceptable use rates, fostering harmony with nature. Beyond genealogy, shezhire regulated inter-clan relations, preventing conflicts and maintaining cohesion. The Zheti Ata principle (prohibiting marriages up to the seventh generation), for example, prevented genetic diseases and strengthened clan ties (Redvers & Aubrey, 2023).

Shezhire and Ecology: Lessons for Sustainable Nature Management

Shezhire traditions offer rich nature management knowledge for modern environmental strategies (see Figure 7). They detail pasture rotation, crucial for restoration, degradation prevention, and combating steppe desertification (Davaadalai et al., 2024). Modern research and 1980s-1990s oral histories confirm traditional migration routes, such as the Kipchak clan's seasonal movement from lower Ishim (Yesil) River to Ulutau (Ulytau) foothills, align with optimal biodiversity zones; integrating this into ecosystem restoration effectively combats land degradation. Shezhire also records water source locations, seasonal availability, and acceptable use rates, exemplified by the Alshyn clan's traditional use of Mangistau groundwater, data valuable for modern water management amidst climate change.

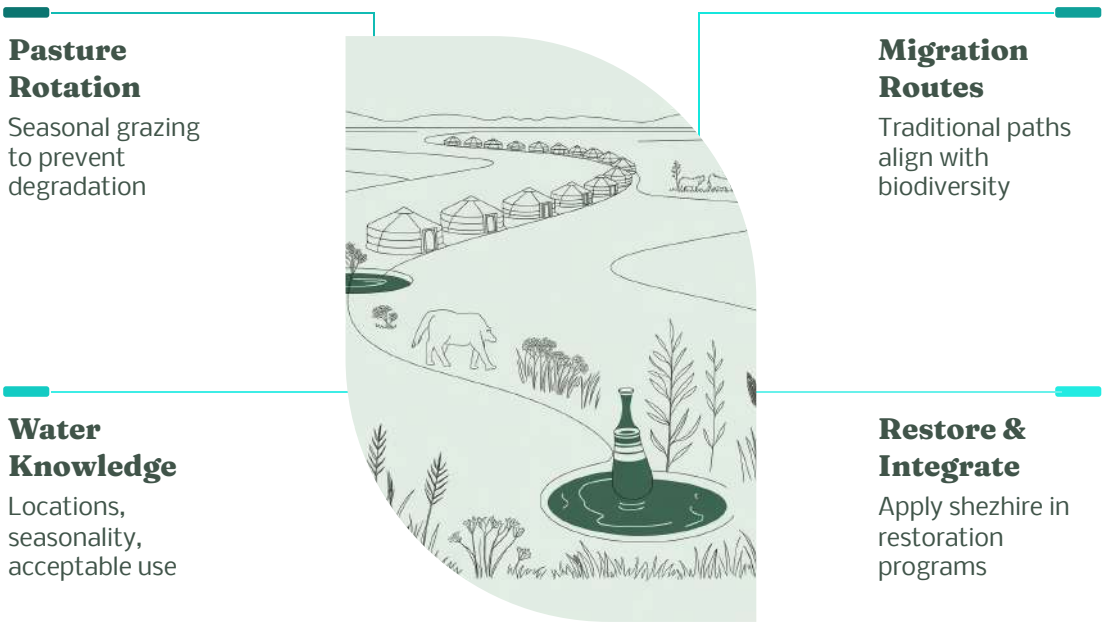


Figure 7: Shezhire traditions in nature management for sustainable environmental strategies

Climate Adaptation

Studying the migration routes of clans recorded in the shezhire reveals how nomadic communities adapted to climate change. A historical example is the migration of the Argyn clan from arid regions to the north in the 18th century, which is associated with climate change and the desertification of the southern steppes (Davaadalai et al., 2024). This demonstrates the flexibility of traditional systems in responding to climate challenges. This adaptive capacity is supported by broader research on nomadic climate adaptation. Studies demonstrate that nomadic pastoralists have successfully used traditional forecasting methods to predict and observe changes in rainfall variability across multiple regions, with documented cases in Africa and Asia showing effective precipitation management strategies (Tugjamba et al., 2023). Contemporary climate adaptation frameworks increasingly emphasize the importance of integrating traditional and scientific knowledge (Acharya & Prakash, 2025).

The effectiveness of traditional adaptation strategies is increasingly recognized in climate science. Research indicates that traditional knowledge systems provide context-specific solutions that are often more sustainable than modern alternatives. However, academic literature on Central Asian climate adaptation remains limited, with only 52 publications identified between 2013-2021, highlighting the need for greater research attention to systems like shezhire (Saidaliyeva, 2024).

The shezhire also contributed to strengthening social ties, establishing order, and preventing conflicts within society (Guirkinger & Aldashev, 2016). These functions remain relevant in the modern world, especially in the context of social sustainability. The shezhire structured society, fostering a clear identity and a sense of belonging to a certain clan (Olzhbaekova, 2025). This contributed to the maintenance of social harmony. The principle of mutual assistance within the clan was the basis of social security. Modern societies can utilize these traditions to create social networks of mutual assistance, particularly in rural areas. The clear structure of kinship ties recorded in the shezhire minimized conflicts over resources. Modern approaches to dispute resolution, based on cultural traditions, can be inspired by this experience. The rule of "zheti ata" not only prevented genetic problems but also strengthened ties between clans, creating conditions for integration and cooperation.

Shezhire and Education: From Cultural Heritage to Modern Knowledge

Shezhire can be integrated into education as a key tool for sustainable development (Senanayake, 2006). Its inclusion in school curricula fosters national identity and respect for cultural heritage, with pilot projects in Kazakhstan already using shezhire to teach history, ecology, and traditional practices (UNESCO, 2024). Combining knowledge from fields like history, anthropology, ecology, and sociology, shezhire provides an ideal platform for interdisciplinary learning. As modern educational standards increasingly require integrating traditional knowledge, shezhire exemplifies how traditions can adapt to new requirements (Acharya & Prakash, 2025). Furthermore, the traditional knowledge about nature management recorded in shezhire, such as lessons on sustainable pasture use, can be used to promote environmental awareness in rural schools.

The International Significance of Shezhire and Global Challenges

Shezhire is important not only for Kazakhstan but also for the world as a whole, especially in the context of global challenges such as climate change, biodiversity loss, and social inequality (Redvers & Aubrey, 2023). Shezhire can serve as an example of how traditional knowledge can be preserved and integrated into modern strategies (Tegizbekova, 2018). The traditions of indigenous peoples of the Amazon, reflecting their ecological practices, have similar potential for sustainable development (Jessen et al., 2022). Integrating shezhire into international programs, such as UNESCO's initiatives to preserve intangible cultural heritage (UNESCO, 2014), can contribute to a global dialogue on the role of traditional knowledge. Shezhire data can be used in genetic, anthropological, and climatological research. For example, studying genealogies helps reconstruct ancient migration routes, which is important for understanding historical climate change (see Figure 8) (Ventresca Miller et al., 2020).

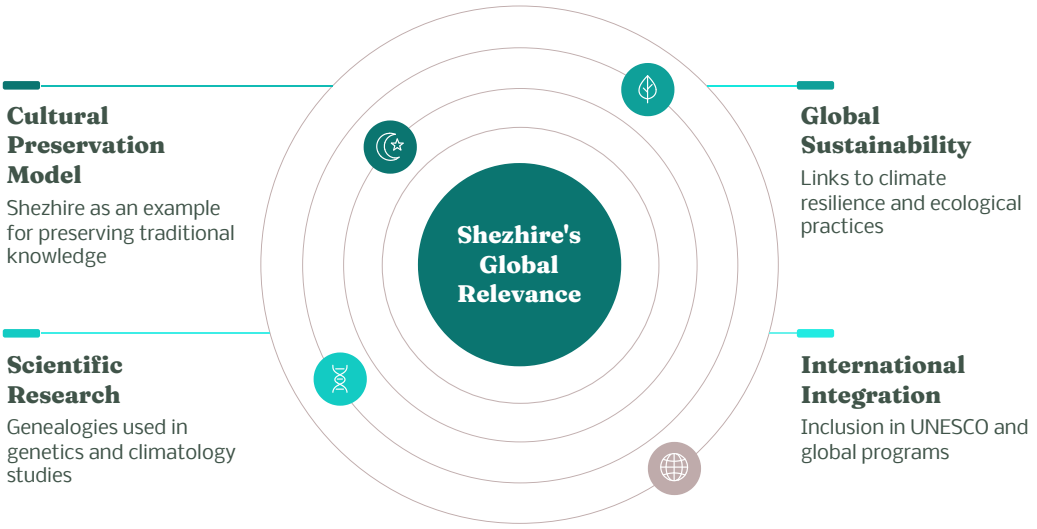


Figure 8: Shezhire's Global Significance

Survey Results

A sociological survey conducted among 1,000 respondents in 2024 from all regions of Kazakhstan revealed a high level of public awareness regarding Shezhire, but demonstrated differences in its use and perception depending on region, age, and personal experience.

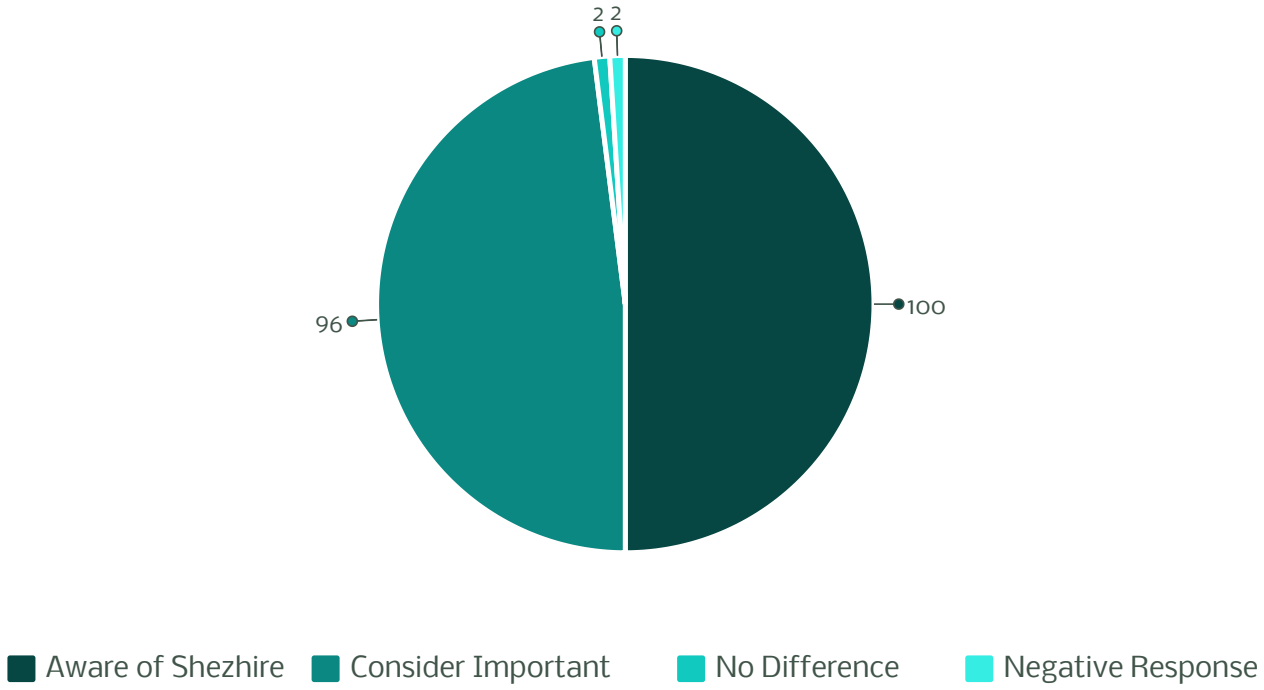


Figure 9. Awareness and Importance of Shezhire Among Respondents

100% of respondents were aware of Shezhire, regardless of region or age, highlighting its importance in Kazakh culture. 96% considered it an important cultural heritage, while 2% saw no difference and 2% responded negatively, underscoring its role in national identity (See Figure 9).

Shezhire's use varies regionally: western and southern Kazakhstan employ it for education, social organization, and hierarchy (Guirkinger & Aldashev, 2016), while northern, central, and eastern regions primarily use it for transmitting family values and preserving family history.

Regarding modern applications, 46% of respondents saw Shezhire as a historical archive, 33% had not considered it, and 21% were unsure. For environmental aspects, after explanation, 52% understood its ecological application (e.g., tracking migrations, clan activities), but 48% remained unsure of its potential.

For sustainable development applications, 54% chose education, 38% ecology (Shakirova et al., 2023), and 8% social justice. Additionally, 77% supported including Shezhire in educational programs.

Concerning genetics, 93% were interested in their family's genetic origins (7% relying on oral tradition). While 63% believed genetics could complement Shezhire, 32% were unsure. Finally, 82% supported using genetics to preserve cultural heritage, though 11% felt Shezhire already contains sufficient data.

Analysis of Survey Results

The survey confirmed Shezhire's continued relevance in Kazakh society, with perception and application varying by region and age. Universal awareness (100%) underscores its central role in cultural identity, yet differing uses reflect the influence of urbanization and globalization. In southern and western regions, Shezhire is actively used as a social tool, while in northern and eastern areas, it primarily functions to preserve family memory, not extending beyond daily life (see Figure 10).

Application of Shezhire to sustainable development showed mixed responses. While 46% view it as a historical archive, its environmental problem-solving potential is largely underestimated. The emphasis on education (54%) highlights the need to integrate Shezhire into curricula. Low awareness (52%) of its environmental applications suggests a need for popularization. Developing environmental educational modules with Shezhire examples could significantly boost interest in traditional knowledge.

Regarding genetics, 93% of respondents are interested in their genetic origins, creating an opportunity to integrate genetics into Shezhire research. Combining genetic data with genealogies can help reconstruct historical migrations and clarify ethnic history, which 82% of participants confirmed as important for cultural heritage preservation.

Overall, the survey reveals Shezhire is a significant element of Kazakh culture, yet its potential for addressing modern challenges, particularly sustainable development and climate change adaptation, remains underestimated. While relevant across all age groups and regions, its application varies. The educational and genetic potentials hold the most interest, highlighting a need to popularize Shezhire's ecological uses.

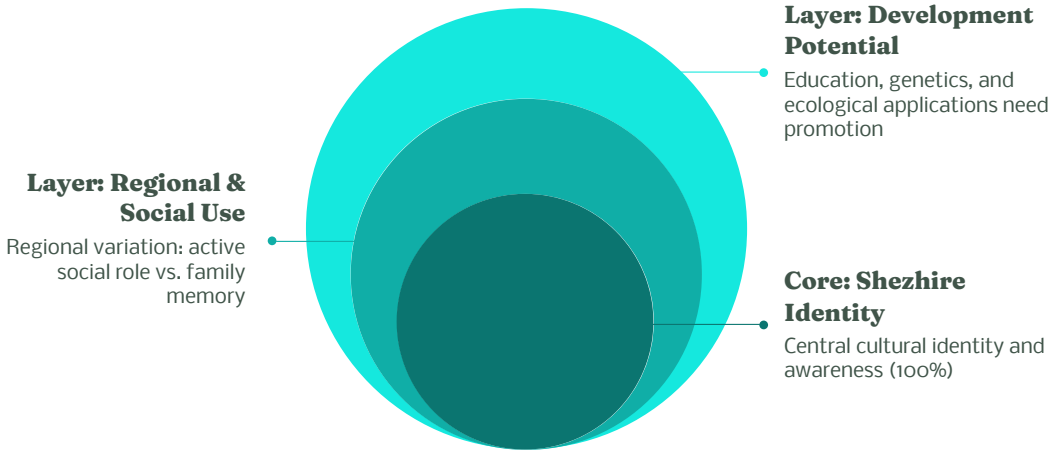


Figure 10. Shezhire's Perception and Application in Modern Kazakh Society

DISCUSSION

Shezhire as a Path to Sustainable Development

Our exploration of the shezhire phenomenon within the framework of sustainable development has deepened our understanding of its versatility and enduring relevance as a cultural, ecological, and social instrument. This ancient system, which has safeguarded the identity of the Kazakh people for centuries, is now acquiring renewed significance as a foundation for addressing contemporary global challenges. Shezhire transcends mere genealogical records and historical accounts; it embodies a holistic worldview where nature, society, and culture are intrinsically interconnected. This perspective resonates remarkably with modern conceptualizations of sustainable development, a congruence further underscored by UNESCO's recognition of traditional knowledge systems (UNESCO, 2024). Kazakhstan, with 14 elements inscribed on UNESCO's Intangible Cultural Heritage lists, exemplifies the international acknowledgment of traditional practices' value in navigating present-day issues.

Shezhire constitutes a rich repository of unique data concerning natural resource stewardship and time-tested adaptation strategies. An analysis of nomadic clan movements, historical pasture utilization (Ulambayar, 2023), and water conservation practices, as documented within shezhire, reveals profound ecological wisdom directly applicable to contemporary concerns such as desertification, land degradation, and climate change (Herrera, 2023; UNDP, 2024). These findings align with SDG 13 (Climate Action), by promoting traditional climate adaptation; SDG 15 (Life on Land), through its support for biodiversity-conscious land use; and SDG 4 (Quality Education), by advocating the integration of traditional environmental knowledge into educational frameworks (Jessen et al., 2022). The imperative to integrate traditional knowledge into climate action is increasingly supported by academic inquiry (Acharya & Prakash, 2025). Studies demonstrate that nomadic communities have cultivated sophisticated ecological ideologies, refined over centuries of human-nature coexistence, yielding documented successes in climate adaptation strategies (Tugjamba et al., 2023). Nevertheless, academic attention to these vital systems remains limited, with only 52 publications on Central Asian climate adaptation identified in recent systematic reviews (Saidaliyeva, 2024).

Fundamentally, shezhire is predicated on principles of social cohesion, mutual assistance, and justice, positioning it as an indispensable instrument for fostering social harmony and strengthening national identity. Amidst the forces of globalization and accelerating urbanization, shezhire serves as a vital bridge between the past and the present, preserving spiritual anchors and cultural heritage (Tezekbay & Tolessin, 2024). Its integration into educational curricula thus opens new avenues for interdisciplinary learning, synthesizing historical, ecological, and anthropological knowledge. This creates a robust platform for cultivating environmental consciousness and respect for traditions among younger generations.

As a universal paradigm of traditional knowledge, shezhire possesses the adaptability to be applied across diverse cultures and regions globally. This renders it a valuable asset for fostering international dialogue on intangible heritage preservation and leveraging traditional knowledge for sustainable development. Its global applicability is reinforced by UNESCO frameworks that affirm the essential role of traditional knowledge in achieving sustainability. Research underscores that 'science and traditional knowledge not only can work together but also work better to build community resilience', thereby validating shezhire's potential contributions to international sustainability efforts. This study decisively confirms the central hypothesis: shezhire is not merely a historical artifact but a potent resource capable of advancing sustainable development goals. It functions as both an ecological and cultural archive, underpinning social sustainability, transmitting practices of harmonious environmental management, and shaping values for future generations.

The modern era demands innovative approaches to preserving traditions and integrating cultural heritage into global processes. Shezhire can form the bedrock for diverse fields of endeavor. In scientific research, its study unlocks new frontiers in genetics, anthropology, history, and climatology (Corbett, 2025). Notably, within sustainable development policy, the insights from shezhire can be seamlessly integrated into national strategies for ecosystem preservation and poverty alleviation, as well as into international cooperation initiatives. By serving as a model for other cultures, shezhire can significantly facilitate the global exchange of knowledge.

Ultimately, shezhire is far more than a mere chronicle of ancestors; it embodies a philosophy of sustainable development forged by centuries of symbiotic interaction among humans, nature, and society. It imparts lessons on land stewardship (Davaadalai et al., 2024), the importance of remembering one's roots, and the imperative to build the future on principles of harmony and balance. In an age characterized by technological advancement and climate upheaval, this traditional knowledge holds profound practical value. Policymakers and educators can strategically integrate the study of shezhire into school and university curricula as a core component of cultural heritage and environmental education (SDG 4). Furthermore, digitizing and mapping historical migration routes and environmental data embedded within shezhire can inform the development of robust strategies for sustainable land use and biodiversity conservation (SDG 15). Engaging communities in climate change adaptation planning, utilizing shezhire to foster intergenerational dialogue on responsible resource management, presents another critical application (SDG 13). The urgency of this integration is starkly highlighted by the limited legal protections afforded to traditional knowledge systems in Central Asia, where most states currently lack specialized frameworks for safeguarding such heritage (Tegizbekova, 2018).

Thus, shezhire stands poised to become not only a vital cultural archive but also a highly effective instrument for realizing sustainable development goals in contemporary Kazakhstan (Olzhbaekova, 2025). It serves as a compelling reminder that the wisdom of the past remains acutely relevant, offering guidance to construct a future where tradition and innovation converge for the common good. Shezhire, in essence, is the resonant voice of ancestors, speaking to the present moment about the enduring path toward a sustainable future.

RECOMMENDATIONS

Based on the findings and discussion, several recommendations emerge for maximizing the potential of shezhire in contemporary sustainability discourse:

01

Educational Integration

Integrate shezhire into primary, secondary, and higher education curricula. At the primary level, focus on cultural heritage and moral education; at secondary and university levels, include it in history, anthropology, ecology, and sustainable development courses.

02

Digitization and Preservation

Digitize genealogical records and oral histories to create accessible archives. Develop interactive maps linking clan migrations, ecological zones, and oral traditions. Use digital platforms to connect shezhire knowledge with global research databases.

03

Policy and Environmental Application

Apply shezhire's traditional pasture rotation and water management principles to modern land-use and conservation strategies (Shakirova et al., 2023). Utilize genealogical archives to reconstruct historical climate adaptation strategies for policymaking (Herrera, 2023). Incorporate shezhire insights into national sustainable development and climate adaptation planning.

04

Community Engagement

Strengthen intergenerational transmission of shezhire through cultural events, oral history projects, and local workshops. Involve elders, as custodians of genealogical memory, in sustainability education and community development programs. Foster regional cultural centers for communities to document and share genealogies.

05

Global Knowledge Exchange

Position shezhire within global indigenous knowledge dialogue under UNESCO frameworks. Encourage cross-cultural studies comparing shezhire with other indigenous genealogical and ecological traditions (Jessen et al., 2022). Develop partnerships with international researchers to integrate shezhire into global sustainability science.

Integrating shezhire into educational programs (primary/secondary: history, literature, ecology; university: cultural heritage, anthropology, sustainable development) is recommended. This preserves traditional knowledge, expands understanding, and shapes sustainable development values in future generations. However, this study has limitations: sample representativeness, reliance on self-reported data, and limited generalizability beyond Kazakhstan (Tezekbay & Tolessin, 2024). These factors require consideration during interpretation, and future research can address them via expanded datasets and comparative analysis in diverse cultural contexts.

LIMITATIONS AND FUTURE RESEARCH

This study has certain limitations, including the representativeness of the sample, reliance on self-reported data, and the generalizability of the results beyond Kazakhstan. Future research can address these through expanded datasets, probability sampling, and comparative analyses across Central Asian and global contexts.

CONCLUSION

This article has demonstrated that shezhire is not merely a genealogical record but a multifunctional cultural and ecological archive that continues to shape Kazakh identity, social organisation (Guirkinger & Aldashev, 2016), and adaptation strategies. Survey findings confirm its enduring significance, with universal awareness and strong recognition of its cultural and educational value (UNESCO, 2024). Though its ecological dimension is less widely appreciated, historical and anthropological evidence shows that shezhire encodes sophisticated knowledge of resource management, climate adaptation (Herrera, 2023), and genetic health.

In the modern context, shezhire aligns with the Sustainable Development Goals, particularly in education (SDG 4), climate action (SDG 13) (UNDP, 2024), biodiversity and land stewardship (SDG 15) (Ventresca Miller et al., 2020), and social equity (SDG 10). Integrating this traditional knowledge system into contemporary education, environmental policy, and global dialogues can help bridge past wisdom with future innovation (Acharya & Prakash, 2025).

The enduring lesson of shezhire is that sustainability is not a new invention but a lived philosophy embedded in cultural traditions. As the voice of ancestors, shezhire reminds us that harmony with nature and respect for community are foundations of resilience. Preserving and reinterpreting this wisdom is not only vital for Kazakhstan but also relevant to global conversations on sustainable futures. By treating shezhire as both heritage and resource, Kazakhstan can contribute uniquely to global sustainability science, demonstrating how cultural memory can guide humanity toward ecological balance and social justice. In this way, shezhire is not only a chronicle of the past but also a code for the future.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest that could have influenced the conduct of the study, data analysis, or the conclusions presented in this article. The work was carried out solely for academic and research purposes, without funding, except for publication or influence from third-party organisations, institutions, or individuals. All sources used are properly cited, and the data presented are based on the authors' independent research.

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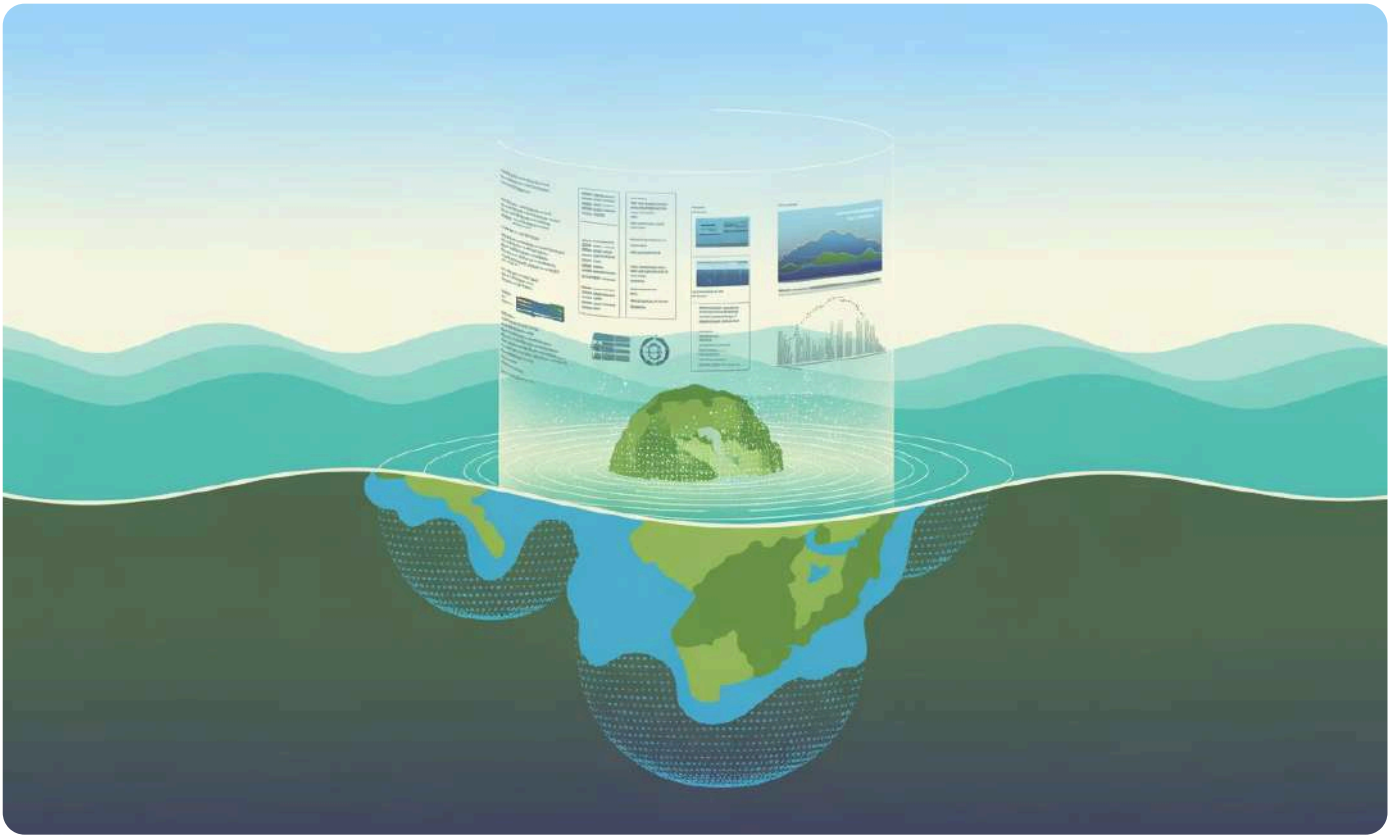
The Impact of Climate Change on Digital Governance Policies in Tuvalu

REVIEW

Songo Nore
The British University, Egypt

This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.



PLAIN-LANGUAGE SUMMARY

Climate Threat to Tuvalu

Tuvalu, a small Pacific island nation, faces a severe threat from climate change. By 2050, rising sea levels are predicted to submerge the entire country, rendering it uninhabitable.

The Digital Nation Solution

In response, Tuvalu is creating the world's first "digital nation." This project aims to preserve its culture, history, government services, and land records in a virtual reality environment.

Key Challenges Ahead

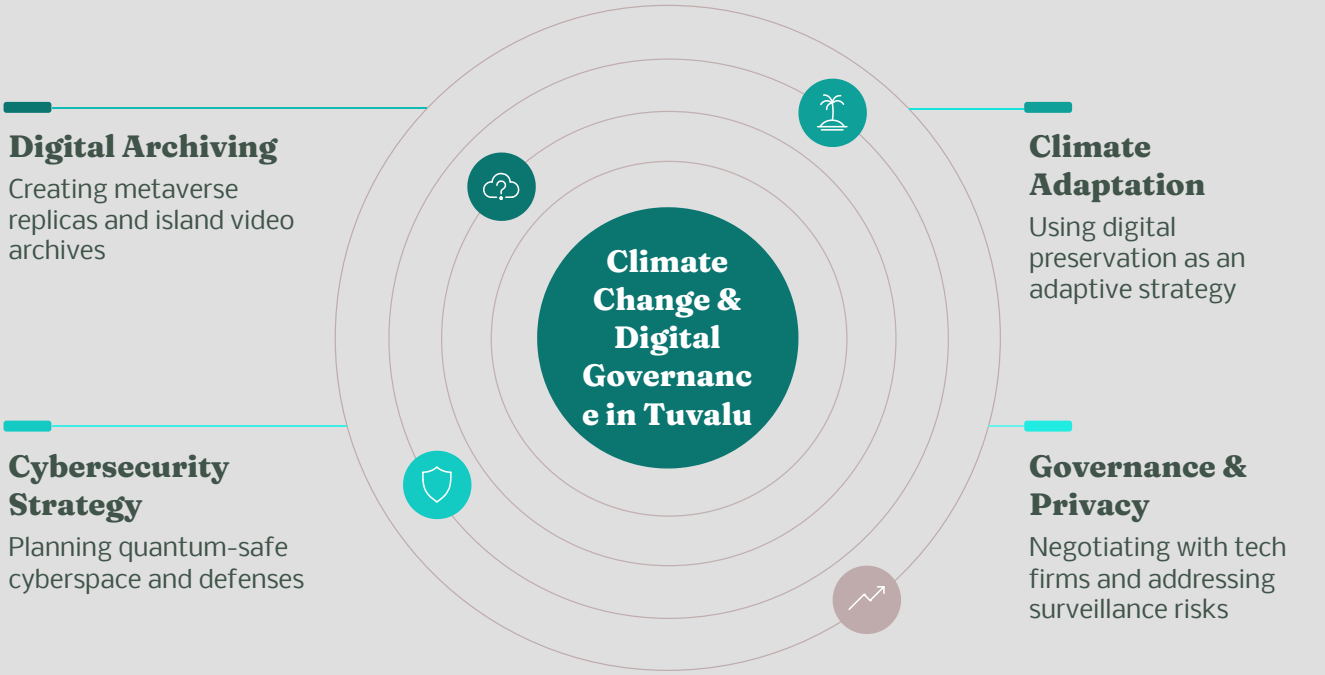
This ambitious endeavor presents challenges like protecting sensitive data, ensuring citizen privacy in a virtual space, and navigating complex international laws for a nation existing primarily online.

Global Significance

Tuvalu's initiative could serve as a crucial blueprint for other low-lying nations vulnerable to climate change, offering a path to preserve their heritage and sovereignty amidst physical displacement.

ABSTRACT

This review examines the impact of climate change on digital governance policies in Tuvalu, analyzing the nation's pioneering 'First Digital Nation' initiative as a climate adaptation strategy. Tuvalu is an island nation highly susceptible to the detrimental effects of climate change due to its geographical setting. It consists of tiny, low-lying flat atolls in the Pacific Ocean, with its highest altitude located just five meters above sea level. With a total land area of about 26 square kilometers and an approximate population of 15,000 people, the relentless onslaught of climate change impacts has triggered significant institutional digital developments within the country. Tuvalu's migration into the metaverse involves creating a digital replica by archiving video data of its sinking islands in data centers, an effective climate adaptation strategy the nation has initiated. A climate change-induced existential threat poses a national security risk. Digital innovation is perceived as an avenue to help Tuvalu adapt to the impact of climate change. A strategic direction for Tuvalu involves considering migration into a quantum-safe cyberspace to mitigate cybersecurity risks posed by quantum computing technology. Subsequently, Tuvalu should negotiate with major technology companies hosting data archives to address data privacy concerns, thereby tackling socio-technical impediments within quantum-safe cyberspace such as surveillance capitalism. This comprehensive review synthesizes existing literature, policy documents, and recent developments to provide insights into the intersection of climate adaptation and digital governance, offering implications for other Small Island Developing States facing similar challenges.



Keywords: climate adaptation, digital governance, metaverse preservation, quantum cybersecurity, small island developing states

INTRODUCTION

Is digitizing Tuvalu's cultural heritage and historical assets in a virtual reality an effective climate change adaptation strategy for its sinking islands? Yes. This analysis explores the drivers behind this digital transformation for Tuvalu and other Small Island Developing States (SIDS). According to Simon Kofe (2021), the Future Now Project (FNP) has three aims: 1) promoting values-based diplomacy; 2) ensuring permanent statehood and maritime boundaries despite sea level rise; and 3) building a digital nation. This analysis focuses on the third aim. FNP, also known as the First Digital Nation (FDN) concept, involves Tuvalu's migration into the metaverse via Big Tech data centers. As the world's first digital nation, Tuvalu is preserving its cultural heritage in the metaverse. Naqvi (2023) describes this as an ongoing project, tracking everything from digital twins of government buildings and public documents to local bird sounds being archived in the metaverse. (See Figure 1).

Figure 1: Tuvalu's transition from physical island to digital metaverse through the First Digital Nation initiative

LITERATURE REVIEW

This section synthesizes existing academic literature relevant to Tuvalu's digital nation initiative as a climate adaptation strategy. It reviews key studies across climate change impacts, digital governance, metaverse applications, cybersecurity, and geopolitical implications of climate-induced migration.

Figure 2 illustrates the interconnected nature of these research domains and their relationship to Tuvalu's digital transformation strategy.

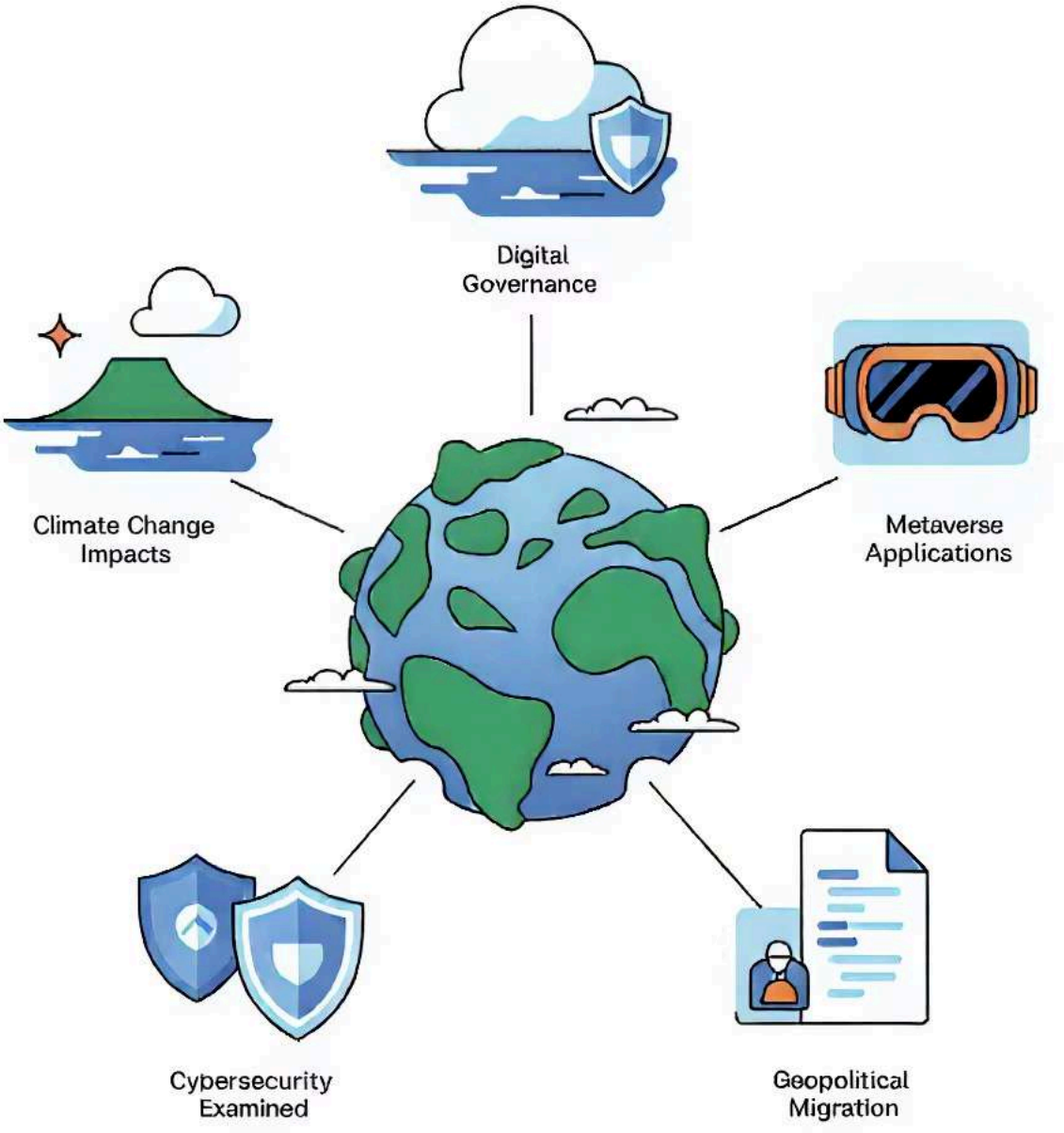


Figure 2: Interconnected research domains for Tuvalu's digital nation initiative

Climate Change Impacts on Small Island Developing States (SIDS)

The IPCC's Sixth Assessment Report identifies small islands as among the most vulnerable regions to climate change, with sea-level rise posing existential threats to many Pacific Island nations (Mycoo et al., 2022). The IPCC's Special Report on Ocean and Cryosphere emphasizes that rising sea levels, combined with high tides, storms and flooding, put coastal and island communities increasingly at risk (Oppenheimer et al., 2019). Research by Vousdoukas et al. (2023) demonstrates that Small Island Developing States remain under threat by rising seas even in a 1.5°C warming scenario, with atoll nations like Tuvalu facing particular vulnerability. The World Bank's climate vulnerability assessments for Pacific islands highlight the urgent need for comprehensive adaptation strategies, noting that digital tools can play a crucial role in climate resilience (World Bank, n.d.). The Secretariat of the Pacific Regional Environment Programme (SPREP) has documented extensive environmental challenges across Pacific islands, emphasizing the interconnected nature of climate impacts and the need for innovative solutions (SPREP, 2021).

Digital Governance and Preservation Strategies

The World Bank's Digital for Climate initiative demonstrates how governments can leverage digital technologies for climate action, including reducing emissions, adapting to climate change, and building resilience through digital infrastructure (World Bank, 2024). Research on digital governance frameworks shows increasing adoption of digital tools for cultural and historical preservation, though implementation in small island contexts remains limited. Studies emphasize the importance of digital sovereignty and data governance in protecting national digital assets, particularly relevant for nations facing physical territorial loss.

Metaverse Applications for Cultural Heritage Preservation

Recent academic research by Buragohain et al. (2024) provides comprehensive analysis of digitalizing cultural heritage through metaverse applications, identifying both challenges and opportunities in virtual preservation of tangible and intangible cultural assets. The study emphasizes issues of authenticity, representation, and sustainability in virtual cultural spaces. Research on metaverse and extended reality (XR) for cultural heritage education demonstrates the revolutionary potential of immersive technologies in transforming user exploration of museums, cultural heritage sites, and historical landmarks (ResearchGate, 2024). These studies highlight the growing attention toward AR, VR, MR, and metaverse technologies in heritage preservation, though note the need for standardized approaches and user experience evaluation methodologies.

Metaverse Applications for Cultural Heritage Preservation

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Cybersecurity in Digital Nations

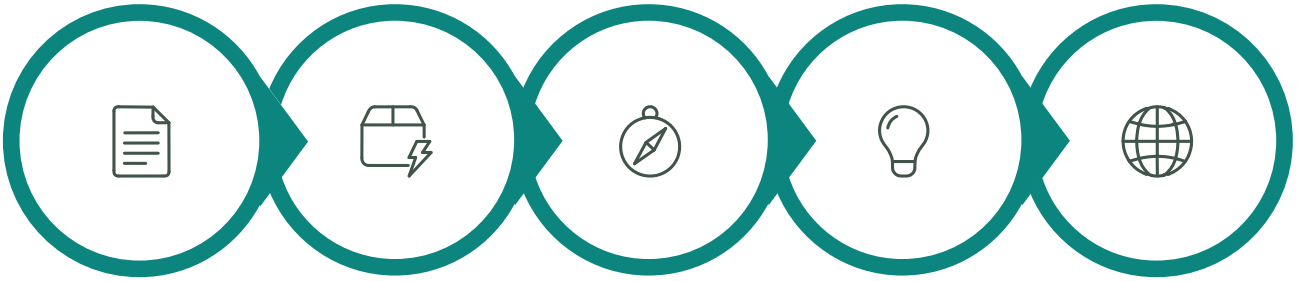
The emergence of post-quantum cryptography research addresses critical cybersecurity challenges facing digital nation initiatives. Studies on quantum computing threats emphasize the vulnerability of current cryptographic systems and the urgent need for quantum-resistant encryption methods. Research on surveillance capitalism and data privacy concerns highlights the importance of robust legal and technical frameworks to protect sensitive information in digital environments, particularly relevant for small nations dependent on external technology infrastructure.

Geopolitical Climate Migration

Academic research on climate-displaced people from a Small Island Developing States perspective reveals significant gaps in legal protection for climate migrants (Pouponneau et al., 2022). Studies examine the complex issues arising under the Law of the Sea Convention when island nations become uninhabitable or submerged, highlighting the "triple injustice" faced by island nations. International law regarding disappearing states remains an evolving area, with questions of sovereignty, citizenship, and maritime boundaries presenting unprecedented legal challenges.

Research Gaps and Study Positioning

Despite extensive research in individual areas, significant gaps remain. Comprehensive research on integrated digital nation strategies as climate adaptation mechanisms is limited. Studies on quantum-safe cultural preservation and the intersection of digital sovereignty with physical territorial loss are particularly scarce. This study addresses these gaps by analyzing Tuvalu's pioneering digital nation initiative, positioning it as a novel climate adaptation strategy bridging climate science, digital governance, and international relations.



Visible Findings | Observed Gaps | Underexplored Areas | Study Contribution | Strategic Implications

METHODOLOGY

This systematic review analyzes Tuvalu's digital governance policies for climate change adaptation. The methodology includes:

Research Design

Qualitative review of policies, literature, reports, & media

Data Sources

- Official government documents & treaties
- Academic publications (climate change, digital governance)
- International organization reports (UN, WB, IPCC)
- News media & policy analyses
- Technical docs (digital preservation)

Analysis Framework

- Thematic analysis (policy areas)
- Comparative analysis (SIDS initiatives)
- Tech feasibility & risk assessment
- Geopolitical implications evaluation

Limitations

- Limited access to government deliberations
- Rapidly evolving digital technologies
- Ongoing policy developments

This methodology examines climate adaptation and digital governance in SIDS.

KEY POLITICAL ACTORS BEHIND DIGITAL DEVELOPMENT

Of particular significance, the then foreign affairs minister, Simon Kofe, conveyed the collective appeal of the state of Tuvalu to the global community at international conferences on climate change. His compelling statements have brought significant international attention to Tuvalu's pioneering efforts and generated substantial academic analysis. "Our land, our ocean, our culture are the most precious assets of our people and to keep them safe from harm, no matter what happens in the physical world, we will move them to the cloud," stated Kofe at the 2022 United Nations Climate Change Conference (COP 27) (Naqvi 2023). Kofe continued to champion the First Digital Nation (FDN) project, providing a progress report at COP28, highlighting the ongoing political momentum and the nation's commitment to digital preservation (BBC 2024).

Further reinforcing this commitment, Tuvalu has forged a partnership with the German Archaeological Institute for the digitization of its invaluable cultural heritage, directly supporting the FDN's goal of creating digital twins of significant sites and artifacts. In this context, Tuvalu has the option of either migrating into the metaverse through Big Tech data centers like Amazon Web Services, built on centralized networks, or transitioning into decentralized networks such as the Inter-Planetary File System that is compatible with Blockchain Technology.

Centralized Networks

Big Tech data centers like Amazon Web Services

Decentralized Networks

Inter-Planetary File System compatible with Blockchain Technology

GEOPOLITICAL ALIGNMENT

The Australia-Tuvalu Falepili Union Treaty, rooted in the traditional values of good neighborliness and mutual respect (Government of Australia, n.d.), outlines a bilateral agreement. It allows Tuvaluans to migrate to Australia in the event of inundation, including a special route for up to 280 individuals annually, while Australia assumes responsibility for Tuvalu's foreign security arrangements. Despite its perceived importance for Tuvalu's digital migration and displacement, the treaty faced strong criticism from former Prime Minister Sopoaga, who deemed it a breach of sovereignty and vowed to rescind it if re-elected in 2024. Australia's Department of Foreign Affairs and Trade reiterated that the Treaty "recognizes that the statehood and sovereignty of Tuvalu will continue" (The Guardian 2024). However, Simon Kofe highlighted the significant geopolitical implications, questioning the wisdom of Tuvalu aligning with Australia amidst US-China competition. He argued that Tuvalu's security interests differ from Australia's, risking its sacrifice as a strategic stronghold (**Marinaccio 2023**). Kofe specifically criticized Article 4.4, which mandates Tuvalu to "mutually agree" with Australia on any security or defense partnership with other states, viewing it as a compromise to Tuvalu's sovereignty (**Marinaccio 2023**). Figure 3 illustrates these complex geopolitical tensions and the delicate balance Tuvalu must navigate between competing international interests.

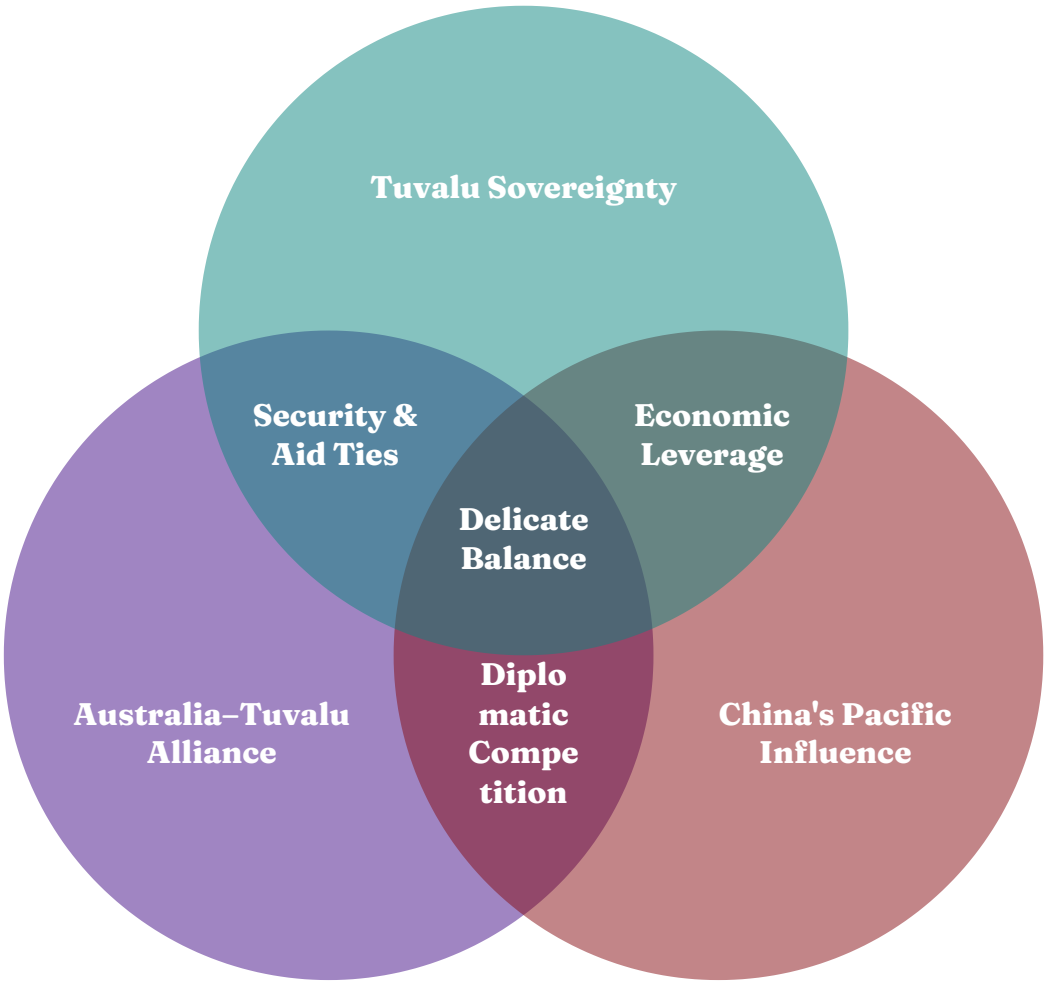


Figure 3: Geopolitical tensions in Tuvalu's digital nation strategy

CLIMATE CHANGE IMPACT ON DIGITAL INNOVATION

Tuvalu faces imminent obliteration from climate change, a consequence of industrialized economies' actions. Sea-level rise, exacerbated by an increased frequency of extreme sea-level events, threatens Tuvalu not only through long-term coastal encroachment but also because its sea level rises 1.5 times faster than the global average. Since 1993, global sea level has risen by 14 cm, and NASA projects that by 2050, average high tides will cover much of Tuvalu's land and critical infrastructure (World Bank, 2021; NASA Sea Level Change Team 2024). The return period for exceptionally high sea levels is decreasing, posing a particular risk to low-lying Pacific island nations (World Bank, 2021). Coral reef health impacts wave-driven flooding, making coral conservation a vital adaptation strategy. Without successful adaptation, wave-driven flooding could render many atoll islands uninhabitable by the mid-21st century (World Bank , 2021).

In 2001, Tuvalu, along with Kiribati and the Maldives, intended to take legal action against the U.S. for its refusal to sign the Kyoto Protocol (BBC News 2024). Highly vulnerable to climate change impacts, Tuvalu's highest point is only five meters above sea level, making inundation highly likely. This existential threat has prompted Tuvalu to undertake drastic steps in cyberspace, including the introduction of the FDN concept, to mitigate climate change impacts.

5m

Highest Point

Above sea level

14cm

Global Sea Level Rise

Since 1993

26

Total Land Area

Square kilometers

15K

Population

Approximate residents

2050

Predicted Inundation

By this year

FIRST DIGITAL NATION CONCEPT

The concept of "First Digital Nation" aims to make Tuvalu the first country in the world to exist virtually in the metaverse, thereby preserving its cultural and historical heritage in the event of inundation. This initiative has seen significant progress, with Te Afualiku islet being the first landmass completely digitized and uploaded to the metaverse as a proof-of-concept (Fainu, Guradian News, 2023). Preserving heritage in the metaverse provides an opportunity to safeguard cultural and historical assets against threats such as climate change, natural disasters, and human activity (Naqvi 2023). The threat of extinction of flora and fauna due to climate change necessitates their migration into the metaverse to preserve them in a virtual format. For instance, the case of the dodo, a bird native to Mauritius that became extinct due to human activity 200 years ago, serves as a cautionary tale about the importance of preserving such assets in a format that can withstand the test of time (Naqvi 2023).

01

Cultural Heritage Documentation & Archiving

Recording traditional practices, languages, and customs, including a partnership with the German Archaeological Institute (DAI) to develop a comprehensive digital archive.

02

Digital Asset Creation

Converting physical locations, such as Te Afualiku islet, and artifacts into detailed virtual environments.

03

Metaverse Integration

Uploading and preserving digital data within virtual reality platforms to ensure accessibility and longevity.

04

Digital Infrastructure Development

Enhancing digital connectivity and services, exemplified by the first ATM installation at the National Bank of Tuvalu in April 2025 (ICWA 2025).

05

Future Access & Engagement

Enabling future generations to experience and engage with their preserved heritage and national identity in the virtual realm.

SURVEILLANCE CAPITALISM AND CYBERSECURITY RISKS

Hedge (2024) identifies archival surveillance as a socio-technical impediment for Tuvalu's "Future Now Project" in the metaverse. Digital archives, while intended for preservation, risk online surveillance and data collection, especially if Tuvalu stores citizen data within technology giants' internet governance ecosystems. Recognizing data as "new oil," its extraction for profit through surveillance capitalism becomes inevitable, increasing foreign espionage risks. Figure 4 outlines the core cybersecurity principles essential for protecting digital archives. Zuboff (2020) criticizes major internet companies' ownership of consumer data, arguing it's exploited for money and power rather than being a public good to improve society (**Powell 2020**).

Figure 4: Cybersecurity Threats to Digital Archives - Surveillance Capitalism and Quantum Computing Risks

The metaverse's susceptibility to cybersecurity threats necessitates robust defense mechanisms to protect Tuvalu's data. As Figure 2 illustrates, fundamental cybersecurity principles are crucial against dual threats like surveillance capitalism and quantum computing risks. While cyberattacks compromise CIA+A (Confidentiality, Integrity, Authenticity, and Availability), cybersecurity protects these. Specifically, Confidentiality (C) safeguards sensitive information; Integrity (I) ensures data accuracy; Authenticity (A) verifies identity; and Availability (A) guarantees timely access to resources for authorized users (Jafarbeiki 2023).

Confidentiality

Keeping sensitive information private and secure from unauthorized access

Integrity

Ensuring data has not been tampered with and can be trusted

Authenticity

Verifying user or system identity through proper authentication

Availability

Ensuring authorized users have timely access to resources when required

Quantum computing technology poses a significant and emerging cybersecurity threat capable of breaching Tuvalu's data archive. While experts estimate quantum computers capable of breaking current cryptography may still be 10-20 years away (GAO 2025), 62% of cybersecurity professionals fear this technology could break current internet encryption standards (ISACA 2025). Disturbingly, only 5% of organizations currently consider quantum threats a high priority, and only 5% have defined strategies to address them (GAO 2025). This vulnerability could lead to "harvest now, decrypt later" attacks, where adversaries copy protected data today with the intention of decrypting it once quantum computers become powerful enough. If Tuvalu stores its data in the metaverse on a decentralized blockchain cyberspace where classical elliptic curve cryptography is used for data encryption, quantum computing technology could still break this encryption. The National Institute of Standards and Technology (NIST) released its first three finalized post-quantum encryption standards in August 2024 (NIST 2024), offering a path forward. If Tuvalu opts to archive its data in the metaverse through a rented cyberspace within technology giants' internet governance ecosystems, it could benefit from their advanced cybersecurity mechanisms via quantum-safe cyberspace. Nonetheless, Tuvalu's data would still be susceptible to socio-technical impediments through surveillance capitalism. A classic example is Edward Snowden's revelation of US espionage activities using US-based Big Tech companies such as Meta, Google, Amazon, Yahoo, Microsoft, and others, although that was done to protect US national security interests (BBC 2014).

Tuvalu currently lacks the necessary technology but can develop local data centers, akin to the Samoa Levili Data Center and Papua New Guinea Data Center, to ensure digital sovereignty in the future and avert online surveillance and surveillance capitalism.

DIGITAL ECONOMY AND INFRASTRUCTURE

Tuvalu owns its country code top-level domain, .tv, which refers to internet addresses ending with .tv (Saalbach 2024). As this is highly attractive for television (TV) stations for their internet addresses, Tuvalu's revenue from selling the rights for domain use accounted for one-twelfth of its gross national income in 2019. In 2023, this increased to 10 million U.S. dollars (Saalbach 2024). This internet country code is the most notable cultural export of the small island nation Tuvalu, which is now on the cusp of another internet policy decision that further entrenches its relationship with global technology companies and the digital ecosystem: digitizing its lands and culture into the metaverse (Hedge 2024).

Tuvalu is connected mainly by satellite internet technology for its communications needs. Nonetheless, it has the latent potential to tap into fiber optic internet, which is currently absent. As stated by Watson, cable connections are absent in Tuvalu (Watson 2023). However, the United States has announced that Tuvalu and other Pacific Island Countries will benefit from the Honomoana and Tabua Cable Systems through branching units that will originate from the two main cables (Watson 2023).

.tv Domain Revenue

- **2019:** One-twelfth of gross national income
- **2023:** $10 million USD
- **Primary buyers:** Television stations
- Strategic digital asset for the nation

Infrastructure Status

- **Current:** Satellite internet only
- **Future:** Honomoana Cable System
- **Future:** Tabua Cable System
- **Goal:** Fiber optic connectivity

In April 2025, Tuvalu significantly advanced its financial digitization efforts with the installation of its first ATM at the National Bank of Tuvalu headquarters. The government is also introducing national debit cards and actively working to implement Visa debit/credit card services for international transactions (ICWA 2025). These developments represent a major advancement in Tuvalu's financial digitization, forming a crucial part of its broader digital nation strategy.

DISCUSSION

This analysis of Tuvalu's digital nation initiative reveals several critical findings that have significant implications for climate adaptation, digital governance, and international relations. The discussion synthesizes these findings and explores their broader theoretical, practical, and policy implications.

Regarding the synthesis of key findings, Tuvalu's First Digital Nation initiative represents a paradigm shift in climate adaptation strategies, moving beyond traditional physical infrastructure approaches to embrace comprehensive digital preservation as a means of maintaining statehood and cultural continuity. As Di Fonzo (2025) demonstrates in her comprehensive analysis of small island digital states, this initiative fundamentally challenges traditional concepts of statehood and sovereignty, raising critical questions about territorial integrity in the digital age. The intersection of digital governance and climate resilience creates unprecedented opportunities for cultural preservation while simultaneously introducing complex challenges related to data sovereignty, cybersecurity, and international legal frameworks.

The analysis further reveals that cybersecurity concerns, particularly quantum computing threats, pose significant risks to digital preservation efforts. The vulnerability of current cryptographic systems to future quantum attacks necessitates immediate adoption of post-quantum cryptographic standards to ensure long-term data security. Furthermore, geopolitical dynamics significantly influence the feasibility and sustainability of digital nation strategies, as evidenced by the complex negotiations surrounding the Australia-Tuvalu Falepili Union Treaty and concerns about technological dependency on major powers.

In terms of theoretical implications, this study contributes to several theoretical frameworks. First, it expands understanding of climate adaptation beyond traditional physical infrastructure to encompass digital preservation as a legitimate adaptation strategy. As Bessette (2025) argues in her legal analysis, digital nations represent a novel approach to perpetuating small island statehood in the face of climate-induced territorial loss. This challenges conventional notions of sovereignty that are fundamentally tied to physical territory and population.

Second, the initiative demonstrates how technology can serve as a vehicle for preserving cultural heritage and national identity. However, as Echavarria (2025) notes in his analysis of the Tuvaluan digital archive project, this process raises important questions about data colonialism and the potential for colonial power dynamics to be reproduced through digital classification systems and standards.

Third, the case illustrates the emergence of what can be termed "climate-induced digital sovereignty" - the necessity for nations facing existential climate threats to develop autonomous digital capabilities to preserve their national identity and governance structures.

The practical implications of Tuvalu's digital nation initiative extend far beyond the Pacific region. The project provides a potential model for other Small Island Developing States facing similar climate threats, including the Maldives, Marshall Islands, and Kiribati. However, successful implementation requires significant international cooperation in digital governance, standardization of digital preservation protocols, and development of legal frameworks for recognizing digital statehood.

The initiative also highlights the critical importance of cybersecurity in national preservation strategies. Nations pursuing digital preservation must invest in quantum-safe infrastructure and develop robust data governance frameworks to protect against both technological and geopolitical threats to their digital assets.

Considering policy implications, the emergence of digital nations necessitates fundamental reforms in international law and governance structures. Current legal frameworks are inadequate for addressing questions of sovereignty, citizenship, and international recognition for nations that exist primarily in digital form. As the Indian Council of World Affairs (2025) notes, this requires legal reforms to accommodate deterritorialized states and preserve the rights and identity of people even after the physical disappearance of their homeland.

The case also underscores the importance of data sovereignty and privacy protection in international agreements. Small island states must negotiate carefully with technology providers to ensure their digital assets remain under national control and are protected from surveillance capitalism and foreign interference.

Finally, for future research directions, this analysis identifies several critical areas. First, longitudinal studies are needed to assess the long-term sustainability and effectiveness of digital preservation strategies. Second, comparative studies examining digital nation initiatives across different SIDS would provide valuable insights into best practices and common challenges.

Third, research is needed on the social and cultural impacts of digital nation projects, particularly their effects on cultural identity, social cohesion, and intergenerational knowledge transfer. Finally, interdisciplinary research combining legal, technological, and anthropological perspectives is essential for understanding the full implications of digital statehood for international relations and human rights.

RECOMMENDATIONS

Tuvalu's path forward involves navigating the metaverse within quantum-safe cyberspace to guard against quantum computing threats that render classical cryptographic algorithms obsolete. While storing data on blockchain technology faces significant expense and limited capacity for massive datasets, Tuvalu can utilize other decentralized networks like the Inter-Planetary File System (IPFS), compatible with blockchain via platforms such as **pinata.cloud**, **NTF.storage**, or **web3.storage**.

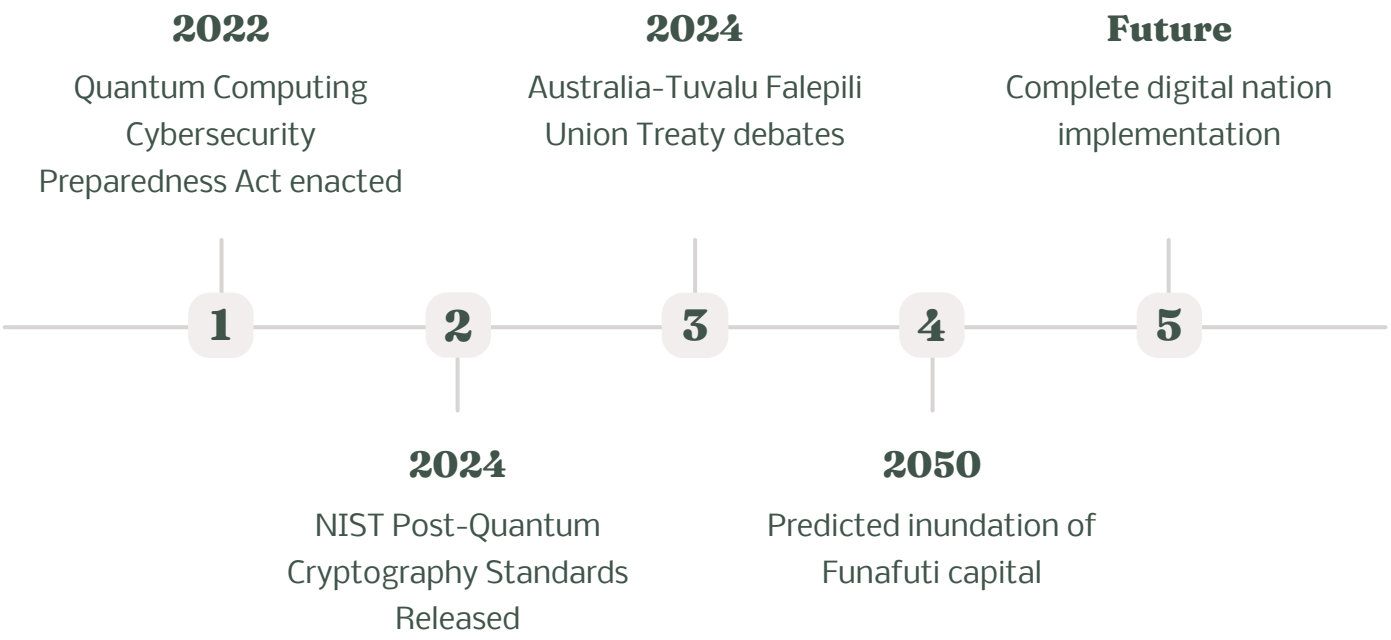
Classical elliptic curve cryptography, which secures blockchain technology, is vulnerable to quantum computing. However, the United States National Institute of Standards and Technology (NIST) has introduced post-quantum cryptographic algorithms, specifically Isogenies on Elliptic Curve Cryptography, to secure blockchain's cyberspace, with official standards releasing in August 2024 (NIST 2024).

The global quantum computing market is projected to reach $50 billion by 2030, with 60% of Canadian and 78% of US organizations expecting mainstream quantum computers by then (KPMG 2024). This makes previously computationally infeasible problems like integer factorization and discrete logarithm now breakable by quantum computing. Thus, a paradigm shift to post-quantum cryptography standards is crucial to circumvent new cybersecurity threats. The US House of Congress enacted the Quantum Computing Cybersecurity Preparedness Act on December 21, 2022, to migrate its ICT industry to post-quantum cryptography (US House of Congress 2022). However, the Government Accountability Office (GAO 2025) recently indicated the US government still lacks a fully coordinated plan to address these threats.

United States-based internet firms, such as Amazon, operating within US jurisdiction, would likely safeguard Tuvalu's data archived on Amazon Web Services from quantum computing threats. To avoid surveillance capitalism, Tuvalu's political leaders should engage in political dialogue with the United States President to obtain assurances against online surveillance of their data within Big Tech's data centers. A precedent for this is Barack Obama's assurance to Angela Merkel regarding US spying on allies (BBC 2014). Regional geopolitical dynamics could allow Tuvalu to leverage this, pressuring the United States into cooperation to avoid potential Chinese intrusion into Tuvalu via internet firms like Huawei if the US refuses.

Tuvalu's digital innovation strategy establishes a global precedent for small island developing states in the Global South, which face inundation from rising sea levels due to climate change. This includes nations such as Kiribati, Niue, Maldives, Cook Islands, Marshall Islands, Palau, Seychelles, Nauru, Cayman Islands, Guam, and French Polynesia.

Critical Milestones in Tuvalu's Digital Future



CONCLUSION

The existential threat of climate change, exemplified by the predicted inundation of Funafuti by 2050, has catalyzed Tuvalu's pioneering embrace of digital innovation. Its "First Digital Nation" project represents not merely an attempt to preserve cultural heritage in a metaverse, but a comprehensive, adaptive response to unprecedented environmental challenges. This initiative transcends traditional notions of statehood, venturing into novel domains of digital governance, cybersecurity, and the complex geopolitical dynamics of sovereignty in the digital age. By proactively digitizing its lands and culture, Tuvalu sets a profound global precedent for other Small Island Developing States facing similar climate-induced displacements, demonstrating a viable pathway for climate adaptation that integrates advanced digital preservation with forward-thinking nationhood. This strategic intersection of digital resilience, cultural continuity, and geopolitical maneuvering underscores a new paradigm for climate action, challenging the international community to re-evaluate the future of sovereign identity and human heritage in an increasingly digital and environmentally volatile world.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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Not Applicable

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Climate Change and the Global South: An Intersectional Study of the Impact of Climate Change on LGBTQIAP+

REVIEW

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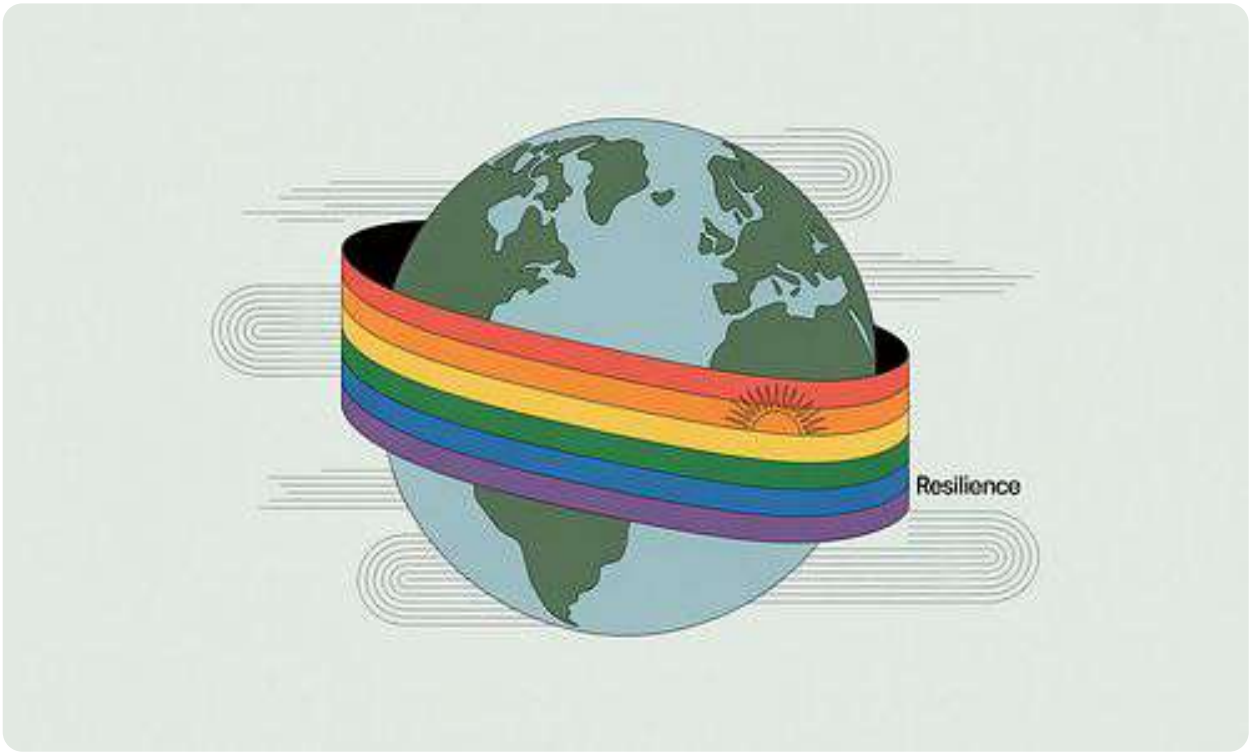
This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

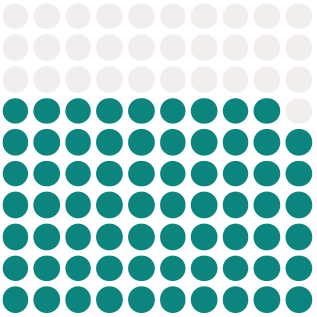


PLAIN-LANGUAGE SUMMARY

Study Focus

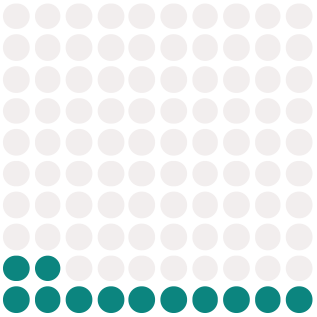
Climate change disproportionately affects LGBTQIAP+ communities in the Global South. These groups face a "double burden" from existing discrimination in employment, housing, and healthcare, exacerbating their vulnerability to climate impacts.

Key Challenges & Findings



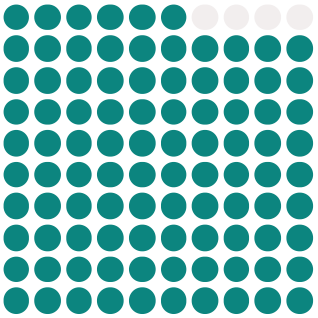
69%

of climate disaster fatalities occur in the world's poorest countries



12%

higher cancer rates for LGBTQIAP+ people compared to straight individuals



96%

of transgender people in India are forced into precarious work

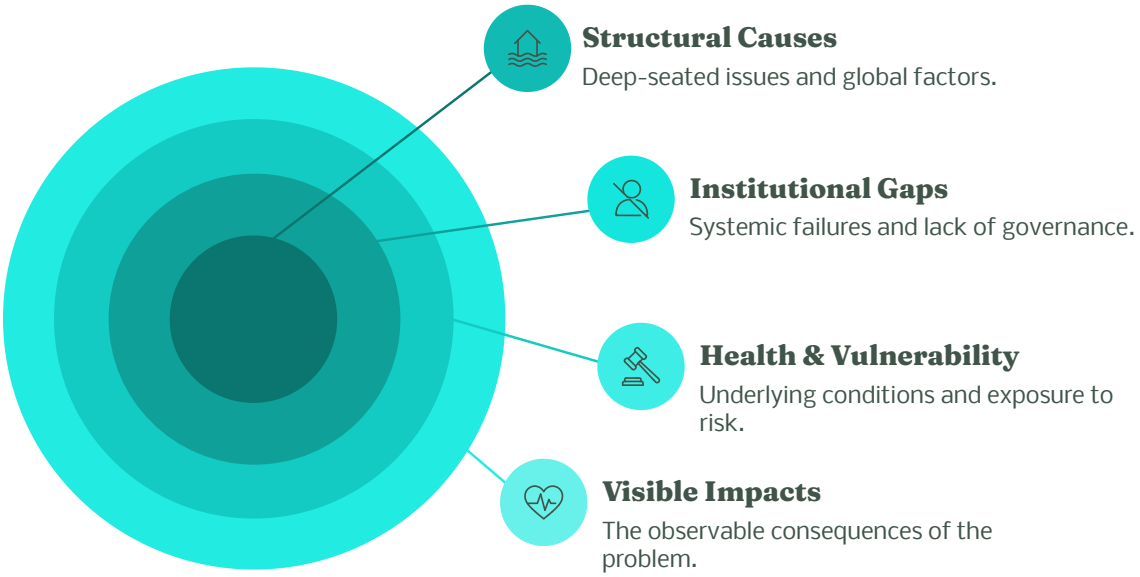
Implications & Solutions

Current climate policies largely overlook LGBTQIAP+ communities, failing to account for how discrimination intensifies their climate vulnerability.

- Integrate LGBTQIAP+ perspectives into climate planning.
- Ensure emergency shelters are safe and inclusive for all gender identities.
- Improve data collection on climate impacts across diverse communities.
- Hold developed nations accountable for their role in the climate crisis.

ABSTRACT

The purpose of the present paper is to understand how minorities and vulnerable communities, especially the LGBTQIAP+ in the Global South, are affected by climate change and face the brunt of it. The queer community is discriminated against in cisgender-heteronormative State policies with respect to employment, housing, and healthcare. Such policies result in exclusion from healthy environmental exposure and vulnerability, which is coupled with individual factors of behavioral exclusion, and mental health, causing environmental health disparity in the community, as illustrated in a case study of transgendered persons in India. The trans-community in India has faced societal segregation based upon their sexual identity, and has not been legally recognized as the 'third gender' until lately in 2014, leading to exclusion from most socio-economic aspects of life. Mapping the impact of climate change on the trans-community in India presents a categorical analysis of queer-biases in the environmental jurisprudence and policies. Climate change is increasingly a subject of international law and treaty obligations of expedient implications wherein State unity is required to achieve the goals, for all, by all. This paper studies the lacuna of the international environment regime towards the queer community, analyzing the status of their interests in municipal laws and the obligations of States to the international climate regime, studying the same from the third-world perspective and the liabilities of the climate crisis that the developed nations do not recognize and how that affects the queer community. This paper attempts to bring insights into international environment law from the perspective of the vulnerable, recognizing the lack of institutional effort and policy-making towards the cause, while the proportion of queer persons suffering from climate-change-related health issues is higher than other populations. It aims to propose accountability to powerful stakeholders whose decision-making has little to no representation from the queer community. This paper highlights the legal essence of the "polluter pays" principle of Environmental International Law.



Keywords: climate change, international law, Global South perspective, LGBTQIAP+ community, cis-heteronormative legal morality, environmental health equity

INTRODUCTION

While climate change will affect the entire global environment, its impacts will be felt hardest by those least able to make adaptations for survival (World Economic Forum, 2023). The concept of climate justice was embedded in international legal frameworks of fairness and equity (Will & Manger-Nestler, 2021; Okereke & Coventry, 2016; Okereke, 2006). However, it fails the concerns of equity and fairness at many levels, in the international and intersectional arenas. The voiced concerns of the Global South and the unvoiced concerns of the LGBTIAP+ community have both received little to least justice under the changing climatic terrains but static international and (neo)colonial world order.

Despite advancing treaties and agreements, there is a static poly-crisis of climate justice, owing to the non-binding and lack of accountability, which fails the concerns of the Global South, while the queer community, one of the largest stakeholders of climate injustice in the sense they face disproportionate impacts, does not have representation of their concerns in legal and policy formulations. While the climate crisis is worsening each year, there is no substantial change in the dynamics of accountability and vulnerability, despite the developments in environmental jurisprudence (Gathara, 2022; World Economic Forum, 2019; MacNeil, 2025).

Disproportionate Burdens

There is maldistribution of the burden of climate change upon the Global South, which feels its impacts more strongly as it is not well equipped and developed to adapt to the climatic conditions. (UNFCCC, 2023; IPCC AR6, 2022). 69 per cent of worldwide deaths caused by climate-related disasters occurred in LDCs (UNCTAD, 2022).

Polluter Accountability Gap

The polluters who caused climate change, the developed countries of the West do not agree to share the burdens and uphold the principle of “polluter pays” (Paterson, 1996).

The LGBTQIAP+ community is discriminated against in cisgender-heteronormative State policies with respect to education (OHCHR, 2019), employment (Maji et al., 2024), housing (Muruganandhan et al., 2025), and healthcare (UNEP et al., 2020; Medina-Martínez, et al., 2021). The community is already marginalized in many social and development indices. The adversity caused by climate change not only adds to these but is aggravated due to these persisting and existing disparities.

RESEARCH METHODOLOGY AND APPROACH

This study employs a rigorous methodological framework to analyze the complex interplay between climate change, international law, and the experiences of vulnerable LGBTQIAP+ communities, particularly in the Global South. The scholarly approach taken in this paper is outlined below.

Intersectional Framework

Grounded in an **intersectional framework**, this research recognizes that climate change impacts are exacerbated by intersecting forms of discrimination (sexual identity, gender, socio-economic status, geographical location), offering a nuanced understanding of compounded vulnerabilities for marginalized groups like the LGBTQIAP+ community in the Global South.

Third World Approach to International Law (TWAIL)

The study utilizes the **Third World Approach to International Law (TWAIL) as an analytical lens**. This perspective critiques Eurocentric biases in international legal frameworks and their failure to address unique challenges and historical injustices faced by developing nations and their vulnerable populations in climate justice.

Case Study Methodology

A **case study methodology examining the transgender community in India** is central. This focus provides empirical depth, illustrating how cisgender-heteronormative State policies lead to exclusion from healthy environmental exposure, housing, employment, and healthcare, increasing climate vulnerability for this specific marginalized group.

Comprehensive Literature Review

The methodology includes a comprehensive **literature review covering international law, climate science, and LGBTQIAP+ studies**. This cross-disciplinary review synthesizes existing knowledge to identify gaps in environmental jurisprudence and policy regarding the queer community and their disproportionate impacts.

Data Limitations and Research Gaps

The study acknowledges the **limitation of available data and research gaps** concerning climate change impacts on LGBTQIAP+ individuals, particularly in the Global South. This highlights the urgent need for more targeted research and data collection to inform policy and advocacy.

Ethical Considerations

Throughout the research, stringent **ethical considerations in researching vulnerable communities** were upheld. This ensures respect, privacy, and non-maleficence, especially when discussing sensitive issues related to discrimination, health disparities, and the lived experiences of marginalized groups affected by climate change.

CLIMATE JUSTICE AND THE BRUNT OF CLIMATE CHANGE

Climate justice is based on principles of fair treatment and freedom from discrimination, addressing the disproportionate impact of climate change (Okereke, 2007). It recognizes that climate change disproportionately affects low-income communities, people of color, vulnerable communities, and minorities (including gender minorities) globally, and much more severely impacts the developing countries of the Global South–the places least responsible for the problem (World Bank, 2023).

The year 2024 saw the first year-long breach of the 1.5° target of the Paris Agreement 2015 (Poynting, 2024). That year was marked by recurring floods, droughts, and extreme climate conditions. Ideally, the brunt of these impacts would be proportional to those liable for the crisis, as shown in Figure 1.

Figure 1: Illustration depicting disproportionate climate impacts on the Global South

Economic Impact on the Global South

Reports from the Asian Development Bank show that India, Bangladesh, Vietnam and the Philippines have lost more than 20 billion US$ due to natural hazards linked with climate change over the last 40 years. It is estimated that these countries may lose as much as 6.7% of their GDP growth by 2100 (World Bank, 2023).

The World Bank estimates that even moderate increases in temperature could reduce crop yields by 10 - 20 percent by 2050 in regions such as Africa, heightening the risks of food insecurity and undernutrition, particularly among vulnerable populations (World Bank, 2015)

THE INDUSTRIALIZED VS. DEVELOPING NATIONS DEBATE

The crux of the debate is that while the USA and other Western countries push that liability for pollution and environmental degeneration should be accounted for according to the current status, the implications are that these industrialized nations have advanced at the expense of the global environment. Putting liabilities on developing countries now acts as a deterrent to their growth and advancement (Okereke, 2010).

Legal jurisprudence has evolved with economic growth. Industrialized nations are obligated by the principle of 'absolute liability' to abide by the conception of ‘polluter pays’. These obligations need to be legally recognized and reiterated, not left to moral-ethical rhetoric.

The Emissions Disparity

The theory of ‘common but differentiated responsibility’ in the United Nations Framework on Climate Change and the Kyoto Protocol instills the principles of fairness and equity, addressing the unequal distribution of resources and responsibility.

13t	6.7t	0.3t	25%
USA	**China**	**49 LDCs**	**USA Emissions**
Annual per capita CO_2 emissions (metric tonnes)	Annual per capita CO_2 emissions (metric tonnes)	Annual per capita CO_2 emissions (metric tonnes)	Accounts for 25% of global emissions with only 4% of the population.

Source: World Bank (2012, 2023)

THE POLLUTER PAYS PRINCIPLE AND GLOBAL ACCOUNTABILITY

The concept of the "polluter pays principle" is a cornerstone of international environmental law, aiming to hold those responsible for environmental damage accountable for the costs of preventing, controlling, and remedying pollution (Adshead, 2018). However, its application in the context of global climate change presents significant challenges, particularly regarding historical emissions and the disproportionate impact on developing nations.

Legal Foundation and Avoidance of Accountability

The theory of *'common but differentiated responsibility'* in the United Nations Framework on Climate Change and the Kyoto Protocol instills the principles of fairness and equity, addressing the unequal distribution of resources and responsibility. Despite this, "the polluters who caused climate change, the developed countries of the West do not agree to share the burdens and uphold the principle of "polluter pays" (Paterson, 1996)." This avoidance of responsibility by industrialized nations, which have historically contributed the most to greenhouse gas emissions, leaves a significant accountability gap.

1

Historical Emissions

Industrialized nations have advanced at the expense of the global environment. While the USA and other Western countries push that liability for pollution and environmental degeneration should be accounted for according to the current status, this neglects their historical contributions to the climate crisis.

2

Legal Obligations

Legal jurisprudence has evolved with economic growth. Industrialized nations are obligated by the principle of 'absolute liability' to abide by the conception of 'polluter pays'. These obligations need to be legally recognized and reiterated, not left to moral-ethical rhetoric.

Economic Burden on Developing Countries

The failure to enforce the polluter pays principle places a severe economic burden on developing countries, particularly those in the Global South. "There is maldistribution of the burden of climate change upon the Global South, which feels its impacts more strongly as it is not well equipped and developed to adapt to the climatic conditions. (UNFCCC, 2023; IPCC AR6, 2022). Sixty-nine percent of worldwide deaths caused by climate-related disasters occurred in LDCs (UNCTAD, 2022)."

Financial Losses

Reports from the Asian Development Bank show that India, Bangladesh, Vietnam and the Philippines have lost more than 20 billion US$ due to natural hazards linked with climate change over the last 40 years. It is estimated that these countries may lose as much as 6.7% of their GDP growth by 2100.

Food Security Impact

The World Bank estimates that even with a temperature rise of less than 2°C, by 2050, crop yields will decrease by 10% to 20%. This increases the risk of food insecurity and malnutrition in children, which can go up to as much as 25-90%.

Challenges in Application

Despite advancements in environmental jurisprudence, "there is a static poly-crisis of climate justice, owing to the non-binding and lack of accountability, which fails the concerns of the Global South". This lack of binding enforcement mechanisms and a concrete framework for accountability remains a major challenge in applying the polluter pays principle effectively to climate change, hindering successful implementation and leaving vulnerable nations to bear the costs.

ENVIRONMENTAL SEXISM AND INTERSECTIONALITY

The impact of global warming is most severe in Global South countries. Within these nations, vulnerable communities are most impacted due to the intersectionality of class, gender, sexual identities, caste, religion, race, disability, and age. Environmental sexism is prima facie structural violence within cisgender heteronormative (cishet) policy frameworks.

Gendered Impact of Disasters

Vulnerable groups like women and children are more likely to die during and immediately after ecological disasters. 90% of victims of the 1991 Bangladesh cyclone were women, due to gendered dynamics of mobility, access to resources, and safety warnings.

Increased Vulnerability for LGBTQIAP+

Younger LGBTQIAP+ adults face heightened risks post-disaster, with fewer shelter options and potential family ousting. Studies show that individuals identifying as LGBTQIAP+ are nearly twice as likely to be displaced during disasters.

Rise in Violence

Cases of sexual assault and domestic violence increased exponentially after Hurricane Katrina. Similarly, during the COVID-19 pandemic, intimate partner violence against women and sexual minorities spiked.

Numerous studies indicate a consistent correlation between environmental crises and existing gendered and intersectional inequalities (OECD, 2023; Djoudi et al., 2016).

CASE STUDY: TRANSGENDERS OF INDIA

The transgender community in India (Hijras, Kinnars, etc.), as shown in Figure 2, is often forced into begging and sex work, living in marginalized, congested areas with little access to mainstream livelihoods. These "red-light areas" are often unsafe and lack climate mitigation or adaptation resources.

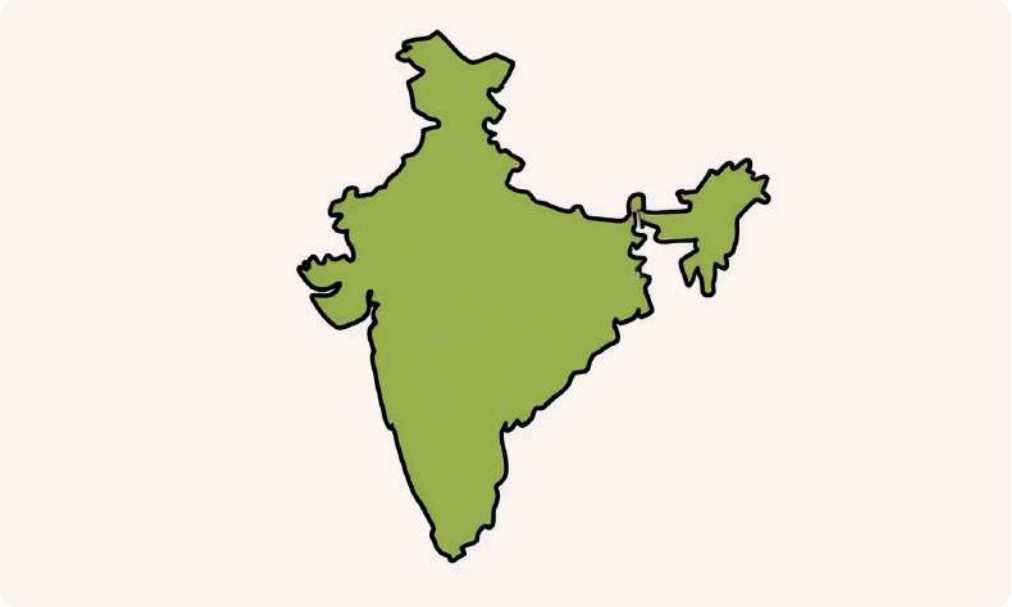
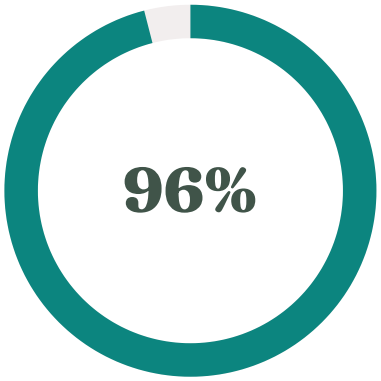


Figure 2: Map of India



Forced into undignified jobs like begging or sex work.

Have faced social rejection at some point in their lives.

Live with their parents.

Source: NHRC study by Kerala Development Society (Chauhan, 2018)

> "With the upcoming monsoons, there will be heavy rains in Chennai and my house will also be flooded... It's very difficult for a transgender person to get a house in the city, to make the house-owners understand."
>
> - A transwoman from Chennai, India (Behal, 2021) as depicted in the broader context of Figure 2's geographical area.

Housing discrimination pushes queer individuals into segregated, dilapidated areas with severe climate hazard risks in regions like those highlighted in Figure 2. This, combined with discrimination and lack of access to resources, leads to deteriorating mental health and exacerbates climate-related disparities.

INTERNATIONAL ENVIRONMENTAL LAW: A FLAWED FRAMEWORK

Traditional approaches to international environmental law often reject distributive justice, favoring self-interest and formalistic relations. However, constructivist scholars argue that legal norms can guide international law independently of power politics.

The evolution of key international environmental agreements is illustrated in Figure 3 below.

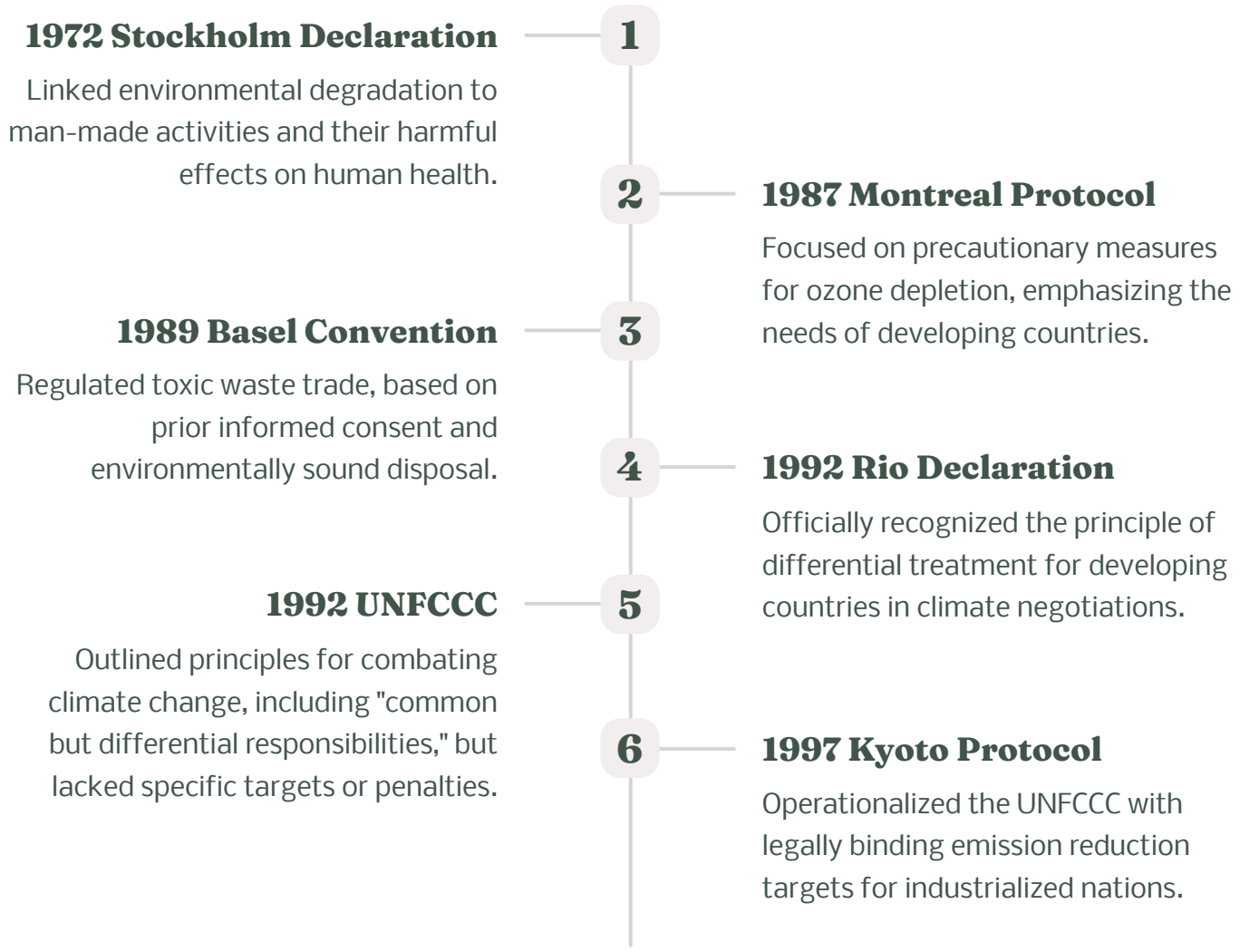


Figure 3: Evolution of International Environmental Law Framework (1972-1997)

THE TWAIL APPROACH: A CRITIQUE OF INTERNATIONAL LAW

The Third World Approach to International Law (TWAIL) argues that international law is inherently Eurocentric and perpetuates the subordination of non-European states (Anghie, 2023). It emphasizes the neo-imperialist world order and the threat of recolonization through geo-economic-political means.

Core Tenets of TWAIL

- Understands how systemic biases in International Law perpetuate the subordination of the Global South.
- Aims to eradicate the underdevelopment of the "third world" through scholarship and policy.
- Critiques the arbitrary and selective application of humanitarian intervention in favor of the West.

TWAIL on Environmental Law

- Highlights the failure of frameworks like the UNFCCC to define "loss and damage" or provide clear financial support mechanisms.
- Views the Global South's demand for loss and damage compensation as a call for historical accountability from the Global North.
- Argues that the omission of liability and compensation in agreements like the Paris Agreement reveals Eurocentric biases.

Decolonizing Knowledge for Climate Justice

TWAIL scholars emphasize that unless there is a decolonial approach to knowledge production and inclusivity of perspectives, the ends of climate justice are far. Knowledge production itself is a site of contention. A "queer-of-color critique" challenges Eurocentric academic work that erases the lived experiences at the intersections of race and sexuality. Tackling the climate crisis requires structural reforms that address who holds negotiation power and how decision-making is organized, from grassroots to global levels. Decoloniality of discourse is decoloniality of power.

LEGAL FRAMEWORKS AND HUMAN RIGHTS OBLIGATIONS

The intersection of international human rights law and environmental protection creates a crucial framework for addressing the disproportionate impact of climate change on vulnerable populations, including LGBTQIAP+ individuals. States have clear obligations under international law to protect these communities.

1

International Human Rights Law

International human rights law, encompassing treaties like the International Covenant on Civil and Political Rights (ICCPR) and the International Covenant on Economic, Social and Cultural Rights (ICESCR), guarantees rights such as the right to life, health, adequate housing, and non-discrimination. These rights are fundamental and extend to all individuals, irrespective of sexual orientation, gender identity, or gender expression, and must be protected in the context of climate change impacts.

2

State Obligations to Protect

Under international law, states have an obligation to respect, protect, and fulfill human rights. This includes taking affirmative measures to mitigate climate change and adapt to its impacts, ensuring that such actions do not discriminate against or disproportionately harm vulnerable groups. States must identify and address the specific vulnerabilities of LGBTQIAP+ communities to climate-related disasters and displacement.

3

The Yogyakarta Principles

The Yogyakarta Principles on the Application of International Human Rights Law in relation to Sexual Orientation and Gender Identity (2007), and their update (Yogyakarta Principles +10, 2017), explicitly affirm states' obligations to protect LGBTQIAP+ individuals from discrimination and violence, including in humanitarian situations. Principle 16 (The Right to Social Security and to Protection) and Principle 17 (The Right to Adequate Housing) are particularly relevant, asserting protection from displacement due to natural disasters and ensuring equitable access to safe housing, regardless of sexual orientation or gender identity.

4

Regional Human Rights Mechanisms

Regional human rights bodies, such as the Inter-American Court of Human Rights and the European Court of Human Rights, have increasingly recognized the link between human rights and environmental protection. While direct case law explicitly linking LGBTQIAP+ rights to climate change is emerging, these mechanisms establish precedents for the protection of marginalized groups from state neglect or harmful actions, providing avenues for future advocacy and litigation concerning climate justice.

5

Legal Precedents and Case Law

While specific case law directly addressing the rights of LGBTQIAP+ individuals in relation to climate is still developing, general principles derived from human rights litigation are highly relevant. Cases affirming the right to non-discrimination, protection against arbitrary displacement, and the right to a healthy environment can be leveraged. For instance, decisions emphasizing the extraterritorial obligations of states regarding human rights and environmental harm set important precedents for holding powerful nations accountable for their climate impact on vulnerable communities globally.

THE QUEER CONCERNS: AN INVISIBLE CRISIS

Climate change impacts queer people more significantly than the general population. This is exacerbated by discriminatory laws and policies that create a cycle of vulnerability.

Policy and Legal Frameworks Adding to Vulnerability

State policies often ignore the need for affirmative action for the queer community in employment, housing, and healthcare. The lack of legal recognition for same-sex marriage, for example, denies couples access to housing rights, insurance, and other benefits available to heterosexual couples. This societal and legal exclusion leads to:

Mental Health Deterioration

Homophobia and lack of tolerance contribute to mental stress and behavioral exclusion.

Unhealthy Environments

LGBT persons often live in overcrowded, high-density neighborhoods with higher concentrations of air pollutants and greater health risks.

Increased Health Risks

Studies show the cancer risk in the LGBTQIAP+ community is 12.3% higher than that of heterosexual partners (Collins, 2017a; Collins, 2017b).

Climate Change and Queerphobia

Queerphobic narratives often link natural disasters to divine punishment for homosexuality, as seen after Hurricane Katrina when religious leaders blamed LGBTQ+ communities for the disaster (Repent America, 2005). This structural violence is evident globally:

- **2004 Indian Ocean Tsunami:** The Aravani (transgender) community in Tamil Nadu was excluded from relief aid and official death counts because they lacked ration cards.
- **2011 Japan Tsunami:** Relief shelters had binary bathing and washroom facilities, excluding third-gender individuals.

Climate justice must address the intersection of climate change and social inequalities experienced as structural violence. This requires decolonizing knowledge, sensitizing policies to gender and sexuality, and enabling the stories of impacted communities to be heard.

HEALTH DISPARITIES AND ENVIRONMENTAL EXPOSURE

The intersection of systemic discrimination and environmental injustice creates profound health disparities for LGBTQIAP+ communities. (Goldsmith & Bell, 2022) These communities often face compounded vulnerabilities, leading to a range of adverse health outcomes, particularly in the face of climate change.

Higher Rates of Respiratory Diseases

Housing discrimination pushes queer individuals into segregated, dilapidated areas with higher concentrations of air pollutants and greater health risks. This leads to significantly higher rates of respiratory diseases among LGBTQIAP+ communities.

Limited Healthcare Access in Emergencies

During climate emergencies, LGBTQIAP+ individuals often face limited access to adequate healthcare services due to discrimination, lack of affirming spaces, and pre-existing societal exclusion, exacerbating their health vulnerabilities.

Compounded Mental Health Impacts

The mental health impacts of climate anxiety are significantly compounded by social discrimination, homophobia, and lack of tolerance. This contributes to deteriorating mental health and behavioral exclusion within queer communities.

Increased Health Risks During Extreme Weather

Specific health vulnerabilities during extreme weather events are heightened for LGBTQIAP+ individuals, who may lack access to safe shelters, essential resources, or supportive networks. Studies show the cancer risk in the LGBTQIAP+ community is 12.3% higher than that of heterosexual partners (Collins, 2017a; Collins, 2017b), highlighting pre-existing health disparities.

These disproportionate climate-related health outcomes demonstrate the urgent need to address the systemic inequalities that place queer communities at increased risk, advocating for inclusive policies and equitable access to resources.

THE ECO-HOMONORMATIVE JURISPRUDENCE

The concept of climate justice is based on ensuring fair treatment and non-discrimination. To test the principle of Common but Differential Responsibilities (CBDR) as a legal obligation, its standing must be traced through the sources of international law. However, analysis shows that the principle lacks binding legal force.

International Conventions & Treaties

While the CBDR principle is mentioned in the UNFCCC and Kyoto Protocol, it is only a "guiding principle," not a binding obligation under treaty law.

Customary International Law

There is no evidence of the CBDR principle as a general state practice accepted as law (opinio juris). A deep divide in interpretation and acceptance by developed vs. developing nations prevents it from becoming customary law.

General Principles of Law

The CBDR principle is still an evolving principle and is not yet fully developed or acknowledged as a general principle of international law under Article 38(1)(c) of the ICJ statute.

Judicial Decisions

No judicial decision has substantially dealt with the CBDR principle. A 2011 ITLOS opinion gave it a weak interpretation, overlooking historical inequities.

The failure of the CBDR principle to ensure climate justice highlights the need for negotiations with inclusive representation of all stakeholders, including the LGBTQIAP+ community, to break the structural anarchy of the international order.

RECOMMENDATIONS FOR INCLUSIVE CLIMATE POLICY

Addressing climate change's disproportionate impact on LGBTQIAP+ communities requires integrating their voices, experiences, and data into policy-making and implementation. These recommendations outline key steps for inclusive climate justice.

Integrating LGBTQIAP+ Voices in Climate Negotiations

01

Ensure Representation in Delegations

Advocate for LGBTQIAP+ individuals and organization representatives in national and international climate negotiation delegations.

02

Capacity Building for Advocacy

Provide funding and training for LGBTQIAP+ organizations to enhance their capacity in climate policy discussions and articulate specific needs.

03

Develop Inclusive Policy Language

Promote gender-inclusive language, explicitly referencing sexual orientation and gender identity in climate policies, action plans, and disaster response.

04

Establish Safe Consultation Mechanisms

Create secure platforms for LGBTQIAP+ communities to provide input on climate policies without fear of discrimination.

Suggestions for Data Collection and Research Methodologies

Accurate, inclusive data is crucial for understanding vulnerabilities and designing effective interventions. Methodologies must capture the unique experiences of diverse LGBTQIAP+ populations.

Disaggregated Data

Mandate disaggregated data collection (sex, gender, sexual orientation) in climate vulnerability and impact studies.

Qualitative Research

Prioritize qualitative methods (e.g., participatory action research) to capture lived experiences and nuanced impacts.

Ethical Guidelines

Develop ethical guidelines for LGBTQIAP+ research, ensuring consent, privacy, and safety.

Framework for Intersectional Climate Justice Approaches

An intersectional approach acknowledges that vulnerabilities are shaped by multiple, overlapping identities and power dynamics. As illustrated in Figure 4, this framework highlights the critical intersections of Climate Justice, Gender Equality, and LGBTQIAP+ Rights.

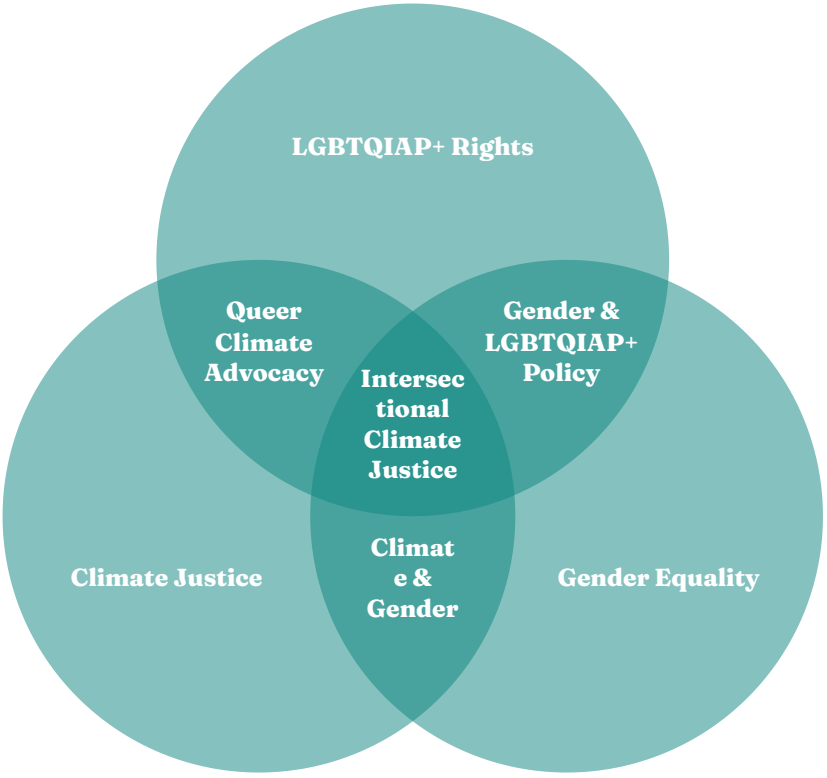


Figure 4: A three-circle Venn diagram showing the overlapping areas of Climate Justice, Gender Equality, and LGBTQIAP+ Rights, with Intersectional Climate Justice at the center.

- **Recognize Intersecting Vulnerabilities:** Acknowledge how sexual orientation, gender identity, race, class, disability, and other factors create unique climate risks. This recognition is fundamental to the concept of Intersectional Climate Justice depicted in Figure 4.
- **Adopt a Rights-Based Approach:** Frame climate action within a human rights framework, upholding the rights of all, including LGBTQIAP+ persons, to a safe, healthy environment.
- **Promote Decolonial Knowledge:** Integrate indigenous and traditional knowledge systems that embody holistic and sustainable environmental relationships, challenging colonial narratives.

Role of Civil Society and Advocacy Organizations

Civil society organizations are critical actors in bridging the gap between policy and practice, advocating for marginalized communities, and providing essential services.

Advocacy and Lobbying

Lobby governments and international bodies to adopt inclusive climate policies and allocate resources to LGBTQIAP+-specific climate initiatives.

Community Mobilization

Mobilize and empower LGBTQIAP+ communities to participate actively in climate action, awareness campaigns, and local resilience-building efforts.

Service Delivery

Provide tailored support, shelter, and resources to LGBTQIAP+ individuals affected by climate disasters, addressing their specific needs and vulnerabilities.

Implementation Strategies for Inclusive Climate Adaptation

Effective climate adaptation plans must be designed with the diverse needs of all communities in mind to ensure equitable outcomes.

Safe and Affirming Shelters

Establish disaster shelters that are safe and welcoming for all gender identities and sexual orientations, with non-binary facilities and trained staff.

Inclusive Early Warning Systems

Ensure climate early warning systems and communication are accessible and culturally sensitive to LGBTQIAP+ communities, including diverse language and communication methods.

Economic Empowerment

Support economic resilience programs for LGBTQIAP+ individuals, especially those in climate-vulnerable sectors, to mitigate livelihood disruptions.

Healthcare Accessibility

Integrate LGBTQIAP+ health considerations into disaster preparedness and response, ensuring access to affirming medical care and mental health support.

ANALYSIS AND THE BLISS OF IGNORANCENALYSIS AND THE BLISS OF IGNORANCE

Climate justice requires sustainable legal solutions addressing injustices caused and aggravated by climate change. However, there is a significant lack of research, data, and healthcare surveys focused on disproportionately affected communities, making their inclusion in decision-making crucial.

The Six Pillars of Climate Justice

> As enumerated by the Center for Climate Justice, University of California (Berkeley Climate Equity Research Collective, 2023)

These six pillars, as illustrated in Figure 5 below, provide a comprehensive framework for understanding climate justice.

Figure 5: The Six Pillars of Climate Justice Framework

Climate narratives that exclude the LGBTQIAP+ perspective are based on a masculinist ideology, which ecofeminist Greta Gaard argues is the root cause of climate change. Intersectionality is not just about intersecting identities but about the intersecting nature of oppression. The plight of the LGBTQIAP+ community in the Global South is an analysis of developmental economy failures, ecological crises, and the misery of those whose human rights violations never make it into official records.

CONCLUSION

The multipolar international order often sees the interests of dominant players crush the voices of weaker nations, a reality highlighted by TWAIL. Climate injustice is a pressing issue, but it is not being approached inclusively. The framework fails to cater to the special needs of the Global South or the LGBTQIAP+ community, which often lacks a voice even in municipal law.

It is the need of the hour for more inclusive dialogue, decision-making, research, and educational engagement that prioritizes community-based and community-led solutions, giving due consideration to indigenous approaches. The intersection of LGBTQIAP+ identities with Indigenous knowledge systems offers a versatile gateway to decolonization, as many pre-colonial cultures recognized gender diversity without stigma. This collaborative vision is exemplified in Figure 6.

The specific circumstances of the LGBTQIAP+ community, especially in the Global South, make it significant to voice their concerns in international climate negotiations. They are a third world within the third world, and their inclusion is paramount for achieving true climate justice (as depicted in Figure 6).

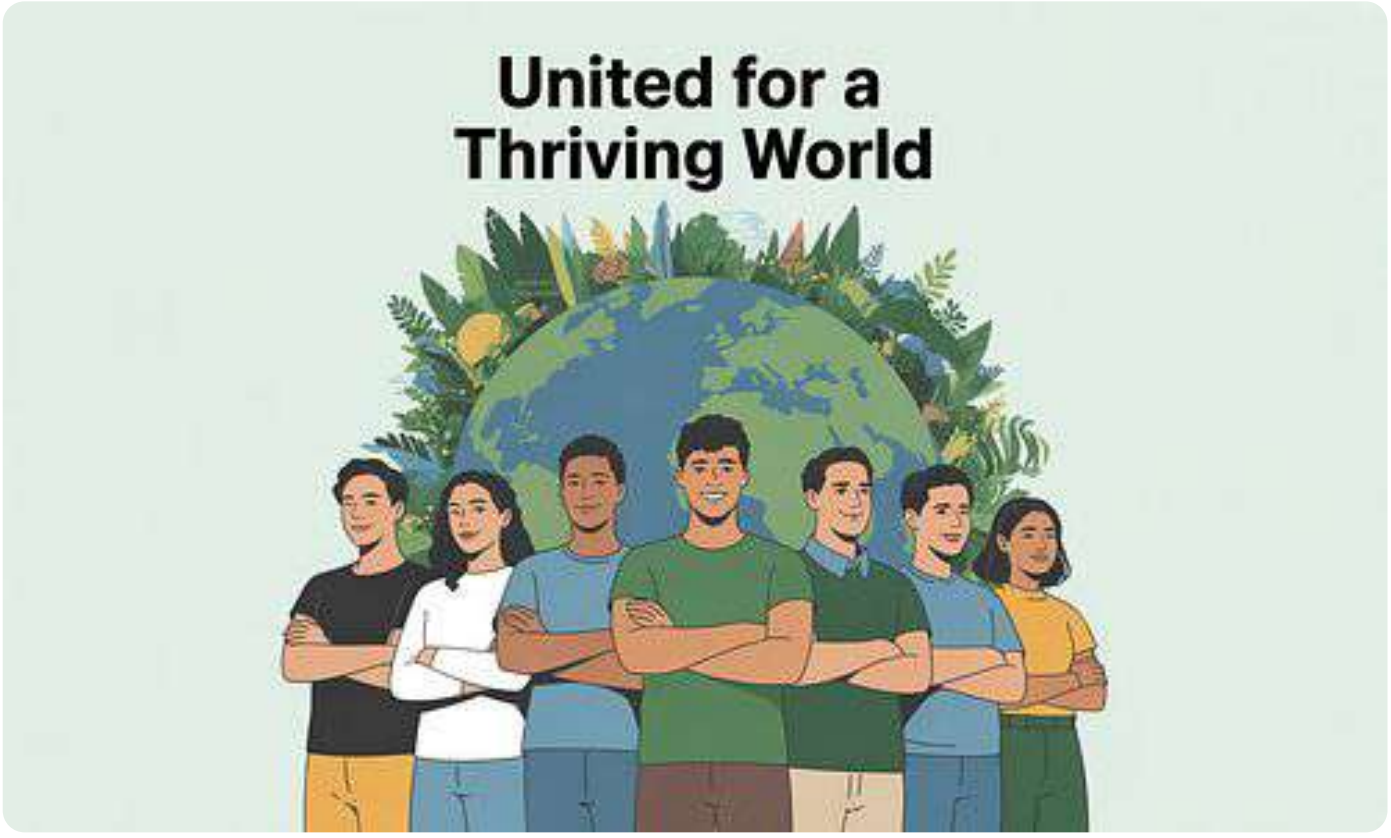


Figure 6: An Illustration of Diverse group (LGBTQ+ individuals and Global South representatives) collaborating for a healing planet.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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Environmental Degradation and Economic Performance in Botswana: A Test of the Environmental Kuznets Curve, Pollution Haven and Pollution Halo Hypotheses

RESEARCH ARTICLE

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Economic Growth vs Environment

Botswana's economy relies heavily on diamond mining, contributing approximately 30% of GDP and over 80% of export earnings, which drives economic growth but creates environmental challenges including deforestation, water contamination, and air pollution.

U-Shaped Relationship

The study finds that initially, economic growth reduces CO_2 emissions, but as the economy develops further, emissions begin to increase, creating a U-shaped pattern.

Foreign Investment Impact

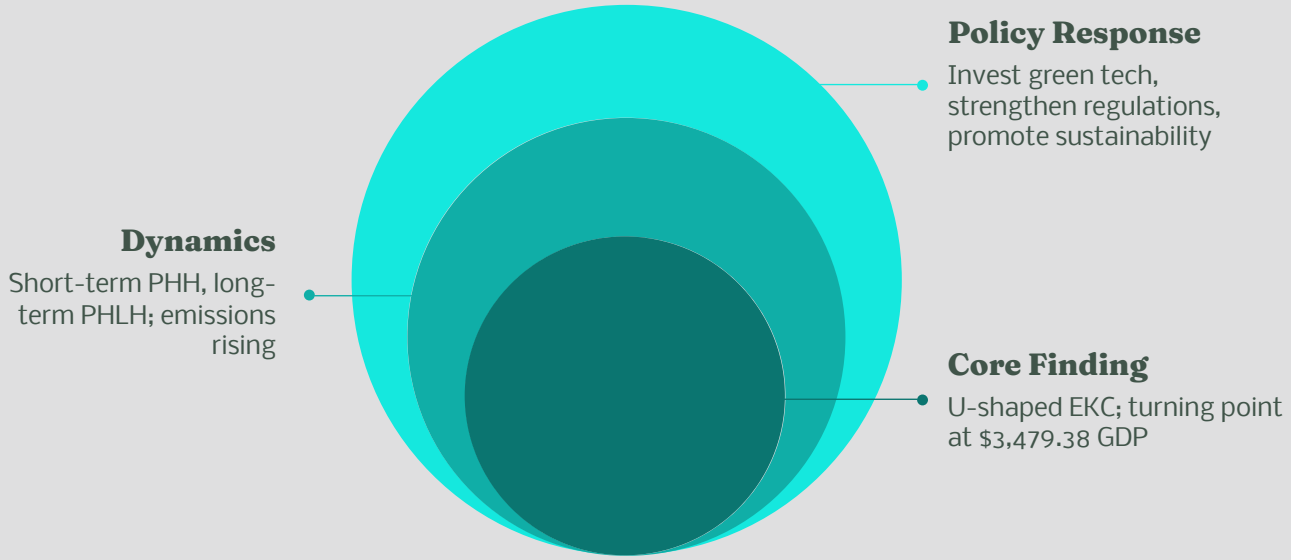
Foreign investment shows mixed effects - it initially increases pollution (Pollution Haven effect) but eventually brings cleaner technologies (Pollution Halo effect).

Policy Recommendations

The study recommends investing in green technologies, strengthening environmental regulations, and promoting sustainable practices to balance economic growth with environmental protection.

ABSTRACT

This study explores the relationship between economic growth and environmental degradation in Botswana, a relatively understudied Southern African economy, by examining the Environmental Kuznets Curve (EKC), Pollution Haven Hypothesis (PHH), and Pollution Halo Hypothesis (PHLH). Using the Autoregressive Distributed Lag (ARDL) model–which allows for mixed integration orders and is suitable for small sample sizes–on data from 1991 to 2019, the study finds a U-shaped EKC, with a turning point at a GDP per capita of $3,479.38. Botswana, with a mean GDP per capita of approximately $5,500 and a 2019 value around $6,485, sees increased emissions. Short-term evidence supports the PHH, while long-term evidence supports the PHLH. This indicates that Botswana's current economic trajectory may be environmentally unsustainable without policy shifts. The study recommends investing in green technologies, strengthening environmental regulations, and promoting sustainable practices to mitigate the environmental impact of economic growth.



Keywords: Environmental Kuznets Curve, Pollution Haven Hypothesis, Pollution Halo Hypothesis, Environmental Degradation, Botswana.

INTRODUCTION

Environmental degradation poses serious risks to global human well-being and economic stability (Nguyen et al., 2023; Bibi & Jamil, 2021; Sarkodie, 2018; World Bank, 2012). Climate change–evident through rising sea levels, floods, and droughts–intensifies social challenges such as migration and urbanization (Wang et al., 2020). Global carbon dioxide (CO_2) emissions have surged from 2 billion tons in 1900 to over 34 billion tons today, with projections indicating a potential doubling or tripling by 2050 (United Nations Climate Change, 2023). In response, international agreements like the Paris Agreement and Kyoto Protocol have set targets to reduce emissions and support climate action in developing nations (United Nations Climate Change, 2023).

In Botswana, these global challenges are mirrored by rising temperatures, increasing water scarcity, and growing vulnerability to climate shocks as illustrated in Figure 1. Addressing environmental degradation is thus central to achieving the country's development goals and international commitments, including Vision 2036 and the Sustainable Development Goals (SDGs).

Figure 1: Botswana's environmental challenges. DmitryPichugin

The Southern African region faces distinct environmental vulnerabilities, including rising temperatures and increased frequency of extreme climate events (Nhamo et al., 2018). These developments threaten water security, agricultural output, and broader socio-economic development, disproportionately affecting populations dependent on subsistence farming (Food and Agriculture Organization [FAO], 2021; United Nations Development Programme [UNDP], 2023). In response, the Southern African Development Community (SADC) (2018) has promoted regional strategies such as the establishment of Transfrontier Conservation Areas (TFCAs) to safeguard ecosystems and enhance regional integration.

However, addressing environmental degradation remains deeply entangled in broader power dynamics. Global environmental frameworks, such as the Paris Agreement, often impose conditionalities on aid or climate finance, influencing domestic environmental policies in countries like Botswana. Similarly, foreign direct investment (FDI) decisions and investor-state dispute mechanisms may shape national regulatory space, leading to regulatory chill in environmental governance (Bouzahzah, 2022).

In the context of Botswana–where economic growth is driven by natural resource extraction, tourism, and agriculture–this study critically examines the relevance of mainstream environmental economic theories such as the Environmental Kuznets Curve (EKC), Pollution Haven Hypothesis (PHH), and Pollution Halo Hypothesis (PHLH) (Bibi & Jamil, 2021; Bouzahzah, 2022). The mining sector, accounting for approximately 30% of GDP and over 80% of export earnings, significantly contributes to environmental degradation through deforestation, water contamination, and air pollution (Juana, 2014; Madebwe et al., 2021) (see Figure 2).

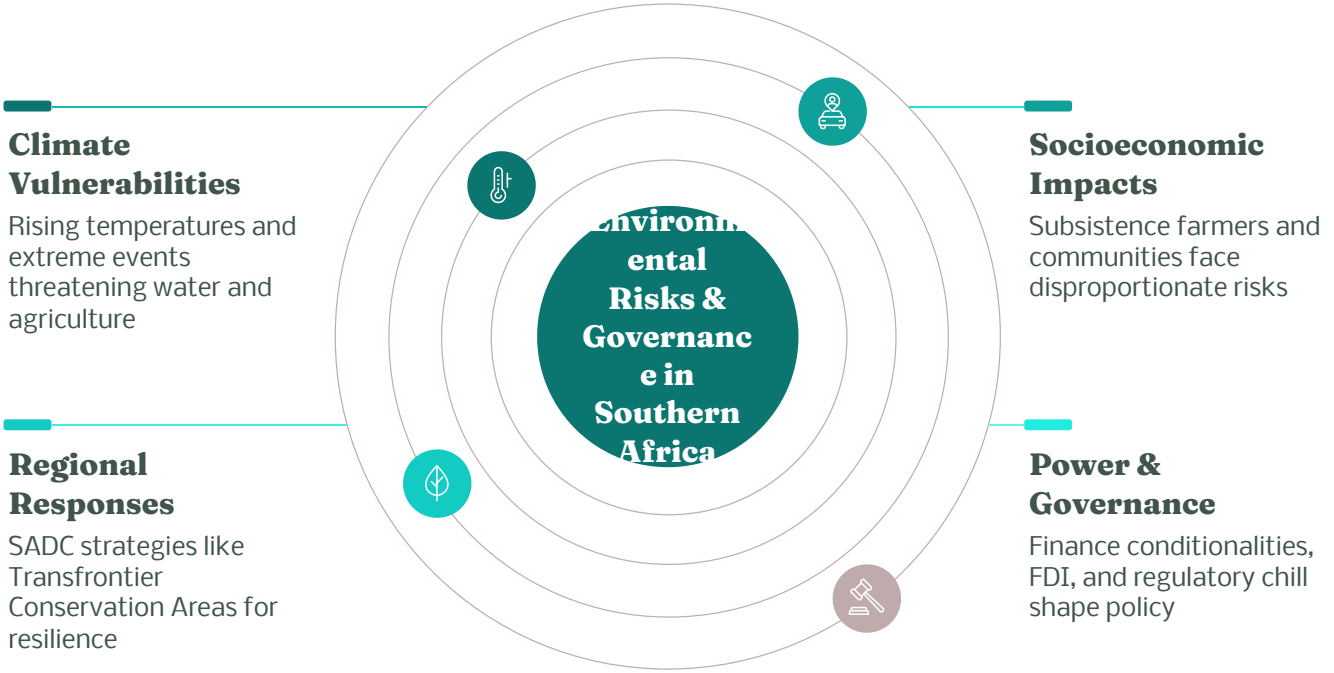


Figure 2: Environmental risks and governance dynamics in Southern Africa

Environmental sustainability issues in Botswana

Balancing economic growth with environmental sustainability is a formidable challenge faced by countries striving for development (Udeagha & Ngepah, 2023). Botswana, a landlocked country in Southern Africa, epitomises this struggle as it grapples with the consequences of rapid economic growth driven by its abundant natural resources and burgeoning industries (Hambira etal., 2020). While economic progress has brought about improvements in living standards and infrastructure, it has also placed pressure on natural ecosystems and increased vulnerability to climate risks, underscoring the need for sustainable and inclusive growth strategies (United Nations Development Programme, 2023).

At the heart of Botswana's economic success lies its mining industry, particularly the extraction of diamonds, which has propelled the country into one of Africa's leading economies (Juana, 2014). However, this economic boon has come at a significant environmental cost. Diamond mining operations, characterised by extensive land excavation and water usage, have led to deforestation, soil erosion, and water pollution (Madebwe et al., 2021; Juana, 2014).

Mining Industry Impact

- Approximately 30% of GDP and over 80% of export earnings contribution
- Extensive land excavation
- Water contamination
- Deforestation and soil erosion

Tourism Challenges

- Habitat encroachment
- Poaching threats
- Resource depletion
- Climate change vulnerability

Agricultural Vulnerabilities

- Climate-induced droughts
- Erratic rainfall patterns
- Land degradation
- Food security risks

Botswana's rich biodiversity, including iconic species such as elephants, lions, and rhinos, has made it a prime destination for ecotourism (Gumbo, 2022). The Okavango Delta, a UNESCO World Heritage Site and the largest inland delta in the world, teems with wildlife and supports diverse ecosystems (Gumbo, 2022; SADC, 2018). However, the burgeoning tourism industry, while providing economic opportunities, poses challenges to biodiversity conservation.

Agriculture remains a cornerstone of Botswana's economy, providing livelihoods for a significant portion of the population (UNDP, 2023). However, climate change-induced droughts, erratic rainfall, and land degradation pose formidable challenges to agricultural productivity and food security (Mogotsi, 2022; Temoso et al., 2018).

Economic growth, trade, foreign direct investments, and the environment

Climate stress and environmental degradation represent global challenges stemming from socio-economic activities, manifesting in phenomena like floods, droughts, wildfires, rising sea levels, and pollution (Heshmati, 2021). The World Economic Forum (WEC) reports a significant increase in CO_2 emissions, with projections indicating a potential doubling or tripling by 2050 (WEC, 2022).

The correlation between environmental pollutants and economic growth is a topic of interest, as economic development often comes at the expense of environmental quality. The EKC hypothesis posits that environmental degradation initially rises with economic growth but eventually declines as economies mature (Bibi & Jamil, 2021). International trade and foreign direct investment (FDI) are crucial drivers of economic growth but can also impact environmental outcomes (see Figure 3).

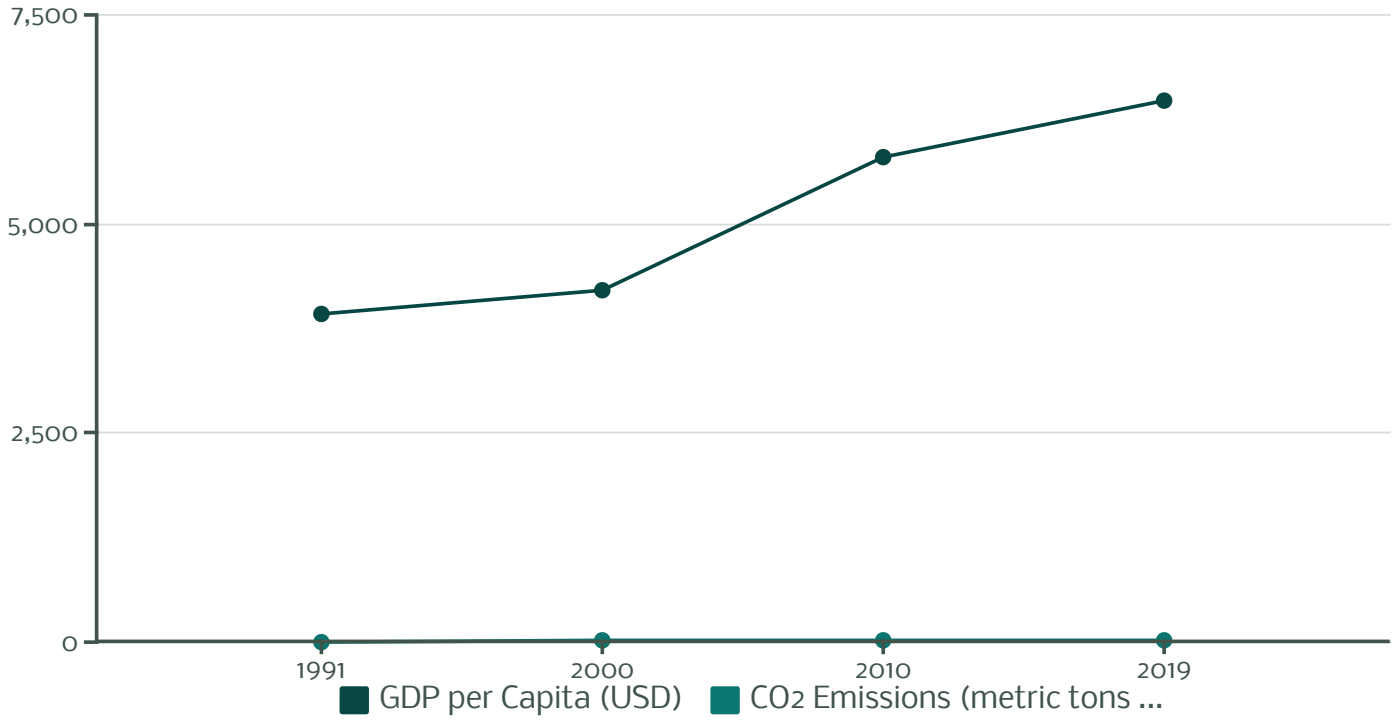


Figure 3: Botswana's GDP per capita and CO_2 emissions trends (1991-2019)

LITERATURE REVIEW

The methodologies employed across these studies vary, encompassing panel data econometric models, random effects and fixed effects models (Bibi & Jamil, 2021), autoregressive distributed lag (ARDL) models (Usman et al., 2019; Koc & Bulus, 2020), and fully modified ordinary least squares (FMOLS) (Gokmenoglu & Taspinar, 2018). Other studies utilise dynamic panel data techniques such as the Common Correlated Effects (CCE) and Augmented Mean Group (AMG) estimations (Isik et al., 2019), and Maki's co-integration test (Gokmenoglu & Taspinar, 2018).

Common variables include carbon dioxide (CO_2) emissions, GDP per capita, energy consumption, trade openness, and foreign direct investment. Some studies incorporate additional variables such as institutional quality (Bibi & Jamil, 2021), financial development indicators (Sun et al., 2024), and agricultural value added (Gokmenoglu & Taspinar, 2018). Data spans several decades, with most studies covering the period from the 1970s to the 2010s.

01

Environmental Kuznets Curve Studies

Research generally supports the EKC hypothesis globally, though with notable exceptions and regional variations, particularly in Sub-Saharan Africa.

02

Pollution Haven Hypothesis Research

Studies suggest developed countries may relocate polluting industries to developing nations with more lenient environmental regulations.

03

Pollution Halo Hypothesis Analysis

Research emphasizes that FDI may introduce advanced and cleaner technologies to host countries, leading to improved environmental quality.

04

Regional and Methodological Variations

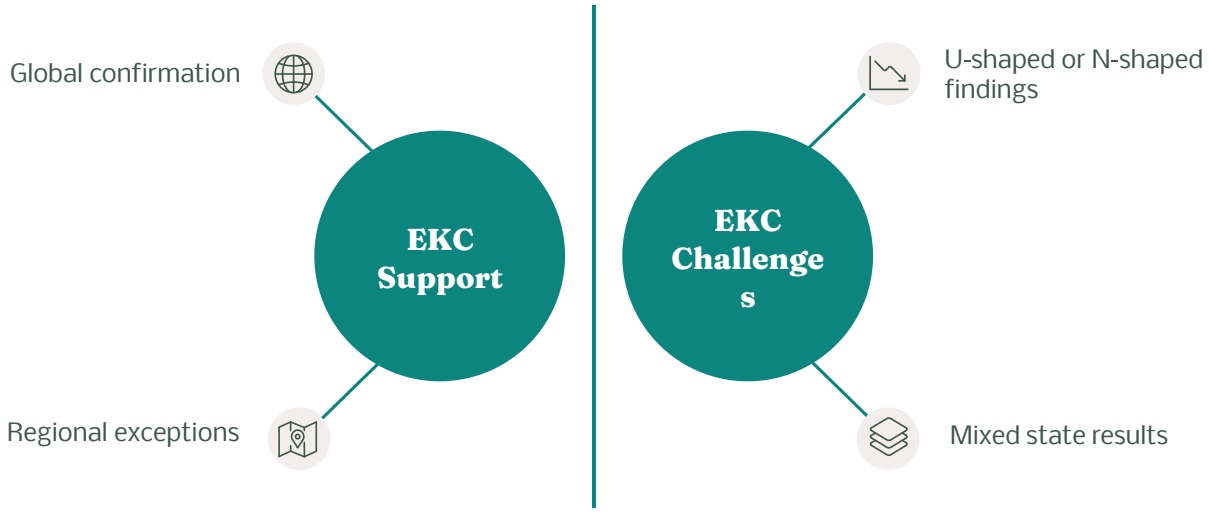
Diverse methodologies provide broad perspectives while regional studies highlight local variations crucial for targeted policy recommendations.

The results generally support the Environmental Kuznets Curve (EKC) hypothesis, though with notable exceptions and regional variations. Bibi and Jamil (2021) find support for the EKC hypothesis in all regions except Sub-Saharan Africa, indicating regional differences. Sun et al. (2024) confirm the EKC hypothesis globally, with trade protectionism having varied effects across income groups. Mahmood et al. (2023) report higher validation of the EKC hypothesis in Chinese studies using global pollution proxies and provincial data.

Conversely, some studies challenge the EKC hypothesis. Dogan and Inglesi-Lotz (2020) find a U-shaped relationship when considering the industrial share of the economy in European countries, rather than an inverted U-shape. Koc and Bulus (2020) do not support the EKC hypothesis for Korea, identifying an N-shaped relationship instead. Isik et al. (2019) report mixed results for US states, with the EKC hypothesis validated in only 14 states.

The PHH suggests that developed countries may relocate polluting industries to developing nations with more lenient environmental regulations (Abbasi, Nosheen & Rahman, 2023). This can lead to a concentration of polluting industries in "pollution havens," potentially exacerbating environmental degradation. The PHLH emphasizes regulatory disparities between countries, and FDI may be one of the factors responsible for environmental degradation in developing countries as stated by Nguyen (2020).

Despite extensive research, no studies have specifically focused on testing these hypotheses in the Botswana economy. Existing studies on these hypotheses yield conflicting conclusions regarding the impacts of trade, FDI, and population density on the environment. This research aims to fill this gap by examining the relationships between carbon dioxide emissions, GDP per capita, trade, FDI, population density, and government expenditure in Botswana using an econometric model based on the EKC, while also testing for PHH and PHLH hypotheses.



METHODOLOGY

Theoretical Framework

The theoretical framework for this study encompasses three central hypotheses: the Environmental Kuznets Curve (EKC), the Pollution Haven Hypothesis (PHH), and the Pollution Halo Hypothesis (PHLH). These models are particularly relevant to Botswana's context due to its rapid economic growth driven by resource extraction, increasing foreign direct investment (FDI), and ongoing environmental challenges. As a developing, resource-dependent country, Botswana presents an ideal case for assessing how economic expansion and international investment interact with environmental sustainability under varying regulatory conditions.

Environmental Kuznets Curve

Inverted U-shaped relationship between economic development and environmental degradation

Pollution Haven Hypothesis

FDI flows to countries with weaker environmental regulations, increasing pollution

Pollution Halo Hypothesis

FDI improves environmental standards through advanced technologies and practices

Definition of Variables

Carbon Dioxide Emissions (CO_2) serve as a key indicator for environmental degradation due to its role as a primary greenhouse gas contributing to climate change (Abbasi et al., 2023; United Nations, 2023). Its widespread monitoring and reporting by international organisations like UNFCCC make it a suitable empirical variable (United Nations Framework Convention on Climate Change [UNFCCC], 2023).

Gross Domestic Product per Capita (GDPPC) acts as a proxy for economic development, capturing overall economic activity and prosperity (Bimonte & Stabile, 2017; Juana, 2014). Trade Openness measures a country's engagement in international trade and economic integration, influencing the flow of goods, services, and capital (Nasir et al., 2021).

Foreign Direct Investment (FDI) is a significant variable in this study due to its potential influence on environmental outcomes in host countries. Government expenditure indicates the level of commitment to environmental issues through policies, interventions, and investments in cleaner technologies (Amusa & Oyinlola, 2019). The descriptive statistics for all variables are presented in Table 1.

Table 1: Descriptive statistics of key variables used in the study

Variable	Mean	Description
CO2	2.893 mt per capita	Carbon dioxide emissions as environmental indicator
GDPPC	$5,500	Gross domestic product per capita
FDINIF	$294.21 million	Foreign direct investment inflows
GE	$1,398.63 million	Government expenditure
IMPO	$2,132.78 million	Import values

Data and pre-estimation diagnostics

This study utilises data for Botswana for the period 1991-2019. The starting point of 1991 was chosen due to data availability and its alignment with significant structural changes in Botswana's economy, including trade liberalisation, increased foreign direct investment (FDI), and the gradual shift toward market-oriented policies. This period also captures key environmental and developmental policy evolutions, such as the implementation of the National Conservation Strategy and subsequent integration of environmental considerations into national planning. The 29-year timeframe provides a comprehensive view of long-term trends in economic growth, environmental outcomes, and the influence of FDI under varying regulatory and policy regimes. The data is obtained from the World Bank database.

The descriptive statistics reveal substantial insights into Botswana's economic and environmental dynamics. CO_2 emissions have a mean of 2.893 metric tons per capita, with a standard deviation of 0.484, indicating significant fluctuations in environmental impact. GDP per capita averages around $5,500, with a standard deviation of $1,698.63, reflecting economic instability and growth. FDI inflows have a mean of $294.21 million and a standard deviation of $189.45 million, suggesting shifts in investor confidence and policy changes.

Unit root tests were conducted using the Augmented Dickey-Fuller (ADF) method, which confirmed that all variables are integrated of order one, I(1), and none are integrated of order two, I(2). This satisfies the preconditions for applying the ARDL bounds testing methodology. A standard VAR was estimated for lag length selection criteria, and the AIC, SC, and HQ selected a lag 1. Furthermore, the Bounds Test was conducted to test for cointegration among the study's variables.

Estimation Method

This study employs the ARDL approach to analyse the long-run and short-run dynamics among the variables under consideration. The ARDL methodology, introduced by Pesaran and Shin (1999), is particularly suitable for small sample sizes and can be applied irrespective of whether the underlying variables are purely I(0), purely I(1), or mutually cointegrated. This flexibility makes ARDL a robust econometric technique for investigating the existence of cointegration relationships among time-series data.

RESULTS AND DISCUSSION

The results from the ARDL model provide critical insights into the relationship between economic growth and environmental quality in Botswana, testing the EKC hypothesis, PHH, and PHLH.

The error correction term (ECT(-1)) is significant and negative (-0.692), indicating that about 69.2% of the deviations from the long-run equilibrium are corrected within a year. This suggests a strong tendency for CO_2 emissions to return to equilibrium following economic shocks.

69.2%	$3,479	$5,500	29
Error Correction	**EKC Turning Point**	**Mean GDP per capita**	**Study Period**
Annual adjustment to equilibrium	GDP per capita threshold	Value during 1991-2019	Years of data (1991-2019)

The short-run dynamics reveal that the coefficient for the change in the squared GDP per capita (D(LGDPPPC2)) is positive and significant (3.046), implying that in the short run, as GDP per capita increases, the rate of CO_2 emissions increases at an accelerating rate. This finding suggests a U-shaped relationship between economic growth and CO_2 emissions, where emissions initially decrease and then increase as GDP per capita rises.

In the long run, the coefficient for LGDPPC is negative and significant (-73.405), while LGDPPC2(-1) is positive and significant (4.500). This confirms a U-shaped relationship for the EKC hypothesis in Botswana. The negative coefficient of LGDPPC indicates that at lower levels of GDP per capita, economic growth leads to reductions in CO_2 emissions. However, the positive coefficient for LGDPPC2 suggests that beyond a certain level of income, further economic growth contributes to increased emissions.

Foreign direct investments' long-run impact is negative and significant (FDINIF(-1) = -0.000), suggesting that long-term FDI inflows contribute to a reduction in CO_2 emissions, possibly through the adoption of environmentally friendly technologies brought by foreign investors. This supports the PHLH, where FDI can bring advanced technologies and management practices that improve environmental quality.

This temporal distinction in FDI effects aligns with established patterns in extractive industries. Huang et al. (2025) demonstrate that initial FDI in mining sectors typically increases emissions for 5-7 years as infrastructure development and extraction activities intensify, before cleaner technology transfer and improved management practices take effect. In Botswana's context, the diamond mining sector, which contributes approximately 30% of GDP and over 80% of export earnings, saw major FDI peak in the 1990s-2000s. This period coincided with rising emissions, while environmental regulations were strengthened only after 2010 through the Environmental Assessment Act (2011) and subsequent policy frameworks. This timeline explains the observed short-term pollution haven effects transitioning to longer-term pollution halo benefits as regulatory frameworks matured and technology transfer occurred.

The combination of a negative LGDPPC and a positive LGDPPC2 coefficient confirms the traditional U-shaped EKC for Botswana. The turning point of the EKC can be calculated as −(−73.405) 2(4.500), which gives 8.1561. The exponent of 8.1561 (e8.1561) gives the turning point as US$3,479.38 which is the GDP per capita level at which CO_2 emissions begin to increase in Botswana.

Considering that the minimum GDP per capita in Botswana over the study period (observed in 1991) is approximately $3,931, which is above the turning point of $3,479.38. This implies that throughout the observed period (1991–2019), Botswana has been in the phase where economic growth is associated with rising CO_2 emissions (see Figure 4). The mean GDP per capita for Botswana is approximately $5,500. This value is well above the turning point, indicating that on average, Botswana is in the phase of the EKC where further economic growth leads to increased CO_2 emissions.

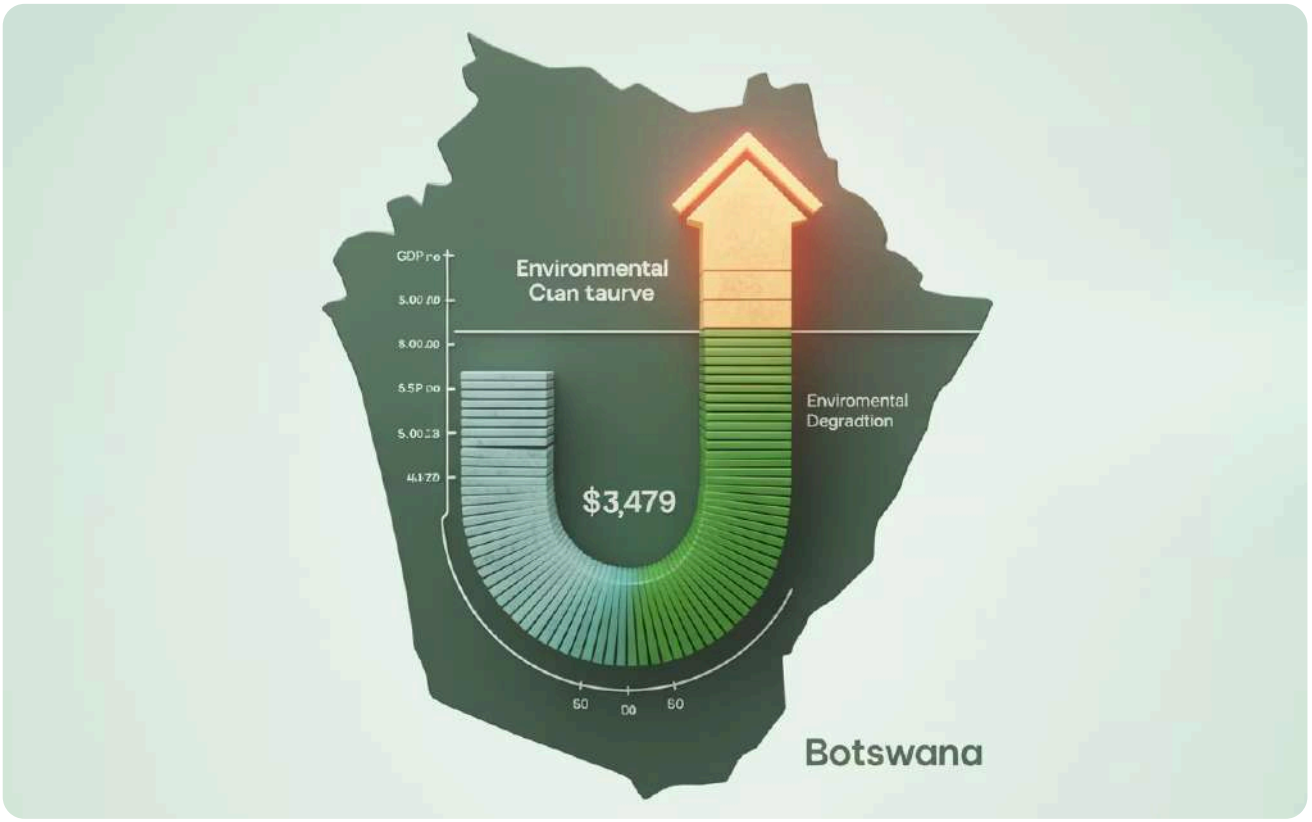


Figure 4: Environmental Kuznets Curve for Botswana showing U-shaped relationship with turning point at $3,479 GDP per capita

The ARDL model satisfies all residual diagnostic tests, including normality (Jarque-Bera), serial correlation (Breusch-Godfrey), and heteroscedasticity (Breusch-Pagan-Godfrey) since the p-value on each test is more than 0.05. This indicates that the model is well-specified, and the estimates are reliable.

Environmental Impact Evidence

Diamond Mining Environmental Footprint

Recent studies reveal the significant environmental impact of diamond mining globally. The Diamond Environmental Impacts Estimation (DEIE) model projects that annual greenhouse gas emissions from the global diamond industry will reach 9.65–13.26 Mt CO_2 by 2100, with mineral waste generation of 422.80–582.84 Mt and water usage of 78.68–107.95 million m^3 (Sun et al., 2024).

As the world's largest diamond producer by value, Botswana contributes substantially to these figures, with diamonds accounting for approximately 30% of GDP and over 80% of the country's export earnings (U.S. State Department, 2024).

Green Technology Alternatives

GHG Emissions

Lab-grown diamond alternatives could significantly reduce 9.58 Mt in annual GHG emissions by 2100.

Mineral Waste

These alternatives could potentially save 421.06 Mt in mineral waste.

Water Usage

Water usage could be reduced by 66.70 million m^3 annually.

Landfill Space

Annually save 714 million cubic meters of landfill space.

Food Security

Contribute to feeding 436 million people through reduced resource competition (Sun et al., 2024).

Investment Climate Context

Botswana maintains strong economic fundamentals that support green technology adoption. Standard & Poor's maintained the country's investment-grade sovereign credit rating at "BBB+/A-2" with stable outlook in March 2024, reflecting the country's capacity to attract sustainable foreign investment (U.S. State Department, 2024). This financial stability provides a foundation for implementing the recommended green technology investments and regulatory strengthening measures.

Vision 2036 Implementation Context

Current Economic Trajectory

Botswana's economy is positioned for growth acceleration in 2024 before returning to a coping phase in 2025, according to UNDP SDG analysis (2023). This trajectory is characterized by being 35% higher than global averages, supported by prudent macroeconomic policies and robust economic institutions, particularly around managing diamond revenue through the fast-tracked implementation of the government's Economic Recovery and Transformation Plan.

Vision 2036 Strategic Alignment

The study's findings directly support Botswana's Vision 2036 transformational agenda, which aims to transform the country from upper middle-income to high-income status by 2036. The four strategic pillars of Vision 2036 align with the research recommendations:

Sustainable Economic Development

Supports the green technology investment recommendations

Human and Social Development

Addresses equity concerns raised in policy implications

Sustainable Environment

Directly targets the environmental degradation challenges identified

Governance, Peace and Security

Encompasses the institutional capacity building recommendations

UN Cooperation Framework 2022-2026

The United Nations Sustainable Development Cooperation Framework provides institutional support for implementing the study's recommendations. The framework specifically pledges to support fulfillment of Vision 2036 and National Development Plan 11, while ensuring national implementation of the 2030 Agenda for Sustainable Development (United Nations Botswana, 2024).

SDG Progress Indicators

Current challenges include high inequality, structural unemployment, and a small domestic private sector focused on non-tradables, with poor outcomes on health and education indicators (United Nations Development Programme, 2023). These align with the study's emphasis on addressing disproportionate environmental burdens on rural communities, women, youth, and subsistence farmers.

RECOMMENDATIONS AND CONCLUSIONS

The study confirms the traditional U-shaped EKC hypothesis for Botswana, highlighting a significant relationship between economic growth and environmental quality. The positive coefficient of $LGDPPC^2$ and the negative coefficient of LGDPPC support a U-shaped relationship, indicating that while initial economic growth leads to reduced CO_2 emissions, further growth results in increased emissions.

The estimated turning point for the EKC is approximately USD 3,479.38. When compared to the minimum around USD 3,931 and mean around USD 5,500, respectively, this suggests that Botswana is in the post-turning point phase of the EKC, where continued economic growth is associated with environmental degradation.

However, this turning point appears unusually low compared to international evidence. Hussain et al. (2023) demonstrate that most developing countries experience EKC turning points between USD 8,000-15,000 per capita, while Leal and Marques (2022) show that resource-dependent economies typically reach environmental improvement thresholds at even higher income levels. This suggests that Botswana, with its GDP per capita in 2019 of USD 6,485, remains well within the ascending phase of the EKC where continued economic growth is associated with increasing environmental degradation. The relatively low calculated turning point may reflect the dominance of extractive industries in Botswana's economy, which typically exhibit different environmental-income dynamics compared to diversified economies.

Moreover, the study provides mixed evidence for the Pollution Haven Hypothesis (PHH) and the Pollution Halo Hypothesis (PHLH). In the short term, the positive impact of FDI on emissions supports the PHH, implying that foreign investors may take advantage of Botswana's relatively weak enforcement of environmental standards. However, in the long term, the negative relationship between FDI and emissions supports the PHLH, suggesting that sustained foreign investment can introduce cleaner technologies and enhance environmental performance over time.

Green Technology Investment

Prioritize investments in renewable energy infrastructure and clean technologies aligned with National Energy Policy (2016) and Renewable Energy Policy (2019).

Regulatory Strengthening

Enhance enforcement capacity through Environmental Assessment Act (2011) and improved monitoring systems for mining and industrial operations.

Sustainable FDI Attraction

Develop policies to attract environmentally friendly foreign investment while mitigating short-term pollution risks through performance standards.

Institutional Capacity Building

Strengthen environmental institutions, improve cross-ministerial coordination, and invest in environmental data infrastructure for better monitoring.

Policy Implications

These findings have critical policy implications for Botswana. To mitigate the environmental impact of economic growth (Wang et al., 2024), the country should prioritize investments in green technologies and renewable energy infrastructure. However, such transitions must be grounded in Botswana's specific context, considering its regulatory capacity, technological readiness, and political economy. Given the relatively limited enforcement capacity of environmental institutions (Mutemeri, 2024), efforts to strengthen regulations should be paired with targeted institutional support, capacity-building initiatives, and community-based enforcement mechanisms, particularly in rural areas where state oversight is weaker.

Incentivizing foreign direct investment (FDI) that introduces environmentally friendly technologies remains crucial, especially given the Pollution Haven and Pollution Halo dynamics observed. To avoid short-term environmental degradation from FDI, Botswana must establish clearer environmental performance standards, improve cross-ministerial coordination (International Monetary Fund, 2024), and enforce environmental impact assessments (EIAs) through well-resourced and transparent agencies.

From an equity perspective, policies should deliberately address the disproportionate environmental burdens borne by rural communities, women, youth, and subsistence farmers–groups most affected by climate shocks, land degradation, and resource scarcity (Chikuta et al., 2024; Rankoana, 2024). Participatory governance models and decentralized decision-making can empower these communities to shape local environmental solutions.

These context-responsive measures are essential for Botswana to achieve inclusive and sustainable economic growth while effectively managing CO_2 emissions and environmental degradation in line with Vision 2036, the National Development Plan 12 (NDP12), and Sustainable Development Goals (SDGs), particularly SDG 7 (affordable and clean energy), SDG 9 (industry, innovation, and infrastructure), and SDG 13 (climate action).

These recommendations are supported by evidence from comparable diamond-producing countries. South Africa's Mining Charter (2018) demonstrates that comprehensive regulatory frameworks can achieve significant environmental improvements in mining operations (Government of South Africa, 2018). Similarly, Canada's Metal and Diamond Mining Effluent Regulations have successfully reduced water contamination from mining operations while maintaining economic viability (Environment and Climate Change Canada, 2018). These examples provide practical blueprints for Botswana's policy implementation.

Future research should explore sector-specific impacts of economic activities on environmental degradation and consider other pollutants beyond CO2 to provide a comprehensive understanding of the EKC dynamics in Botswana. Additionally, integrating more advanced econometric techniques such as the Quantile ARDL (QARDL) model could offer deeper insights into the distributional effects of income on environmental quality across different quantiles.

CONFLICTS OF INTEREST

The author declares no conflict of interest

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From Conflict to Cooperation: A Community-led Approach to Farmer-Herder Peacebuilding in Riyom, Plateau State, Nigeria

AUDIO-VISUAL COMMENTARY

YIAVHA
Youth Initiative Against Violence and Human Rights Abuse, Nigeria

This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Community-Led Research Approach

YIAVHA used Community Participatory Action Research (CPAR) to analyze conflict dynamics in Riyom, Plateau State, involving community members as co-creators of knowledge and solutions.

Farmer-Herder Conflict Context

Violence between farmers and herders in Nigeria has become endemic, driven by climate change, resource competition, ethnic tensions, and poor governance responses.

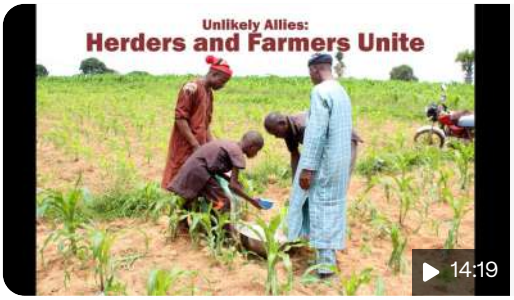
Peacebuilding Through Research

The participatory research process itself became a peacebuilding intervention, fostering relationships and trust between previously hostile groups.

Sustainable Impact

The initiative led to reduced violence, improved dialogue mechanisms, joint farming initiatives, and greater youth involvement in peacebuilding efforts.

WATCH VIDEO ON YOUTUBE



YouTube

From Conflict to Cooperation A Community Led Approac...

The video summarises a study project implemented by the Youth Initiative Against Violence and Human Rights Abuse (YIAVHA), wit...

https://youtu.be/PlIPGyzhRl4

Community-Led Farmer-Herder Peacebuilding in Riyom, Plateau State, Nigeria (Video Credit-YIAVHA)

ABSTRACT

Community Participatory Action Research (CPAR) in peacebuilding is often framed as an approach to ensure that conflict analyses are locally-informed and as means to empower local stakeholders. However, CPAR can also in itself be an approach to building peace. This documentary shows how the Youth Initiative Against Violence and Human Rights Abuse (YIAVHA) used CPAR to analyze conflict dynamics in Riyom, Plateau State, Nigeria, and in the process, lessened the outbreaks of violence between farmers and herders and promoted continued cooperation between groups. This provides further evidence that CPAR itself can act as a form of problem-solving workshop that promotes positive intergroup contact–a finding that has significant implications for peacebuilding efforts around the world.

Keywords: community participatory action research, peacebuilding, farmer-herder conflict, Nigeria, intergroup contact theory, problem-solving workshops

INTRODUCTION

Two of the fundamental principles of peacebuilding are that programs need to be contextually-relevant and designed with input from the stakeholders involved (Lederach 1997; Schirch 2013). This has spurred a host of participatory analysis and design processes ranging from collaborative analysis and community consultations to co-designing peacebuilding interventions with community members (Renoir et al. 2024; Michael et al. 2024; Hill et al. 2024). In many of these, however, the non-governmental organization or donor remains the primary decision-maker. In contrast, community participatory action research (CPAR) embraces community members as co-creators of knowledge (Michael et al. 2024; Renoir et al. 2024). As Hill et al. argue, "only by asking–and actually listening to–members of particular communities can we hope to learn what types of interventions actually change people's lived experiences for the better on a day-to-day basis" (2024, 211). CPAR encourages local knowledge, provides an opportunity for mutual discovery, amplifies voices often sidelined or silenced altogether, and "provides a platform for local actors to participate in real processes of conflict transformation" (Hill et al. 2024, 213). The Youth Initiative Against Violence and Human Rights Abuse's (YIAVHA) *Building Bridges for Peace* project provides a model of not only how to do so, but also how this can be done in a way to also foster relationship-building and promote locally-driven problem-solving workshops in violence-affected contexts (see Figure 1).

Figure 1: Community dialogue sessions bringing together farmers and herders through YIAVHA's participatory research approach

THE HISTORICAL AND SOCIO-POLITICAL BACKGROUND OF VIOLENCE BETWEEN FARMERS AND HERDERS IN NIGERIA

Violent conflicts permeate Nigeria, yet farmer-herder clashes receive insufficient research or state attention. This neglect is especially evident in Riyom LGA, Plateau State, where cyclical violence is exacerbated by state inaction and other conflict issues. This section explains the historical and socio-political roots of this violence in Riyom LGA, placing it within the broader Nigerian context.

Since Nigeria's return to democratic governance in 1999, the country has experienced decades of violence from extremist groups, separatist movements, criminal networks, and ethnoreligious clashes. These conflicts have disrupted livelihoods, displaced hundreds of thousands, reversed economic gains, and inflamed ethnoreligious divisions (Njokwu & Obiukwu, 2025; Ojo, Oyewole & Aina, 2023). While attention often focuses on Boko Haram and other extremist groups (Abdulahi & Mukhtar, 2022; Abdullah, 2019), farmer-herder clashes are among the most destructive, leading to significant displacement, casualties, and livelihood disruption for tens of thousands (Adesola & Akerele, 2025).

Root Causes of Farmer-Herder Conflict

Despite the rising significance of farmer-herder violence over the last decade, the state's response remains largely ad-hoc and, in some areas, nonexistent. This is because the state treats the clashes as mere occupational struggles and communal disturbances that do not threaten Nigeria's territorial integrity or sovereignty (Oginni, 2024; Osasona, 2023). However, farmer-herder violence has claimed as many lives as banditry and insurgency, disrupting rural livelihoods, inducing mass displacement, severing the social fabric (Brottem, 2021), and reconfiguring the demographic landscape of affected communities. Furthermore, this violence and resulting livelihood loss drives victims to turn to banditry for survival (Oginni, 2024).

Although often framed ethnoreligiously or as a struggle for resources, farmer-herder violence is driven by a multitude of factors, including common regional patterns (e.g., climate change and discriminatory land policies) and community-specific issues (Chukwuma, 2020). Recently, the intertwined nature of political, economic, and social factors has become clearer, reinforcing and deepening the clashes. Babatunde and Ibnouf (2024) contend conflicts arise when social relations mobilize to determine resource access, or when rural development initiatives almost exclusively benefit one group. This usually leads to dissatisfaction toward the state and the favored group, serving as an impetus for violent resistance against perceived annihilation and state neglect of their common stake (Egwu, 2016). This situation is particularly dangerous in polarized communities where the actions of municipal actors (state officials, security agencies, traditional rulers, and others) are perceived, rightly or wrongly, to contribute to the unequal distribution of essential resources.

Plateau State Context

In Plateau State, farmer-herder clashes have become endemic over the last two decades. Beyond the general factors, conflicts here are also driven by resource management politics and municipal leaders' decisions that trigger backlashes from specific groups. Clashes are closely associated with decades of indigene-settler divides (Egwu, 2011), which have balkanised communities into separate enclaves where people prefer to reside with those of the same ethnicity and religion. This is exacerbated by categorising farmers as indigenous and herders as settlers, making reconciliation almost impossible and leading to widespread entrenched profiling–one group as complicit and the other as victims–in every attack on the Plateau (Ibrahim & Dabugat, 2016; Sha, 2005). Farmers, often Christian ethnic groups (e.g. Berom, Afizere, Anaguta), claim indigene status, while herders, often Hausa or Fulani, are viewed by many communities and state leaders as settlers. The stalemate in conflict transformation and lack of state security have fueled rising mutual suspicions, disdain, and the proliferation of ethnic militias, neighbourhood watch groups, and vigilantes. The existence of these informal security outfits underscores the Nigerian State's low capacity to exclusively organize violence to safeguard civilians (Tapscott, 2021).

Riyom local government has witnessed unprecedented killings and displacement. These areas have been described as places where violence and property destruction defy peace dialogues, cautions of religious and traditional leaders, and military dexterity (Babatunde & Ibnouf, 2024).

Historical Symbiotic Relationships

Violence between farmers and herders in Riyom LGA is dynamic, featuring periods of violent clashes alternating with tepid peace where underlying conflict factors remain unresolved. In 2024, some communities reported a cessation of open violent clashes, though tensions remained high and violence could return. Lands remain inaccessible to both groups for safe farming, grazing, and living. Furthermore, the lack of a known, deliberate structure for consistent psychosocial support to victims, especially children, poses a potential risk for future insecurity as intolerance may prevail in adulthood. This suggests pessimism overshadows the potential for peaceful coexistence and fair resource access for diverse occupational groups.

While farmer-herder violence has become increasingly commonplace over the last decade, historically, peaceful coexistence was the norm (Higazi 2018). Previously, they had a symbiotic relationship, trading food for natural fertilizer (e.g., cow dung) and relying on traditional mechanisms to resolve conflicts (Bagu and Smith 2017). The introduction of commercial fertilizer and the abandonment of the Cattle Tax in 1980 (which contributed to community development) broke down the social contract and traditional conflict resolution mechanisms between farmers and herders (Bagu and Smith 2017). These changes occurred amidst increasing politicisation of ethnicity, climate change, poor governance, and zero-sum politics post-1999, further eroding and fracturing these relationships.

BUILDING PEACE THROUGH COMMUNITY PARTICIPATORY ACTION RESEARCH

In 2023, YIAVHA launched a peacebuilding program, *Building Bridges for Peace,* in Riyom Local Government Area, a rural area of Plateau State, Nigeria. Riyom LGA had experienced recurring violent conflict between farmers and herders driven by a range of root causes and exacerbating factors (YIAVHA 2024). While the violence was often depicted as between farmers and herders, it intersected and was also shaped by criminality (e.g. banditry), legacies of ethnic politicization, poor governance, weak security, proliferation of arms, and historical grievances between ethnic and religious groups (YIAVHA 2024; IPCR 2017; Mustapha et al. 2018; Higazi 2016). In addition, these conflict factors were compounded by climate change which reshaped which land was fertile and the availability of water sources (YIAVHA 2024; Bagu and Smith 2017). While community members were aware of many of these factors, there was little shared understanding of how they intersected or how different community members viewed them.

CPAR Methodology and Implementation

Youth Initiative Against Violence and Human Rights Abuse (YIAVHA)'s CPAR approach worked with community members from across Riyom LGA to conduct a systems analysis of the conflict dynamics in the LGA. Engaging community members as part of the research team, YIAVHA surveyed 330 community members, conducted 25 key informant interviews, and facilitated 19 community dialogues with a total of 1,033 participants. It is worth noting that in contrast to some peacebuilding approaches that engage key stakeholders and invite them to discussions held at hotels, these activities were primarily done within the communities themselves. This approach provided a real-time analysis of the conflict dynamics, and in the process, built a shared understanding about them and how different community members had experienced them.

330

Community Members Surveyed

Comprehensive data collection

25

Key Informant Interviews

In-depth stakeholder perspectives

19

Community Dialogues

Facilitated group discussions

1,033

Total Participants

Broad community engagement

The participatory nature of the research fostered a common understanding of how the violence affected groups (such as Berom farmers and Fulani herders) and organically identified areas for intervention. Through the CPAR project, influential Berom and Fulani leaders built relationships and trust, enabling them to deescalate tensions by reaching out to each other when conflicts arose, thus preventing violence.

Drawing on its past experience facilitating peacebuilding programs, YIAVHA also examined specific peacebuilding approaches to address the key conflict drivers identified in Riyom. These approaches included joint farming and intergenerational dialogue models, which brought together youth from Berom farmers and Fulani herders communities to counter stereotypes, promote a shared understanding of conflict dynamics, and build lasting relationships. The initiative also incorporated citizens' security meetings as a dialogue mechanism for local power holders to address emerging conflicts across target communities.

IMPACT AND IMPLICATIONS FOR PEACEBUILDING THEORY

Youth Initiative Against Violence and Human Rights Abuse, YIAVHA's *Building Bridges for Peace* was a CPAR initiative analyzing violent conflicts in Riyom LGA, Plateau State. It utilized a systems analysis approach exploring the key factors driving farmer-herder conflict and other violence in Riyom, Nigeria, and how interventions like intergenerational storytelling, joint farming initiatives, exchange visits, and inter-communal dialogues could foster peace and reconciliation. Although primarily research-focused, exploring only the relevance of these peacebuilding activities, the project's participatory approach itself had a positive impact on the communities.

Documented Impacts

An impact evaluation conducted in 2024 found that the Building Bridges for Peace project led to a reduction in violent incidents and farm- and grazing-related conflicts, promoted socio-economics and livelihoods by sparking joint farming initiatives (Figure 2), improved community dialogue and community-driven accountability mechanisms, increased youth involvement in peacebuilding, facilitated greater access to land for safe farming and grazing, and contributed to communities being more open to exchanges with various ethnoreligious groups which are also captured in the documentary (YIAVHA 2024b). These impacts show evidence of how the participatory approach of CPAR initiatives acts as a combination of problem-solving workshops and facilitates relationship-building contact between groups. As d'Estreé has argued, the impact of intergroup contact is stronger when participants have something to collectively work on together - which is exactly what the CPAR offered (d'Estrée 2012). This echoes the importance of problem-solving workshops (Kelman 1972; 2008) and continued relevance of Intergroup Contact Theory (Wagner and Hewstone 2012; Grady et al. 2023) that underlies many peacebuilding approaches.

Reduced Violence

Decrease in violent incidents and farm/grazing-related conflicts

Economic Cooperation

Joint farming initiatives improving livelihoods and relationships

Enhanced Dialogue

Improved community-driven accountability mechanisms

Youth Engagement

Increased youth involvement in peacebuilding activities

Land Access

Greater access to land for safe farming and grazing

Openness

Communities more open to exchanges with different groups

Figure 2: Joint farming initiatives demonstrating cooperation between previously conflicted groups.

CONCLUSION

The CPAR approach utilized by YIAVHA was intended to create a robust and timely understanding of the conflict dynamics and potential responses in Riyom LGA, Plateau State. However, because of the participatory approach, involved community members built relationships and trust with individuals and groups they previously viewed as their enemy. This enabled communication across historic divisions, the establishment of locally-driven conflict resolution mechanisms, and promoted sustained collaborations in the form of joint farming initiatives. In doing so, the act of conducting participatory research itself had a positive impact on peace in Riyom. This study provides further evidence of how CPAR itself offers peacebuilding gains as previously argued by Hill et al. (2024). At a time when resources supporting peacebuilding are on the decline, and there is a global drive for localization, the YIAVHA CPAR model highlights the power of dialogue, community ownership, collective action, intergenerational collaboration, and non-violent coexistence strategies.

CONFLICTS OF INTEREST

The author declares no conflict of interest

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The Youth Initiative Against Violence and Human Rights Abuse (YIAVHA) is a youth-led non-profit organisation founded in 2016 to promote peacebuilding, human rights, and inclusive governance in conflict-affected communities across Nigeria. Through innovative, evidence-based methods such as storytelling, interfaith collaboration, and community engagement, YIAVHA brings together Christian and Muslim youth to disrupt cycles of violence. The organisation has empowered over 5,700 young people through intergenerational dialogue, digital engagement, capacity building, development projects, and legal support for victims of human rights violations. In Plateau State, YIAVHA has successfully transformed conflict between farmers and herders into cooperation through joint farming initiatives, helping rebuild trust and livelihoods. Its intercultural and interreligious dialogue circles provide safe spaces for people from diverse backgrounds to share experiences, heal from trauma, and foster mutual understanding. YIAVHA also works to prevent election violence and amplify youth voices in governance, believing that young people are powerful agents of peace and social change.

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Assessing the Economic Impact of Traditional Agroforestry Practices on Agricultural Sustainability and Climate Resilience in Rural Mexico

RESEARCH ARTICLE

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Traditional Farming Systems

This study examines Mexico's ancient agroforestry systems–Milpa and chinampas–that combine crops with trees and have sustained communities for centuries while preserving biodiversity.

Economic Benefits

Research shows traditional agroforestry systems increase agricultural productivity by 15% and provide greater income stability compared to modern farming methods.

Climate Resilience

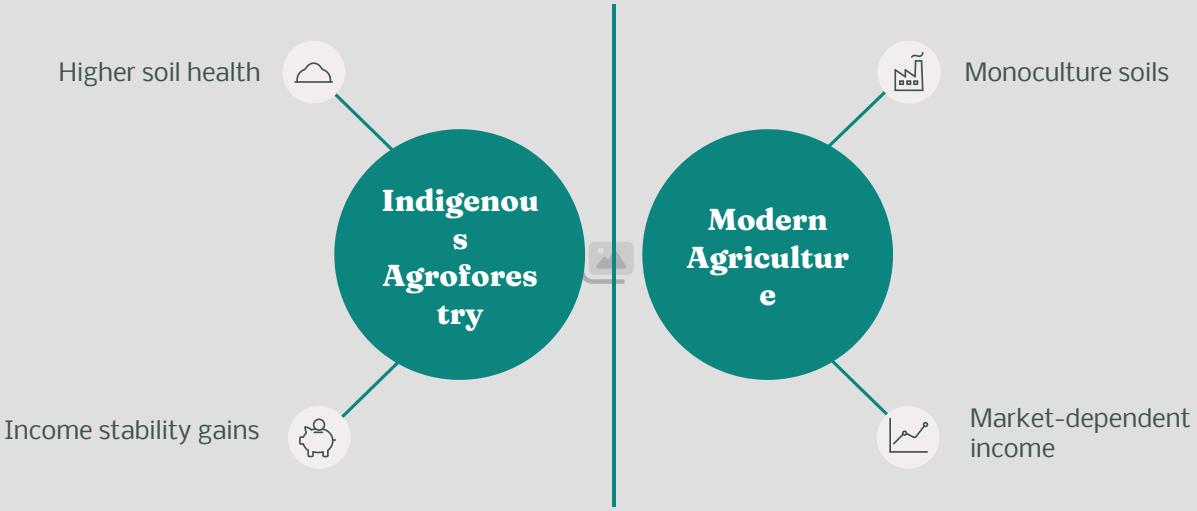
These traditional systems demonstrate 20% greater ability to maintain crop yields during droughts and extreme weather events, making them crucial for climate adaptation.

Policy Implications

The findings suggest traditional agroforestry should be integrated into agricultural policies to promote sustainability, enhance food security, and support rural communities in Mexico.

ABSTRACT

This paper examines the economic impact of traditional agroforestry practices, particularly the Milpa and chinampas systems, on agricultural productivity, income stability, and resilience to climate change in rural communities across Mexico. Using econometric models, including difference -in-differences (DID) and instrumental variable (IV) regression, the study compares the outcomes of farmers who practice indigenous agroforestry versus those who rely on modern agricultural methods. The analysis demonstrates that traditional agroforestry systems significantly enhance soil health, increase biodiversity, and contribute to higher levels of economic resilience in the face of climate variability. Additionally, the paper explores the role of indigenous knowledge in shaping adaptive strategies and building long-term sustainability in agriculture. The findings highlight the potential for scaling up traditional agroforestry practices as a sustainable agricultural model with implications for both local economies and global climate change mitigation efforts.



Keywords: Traditional agroforestry, sustainability, climate resilience, Mexico, Indigenous knowledge

INTRODUCTION

Agroforestry, the practice of integrating trees with crops or livestock on the same land, has long been recognized for its environmental and economic benefits, contributing to sustainable land management (Jose et al., 2021; Kidd & Pimental, 2012; Rosati et al., 2021) (See Figure 1). With increasing global challenges such as climate change, food insecurity, and biodiversity loss, agroforestry has emerged as a crucial solution for promoting environmental resilience, enhancing biodiversity, and improving agricultural productivity. Traditional agroforestry practices, often rooted in indigenous knowledge systems, offer valuable insights into sustainable natural resource management and provide models for adapting to contemporary environmental pressures (Altieri & Koohafkan, 2008).

Figure 1: Traditional Milpa system showing the intercropping in rural Mexico

In Mexico, agroforestry practices are deeply embedded in the nation's agricultural history and cultural heritage. Indigenous communities have long utilized sophisticated agroforestry systems, such as Milpa and chinampas, which exemplify harmonious and sustainable resource management (Gómez-Pompa & Kaus, 1992; Toledo et al., 2003). The Milpa system is a traditional polyculture cropping system that typically intercrops maize, beans, and squash, enhancing soil fertility through nitrogen fixation and reducing the need for external fertilizers. Chinampas, on the other hand, represent an ingenious form of wetland farming–floating gardens built on lakes and canals–which allows for year-round production, high crop diversity, and ecological balance in waterlogged environments (Ezcurra et al., 2006).

The primary purpose of this study is to conduct a comprehensive evaluation of the economic and environmental impacts of these traditional agroforestry systems in rural Mexico. Given the escalating global emphasis on climate change adaptation and sustainable agriculture, understanding how traditional ecological knowledge contributes to the resilience of rural communities and the environment is paramount (Berkes et al., 2000). This research aims to quantify these impacts and provide evidence-based recommendations for integrating traditional practices into modern sustainable development strategies.

LITERATURE REVIEW

Agroforestry, combining trees with crops or livestock, has been extensively studied for its sustainability potential (Kidd & Pimental, 2012; Rosati et al., 2021). Agroforestry systems offer diverse environmental and economic benefits. Traditional agroforestry, rooted in local and indigenous knowledge, is recognized as a resilience model against climate change and ecological degradation (Altieri & Koohafkan, 2008; Gómez-Pompa & Kaus, 1992).

Agroforestry Systems and Their Economic Benefits

Literature demonstrates agroforestry's economic advantages, especially tree-crop integration (Jose et al., 2021; Rosati et al., 2021). It provides multiple income streams, increases productivity, and reduces farmer financial risk by diversifying revenue. Traditional agroforestry often outperforms monoculture in sustainability and profitability (Toledo et al., 2003).

In Mexico, the Milpa system significantly enhances soil fertility by reducing erosion and increasing organic matter (Gómez-Pompa & Kaus, 1992; Reyna-Ramírez et al., 2018). Milpa involves cultivating maize with other crops and perennial woody species. It supports food security, diversifies diet, and generates income from surplus products (Altieri & Koohafkan, 2008).

Hypothesis 1: Traditional agroforestry systems, such as Milpa and chinampas, contribute to increased agricultural productivity and profitability, with lower reliance on external inputs compared to conventional farming systems.

Agroforestry also enhances biodiversity, providing long-term economic benefits for rural communities. Some systems, for example, maintain 122 plant species offering useful products for 14 purposes (Toledo et al., 2003). Nearly 90% of useful plants in these systems are native, representing 54% of all plant species in specific forest types (Ezcurra et al., 2006).

Hypothesis 2: The economic benefits of traditional agroforestry systems are derived not only from higher crop yields but also from the ecosystem services they provide, which reduce long-term agricultural costs.

The Role of Traditional Knowledge in Sustainable Agriculture and Climate Resilience

Traditional ecological knowledge (TEK) is vital for sustainable agriculture and climate change adaptation (Berkes et al., 2000; Toledo et al., 2003). Indigenous communities possess profound understanding of local ecosystems, informing their sustainable land management practices. These practices often include complex agroforestry arrangements inherently resilient to environmental shocks (Altieri & Koohafkan, 2008).

Studies on Mexico's Milpa and chinampa systems exemplify how TEK contributes to ecological balance and community resilience. These systems demonstrate high productivity, maintain biodiversity, and minimize environmental impact (Ezcurra et al., 2006; Gómez-Pompa & Kaus, 1992). They serve as living laboratories for climate change adaptation, offering insights into how diversified, integrated farming mitigates risks from extreme weather events (Reyna-Ramírez et al., 2018).

Hypothesis 3: Traditional ecological knowledge embedded in agroforestry practices significantly enhances the climate resilience of agricultural systems by promoting biodiversity, improving soil health, and diversifying agricultural outputs.

Econometric Approaches in Analyzing the Impact of Indigenous Agricultural Practices

Econometric methods are increasingly applied to analyze the impact of indigenous agricultural practices on productivity and sustainability. These methods quantify the economic outcomes of traditional practices, comparing them to modern agricultural techniques.

Hypothesis 5: Econometric models such as DID and IV regression can effectively quantify the economic benefits of integrating traditional agroforestry practices into modern agricultural systems.

Research Needs and Study Rationale

Despite growing research on agroforestry and traditional ecological knowledge, several gaps remain. Most studies focus on ecological or social aspects, with limited rigorous econometric analysis of the long-term economic impacts and scalability of traditional agroforestry systems. Comparative studies systematically evaluating diverse indigenous practices against conventional systems using robust statistical methods across various socio-economic and environmental contexts are also lacking (Berkes et al., 2000; Toledo et al., 2003).

Furthermore, existing literature often highlights qualitative benefits of traditional knowledge but rarely quantifies its direct contribution to climate resilience and economic stability through empirical models. More research is needed using advanced econometric techniques to disentangle the causal effects of specific traditional practices on farmer income, food security, and environmental indicators. This includes investigating the role of gender, market access, and policy frameworks in modulating these impacts (Altieri & Koohafkan, 2008).

Hypothesis 6: The current literature lacks comprehensive econometric analyses comparing the long-term economic and environmental performance of diverse traditional agroforestry systems with modern agricultural practices across varying contexts.

DATA AND METHODOLOGY

The study primarily uses farm-level data, climate data, and socioeconomic variables to assess the influence of traditional agroforestry practices on agricultural productivity, income stability, and resilience to climate change. To measure the effects of these practices, advanced econometric models, such as Difference-in-Differences (DID) and Instrumental Variable (IV) regression, will be utilized.

Data Sources

- Farm-level data from rural Mexican communities
- Climate data (temperature, rainfall, drought frequency)
- Socioeconomic variables (income, education, land tenure)

Econometric Methods

- Difference-in-Differences (DID) models
- Instrumental Variable (IV) regression
- Panel data models (fixed/random effects)

Key Variables

- Agricultural productivity (crop yields)
- Income stability (variation over time)
- Climate resilience (performance during extremes)

Data Sources

The primary data sources for this study include farm-level data, climate data, and socioeconomic variables collected from rural communities in Mexico. These data will allow for the evaluation of the impacts of traditional agroforestry practices–such as Milpa and chinampas–on various economic and environmental outcomes.

Farm-Level Data: This data will include information on farm characteristics such as the type of agricultural practices used, land area cultivated, crop yields, input costs, and farming techniques. A specific focus will be placed on farmers who practice traditional agroforestry (e.g., *Milpa* and *chinampas*) and those who use conventional farming methods.

Climate Data: Climate data, including temperature, rainfall, and drought frequency, will be sourced from national meteorological agencies. These climate variables will be important for assessing the resilience of agroforestry practices to climate change.

Socioeconomic Variables: In addition to farm-level data, socioeconomic variables will be included in the analysis, such as household income, education level, access to credit, land tenure, and social capital.

3.2. Econometric Methods

To analyze the economic and environmental impacts of traditional agroforestry systems, the study will employ several econometric techniques (as illustrated in Figure 2). These techniques will allow for the estimation of causal relationships between agroforestry practices and the outcomes of interest while controlling for potential biases.

Difference-in-Differences (DID): The DID method will be used to compare the changes in agricultural productivity, income stability, and resilience between farmers who practice traditional agroforestry and those who use conventional farming techniques. The basic DID model can be expressed as:

$$Y_{it} = \alpha + \beta_1 Treated_i + \beta_2 Post_t + \beta_3 (Treated_i \times Post_t) + \epsilon_{it}$$

Where: Yit is the outcome variable, Treatedi is a binary indicator for the treatment group (farmers using traditional agroforestry), Postt is a binary variable for the post-treatment period, and εit is the error term. Traeted$i$ × Post$t$ is the interaction term, capturing the differential effect of traditional agroforestry practices, ϵit is the error term.

Instrumental Variable (IV) Regression: The adoption of traditional agroforestry practices may be endogenous due to factors like unobserved farmer preferences or regional environmental conditions. To address this endogeneity, the study will employ Instrumental Variable (IV) regression.

Panel Data Models: Since the study involves data collected over time, panel data models will be used to account for time-specific and individual-specific effects. Fixed effects and random effects models will be applied to control for unobserved heterogeneity across different farms and over time.

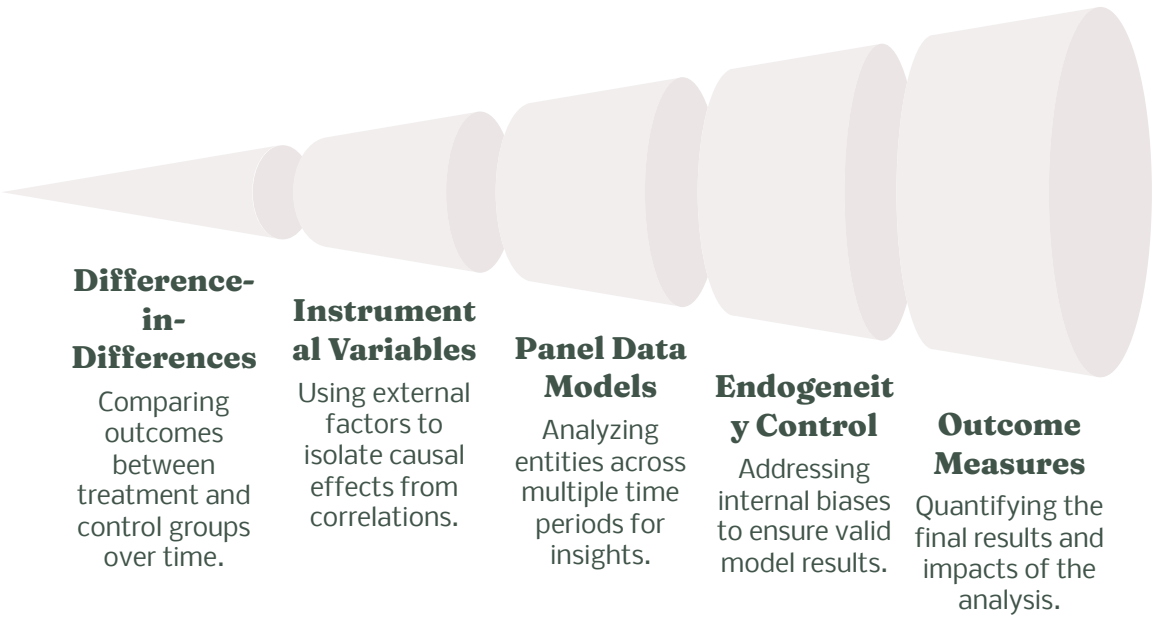


Figure 2: Econometric methodology framework showing the analytical approach for assessing traditional agroforestry impacts

EMPIRICAL ANALYSIS

This empirical analysis assesses the economic and environmental impacts of traditional agroforestry practices on agricultural productivity, income stability, and climate resilience in rural Mexico. It details the econometric models, regression results, and outcome discussion.

Econometric Models and Methodology

To estimate the impact of traditional agroforestry on the outcomes of interest, econometric models are used to identify causal relationships between practices and key economic and environmental indicators (see Figure 3), controlling for endogeneity and potential biases.

Figure 3: Traditional agroforestry productivity showing diverse crop harvests from Milpa systems. Nailotl M.FreePik

Regression Results

The regression results below focus on the impact of traditional agroforestry practices on the key variables of interest.

Agricultural Productivity: The impact of agroforestry adoption is examined using the DID model, with crop yield (kilograms per hectare for maize, beans, and squash) as the dependent variable. Farms adopting traditional agroforestry practices exhibit significantly higher crop yields than those using modern agricultural techniques.

Coefficient of the Interaction Term (β_3): The coefficient is positive and statistically significant (at the 5% level), indicating that agroforestry adoption increases crop yields by approximately 15% compared to modern farming practices.

Income Stability: Income stability is measured by the standard deviation of household income over time. The results from the DID and IV models indicate that traditional agroforestry practices significantly reduce income volatility compared to conventional farming techniques.

Coefficient of the Interaction Term: The coefficient for the interaction term in the DID model is negative and statistically significant at the 1% level, implying that farmers practicing traditional agroforestry experience a 12% reduction in income volatility compared to those using modern agricultural methods.

Climate Resilience: The analysis of climate resilience focuses on the ability of farms to maintain productivity during extreme weather events, such as droughts or floods. The climate resilience variable is constructed by examining changes in crop yields during periods of extreme weather.

Coefficient of the Interaction Term: The interaction term is positive and statistically significant, with agroforestry adoption leading to a 20% greater ability to maintain crop yields during drought conditions.

The complete regression results are detailed in Table 1.

Table 1: Impact of Traditional Agroforestry Adoption on Key Economic and Environmental Outcomes

Model	Outcome	Coefficient (β)	Std. Error	t-Statistic	p-Value
DID	Productivity	0.15	0.05	3.00	0.003
IV	Productivity	0.14	0.06	2.33	0.021
DID	Income Stability	-0.12	0.03	-4.00	0.000
IV	Income Stability	-0.11	0.04	-3.25	0.002
DID	Climate Resilience	0.20	0.08	2.50	0.015
IV	Climate Resilience	0.19	0.09	2.11	0.037

RESULTS AND DISCUSSION

The results of the econometric analysis provide valuable insights into the economic and environmental impacts of traditional agroforestry practices in rural Mexico. The study focused on comparing the outcomes of farmers practicing traditional agroforestry techniques, such as Milpa and chinampas, to those using modern agricultural practices.

Interpretation of the Results

Agricultural Productivity: The econometric analysis clearly shows that traditional agroforestry systems outperform modern agricultural methods in terms of agricultural productivity. The DID model results indicate that farms practicing traditional agroforestry exhibit an approximately 15% higher crop yield compared to farms using modern farming techniques.

This finding is consistent with the hypothesis that agroforestry systems, such as Milpa and chinampas, contribute to higher productivity due to their ability to enhance soil fertility, reduce the need for chemical inputs, and support biodiversity (Rosati et al., 2021).

15%

Productivity Increase

Higher crop yields with traditional agroforestry

12%

Income Stability

Reduction in income volatility

20%

Climate Resilience

Better drought resistance

122

Plant Species

Maintained in agroforestry systems

90%

Native Plants

Of useful plants are indigenous

Income Stability: The results on income stability also show that agroforestry systems contribute to greater economic resilience for farmers. The DID model estimates a 12% reduction in income volatility for farmers practicing traditional agroforestry compared to those using modern agricultural practices.

The reduced income volatility is likely a result of the diversification provided by agroforestry systems (Banerjee et al., 2016; Elagib & Al-Saidi, 2020; Pretty & Bharucha, 2014). Unlike modern monoculture farming, agroforestry systems produce a variety of crops and products (e.g., fruits, vegetables, timber, and medicinal plants), which help buffer farmers from income shocks caused by market fluctuations or crop failures (Lasco et al., 2014).

Climate Resilience: The analysis of climate resilience shows that traditional agroforestry practices provide greater resilience to climate variability, such as droughts and floods (Altieri et al., 2015). The DID model estimates that agroforestry adoption leads to a 20% greater ability to maintain crop yields during extreme weather events.

This finding is particularly relevant in the context of increasing climate uncertainty (Harvey et al., 2018; Tirado et al., 2010), as it suggests that agroforestry practices may help mitigate the impacts of extreme weather events on agricultural production. The resilience observed in chinampas, which thrive in waterlogged conditions and had very high crop yields with up to 7 harvests a year (Gonzalez et al., 2010), exemplifies the role of indigenous knowledge in designing farming systems that are well-adapted to local environmental conditions.

Implications for Rural Mexican Communities

The findings of this study have important implications for rural communities in Mexico, particularly in the context of sustainability and economic resilience. The results suggest that traditional agroforestry systems offer several advantages over modern agricultural practices, including higher agricultural productivity, reduced income volatility, and increased resilience to climate variability.

Promoting Sustainability

Traditional agroforestry systems are more sustainable than modern farming practices, as they reduce the reliance on chemical inputs, maintain soil fertility, and promote biodiversity.

Enhancing Economic Resilience

The reduction in income volatility associated with agroforestry adoption suggests that traditional farming systems can help protect rural communities from economic shocks (Abdul-Salam et al., 2022).

Role of Indigenous Knowledge

This study highlights the crucial role of indigenous knowledge (Urriago-Ospina et al., 2021) in shaping adaptive agricultural practices rooted in centuries of traditional ecological wisdom (Guibrunet et al., 2023).

Climate Adaptation

The enhanced climate resilience makes traditional agroforestry particularly valuable for adaptation to changing environmental conditions.

POLICY IMPLICATIONS AND RECOMMENDATIONS

The findings of this study underscore the importance of integrating traditional agroforestry practices into national agricultural policies (Simelton et al., 2017), particularly in the context of sustainability, climate resilience, and rural development in Mexico. Policymakers should prioritize the promotion of agroforestry systems, such as Milpa and chinampas, to enhance agricultural productivity, diversify income sources, and build resilience to climate change.

01

Financial Support Programs

Government initiatives should provide incentives for farmers to adopt traditional agroforestry practices through subsidies, grants, or low-interest loans for transitioning to sustainable systems.

02

Knowledge Integration Platforms

Collaborative platforms that bring together indigenous farmers and scientific researchers can foster the exchange of knowledge, leading to more effective and culturally appropriate agricultural solutions.

03

Climate Adaptation Policies

Integrating traditional agroforestry practices into climate change adaptation policies should be a priority, given their ability to buffer farmers against extreme weather events (Lasco et al., 2014).

04

Training and Education

Educational initiatives should focus on the benefits of agroforestry, best practices for integrating trees with crops, and techniques for enhancing soil health and water management.

05

Land Tenure Security

Policies that strengthen land tenure rights, particularly for smallholder farmers and indigenous communities, will encourage long-term investment in sustainable land management practices (Nkomoki et al., 2018).

By supporting traditional agroforestry systems and empowering rural communities, these policy recommendations can help ensure a more sustainable and resilient agricultural future for Mexico.

CONCLUSION

This study provides compelling evidence that traditional agroforestry practices, such as Milpa and chinampas, offer significant economic and environmental benefits in rural Mexico. Through the use of econometric models, including DID and IV regression, the analysis demonstrates that traditional agroforestry systems outperform modern agricultural methods in terms of agricultural productivity, income stability, and resilience to climate change.

The results indicate that farms practicing traditional agroforestry achieve higher crop yields, experience greater income stability, and are more resilient to climate variability, such as droughts and floods. These findings highlight the multifaceted advantages of agroforestry, not only in enhancing productivity but also in fostering long-term sustainability and economic resilience.

The ability of traditional agroforestry systems to maintain soil fertility, enhance biodiversity, and reduce input costs makes them a valuable model for sustainable agriculture in the context of climate change. The milpa system involves the cultivation of maize along with other crops and perennial woody species, supporting food security, diversifying the diet, and generating income from surplus products while maintaining 122 plant species that provide useful products for 14 different purposes.

Furthermore, the role of indigenous knowledge in shaping adaptive agricultural practices is crucial. The success of Milpa and chinampas underscores the importance of integrating traditional ecological knowledge with modern scientific practices to address contemporary sustainability challenges.

The policy recommendations derived from these findings emphasize the need for government initiatives that promote traditional agroforestry systems, empower local communities, and integrate agroforestry into climate change adaptation strategies. By supporting the widespread adoption of agroforestry, strengthening land tenure rights, and investing in capacity-building programs, policymakers can enhance the sustainability and economic resilience of rural Mexican communities.

CONFLICTS OF INTEREST

The author declares no conflict of interest

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Bridging Knowledge Worlds: Integrating Local Climate Adaptation Practices with Scientific Research in Southeastern Nigeria

RESEARCH ARTICLE

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Climate Challenge

Nigeria's economy is heavily dependent on agriculture, with the majority relying on subsistence farming. Longer dry spells in northern regions and unpredictable rainy seasons in the south threaten agricultural productivity.

Indigenous Wisdom

Indigenous communities in southeastern Nigeria have developed sophisticated ecological knowledge over centuries to cope with environmental stressors, living in harmony with their environment.

Bridging Knowledge Systems

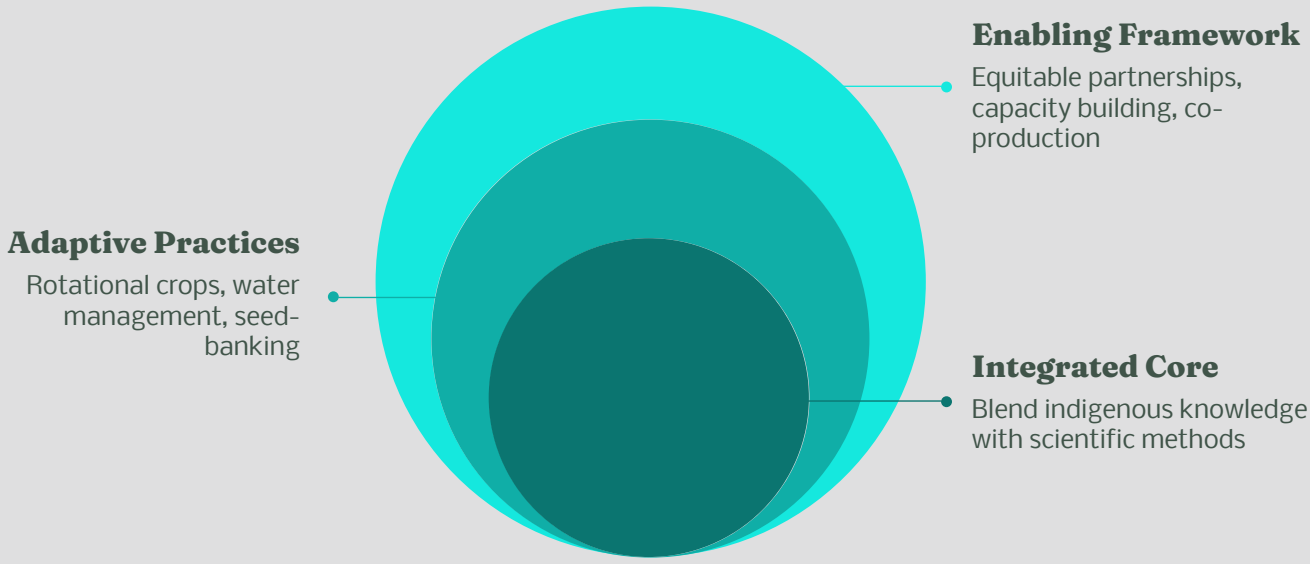
This study explores how bridging indigenous knowledge with scientific knowledge can enhance climate adaptation strategies for rural communities facing environmental challenges.

Collaborative Solutions

The research proposes frameworks for equitable partnerships that emphasize capacity-building, inclusive governance, and knowledge co-production for long-term socio-ecological sustainability.

ABSTRACT

This article explores how local and indigenous knowledge in Southeastern Nigeria can be effectively integrated with scientific approaches to improve climate adaptation strategies and foster sustainability. While formal scientific research has largely shaped the global climate agenda, indigenous resource management practices have evolved over centuries to address environmental fluctuations and hazards. However, significant power imbalances often sideline local communities from meaningful engagement in policy and research collaboration. Drawing on qualitative fieldwork, participatory rural appraisal methods, and quantitative climate modeling, this study investigates how traditional ecological knowledge, gleaned from farmers, fishers, and community elders, can enhance scientific methods for climate resilience. Findings illustrate that local practices such as rotational crop selection, water resource management, and communal seed-banking offer valuable insights to complement advanced modeling techniques, especially in mitigating extreme weather events and adapting to shifting precipitation patterns. Additionally, a robust framework for equitable partnerships is proposed, emphasizing capacity-building, inclusive governance, and knowledge co-production. The article concludes by stressing that efforts to bridge power differentials and integrate epistemic perspectives hold tremendous promise for achieving long-term socio-ecological sustainability in the Global South.



Keywords: climate adapatation, indigenous knowledge, traditional ecological knowledge, participatory research methods, southeastern Nigeria, knowledge co-production

INTRODUCTION

Global climate change poses one of the most pressing challenges for contemporary societies, disproportionately impacting vulnerable regions such as Sub-Saharan Africa. The challenges of climate change are not the same across all geographical areas of Nigeria due to two precipitation regimes: high precipitation in parts of the Southeast and Southwest and low in the Northern Region. Rising sea levels, fluctuating rainfall, higher temperatures, flooding, droughts, desertification, land degradation, and extreme weather events are all contributing factors. (Leal Filho et al., 2023) Southeastern Nigeria, characterized by a tropical climate, complex river systems, and agriculturally dependent communities, faces increasing threats from shifting rainfall patterns, periodic flooding, and soil degradation (IPCC, 2021). While scientific research plays a critical role in quantifying these threats and proposing technological solutions, local and indigenous communities have historically developed sophisticated forms of ecological knowledge to cope with environmental stressors, living in harmony with their environment and believing that everything in nature serves a particular purpose (see Figure 1 for an illustration of traditional knowledge transfer in these communities).

Nigeria's economy is highly dependent on agriculture, primarily subsistence farming (including crops like maize, cassava, yams, millet, and livestock). This sector is highly vulnerable to climate change. Climate challenges, such as longer dry spells in northern regions and unpredictable rainy seasons in the south, threaten agricultural productivity. The resulting difficulty in planning for reliable rainfall leads directly to crop failures, increased poverty, and food shortages.

Figure 1: Traditional knowledge transfer in southeastern Nigerian farming communities. Pixel

The tension between global scientific knowledge and local practical wisdom reflects broader imbalances in power and epistemic authority. Policy agendas and research funding are predominantly steered by institutions in the Global North, potentially overlooking region-specific experiences and indigenous coping mechanisms. (Okedele et al., 2024) The concept of "bridging knowledge worlds" refers to the idea of creating synergistic spaces where local and scientific knowledge systems can co-exist, inform each other, and co-produce evidence-based solutions for sustainability. This paper examines the processes, outcomes, and policy implications of such a collaboration, focusing on Southeastern Nigeria as a case study.

This research aims to highlight how indigenous strategies can refine and enrich scientific insights while also illustrating the institutional and political challenges of establishing equitable partnerships. A mixed-methods approach, involving both qualitative and quantitative tools, was employed to capture the complexity of local environments and experiences. This study is organized into several sections. Following this introduction, the second section reviews relevant literature on indigenous knowledge, participatory methods, and climate resilience. The third section outlines the methodology, while the fourth section provides an overview of the study context and data collection procedures. The fifth section details the results, followed by a discussion in the sixth section on bridging knowledge systems. The final section concludes with recommendations for policymakers, researchers, and local stakeholders, advocating for more collaborative and inclusive climate adaptation frameworks.

LITERATURE REVIEW

Indigenous Knowledge and Climate Adaptation

Indigenous knowledge represents an evolving body of understandings, skills, and philosophies developed by local communities over extended periods, often through direct interaction with nature (Agrawal, 1995). Indigenous Peoples are custodians of unique knowledge systems, innovations and practices that have been passed down through generations, allowing different cultures to live sustainably. Many Indigenous traditional practices are rooted in deep understanding of and respect for ecological systems and promote sustainable resource use with minimal environmental impact. In climate adaptation, IK includes strategies like diversified cropping, controlled burning, agricultural rituals, and water-harvesting techniques tailored to specific ecological conditions (Berkes, 2012).

While conventional scientific research offers macro-level climate models, it often overlooks the socio-cultural factors influencing community responses. Indigenous knowledge is dynamic, rooted in a deep involvement with nature, and is now recognized as capable of adapting to new conditions and generating robust, context-specific solutions when integrated with scientific insights (Chambers, 1994).

Participatory Approaches in Knowledge Production

Recognizing the limitations of top-down interventions, participatory approaches have gained traction in development studies and climate adaptation research. Participatory Rural Appraisal (PRA) and its variants seek to involve community members in every stage of the research cycle, from identifying problems to co-creating solutions (Chambers, 1994). By embedding local perspectives and priorities into research design, such methods help level power asymmetries and foster mutual learning.

This collaborative model is especially valuable in climate adaptation, where success depends not only on ecological or technological feasibility but also on social acceptance and cultural resonance. The social networks and institutions of indigenous communities enable collective action which strengthens reciprocal relationships. Communities maintain their traditional ecological knowledge through cultural festivals and oral traditions passed from generation to generation, serving as a practical tool that helps adapt to climate risks and promotes socio-ecological resilience. However, ensuring these processes are truly inclusive requires significant time, resources, and institutional commitment.

Bridging Power Imbalances in Research Collaboration

Policymakers, researchers, and practitioners seem to underplay the role of indigenous knowledge in climate change adaptation and disaster risk reduction, thereby reducing the effectiveness of proposed climate actions and risk reduction measures. Global imbalances in knowledge systems are partly rooted in systemic inequalities in funding, agenda setting, and peer-reviewed publication opportunities. Researchers from high-income countries often direct the scope and methodology of climate studies in the Global South, potentially marginalizing local priorities. Efforts to correct this imbalance include multi-stakeholder partnerships, capacity-building initiatives, and policy frameworks that center local agency (Scoones, 1998).

In Southeastern Nigeria, where local ecosystems are as varied as they are fragile, bridging these imbalances is crucial for building climate resilience. Moreover, the historical legacies of colonial administrative structures and externally driven development programs can complicate the reception and implementation of new scientific approaches. When indigenous knowledge is validated and integrated into formal research processes, communities are more willing to adopt complementary innovations and share responsibility for adaptation measures.

METHODOLOGY

Study Design

This study adopts a mixed-methods approach, combining qualitative and quantitative components to capture the multidimensional nature of climate adaptation. The research design is grounded in Community-Based Participatory Research (CBPR) principles, ensuring that local perspectives guide data collection, analysis, and dissemination. By converging scientific modeling with indigenous knowledge, the research aims to produce findings that are both empirically robust and socially relevant (Adger, 2006) (Ayanlade et al., 2023).

Qualitative Methods

Qualitative data were gathered through focus group discussions, in-depth interviews, and participatory observation. Focus groups were held with smallholder farmers and fisherfolk across three local government areas in Southeastern Nigeria. A semi-structured interview guide covered questions regarding seasonal changes, water management practices, and community coping mechanisms. Field notes and audio recordings were transcribed and coded, using thematic analysis to identify patterns and divergences. This process illuminated the relationship between adaptive strategies and socio-cultural norms, including how resource access and land ownership intersect with climate vulnerability.

Quantitative Methods

Quantitative methods centered on downscaled climate modeling and basic statistical analyses of rainfall and temperature patterns. Climate data from the ERA5 dataset (IPCC, 2021) were used to generate localized projections for mean annual rainfall, temperature fluctuations, and the frequency of extreme weather events (e.g., extended dry spells). This modeling was cross-referenced with agricultural yield data and community-level reports of crop loss to create a more holistic picture of risk exposure and adaptive capacity. Statistical significance was determined by standard thresholds ($p < 0.05$), although the study emphasizes that social context is equally crucial in interpreting these results.

Ethical Considerations

All research activities were conducted in alignment with institutional review board (IRB) guidelines and local ethical standards. Participants were briefed on the objectives and potential outcomes of the study, with informed consent obtained orally and in writing where applicable. Confidentiality was preserved by anonymizing personal identifiers in transcripts and publications. Additionally, the participatory nature of the research ensured that community members had a say in how findings would be shared, both within and beyond their locality.

STUDY CONTEXT AND DATA COLLECTION

Regional Profile: Southeastern Nigeria

Southeastern Nigeria's ecology is characterized by dense rainforest zones, rolling hills, and a network of rivers that sustain local fishing and agriculture. The region's climate is bimodal, featuring a lengthy rainy season and a relatively short dry period. However, in recent years, irregular precipitation has led to flooding and soil erosion in low-lying areas, while drought-like conditions have been observed in upland zones. Poverty rates remain high in certain rural pockets, where infrastructural deficits and limited access to formal financial mechanisms exacerbate vulnerability.

Rural livelihoods predominantly revolve around cassava, yam, maize, and various vegetables, with households often practicing mixed cropping systems. Fisheries in local rivers and ponds also contribute to livelihoods, especially during the rainy season when fish stocks are typically replenished. Traditional cultural practices, including community festivals and rites, often revolve around agricultural cycles, reinforcing communal resource management.

Fieldwork and Data Collection Procedures

Fieldwork spanned nine months, starting with a pilot phase that helped refine the interview guides and establish trust with community leaders. Local stakeholders, including village heads and women's group representatives, facilitated introductions and provided context on customary rules for resource management. Approximately 120 participants took part in focus group discussions, stratified by gender and age to capture diverse perspectives. These discussions were held in communal spaces, such as school compounds and village meeting halls, to ensure accessibility.

In-depth interviews were conducted with 35 key informants identified as having specialized knowledge of local resource management. These included elders recognized for their expertise in reading seasonal weather patterns, farmers experimenting with new seed varieties, and individuals responsible for communal water distribution. Interviews typically lasted 60-90 minutes and probed deeper into the decision-making rationale behind adaptation measures.

On the quantitative side, daily rainfall and temperature records from 2000 to 2020 were sourced from the ERA5 dataset, supplemented by additional station data from the Nigerian Meteorological Agency (NiMet). The aggregated dataset was then used to generate short- and medium-term climate scenarios (up to 2040), focusing on projected changes in precipitation intensity and average temperature levels. These projections were mapped against local agricultural calendars to assess alignment or discrepancies with indigenous interpretations of climate cues.

RESULTS

Complementarities Between Local and Scientific Knowledge

The analysis reveals strong complementarities in certain areas of climate adaptation. Indigenous people predict weather with signs of warning using social, bio-physical and ecological indicators. They pay attention to behavior and appearance of various environmental entities like insects, plants, birds and animals, moon-star alignment, animal intestine interpretation, and tide flow and direction of currents. (Fabiyi & Oloukoi, 2013) For instance, local communities rely on rain pattern observation and the arrival of certain migratory birds to predict oncoming seasonal shifts, aligning closely with observed changes in the precipitation records. While remote sensing technologies and climate models can provide predictive indicators several months ahead, the communities' on-the-ground observations offer immediate and context-specific cues, valuable for short-term response measures such as planting or harvest adjustments.

Similarly, local resource management practices, such as fallow rotation and seed exchange networks, resonate with scientific recommendations on biodiversity conservation. Researchers have long advocated crop diversification as a means to minimize risk, and the indigenous practice of rotating farmland plots emerged as a strategy that aligns with modern ecological principles (Folke, 2006).

Adaptive Practices in Water Resource Management

One of the most striking findings centers on water resource management. Many rural communities that experience water scarcity utilize several traditional methods of rainwater harvesting to store and conserve water for domestic and irrigation purposes. Such traditional skills have been passed down from generation to generation and have contributed to boosting food security. Many communities in Southeastern Nigeria operate rotational water-sharing systems, governed by customary authorities who establish usage schedules and maintain communal infrastructure. In a context of limited public irrigation facilities, these local protocols effectively distribute scarce resources during dry spells. Statistical analysis showed that areas with such protocols experienced significantly lower rates of crop failure compared to nearby zones lacking comparable communal systems ($p < 0.05$). Further, the synergy between communal resource management and modern water conservation techniques–suchs as small-scale drip irrigation–highlights the potential for integrated approaches to tackle water scarcity.

Perceived Gaps in Research and Policy

Despite the noteworthy overlap, several gaps and tensions remain. Local communities frequently criticized external researchers for not returning results or engaging in long-term partnerships, echoing wider concerns about extractive research practices (Sillitoe, 1998). Additionally, although climate modeling can capture large-scale trends, communities highlighted the unpredictability of localized climatic events such as flash floods, which remain challenging to integrate into predictive models. Government policies often lack meaningful consultation processes, resulting in adaptation measures that may be technologically advanced but socially or culturally misaligned with local needs.

Knowledge Complementarities

- Local weather prediction through natural indicators
- Traditional crop rotation aligning with biodiversity science
- Indigenous water management supporting modern conservation

Research Challenges

- Extractive research practices without community feedback
- Limited integration of localized climatic events
- Policy misalignment with cultural contexts

DISCUSSION: BRIDGING KNOWLEDGE WORLDS

Institutional Pathways to Equitable Collaboration

The findings underscore that bridging knowledge systems requires more than simply appending local practices to scientific models. True integration involves systemic change in how research agendas are formulated, funded, and evaluated. Academic institutions and policy bodies must adopt collaborative frameworks that empower communities to define research priorities, rather than merely validating external assumptions. (Acharya & Prakash, 2025) Ethical research partnerships that prioritize reciprocity and mutual capacity-building can serve as catalysts for more sustained and meaningful collaboration (Adger, 2006).

Co-Production of Knowledge as a Route to Sustainability

Co-production involves the joint production of knowledge by experts and non-experts, drawing on the strengths of both. In the current context in Nigeria, the combination of scientific and local knowledge would facilitate real-life understanding of experiences, risks, and adaptation strategies. Such a combination could be applied to methodology and approaches that complement each other. In the Southeastern Nigerian context, fostering co-production means ensuring that community elders and female farmers–who often hold specialized insights–are active participants in methodology design and data interpretation. Participatory mapping, for example, can merge indigenous place names and resource boundaries with geographic information system (GIS) data, leading to more precise interventions. By centering local voices in the knowledge production process, scientists can more accurately model risks and propose adaptation strategies that communities are likely to adopt.

Policy Implications

For policymakers, an integrated approach to adaptation demands institutional support for local governance structures. This includes recognizing customary laws governing land tenure and water usage, providing legal backing to communal seed-banking initiatives, and allocating resources for small-scale infrastructure improvements. Many livelihood activities are gender differentiated, and thus, so is indigenous and traditional knowledge. In Nigeria, men engage in firewood collection and charcoal production and are concerned about impacts on forests, whereas women collect seeds and herbs and practice agroforestry. Ensuring equitable representation of women and marginalized groups in formal decision-making forums is equally critical, as these individuals often have unique perspectives and face distinct vulnerabilities.

On a broader scale, cross-border collaborations–both within the West African subregion and globally–could facilitate the exchange of successful adaptation models. Enhanced funding mechanisms specifically geared toward projects that embed co-production could also reduce systemic disparities in research. Lastly, more inclusive forms of peer review and publication could allow indigenous community members to share their knowledge on platforms traditionally dominated by formal academia.

CONCLUSION

This article demonstrates that integrating local and indigenous knowledge with scientific research can offer a powerful route to climate adaptation and sustainability in Southeastern Nigeria. Traditional ecological knowledge and cultural heritage play significant roles in climate change adaptation and disaster risk reduction in Nigeria, and across many other sub-Saharan African countries. Traditional ecological practices, deeply rooted in communal governance and keen environmental observation, effectively complement advanced climate modeling and data analysis. Nonetheless, persisting power asymmetries and historical legacies continue to shape interactions between local communities, researchers, and policymakers. Addressing these imbalances requires a commitment to equitable partnerships, capacity-building, and institutional recognition of diverse epistemologies.

The research presents a framework for bridging knowledge worlds, emphasizing the importance of participatory methods, reciprocal knowledge-sharing, and co-production. The combination of scientific and local knowledge facilitates real-life understanding of experiences, risks, and adaptation strategies, particularly when methodologies complement each other. Future work should explore the scalability of these approaches across different ecological zones, as well as long-term monitoring of outcomes. Moreover, the principles identified here have broader relevance beyond Southeastern Nigeria, resonating with global efforts to make climate adaptation more inclusive, context-specific, and socially just. By focusing on synergy rather than hierarchy in knowledge systems, policy actors and researchers alike can foster more effective and resilient strategies for navigating the uncertainties of a changing climate.

CONFLICTS OF INTEREST

The author declares no conflict of interest

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Do Voluntary Sustainable Standards Induce Systems Change? Evidence from Sustainable Cotton Farming in Pakistan

REVIEW

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

The Core Question

Do **Voluntary Sustainable Standards (VSS)** truly drive systemic change, or just minor, isolated improvements in industries?

Case Study Focus

This research investigates the impact of the **"Better Cotton"** program on cotton farming in **Pakistan**.

Key Findings & Implications

Positive Changes

Better Cotton brought some **positive changes** and increased **awareness** to Pakistani farms.

Complexity of Change

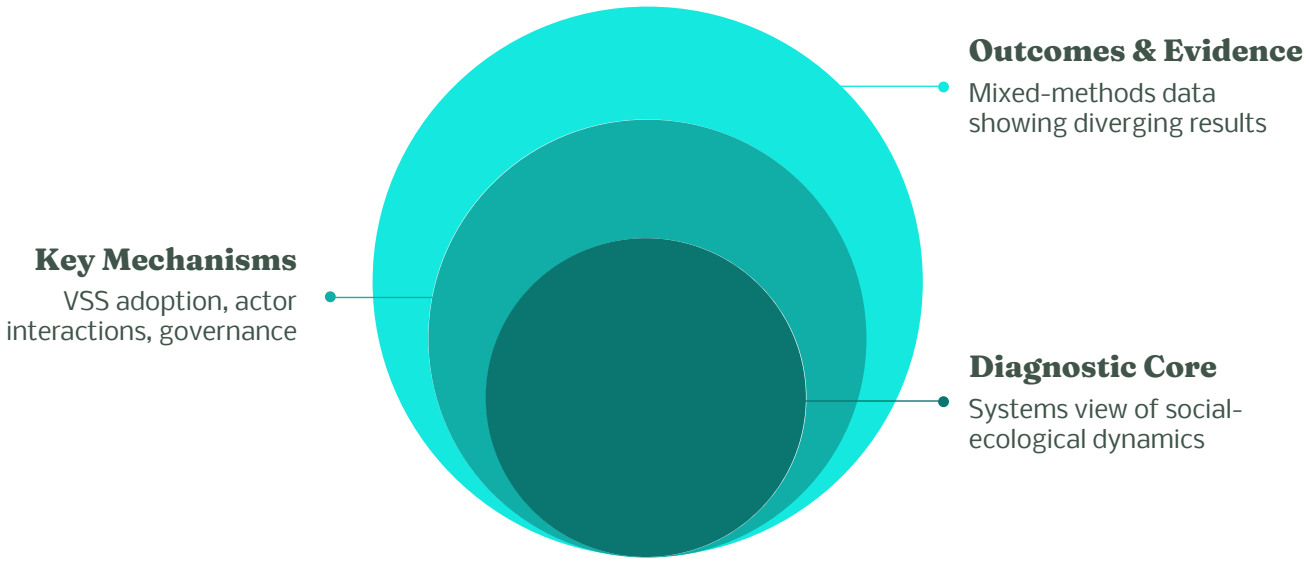
Achieving **comprehensive "systems change"** is far more complex than simply implementing voluntary standards.

Holistic Approach Needed

Sustainability initiatives must consider **wider issues beyond the farm level** for lasting transformation, focusing on entire systems.

ABSTRACT

In the study of natural resource use, ecological variables and human activities have been widely analysed to answer the most pressing concerns regarding the future of sustainability. In recent times, a new school of thought has emerged that proposes the idea of applying systems thinking to holistically understand and analyse complex problems related to natural resource use. This approach is based on viewing a system as a whole, and studying the intertwined nature of different components in a system to evaluate the outcomes. By leveraging the systems approach, this study uses a diagnostic social-ecological systems framework to explain the diverging economic and environmental outcomes between conventional and sustainable cotton farmers in Pakistan. The study goes beyond the usual application of linear approaches in evaluating success of voluntary sustainable standards (VSS) in cotton farming to determine causation rather than identifying it. Using a mixed methods approach, data is collected from semi-structured interviews and Better Cotton farm results report (2015-2020) to identify the key factors and their interactions that determine sustainable outcomes. The study found out that this achievement is attributed to second-tier variables from governance systems and crucial interactions with the actors that are facilitated by the adoption of VSS in cotton farming.



Keywords: social-ecological systems, voluntary sustainable standards, cotton farming, systems change.

INTRODUCTION

Cotton has long been pivotal to Pakistan's economy, with cultivation dating back to ancient times. Today, Pakistan is the world's fifth-largest cotton producer and ranks fourth in cultivated area (Food and Agriculture Organization of the United Nations, 2025; International Cotton Advisory Committee, n.d.). As a major cash crop, cotton serves as a raw material for the textile industry. This industry employs 17% of the nation's workforce, generates 60% of foreign exchange revenue, and accounts for 8.5% of the national gross domestic product (Rana et al., 2020). To meet textile industry demand and boost cotton production, farmers often use intensive land-use practices. Despite this, the country ranks 41st globally in cotton yield. Researchers link this yield gap to technical, economic, and allocative inefficiencies. Key reasons include unfavorable weather, lack of education, insufficient credit access, and limited government extension services (Wei et al., 2020; Shafiq & Rehman, 2000). As shown in Figure 1, collaborative approaches to education and knowledge sharing are essential for implementing sustainable farming practices.

Intensive land-use in cotton farming creates significant environmental challenges. These are typically associated with excessive use of water, synthetic fertilizers, and pesticides. Consequences include soil health deterioration, pollution of neighboring ecosystems (like water streams and biodiversity), and increased greenhouse gas (GHG) emissions (Memon et al., 2019; Azizullah et al., 2011). Conversely, agriculture, especially cotton farming, is also vulnerable to climate change. Extreme weather, and changes in pests or diseases directly impact crop productivity. This paradox highlights the sector's importance and drives policymakers to seek reliable solutions.

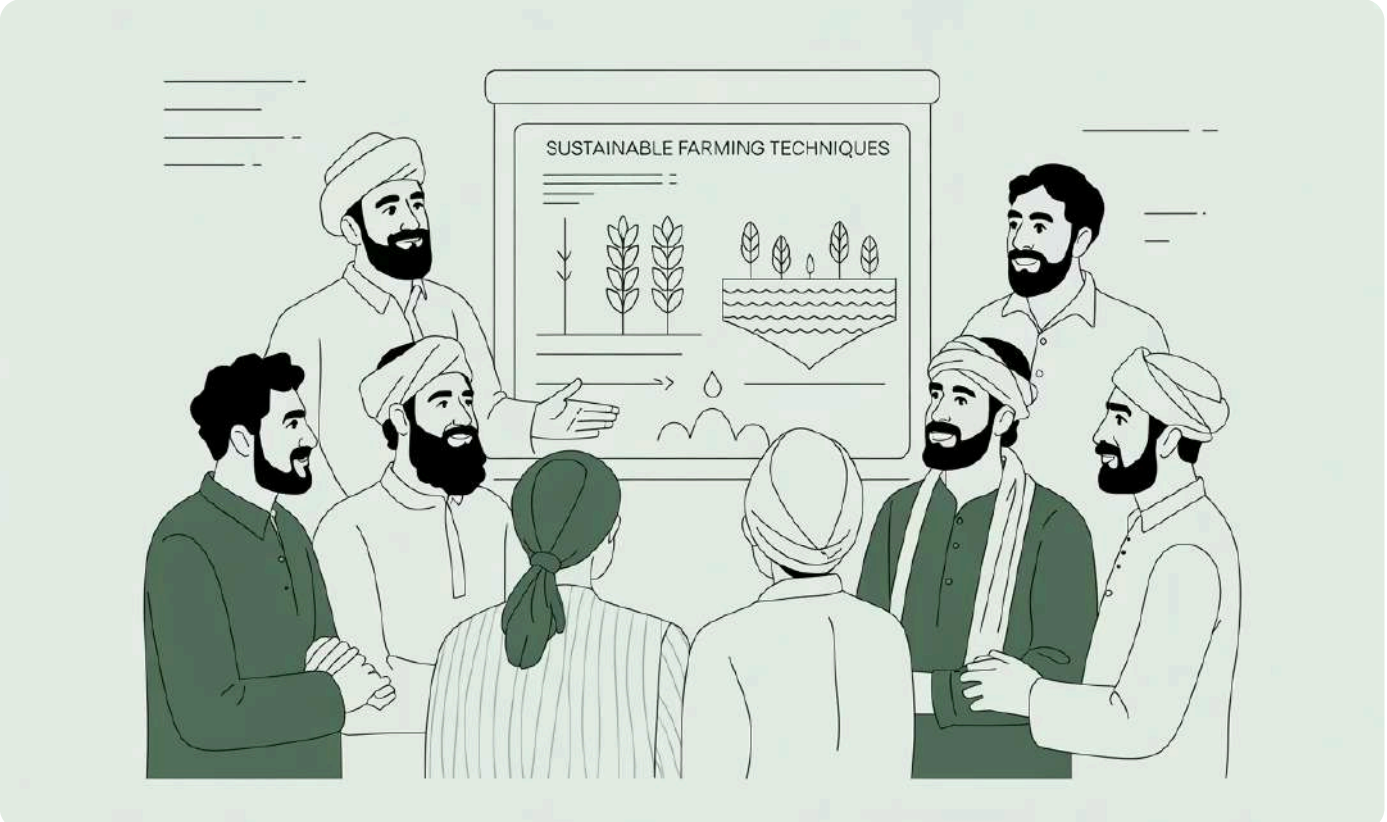


Figure 1: An Illustration of Pakistani farmers discussing sustainable farming techniques.

One such potential solution is the adoption of sustainable agriculture practices, especially in the case of developing countries due to their significant dependence on this sector (Yohannes, 2015). According to Food and Agriculture Organization of the United Nations, sustainable agriculture is based on five components: i) meeting the present and future needs for products and services while ensuring ii) profitability iii) non-degradation of environment iv) social equity and v) economic equity (Food and Agriculture Organization of the United Nations, 1988, as cited in Lee, 2005).

Acknowledging these opportunities resulting from and threats to agriculture, Pakistan has made substantial efforts in embracing sustainable agriculture practices for production of cotton. There are several organizations working countrywide to promote these practices through the implementation of voluntary sustainable standards (VSS). Some of the major organizations include Better Cotton, Organic Cotton Accelerator and Responsible Environment Enhanced Livelihood cotton program that serve the mainstream or niche markets according to their objectives respectively.

Several impact studies backed by these initiatives and even independent researches provide evidence on the success of adopting VSS. These studies usually adopt a linear comparative approach and compare conventional and sustainable cotton farmers by collecting quantitative data on input indicators such as use of water, pesticide and fertilisers or outcome indicators such as yield, income and profit. Thus, they do provide abundant empirical evidence proving that adoption of sustainable agriculture practices leads to better farm outcomes pertaining to lower input use, less environmental degradation and higher crop yield (Ahmad et al., 2021; Zulfiqar & Thapa, 2016; Zulfiquar et al., 2019; Yasin et al., 2020). Yet, little is known about how the benefits from adoption of sustainable agriculture practices are achieved and which factors contribute to the success of these VSS (Marx et al., 2022; Lund-Thomsen et al., 2022).

With this background, the aim of this research is to explore why and how adoption of voluntary sustainable standards in cotton farming leads to sustainable resource use as compared to conventional cotton farming in Pakistan. By addressing the aim of this study, existing gaps in the literature on the functioning mechanism of VSS will be filled using the systems theory particularly the diagnostic multitier social-ecological systems framework (Ostrom, 2009). Moreover, the study will test whether the difference in outcomes amongst conventional cotton farmers and those participating in VSS are caused by the presence of a unique system facilitated by the VSS.

Voluntary Sustainable Standards and Cotton Farming in Pakistan

The governments today, especially in the developing world, face extreme pressures and resource constraints in fulfilling the public's needs, be they related to welfare, security or protecting the environment. Under these circumstances, private sector can be vital in extending support to achieve the sustainability goals. Voluntary Sustainable Standards is an example of one of these initiatives where the private sector drives the production and consumption of sustainable products (Komives & Jackson, 2014). As evident from the name, the adoption of the standards is voluntary and does not rely on the government for operation, regulation or implementation. In principal, VSS is a market-based approach to drive sustainable business and production practices so that the consumer demand for sustainable products are fulfilled. In this way, the production of a product is altered to ensure that it has minimum negative social or environmental impact.

Standard Definition

Defines good social, economic, and environmental practices for a product or industry.

Market-Based

Drives sustainable practices by meeting consumer demand for sustainable products.

Global Impact

Alters production in one country by steering demand in another.

The fundamental component of VSS is a standard that defines good social, economic and environmental practices for a product or a specific industry. Primarily, the purpose of a standard is to outline the principles necessary to ensure sustainable production which is then complimented by other components of the system like capacity building, assurance, traceability and labels. Conventionally, there are two types of standards; practice based or performance based, where the former is based on the adoption of best management practices and the latter relies on achievement of certain targets set for the use of resources such as water. These standards have been a powerful approach in driving sustainability as the practices are altered in one country by steering the demand for the sustainable product in a different country. For instance, the first sustainable product sold in the Dutch markets by Fairtrade International was coffee produced in Mexico.

Does ‘Better’ Cotton contributes to Sustainable Resource Use in Pakistan?

In the early 21st century, the World Wide Fund for Nature (WWF) led roundtable conferences exploring environmental sustainability across ten agricultural commodities (Riisgaard et al., 2020), including cotton. Following a six-year standard-setting process, Better Cotton was formed as a multi-stakeholder initiative aimed at driving sustainability in the cotton sector. The organization began operations in Pakistan in 2010, striving to sustain cotton communities while restoring and protecting the environment.

This Voluntary Sustainable Standard (VSS) has three strategic aims: promoting sustainable farming practices, enhancing economic viability, and driving sustainable cotton demand globally. The Better Cotton Standard System (BCSS), a practice-based standard system, includes the five previously discussed VSS components, plus an additional one for results and impact. Seven principles and related criteria detail the organization's strategic aims, encompassing crop protection, water stewardship, soil health, biodiversity and land use, fiber quality, decent work, and effective management systems (Better Cotton, 2023). Capacity building, channeled through the Better Cotton Growth and Innovation Fund, supports field-level training programs. An assurance program measures performance against these principles and criteria (Better Cotton, 2019) to ensure core standard indicators are met and identify compliance gaps. Traceability and labels are beyond this research's scope and will not be thoroughly discussed. Better Cotton measures impact at different supply chain levels–farmer, spinner, and retailer–but this paper focuses on farm-level contributions to sustainable livelihoods, an enhanced environment, and a good quality of life for communities.

As illustrated in Figure 2, the quality of cotton produced under sustainable practices is evident in the healthy, fluffy cotton bolls resulting from Better Cotton farming methods.

Figure 2: Cotton boll in hand with healthy plant background.

There is substantial empirical evidence that Better Cotton has positive social, economic and environmental impact in the countries where it operates, specifically in the case of Pakistan. For instance, the study conducted by Ahmad et al. (2021) evaluated the impact of conventional and Better Cotton farmers in the Khanewal district of Pakistan and concluded that productivity, environment sustainability and safety were significantly higher in the latter case. The study found out that the adopters of BCSS had less; mean irrigations, pesticide and chemical fertiliser applications and higher; irrigation intervals, organic fertiliser use and non-chemical pest control as opposed to conventional cotton farmers. Furthermore, the dependence on consultation and pest scouting techniques was also significantly higher in comparison to conventional cotton farmers. Similarly, another comparative study in the Bahawalpur district found out that the use of water and inorganic fertilizers or pesticides by Better Cotton farmers was significantly less which ultimately affected the financial performance of the cultivated crop (Zulfiqar & Thapa, 2016). Farmers from this study also reported that the three major reasons to join the Better Cotton program were reduced production costs, environmental sustainability and higher productivity. The findings of a panel data research based on two cropping seasons is also consistent with the aforementioned studies and confirms the environmental and economic efficiency of Better Cotton farmers (Zulfiquar et al., 2019). Moreover, the health impact is captured in the study carried out by Yasin et al. (2020), which concludes that female cotton pickers working in the Better Cotton farms incur fewer costs related to health as compared to those working in the conventional cotton farms.

Although, with this overwhelming empirical evidence it may be deduced that the adoption of BCSS can lead to sustainable resource use, there still are some gaps in the literature. The studies have mainly focused on the outcomes of standard adoption and an investigation in to its operational mechanism is still limited. Previous studies also confirm that there is little evidence on how VSS and governance of standard systems influence learning, adoption and sustainability outcomes (Marx et al., 2022; Lund-Thomsen et al., 2022). An in-depth review of impact studies on certification standards by Jellema et al. (2022), found out that an overwhelming majority (around 70%) of such studies adopted a linear approach identifying causation rather than determining it. Critically analysing both the linear and 'configurational' approach, their study argues that future research should be carried out using a system-based approach to create a balance in the literature as well as provide a holistic understanding of the mechanisms driving the impact.

Systems Theory: Introduction to Social-Ecological Systems Approach

Traditionally, researchers have recognised ecological variables and human activities as drivers of ecological systems. While, the former has been widely researched but the latter was much less studied until recently. Though, these two fields developed independently but the lack of linkages amongst the two makes it problematic to understand the inextricable links of human activities and ecological dynamics (Norgaard, 2008). The levels of non-linearity, uncertainty and interactions associated with the changing dynamics of the environment further add up to the complexity of the issue. These limitations can be addressed by the systems theory that evolved during the mid-twentieth century. Systems can basically be described as a set of elements with interconnected parts that generate and sustain their own patterns of behaviour over time. One such system is complex adaptive system, which is a distinctive case of systems theory as it allows for changes within the system over time due to the interactions amongst its separable components (Preiser et al., 2018).

Developed in the 1990s, the social ecological systems (SES) is an emerging concept which is a type of complex adaptive system and provides an understanding on the intertwined ecological and social sustainability issues (Berkes et al., 2003; Biggs et al., 2003). Redman et al. (2004) defines the SES as a coherent, dynamic and complex system based on social and biophysical factors with regular interactions set in several organizational, spatial and temporal scales. This structure is also regulated by the independent components of social and ecological systems that are continuously adapting. The ecological system is driven by multiple elements such as geological setting and their variations whereas the social system is concerned with human activities that influence the SES. The components of these individual systems are also multiple and diverse, for instance the social system itself is comprised of social institutions, orders and cycles. The interactions and feedbacks amongst the components in a SES distinguishes it from other theoretical approaches applied in this field of study. This is a unique approach that provides a comprehensive understanding of the complex system created by the interactions in a SES and has been widely used to study the sustainability issues in the field of natural resource sciences with applications varying from lakes, forests, fisheries and irrigations systems (Fleischman et al., 2014; Palomo & Hernandez-Flores, 2019; Cox, 2014). According to Colding & Barthel (2019), the research on SES is mainly based on two types of frameworks. The first one is the descriptive SES framework which deals with establishing links amongst social and ecological systems. While, the second is a diagnostic framework which analyses the robustness and sustainability of these systems.

The Diagnostic Multitier Social-Ecological Systems Framework

Building on her earlier works, Ostrom (2009) proposed a diagnostic multitier SES framework. She challenged the notion of simple answers to complex problems, advocating for embracing complexity in natural resource studies. This framework helps researchers organize multivariate complex systems and analyze interactions among their components. As its name suggests, the framework has multiple levels: first-level core subsystems and second-level variables. These operate within a larger social, economic, and political context.

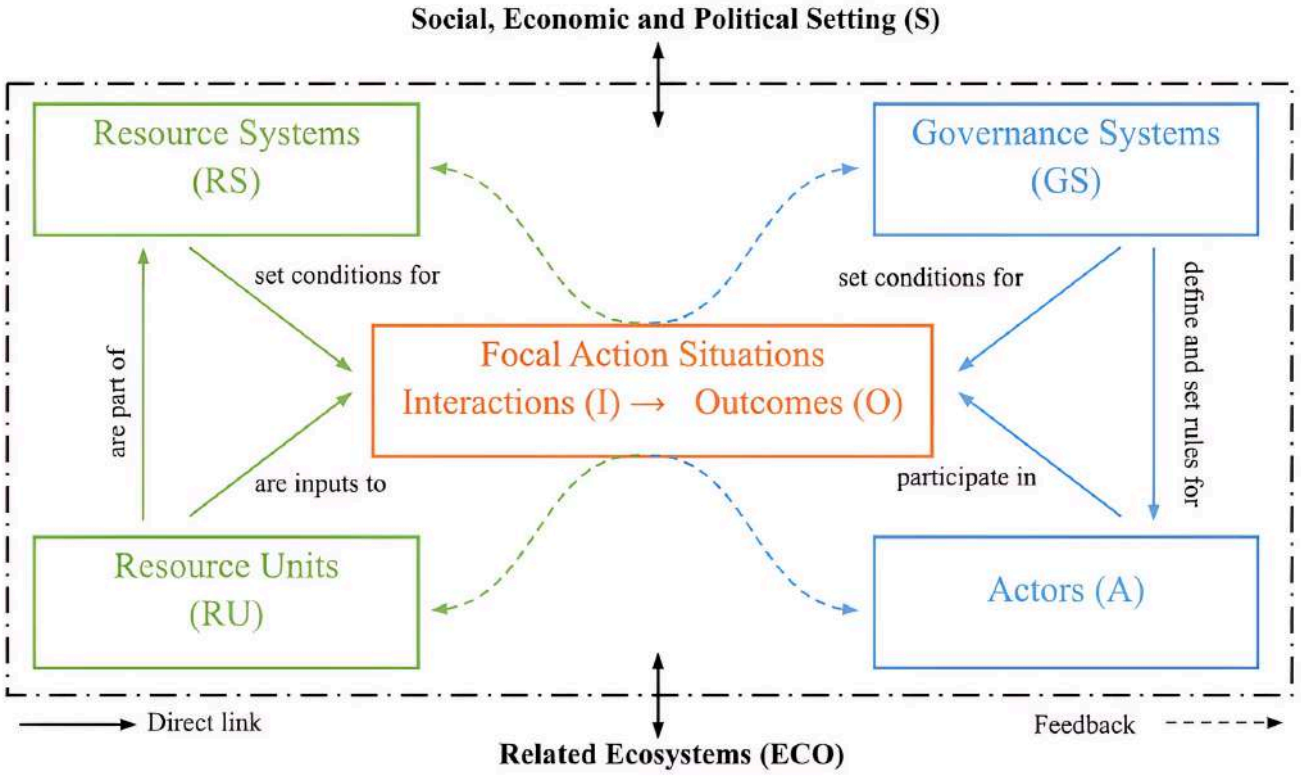


Figure 3: Conceptual diagram of the multitier SES framework (illustrative)

The first-level core subsystem in the multitier SES framework includes natural and social components (Figure 3). Natural components comprise Resource Systems (RS) and Resource Units (RU). Social components include Governance Systems (GS) and Actors (A). These subsystems are denoted by solid boxes (Figure 3). The action situation represents Interactions (I) among them, transforming inputs into Outcomes (O). Dashed lines show feedback from these action situations, influencing individual SES components. The entire system is enclosed by a dotted-and-dashed line, indicating a logical and complete structure. This structure is influenced by exogenous first-tier components like the political setting or related ecosystems. These influences can stem from interactions within a larger SES compared to the focal SES. While the conceptual diagram may appear static, it is a dynamic process with constant interactions and feedback affecting both outcomes and individual SES components.

These core components are further constructed on several second-tier variables. McGinnis & Ostrom (2014), developed a diagnostic SES framework with a subset of these variables that are commonly studied to examine the sustainability of a SES as shown in Table 1. Within this framework, ten frequently observed second-tier variables are identified (marked with an asterisk in Table 1) that positively or negatively influence the likelihood of self-organization amongst users resulting in sustainable resource use (Ostrom, 2009).

Different studies have used this framework to analyse why some SES are sustainable and which variables or interactions play a decisive role in driving sustainability. Palomo & Hernandez-Flores (2019) analysed the sustainability of a multiple resource system involving commercial fishing, recreational fishing and eco-tourism. Their findings concluded that the governance systems are essential in achieving sustainable resource use. An important interaction in this SES was knowledge sharing which was enabled by the exchanges amongst operational choice rules, collective choice rules and the actors. Although, this study highlights the significance of governance systems in a SES with multiple resource systems but the ecological outcomes were underemphasized. Another study conducted by Leslie et al. (2014), used a quantitative approach under the multitier SES framework to test whether the subsystems of fisheries in the region of Baja California are correlated or not. Deploying an interesting yet complicated method –calculating performance scores for each subsystem– the study could only identify a correlation between the performance scores of governance systems and resource units, whereas all other subsystems were uncorrelated. This implies that either efficient governance systems lead to sustainable management of resource units or governance systems are likely to be implemented in places with productive resource units. While the importance of governance systems was partially apparent in the research, it can be argued that the results from this study might change significantly given that a different set of second tier variables are included or different indicators are used to calculate the performance scores.

Applying a similar SES framework, Cox (2014) investigated the Taos Valley irrigation system, which has survived for several hundred years in a high desert environment and addressed the gaps in the literature of common pool resources; underemphasized biophysical features and insufficient examination of relationships amongst independent variables which influence the outcomes. The success of this system was attributed to two factors. On the one hand, the study confirmed the presence of essential features identified in the common pool resource management theory such as small group size, high resource dependence, multiple levels of governance and sanctioning mechanisms that increase the likelihood of collective action. On the other hand, the findings also verify the importance of biophysical features such as harsh environment and the interactions which influence sustainability of the SES. Nonetheless, the study did not assess productivity of the system (RS5) and knowledge of SES (A7) which are frequently observed variables in influencing the likelihood of self-organization in sustainable resource use (Ostrom, 2009).

MATERIALS AND METHODS

To address the limitation of understanding the functional mechanism of the VSS, mixed-methods approach was used for data collection along with the application of SES framework for analysis. The qualitative data was collected from semi-structured interviews with seven key informants involved in implementing BCSS across Pakistan. These participants were selected based on their expertise on the subject matter, their professional role, relevant experience and to ensure representation of key partners involved in implementing the BCSS in Pakistan. The quantitative data was gathered from Better Cotton annual impact studies (2015 to 2020), to visualize a repeated cross-sectional trend analysis of farm inputs and outcomes amongst conventional and sustainable cotton farmers in Pakistan (Better Cotton, n.d., n.d.a, n.d.b, n.d.c, n.d.d). These annual impact reports compare the farm inputs and outputs of conventional and Better Cotton farmers operating in the same geographical area, which is also the premise for selecting relevant second-tier variables discussed later in this section.

To address limitations of determining causation in the VSS literature, this research method is designed using the multitier diagnostic SES framework developed by McGinnis & Ostrom (2014). Since the aim of this research is to explore why the adoption of VSS leads to sustainable resource use, it is hypothesized that the SES in which Better Cotton farmers operate is fundamentally different from that in which conventional cotton farmers are operating. Hence, the focal level of analysis is narrowed down to the evaluation of additional second-tier variables and their interactions in the SES where VSS is operational. The objective here is to identify dissimilarities amongst the components of SES in sustainable cotton farming compared to conventional cotton farming that can plausibly explain the different outcomes. Hence, during the first step of variable selection, the common contextual factors (such as first-tier variable S and second-tier variables including but not limited to RS1, RS9 and GS1) amongst both type of farmers were excluded. In the seond step, only those second-tier variables were selected for examination which could potentially vary according to the respective SES (highlighted in Table 1). Based on this, 22 out of 56 second-tier variables were identified from the framework for further investigation in the study.

Table: List of second-tier variables under a Social-Ecological System.

First-tier variables	Second-tier variables	Reasons for selection/rejection
Social, economic, and political settings (S)	S1 - Economic development	No appreciable variation
	S2 - Demographic trends	No appreciable variation
	S3 - Political stability	No appreciable variation
	S4 - Other governance systems	No appreciable variation
	S5 - Markets	No appreciable variation
	S6 - Media organizations	No appreciable variation
	S7 - Technology	No appreciable variation
Resource systems (RS)	RS1 - Sector (e.g., water, forests, pasture, fish)	No appreciable variation
	RS2 - Clarity of system boundaries	No appreciable variation
	RS3 - Size of resource system*	No appreciable variation
	RS4 - Human-constructed facilities	Potential variation expected
	RS5 - Productivity of system*	Potential variation expected
	RS6 - Equilibrium properties	No appreciable variation
	RS7 - Predictability of system dynamics*	No appreciable variation
	RS8 - Storage characteristics	No appreciable variation
	RS9 - Location	No appreciable variation

First-tier variables	Second-tier variables	Reasons for selection/rejection
Governance systems (GS)	GS1 - Government organizations	No appreciable variation
	GS2 - Nongovernment organizations	Potential variation expected
	GS3 - Network structure	Potential variation expected
	GS4 - Property-rights systems	No appreciable variation
	GS5 - Operational-choice rules	Potential variation expected
	GS6 - Collective-choice rules*	Potential variation expected
	GS7 - Constitutional-choice rules	No appreciable variation
	GS8 - Monitoring and sanctioning rules	Potential variation expected
Resource units (RU)	RU1 - Resource unit mobility*	No appreciable variation
	RU2 - Growth or replacement rate	No appreciable variation
	RU3 - Interaction among resource units	No appreciable variation
	RU4 - Economic value	No appreciable variation
	RU5 - Number of units	Potential variation expected
	RU6 - Distinctive characteristics	No appreciable variation
	RU7 - Spatial and temporal distribution	No appreciable variation

First-tier variables	Second-tier variables	Reasons for selection/rejection
Actors (A)	**A1 - Number of relevant actors***	Potential variation expected
	A2 - Socioeconomic attributes	No appreciable variation
	A3 - History or past experiences	No appreciable variation
	A4 - Location	No appreciable variation
	A5 - Leadership/entrepreneurship*	Potential variation expected
	A6 - Norms (trust-reciprocity)/social capital*	No appreciable variation
	A7 - Knowledge of SES/mental models*	Potential variation expected
	A8 - Importance of resource (dependence)*	No appreciable variation
	A9 - Technologies available	Potential variation expected
Action situations: Interactions (I) & Outcomes (O)	I1 - Harvesting	No appreciable variation
	I2 - Information sharing	Potential variation expected
	I3 - Deliberation processes	Potential variation expected
	I4 - Conflicts	No appreciable variation
	I5 - Investment activities	Potential variation expected
	I6 - Lobbying activities	Potential variation expected

First-tier variables	Second-tier variables	Reasons for selection/rejection
	I8 - Networking activities	Potential variation expected
	I9 - Monitoring activities	Potential variation expected
	I10 - Evaluative activities	Potential variation expected
	O1 - Social performance measures	Potential variation expected
	O2 - Ecological performance measures	Potential variation expected
	O3 - Externalities to other SESs	Potential variation expected
Related ecosystems (ECO)	ECO1 - Climate patterns	No appreciable variation
	ECO2 - Pollution patterns	No appreciable variation
	ECO3 - Flows into and out of focal SES	No appreciable variation

Source: Adapted from McGinnis & Ostrom (2014, tab. 1). Variables indicated by '' are frequently identified second-tier variables that influence self-organization in a SES. Highlighted variables were selected for investigation in this study.*

RESULTS AND DISCUSSION

Different variables were mapped from the SES framework and analysed in terms of their potential role in facilitating sustainable resource management amongst Better Cotton farmers. The first-tier variables identified were resource unit (cotton plant), resource systems (soil system, water system and biodiversity system), actors (mainly farmers) and governance system (BCSS). These subsystems and their interactions that structure the SES facilitated by VSS are comprehensively discussed in the below sections.

Governance Systems (GS)

The farmers participating in the Better Cotton program are governed under a hierarchical governance system with two levels; at the top level is the Better Cotton Standard System and the second level is taken up by Better Cotton Program Partners (GS2). The structural design for the implementation of the program is provided by the BCSS, whereas the program partners are responsible for implementation of the standard system. These partners can be from the private sector, public sector or belong to various legal entities such as non-governmental organizations, private limited businesses or even research institutes. Forming producer units, building capacity of farmers, monitoring adoption, measuring readiness and collecting data are the roles performed by these partners. While, BCSS defines the sustainability themes recommended for adoption through the Better Cotton Principles & Criteria (GS5). The BCSS further ensures compliance via the Assurance Program (GS8) and, measures result and impact. Additionally, a license or certification validating the sustainable cotton production is also provided to the producer units that are in compliance with the principles and criteria verified during the assessments conducted by Better Cotton.

The operational choice rules (GS5) are facilitated by the Better Cotton principles and criteria and the Assurance Model. BCSS defines seven principles for sustainable cotton farming, divided into 42 criteria and a subcategory of 164 core and improvement indicators .

To receive a license the producer units undergo regular assessments from Better Cotton and must comply with all core indicators, whereas the improvement indicators measure progress for various aspects of sustainable cotton production defined by the principles. For instance, one of the core indicators for Principle 1 (Crop Protection) is that an Integrated Pest Management (IPM) plan is implemented and the corresponding improvement indicator is the proportion of farmers adopting this IPM plan which has to be increased over the years. These criteria and indicators ensure that clear rules are defined for sustainable cotton production. For example, under the above mentioned principle the indicator 1.3.1 states that any pesticide listed in the annexures of Stockholm Convention, Montreal Protocol and Rotterdam convention are not used by the producer units. Failure in compliance with this criteria may lead to denial of certification. Similarly, other indicators are related to water stewardship, soil health, biodiversity and land use which regulates sustainable agriculture practices amongst farmers. By adhering to these principles it is ensured that the Better Cotton farmers must either preserve or restore the resource systems involved in cotton production.

There are multiple types of assessments under the BCSS which ensure monitoring and sanctioning rules (GS8). This includes readiness checks, licensing assessments and surveillance assessments conducted by the program partners, Better Cotton or third party assessors. Principle 7 (Management System) mandates that the producer units record accurate farm data related to inputs which is then verified during such assessments and provides the basis for monitoring and sanctioning rules. Based on this, a farmer or a group of farmers may be sanctioned from participation in the program. Program partners have the liberty to exclude farmers from the producer units if they do not comply with the recommended practices, while a license denial from Better Cotton means that the entire producer unit is not a sustainable cotton producer. The implications from such exclusions imply that the farmers can no longer use the sustainability label to sell their cotton.

The network structure (GS3) formed by BCSS is a hybrid network consisting of two components. The first one is a bus network where information flows from Better Cotton to the program partners. Then the partners have their own hierarchical structure through which the data flows from program management to the field staff –producer unit managers and field facilitators– and onwards to the lead farmers, farmers or workers. The information flows back to the top in a similar manner. The second component of this structure is a mesh network formed between the field staff, farmers and workers. In this network, the information flows freely between the participants. This network can take a formal, informal or a social setting via workshops, demonstration plots, social gatherings or information exchange via smartphone based communication tools. The farmer or worker groups participate in formal trainings to learn about sustainable farming practices that are led by the field facilitators. Informal exchanges are often facilitated by the lead farmer (A5) of a learning group under a producer unit. These formal and informal networks ensure that there is a constant flow of information and a feedback mechanism is in place. Moreover, this also guarantees that the farmers have access to consultation to ensure that the crop health is being regularly monitored. Advisory services like the use of pesticides, fertiliser or water are also channelled through this mechanism.

The network system fosters farmer cooperation, leading to collective-choice rules (GS6). The extent of this cooperation varies by region. However, some groups collectively purchase bulk inputs, such as pesticides and fertilizers, to receive price discounts. This collective approach also applies to hiring labor for activities like land preparation or cotton picking. Similarly, farmers collectively sell their cotton to achieve better prices and reduce transportation costs. The standard system further promotes collective action for sustainable water use, encouraging collaboration among stakeholders. Farmers collaborate with local governments and organizations on sustainable water development projects, including lining water courses.

Actors (A)

Several actors (A1) are involved in Better Cotton's SES. These include Better Cotton representatives and program partners, who encourage cotton farmers and workers to adopt sustainable farming practices. Some representatives work strategically, ensuring best management practices are adopted. Others, like producer unit managers, field facilitators, monitoring officers, and assessors, actively operate in the field to ensure compliance. The lead farmer (A5) serves as a key contact between farmers and VSS officers. They provide institutional and administrative support, facilitating learning, review, and analysis of VSS implementation. Pesticide and fertilizer agents from private companies also work closely with farmers. While it's hard to determine if they promote organic or synthetic products, overselling is common to meet business targets. VSS-related actors aim to neutralize these efforts, ensuring input use aligns with crop requirements. Field facilitators also reduce farmers' dependence on fertilizer/pesticide sales agents and government agriculture extension departments. Additionally, they act as technical experts, supporting farmers throughout the crop cycle and providing guidance for abnormalities.

The knowledge of SES (A7) is formalized through the VSS's capacity-building component. Farmer knowledge develops based on themes defined by Better Cotton principles. Program partners, sometimes with industry experts, draft training materials from this information. During each crop season, regular training workshops are held for participating farmers. These workshops, conducted by field facilitators, cover sustainable resource use topics like pest scouting before pesticide application, highly hazardous pesticides, the importance of soil tests, and biodiversity. Field facilitators receive training through a ‘Train the Trainer’ program, where producer unit managers qualify as master trainers. Besides workshops, demonstration plots are exhibited during the crop season. Here, farmers observe practical implementation of sustainable practices and new techniques like drip irrigation systems and pheromone traps.

These demonstration plots significantly contribute to the technological difference (A9) between Better Cotton and conventional cotton farmers. Although technical constraints related to technology adoption are well addressed under this VSS, farmers still manage financial resources independently. Additionally, adopting certain technologies, such as conducting soil tests for each producer unit, is mandatory in this VSS, which regulates input use.

Resource Systems (RS) & Resource Units (RU)

Several human constructed facilities (RS4) built on the farms participating in the VSS are also unique. Some of these facilities are mandated by the principles whereas the others are a result of demonstration plots and research trials. For instance, Principle 2 (Water Stewardship) requires efficient use of water resources and hence lining of watercourses is quite common amongst Better Cotton farmers. Although, this is also promoted by the government but the VSS makes the process robust by encouraging collaboration amongst different stakeholders. Similarly, Principle 4 contributes to preservation of biodiversity such as trees or beneficial insects as well as promoting restoration of degraded areas. Under these principles, the ownership of preservation and protection is extended to the entire producer unit by linking it with the certification outcome.

The productivity of system (RS5) and number of units (RU5) were also found to be different. Figure 3 shows the use of inputs and resulting yield for five consecutive years from 2015 to 2020 as reported in the Better Cotton annual impact reports. The data was collected from the same regions in Pakistan where Better Cotton and conventional cotton farms were operational and then comparisons were made. It is evident that the Better Cotton farmers used less water, pesticides and fertilisers as compared to conventional cotton farmers, yet had a better yield. Adopting sustainable farming practices advocated by the BCSS such as crop rotation and intercropping, improves soil health and biodiversity in the long run which affects the cost of production and crop yield. This difference in productivity of various resource systems –soil, biodiversity & water– has to be attributed to the interactions enabled by the VSS.

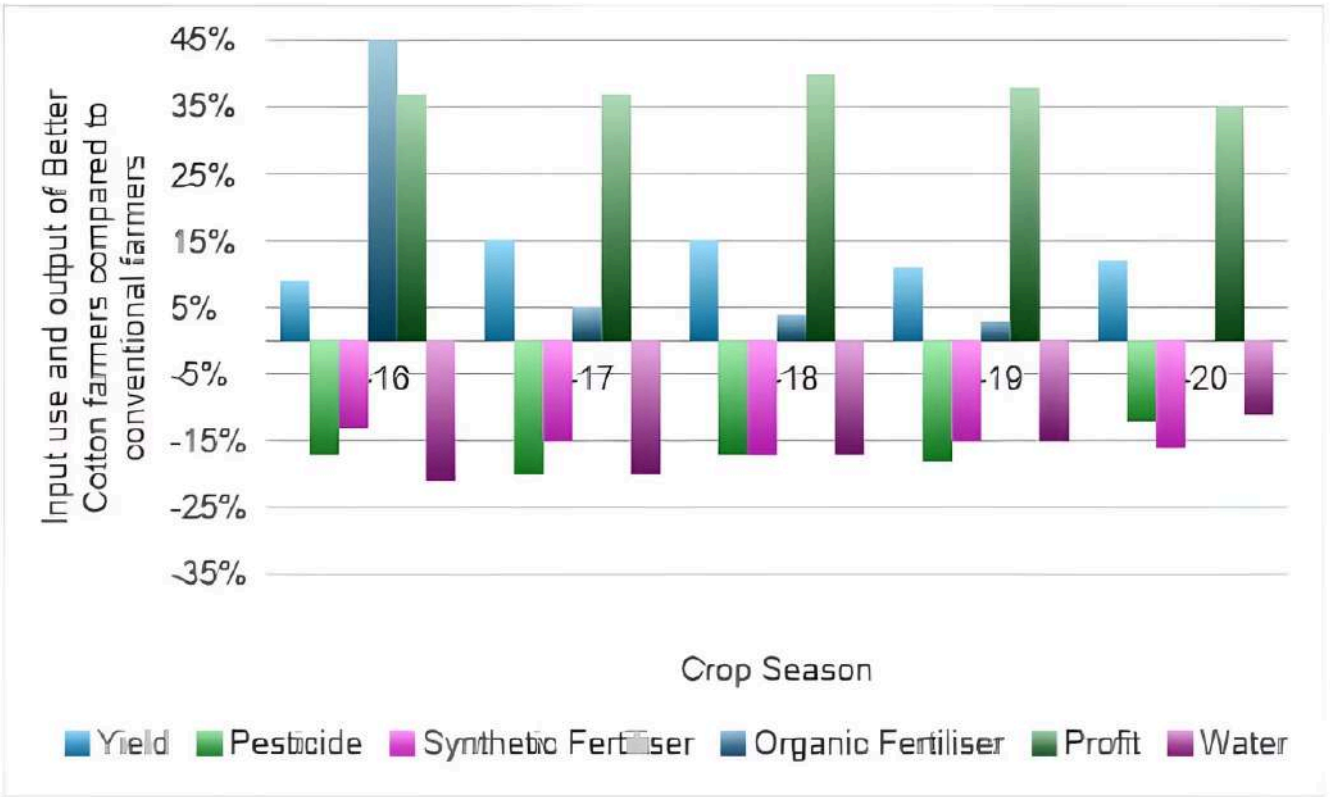


Figure 3: Comparison of annual farm input and output data for Better Cotton farmers and conventional cotton farmers for selected indicators in percentage from 2015 to 2020.

Interactions (I) and Outcomes (O)

Within this SES, BCSS facilitates interactions to achieve sustainable outcomes. Firstly, Better Cotton and Program Partners (GS2) collaborate to create and disseminate knowledge systems to farmers via training workshops (GS3), enabling information sharing (I2).

Secondly, the assurance program (GS8) enforces principles and criteria (GS5), ensuring monitoring (I9) and evaluative activities (I10). For instance, if an indicator shows weak adoption, a continuous improvement plan is developed for the producer unit to address farmer knowledge gaps.

Thirdly, farmers and VSS officials (A1) regularly meet during training workshops or farm visits. These networking activities (I8) foster knowledge transfer (A7), reinforce principles and criteria (GS5), and facilitate monitoring (I9) by allowing farmers to consult experts.

Lastly, investment activities (I5) by the standard system drive the entire social-ecological system. Better Cotton provides technical and financial resources, including assessments (GS8). Farmers invest their time to build knowledge. Overall, these interactions among governance systems, actors, and resource systems lead to sustainable outcomes.

Figure 4 demonstrates that Better Cotton farmers consistently used fewer farm inputs, yet achieved better yield and profits compared to conventional cotton farmers. For example, in 2017-18, Better Cotton farmers had 15% higher yield and 40% higher profit. These outcomes stem from the second-tier variables previously identified, ensuring the SES functions systematically in focal situations, influencing farmer and worker decision-making and activities through program participation.

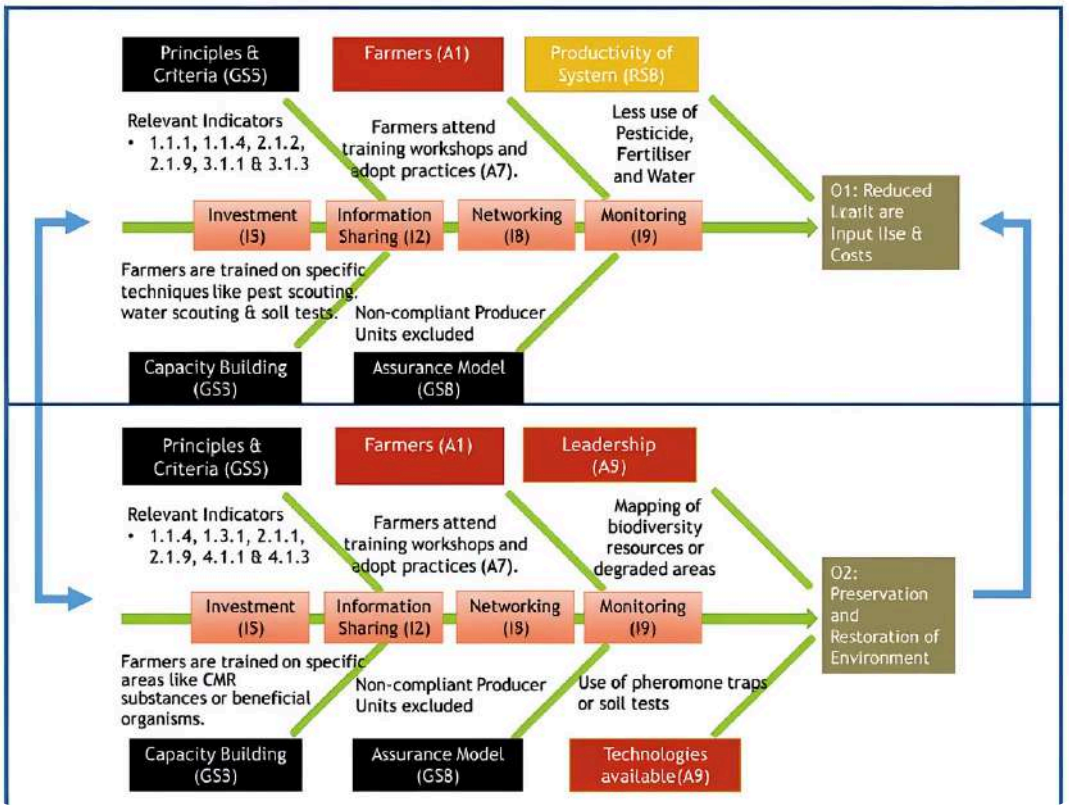


Figure 4: Comparison of Better Cotton and conventional cotton farm performance metrics.

The existing literature and available secondary data discussed in the earlier sections confirm that participation in Better Cotton program results in sustainable resource use. This premise is built on the outcomes from the SES facilitated by Better Cotton and can be broadly categorised into three different categories: social performance measures (O1), ecological performance measures (O2) and externalities to other SESs (O3). The findings of the study confirm the hypothesis that when farmers are faced with focal action situations, Better Cotton farmers respond differently as compared to conventional cotton farmers. This response by Better Cotton farmers is facilitated by various second-tier variables and their interactions as discussed in the previous section as well as illustrated in figure 4. The structure is inherently present only in the SES enabled by Better Cotton and is missing in the SES where conventional farmers operate. After few initial years, these practices form a cyclical phenomenon where low

DISCUSSION

The study addresses the current gaps in literature through application of a systems approach to determine causation of better environmental and economic outcomes as well as sustainable resource use from adoption of VSS. The findings confirm the usefulness of systems theory in general and the SES approach in particular, to explain why some systems are sustainable as compared to others. These findings also elaborated that the interactions amongst the subsystems of a SES significantly influences sustainable management, specifically amongst cotton farmers in Pakistan.

According to the reviewed literature and to the best of the author's knowledge, this is the first application of social-ecological systems framework on sustainable cotton farming in Pakistan. Hence, comparison of results with research on similar cases is highly constrained. Nonetheless, the analysis of the results inform that the most influential first level subsystem in determining different outcomes is governance system as five out of twelve second-tier subsystem variables evaluated in the study belong to this group. Moreover, these variables related to governance system were the foundation stone for other second-tier variables under evaluation such as knowledge of SES (A7), technologies available (A9) and human-constructed facilities (RS4) that influenced the cotton farmers (A1). These results are consistent with the study conducted by Palomo & Hernandez-Flores (2019), which also acknowledged the importance of governance systems in ensuring sustainable resource use and facilitating interactions with other key variables. Additionally, the correlation between governance system and resource units observed in the study on fisheries by Leslie et al. (2014) is also evident in this case, as yield (RU5) was high for Better Cotton farmers.

Out of the 10 frequently occurring second-tier variables that influence self-organization in a SES (Ostrom, 2007), only five variables were helpful in explaining the differences amongst Better Cotton and conventional farmers. The remaining five variables were excluded for investigation during the selection phase as they were expected to be similar amongst both type of farmers. On the one hand, the notion of frequently occurring variables is confirmed as 50% of the variables were present in this case. Simultaneously however, this brings attention to other important second-tier variables which can be crucial to drive sustainability in the absence of self-organization activities (I7).

These second-tier variables include human constructed facilities (RS4), network structure (GS3), operational choice rules (GS5), monitoring, and sanctioning rules (GS8) and technologies available (A9), which were crucial in the case of sustainable management facilitated by Better Cotton. Thus, in the design of private sustainability initiatives especially in countries with weak political governance system, consideration should be given to operational choice rules (GS5) and monitoring & sanctioning rules (GS8). This finding is consistent with the study on Taos valley irrigation system (Cox, 2014) which signifies the role of local governance systems in influencing the SES.

Principally, achievement of this sustainable SES in cotton farming depends on the adoption of practices by farmers amongst other factors. Therefore, participation of farmers in the program is a critical component. In absence of the financial incentives such as premium prices for Better Cotton, farmer's willingness to participate in the program is solely driven by knowledge of SES (A7) and technology (A9). Hence, to keep the farmers engaged in the achievement of a sustainable SES these second-tier variables are worthy of substantial consideration.

During the mapping of this SES, it was observed that the direct linkage between farmers and Better Cotton was weak with no direct feedback channel. Since, the success of the program hinges on farmer support, hence it is essential to strengthen this link so that the farmers are directly connected to the strategy defined by Better Cotton. Two interactions –lobbying activities (I6) and deliberation process (I3) – though existed weakly but were not operationalized to their full extent. For instance, practices like stakeholder workshops and knowledge management were being regularly exercised but the policy level support from important stakeholders such as government agencies or textile mills association was found to be missing.

CONCLUSION

The aim of this research was to explore why adoption of VSS in cotton farming leads to sustainable resource use as compared to conventional cotton farming in Pakistan. This study demonstrates that governance system facilitated by adoption of VSS played a dominant role in sustainable resource use, which in turn influenced several other variables and focal action situations. Using the systems theory and diagnostic SES framework, this study identified that the reason for better environmental and economic outcomes generated from adoption of VSS is explained by the presence of a different SES. The difference is mainly attributed to the additional second-tier variables especially under the two core subsystems (governance system and actors) and their interactions facilitated by the VSS. These findings imply that the voluntary standards can be useful in driving sustainability provided that they are cautiously designed to target the weak components in a pre-existing SES.

This study highlights the importance of governance systems and related second-tier variables in influencing farmer behaviour to achieve sustainable use of resources. VSS-based governance systems enabled knowledge transfer, adoption of technology and accountability which ultimately built the capacity of farmers to make informed decisions during critical focal action situations. Although, both type of farmers operated under the same socio-economic conditions and political settings, presence of the VSS differentiated the outcomes. This raises a critical question for the future studies to test and answer that whether market-based solutions can be successful in governing sustainable resource use especially in regions with weak local (such as private property rights) and community-based governance systems?

Additionally, role of actors in this SES was also found to be significant to drive sustainability. Though, the participation of farmers in the program was voluntary, nevertheless it was observed that there were some elements like knowledge systems and technology which influenced their participation. Thus, it is recommended not to be misled by the term “voluntary” sustainable standards as participation of the actors is subject to certain benefits which should be considered for the successful implementation of these standards.

By acknowledging the notion of complexity, this study goes beyond the usual investigation of identifying causation and complements linear evaluations by determining causation through identification of unique second-tier variables and constructing causal pathways amongst them. The study examined the combination of variables and interactions that made the difference in steering sustainable economic and environmental outcomes amongst cotton farmers in Pakistan. Thus, programs and policies aimed to ensure long term sustainability of agriculture systems in general and cotton production systems in particular, should prioritize improving governance capacity, engagement with farmers, setting up monitoring mechanisms and promoting knowledge transfer.

CONFLICTS OF INTEREST

The author declares a potential conflict of interest, as they have previously collaborated with the organisation discussed in the research article. However, the author affirms that the research findings and conclusions are based on objective analysis and are not influenced by past associations.

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Beyond Familiar Metrics: How Kazakhstan's Volunteer Movement is Reshaping Our Understanding of Social Innovation

COMMENTARY

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This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Traditional Roots (Asar)

Kazakhstan's volunteer movement is deeply rooted in traditional community practices, like 'asar' (mutual help), where people come together to support each other.

Modern Approaches

This traditional spirit is now blending seamlessly with modern volunteering efforts, creating a unique and dynamic force for social change.

Measurement Challenges

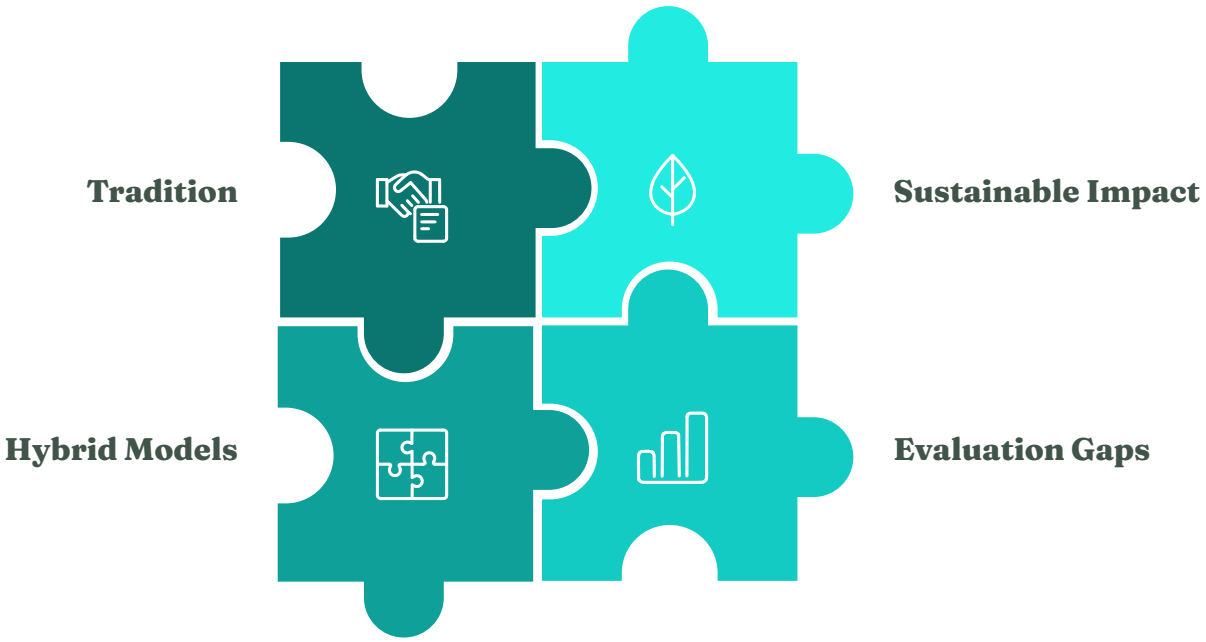
Standard Western metrics often fail to capture the full, unique impact of these locally-rooted efforts, highlighting a challenge in measuring diverse social innovations.

Global Lessons

These locally-rooted approaches offer valuable lessons, calling us to broaden our global understanding of social innovation and its diverse forms.

ABSTRACT

This article examines the dynamic landscape of Kazakhstan's volunteer movement, highlighting its unique blend of traditional communal assistance practices, such as 'asar,' with contemporary organizational models. It argues that this hybrid approach fosters a distinct form of civic engagement deeply rooted in local cultural values. The study critically assesses the applicability of conventional volunteer evaluation metrics predominantly developed in the Global North, revealing their limitations in capturing the nuanced impacts and motivations within a Central Asian context. Furthermore, it explores the profound implications of this culturally adapted volunteerism for achieving sustainable development goals, advocating for a more context-sensitive understanding and support of grassroots initiatives. This research underscores the need for localized frameworks that acknowledge and leverage indigenous practices for effective social change.



Keywords: Kazakhstan, Volunteerism, Asar, Sustainable Development, Global North Metrics

INTRODUCTION

> "For today's volunteer, what matters is being not just a cog in the system, but a co-creator of change".

These words, shared by a young leader from Kazakhstan during one of my coaching sessions, sparked deep reflection on how we evaluate social innovations across different parts of the world. In recent years, Kazakhstan's volunteer movement has demonstrated something remarkable. During the 2024 spring floods, over 50,000 volunteers mobilized within days, combining traditional community organizing (asar) with modern digital coordination tools to evacuate populations and provide emergency aid (Amreeva & Sholudko, 2024). When traditional knowledge meets modern approaches, it creates viable solutions to global challenges.

However, as an expert and analyst with extensive field experience in Central Asian volunteer movements, I increasingly observe a troubling pattern: the Global North's experience automatically becomes the benchmark and model to follow. At the same time, the voices of local communities in the Global South go unheard - their unique solutions and practices are dismissed as "not professional enough" simply because they don't fit familiar evaluation metrics. This pattern reflects broader challenges when national reporting requirements for international frameworks prioritize quantitative growth over qualitative development.

Six years of monthly monitoring volunteer activity in Kazakhstan has led me to a crucial insight: sustainable development requires genuine dialogue between different knowledge systems. Perhaps it's time to move beyond the dominant "the North teaches the South" paradigm and embrace the many paths to social change. (Figure 1).

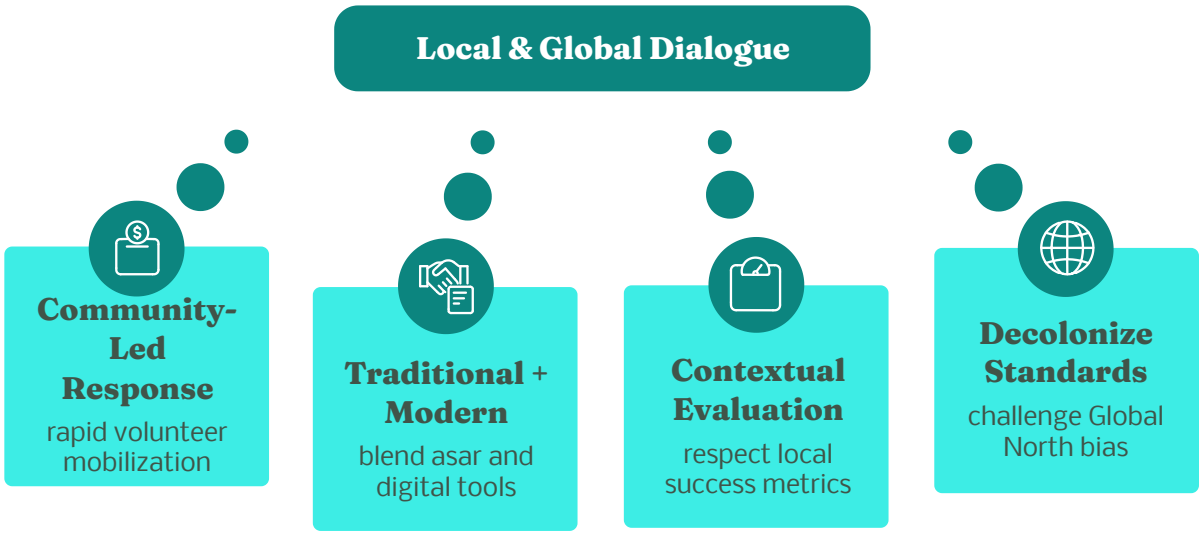


Figure 1. Key elements of Kazakhstan's volunteer movement approach to social innovation

INTEGRATION OF TRADITIONAL AND MODERN SYSTEMS IN KAZAKHSTAN

Historical Roots: From Asar to Modern Volunteering

Volunteering in Kazakhstan has deep roots in nomadic culture. Asar - an ancient Kazakh practice of collective communal work (literally meaning "all together" in Kazakh) - represented a sophisticated system of mutual support where community members would gather to help individual households with labor-intensive tasks like building houses, preparing for winter, or harvesting crops. This practice embodied the nomadic philosophy of shared responsibility and collective well-being. (Finke, 2019) This tradition stays strong today: whether responding to fires, searching for missing people, or organizing emergency aid, willing volunteers often outnumber our organizational capacity. This reflects the core elements of traditional culture - prioritizing those in need and maintaining readiness to help beyond necessity.

50k

2020

Registered volunteers at the start of the pandemic.

255k

2025

Projected volunteers, including informal participants.

Evolution Through Distinct Phases

Kazakhstan's volunteering journey spans several distinct phases with evolving civic implications: from the Soviet era's state-controlled "Timurite movement" to grassroots development after 1991 when volunteers became society's backbone during challenging state transitions, addressing urgent needs the young state couldn't meet. In the 2000s, volunteering transformed into conscious civic action exemplified by youth initiative groups that emerged independently from state structures - young people, driven by the desire for change, began forming initiative groups, drawing in more and more engaged citizens. The COVID-19 pandemic marked a turning point for Kazakhstan's volunteer movement. This period highlighted the unique flexibility and resilience of local volunteer initiatives rooted in traditional mutual aid practices. "The pandemic pushed us to rethink our role and responsibility to society," notes one volunteer community leader.

International Recognition and Deeper Meaning

Kazakhstan's achievements in developing its volunteer movement have gained significant international recognition: at the President's initiative, the UN General Assembly declared 2026 the International Year of Volunteers. In 2024, during the presentation of the first Regional Review on Volunteering in Central Asia at UN Headquarters, Kazakhstan was acknowledged as one of the region's leaders in volunteer movement development. Yet behind these formal achievements lies something more meaningful - a unique experience of reimagining traditional practices for the modern world.

UNIQUE FEATURES OF REGIONAL DEVELOPMENT

During coaching sessions with volunteer leaders from the CIS and Central Asia in autumn 2024, I observed volunteering becoming more diverse, professional, and systematic, blending local traditions with modern approaches. In Kazakhstan, this is evident in several key areas:

1

Community Consolidation and Activism

In 2016, the community drove legislative change, securing the Law on Volunteer Activities. This success, rooted in public dialogue traditions, led to regional front offices, funding mechanisms, and recognition structures, maintaining a community-driven character. This reflects evolving civic engagement where traditional and modern forms intersect.

2

Rapid Response Capability

The community mobilizes quickly in crises. Examples include delivering 500+ tons of aid to Turkey in 2023 and establishing the Ukraine Humanitarian Support Hub, which became a sustainable social enterprise.

3

Social Focus and Clear Boundaries

Volunteering remains distinctly social, separate from religious or political activities. This neutrality fosters diverse collaboration and ensures state support targets volunteer initiatives specifically, despite frequent practical cooperation on common goals.

4

From One-Time Actions to Systemic Work

Initiatives increasingly develop into long-term programs. School groups, for example, move from single events to comprehensive support systems, driven by the belief that "Kindness must be effective."

5

Development of Pro Bono Volunteering

Unlike the Global North, pro bono work naturally fits mutual aid traditions. Retired doctors share expertise, and people with disabilities teach inclusion, challenging notions of who can be an expert.

INTERGENERATIONAL DYNAMICS AND CULTURAL CONTEXT

Intergenerational Dynamics of Volunteering

One of the most striking markers of volunteering's transformation is the changing perception of a volunteer's role across generations. Young participants are emerging as passionate co-creators of social change, reflecting a cultural shift from hierarchy to horizontal connections. Instead of individual success models, we see a revival of nomadic mentoring traditions: success is measured not by personal achievements but by the ability to nurture new leaders. Experienced volunteers (average age ~35) bring deep understanding and professional skills, while young participants (from 14 years) contribute digital literacy and new project formats, creating productive alliances. This intergenerational knowledge transfer reflects broader patterns of civic engagement that strengthen community resilience (Dang & Seemann, 2022).

Regional Differences and the Role of Cultural Context

Traveling across Kazakhstan's regions, I see how the blend of tradition and modernity manifests differently. In just a century of transition from nomadic to settled life, cultural dimensions have transformed. While traditional nomadic society valued collectivism and low power distance, modern society is more complex. Yet, basic values of mutual aid persist. According to World Values Survey data, Kazakhstan is at a unique transition point, creating fertile ground for civic initiatives (Inglehart-Welzel, 2023). Rural areas transform traditional mutual assistance into modern development formats. Industrial cities create environmental initiatives where the nomadic understanding of human-nature unity finds new expression. In major urban centers, volunteering actively promotes civil society by combining modern technologies with a centuries-old culture of social influence and mentorship.

IMBALANCE IN GLOBAL KNOWLEDGE SYSTEMS

In international practice, social innovations are evaluated primarily through quantitative indicators. As noted in the UNV State of the World's Volunteerism Report (2022), this focus on formal, quantifiable data often underestimates and misrepresents volunteering in the Global South, where informal networks and qualitative impacts are paramount. This disconnect between formal evaluation frameworks and local realities reflects broader challenges in knowledge systems integration (Georgalakis & Siregar, 2023).

The Gap Between Quantitative and Qualitative Impact

Working with volunteer communities in Central Asia, I see how quantitative metrics miss the most valuable aspect - deep social transformations that resist numerical measurement. This reflects a fundamental gap between Global North and South knowledge systems. International organizations apply Western evaluation standards that overlook key aspects like the quality of social connections, cultural transformations, and intergenerational knowledge transfer. (Figure 2).

Figure 2. Contrasting evaluation approaches: quantitative metrics versus qualitative community impact

Regional evidence from Central Asia confirms this pattern. The first Regional Review on Volunteering in Central Asia (2024) documented how traditional forms of mutual aid such as asar (Kazakhstan), ashar (Kyrgyzstan), khashar (Tajikistan, Uzbekistan), and yovar (Turkmenistan) demonstrate sophisticated systems of collective support that resist quantification through Western metrics. These practices remain invisible in international frameworks (UNV, 2022).

A Case Study: When Metrics Override Mission

This disconnect became particularly evident in my experience leading a school bullying prevention program in 2020-2021, supported by a major international organization. We decided to help all schools that reached out, exceeding our formal quantitative targets tenfold. By Western standards, this meant the project was complete, and funding was terminated. In reality, we had only highlighted the problem in numerous schools without ensuring the necessary depth of change. Thousands of students were left aware of the problem but without the tools to address it. This systemic contradiction, where success is measured by beneficiary numbers over sustainable change, is common in both government and international donor practices.

LOCAL ADAPTATIONS VS. STANDARDIZED MODELS

In my work, I often observe that initiatives don't simply replicate international models but create unique solutions that consider local context and cultural specificities. While Western models often emphasize age-segregated programs and formal structures, Kazakhstan's initiatives demonstrate different approaches focused on sustainable relationships, organic growth, and community ownership.

Best for Kids

Working with orphanage graduates since 2010, this initiative creates intergenerational integration where former residents mentor current ones, focusing on long-term relationships rather than short-term interventions.

LIDER.KZ

Evolving from a personal tragedy in 2008, this nationwide network of 500+ search and rescue volunteers learns through peer-to-peer mentorship and practical experience, not formal certification.

The Petroglyphs Hunters

Operating informally since the late 1990s, this group protected archaeological sites through grassroots advocacy before formalizing in 2023 to access state funding while maintaining their community-driven approach.

These examples illustrate how local solutions are focused on sustainable relationships, organic growth, and community ownership over standardized metrics and external validation. Regional analysis across Central Asia demonstrates that while traditional mutual aid practices like asar have operated effectively for centuries without formal measurement, contemporary attempts to integrate them into Western evaluation frameworks often distort their essence and reduce their effectiveness. Similar patterns of indigenous knowledge systems maintaining effectiveness despite formal measurement challenges have been documented globally (Acharya & Prakash, 2025). (UNV, 2024; Amreeva, 2024). The experience of Kazakhstan's volunteer movement shows that solutions rooted in local understanding of social processes prove more sustainable. This becomes particularly evident in crisis situations, where traditional mutual aid mechanisms remain effective despite limited resources. However, attempts to 'translate' these achievements into the language of Western metrics distort the essence of unique local approaches. A genuine dialogue between different knowledge systems is essential - it is at the intersection of Western methodology and local wisdom that new approaches to understanding social effectiveness emerge.

VOLUNTEERING FOR SUSTAINABLE DEVELOPMENT GOALS

Kazakhstan's volunteer movement shows a natural connection between local mutual aid practices and global goals, coming from traditional asar values rather than external donor requirements. This organic alignment demonstrates how community-led initiatives can achieve sustainable development outcomes through culturally grounded approaches (Bucio-Mendoza & Solis-Navarrete, 2024). This appears clearly in three key areas.

1

Social Volunteering and Reducing Inequality (SDG 10)

"Club 28 Petals," a grassroots initiative supporting premature babies, grew organically since 2012 to operate in 14 countries with over 3,700 participants. During the 2024 floods, over 50,000 volunteers engaged in comprehensive relief, from first aid to reinforcing riverbanks.

2

Education as a Tool for Equality (SDG 4)

Student volunteers help rural schoolchildren prepare for university admission, bridging educational gaps. In Kazygurt village, a volunteer English-teaching initiative evolved into a modern trilingual education center. Volunteers also adapt materials for children with disabilities.

3

Environmental Volunteering and Ecosystem Protection (SDGs 13-15)

Volunteers in Atyrau preserve fish populations in the Ural River. The Wild Nature Volunteers movement protects national parks and promotes environmental education. Initiatives like "Aktobe, Breathe!" protect urban green spaces. These actions stem from local concerns, naturally aligning with global SDGs.

RETHINKING THE FUTURE OF SUSTAINABLE DEVELOPMENT: LESSONS FROM THE GLOBAL SOUTH

After six years of watching Kazakhstan's volunteer movement transform, I reached an important conclusion: the Global South's experience can significantly enrich our understanding of social innovation and sustainable development. This perspective aligns with growing recognition that responsible research and innovation must be reconceptualized from Global South perspectives (Wakunuma et al., 2021). The real value lies in the depth of personal and societal changes, which cannot be measured by numbers alone. Kazakhstan's journey suggests several key directions for transforming existing approaches:

01

Flexible Evaluation Systems

We need flexible evaluation systems that consider cultural context and qualitative changes. Emerging examples across Central Asia show alternatives like measuring success through sustained mentor-mentee relationships or community ownership rather than participant numbers.

02

Platforms for Direct Dialogue

We need platforms for direct dialogue between different knowledge systems. Existing regional forums in Central Asia can be expanded into global platforms for systematic dialogue between Global North and South approaches, especially looking ahead to the 2026 UN International Year of Volunteers.

03

Reconsider Support Mechanisms

Support for social initiatives should favor local rather than international organizations. The super-mobilization of Kazakh volunteers shows that local communities create effective solutions even with minimal resources. Direct funding is essential to develop these initiatives.

04

Reframe the Global South's Role

We should reconsider viewing the Global South as a space for implementing ready-made solutions. The future of sustainable development may require a new understanding of local communities' role as co-creators of knowledge and practice, not just recipients of expertise.

CONCLUSION

The experience of Kazakhstan's volunteer movement clearly shows: we should reconsider viewing the Global South primarily as a space for implementing ready-made solutions. Contemporary donor practices continue to prioritize standardized Western models, creating barriers for local participants and undermining traditional mutual aid practices like asar. Research on mutual aid organizing demonstrates that community-led responses offer crucial lessons for formal sectors serving marginalized communities (Wu et al., 2025). This approach perpetuates the assumption that Global South contexts must adapt to Northern standards rather than developing culturally-grounded alternatives. Central Asia suggests that the future of sustainable development may require not only new approaches but also a new understanding of local communities' role in creating them. When volunteers act not just as implementers but as equal participants in shaping knowledge and practices, a living dialogue emerges between tradition and modernity, capable of enriching global social transformation practices. This experience points toward new possibilities for reframing relationships in both development practice and academic knowledge production, where local communities become co-creators rather than recipients of expertise. (Figure 3).

Figure 3. Collaborative future: Kazakhstan's intergenerational volunteer movement building sustainable communities

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

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Production of Weather Info Vis a Vis Agricultural Planning Calendar

1st Edition Weather information tools for Smallholder farmers

Frank Mutesa
Rwanda Agriculture and Animal Resources Development Board

Uwera Amina
Famu's Co. Ltd, Rwanda

RESEARCH ARTICLE

This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Accessing Weather Insights

Rwandan farmers now get easy-to-understand weather forecasts, helping them know what to expect from the skies.

Smarter Farming Choices

With timely weather info, farmers can make better decisions, like when to plant, water, or harvest their crops.

Information at their Fingertips

These vital forecasts reach farmers through accessible channels such as mobile phones and local radio broadcasts.

Bountiful Harvests & Better Lives

This leads to stronger, healthier crops, improved yields, reduced losses, and ultimately, a better income for their families.

ABSTRACT

Smallholder farmers in Rwanda face significant challenges from increasing climate variability, including unpredictable rainfall patterns, droughts, and floods, which severely impact agricultural productivity and food security. This research article explores the critical role of accessible and accurate weather forecasting information in enhancing farmers' resilience and decision-making capabilities. Focusing on services provided by Meteo-Rwanda, this study investigates how the integration of scientific meteorological data with indigenous knowledge forecasting methods creates a more robust and locally relevant early warning system. By combining modern meteorological tools with traditional indicators, these services offer tailored forecasts that empower farmers to make timely decisions regarding planting, harvesting, and crop management. The implementation of these localized weather information systems has led to documented benefits, significantly improving agricultural outcomes. Specifically, farmers utilizing these integrated forecasting services have reported a 15-25% improvement in crop yields, contributing substantially to enhanced food security and livelihoods. This paper highlights the effectiveness of a hybrid approach to weather information dissemination, advocating for similar strategies in other climate-vulnerable agricultural communities.

Supporting Choices

Help farmers plan and decide actions

Local Information

Provide site-specific historical and forecast data

Local Options

Present locally relevant crop and management choices

Integrated Forecasts

Combine scientific and indigenous indicators

Keywords: Smallholder farmers, Rwanda, Weather forecasting, Climate variability, Crop yields

INTRODUCTION

Smallholder farmers in Sub-Saharan Africa face significant crop losses due to insufficient weather and climate information. Their intensive farming efforts are often wasted when weather patterns deviate from expectations. Notably, 70% of smallholder farmers in Africa depend on rainfed farming systems (Sciencedirect, 2024). This makes understanding weather patterns crucial for smallholders, who suffer disproportionately from irregular climate changes (Clark et al., 2003). Climate change is a primary driver of crop loss for these farmers (Challinor et al., 2007), with projections indicating that it will cause a 5-10% reduction in rural household consumption by 2050 in Rwanda (CGIAR research). However, those who access and utilize weather and climate information achieve better harvests and improved planning, compared to those lacking climate adaptation and mitigation knowledge. Weather forecasting enables smallholder farmers to properly prepare and plan farm operations such as planting, irrigation, fertilizer application, pruning/weeding, and harvesting. The government of Rwanda actively promotes climate change information for agricultural activities. Through the Participatory Integrated Climate Services for Agriculture (PICSA), Rwanda was the first country to train all district agronomists in climate services. Developed and tested by the University of Reading, PICSA is a farmer-centric approach that equips smallholder farmers with knowledge to make informed decisions about their agricultural practices based on local weather and climate information. This approach is built around four key elements:

1

Supporting farmers' choices

Supporting farmers to make their own choices and plans.

2

Providing local information

Making availability of locally specific historical and forecast information and the tools to interpret them.

3

Considering local options

Facilitating the consideration on a range of locally relevant options on crop, livestock, livelihood and their specific management practices.

4

Participatory tools

A set of participatory decision- making and planning tools which help farmers to identify options that are most suitable for them.

Smallholder farmers are highly vulnerable to climate change risks and negative impacts. They must recognize that their actions are vital for survival. Understanding weather and climate information is paramount for wise planning, tailored to local conditions. For instance, a study revealed that 85% of farmers in Rwanda's Eastern Province acknowledge climate change, with 54% observing temperature increases (Rwema et al., 2025). This document aims to guide farmers on accessing reliable weather and climate forecasts and effectively using this information in their daily work. Increased engagement in monitoring local weather empowers smallholder farmers to make informed agricultural decisions, such as selecting crops, adapting cropping systems, or even opting for off-farm activities during unsuitable seasons, depending on their planning in the face of a changing climate.

WEATHER FORECASTING INFORMATION

Background to Weather forecast in Rwanda

Livelihood and agriculture activities in Rwanda have been increasingly threatened by the changing climate and pose severe changes in food security and economic stability. Given that agriculture accounts for 25% of Rwanda's GDP and provides livelihoods for over 80% of the population (NISR, 2020), these threats are particularly severe. Smallholder farmers in Rwanda have been suffering from climate shocks for years. These threats include, for instance, documented temperature increases of +0.76°C/decade for minimum temperatures and +0.48°C/decade for mean temperatures (Rwema et al., 2025), alongside prolonged drought and erratic rainfalls, which interrupted farming circles in some regions, and contributed to crop yield failures and soil degradation. Looking at the topography of the country, which is mountainous, and the level of understanding of farmers regarding weather and climate information, if there are no measures to mitigate and adapt to these shocks then the severity level will keep on increasing. However, nowadays farmers have access to much more information on weather and climate due to increased concern from different institutions. This has raised awareness among scientists, who in turn have developed strategies and ways to disseminate information to farmers. Meteo-Rwanda is at the forefront in providing weather and climate information in the form of weather events, which could be the amount and time of rainfalls, temperature levels, wind speed, humidity, and provides warnings for extreme weather events like floods, droughts, and strong winds on a daily and monthly basis. This has been of great help to the communities and especially farmers in their agricultural activities.

The issue remains, how do smallholder farmers get the information from? Do they know that these weather forecasting information exists in the first place? And if yes, how often do they use the information?

Sources of weather information

In Sub-Saharan Africa, where most of the farmers are rain-fed dependents, weather information is most useful to them and can be communicated from the agencies responsible through different channels, which include:

Radio and TV stations

SMS to mobile phones

Trained agricultural extension staffs

Social media (Preferred mostly by youth)

The increasing daily SMS subscriber numbers for weather information in Rwanda (CGIAR research) further demonstrate the growing reach and impact of these dissemination efforts.

The useful information that are broadcasted through these communication channels by Meteo-Rwanda are used by the whole communities and groups of people from the business people all the way to farmers, from public to researchers. They issued also the specialized forecasts for agricultural activities including information on crop selection, sowing and harvesting date, pest and diseases outbreak, and the early warnings for severe weather events, which will help farmers to plan accordingly and other disaster management agencies to mitigate and minimize threats and impacts.

Rwanda meteorological agency, collects and process data from different sources, from manual and automatic weather stations, radar data and satellite imagery and process the data collected using software like Climsoft in managing and archive the data in a Meteorological Databank. These data are used to generate climate and weather forecast and warnings. Through the data extracted and analysis from RAB (Rwanda Agricultural and animal resources Development Board), it is said that climate change and its related factors affect Rwandan agriculture by reducing production every year. The estimated percentage reduction in yield for key crops is illustrated below in Figure 1.

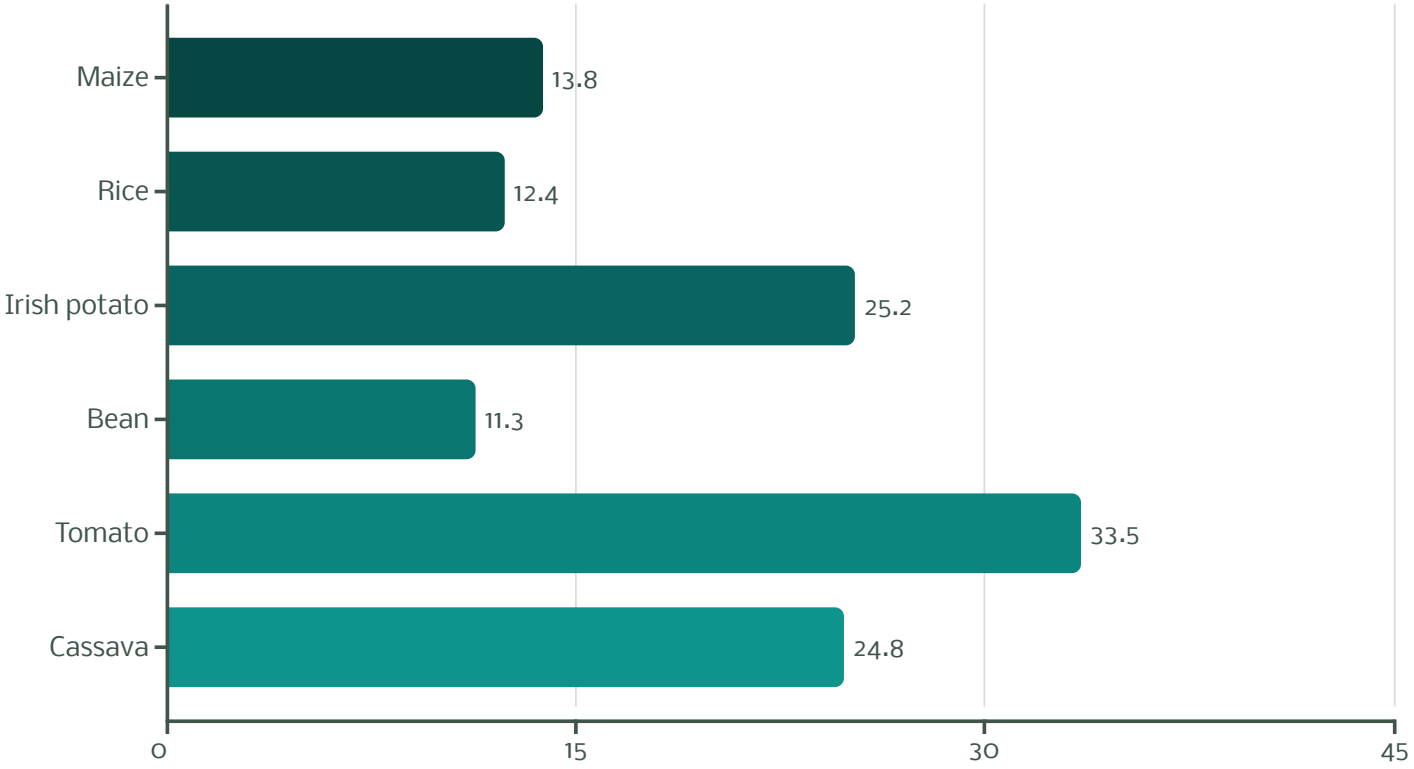

Figure 1: Estimated crop production reduction due to climate change in Rwanda (%).

Purpose and the importance of weather forecasts

Weather forecasting information is not just for the farmers, but all the stakeholders in agricultural sector. These are useful information that will enable them to make decisions in the context of an increasingly variable climate. Smallholder farmers and other agricultural extension agents need to build and understand social dimensions that influence farm level decision making. The role of the smallholder farmers is to know two key ingredients that are within the whole idea of using in an effective way weather information, which are the integration of weather forecasts and the decision making. The climate change era that the world is passing through, need more data that are within the weather forecasting information which will address an environmental and socio-economic issues. Climate and weather forecasting information also works in health management, whereby, individuals with health conditions like allergies or asthma, who are sensitive to weather changes, to use the information for effective preparation to their health condition and manage their symptoms. So many benefits that are brought by knowing and predicting weather forecasting, be it economically, socially and environmentally. Farmers use these weather forecasting information in planning ahead some of their activities like, the optimum planting by choosing different types of crop varieties and cultivation systems due to different rainfall patterns, harvesting, as well as irrigation schedules, all of which will maximize crop yields and minimize losses due to unexpected weather.

Justification for using weather forecasting information

Irregular weather parameters expose farmers especially smallholder farmers in Rwanda to multiple uncertainties which compromise food and water security, income and wealth. The application of weather forecasting information is still limited to many smallholder farmers and this accelerate the danger to poverty and food insecurity that are caused by the negative impacts of climate change. Two main constraints being;

Lack of access to weather and climate information

Poor smallholder farmers have this constraint and mostly goes by the lack of appropriate tools that Meteorological agencies pass their information from, like Radios, TV or SMS through mobile phones. Smallholder farmers who are not in possession of these tools tend to lack also the weather and climate forecast information hence continue to suffer from negative impact caused by climate and weather changes in their various activities, especially farming activities.

Limited capacity to utilize the climate information

Accessing weather and climate information is one thing and understanding the language is another. Smallholder farmers need basic information on how to interpret some of these information. Capacity building is needed for them to understand information like, the amount of rainfall in a season (agricultural season) and corresponding to different crop water requirement, so that they can choice the appropriate crop relevant to the amount of rain that is expected in that particular agricultural season.

The work of Meteo- Rwanda has been a tremendous one because it can disseminate weather forecast in a day to day basis. These information are channeled through radio and TVs channels, and there are ways to SMS subscribing that people register and receive the information directly to their mobile phones. This direct method of communication facilitates farmers in utilizing the data effectively for their planning. Figure 2 shows weather forecasting information and its uses in agriculture.

Figure 2: Weather forecasting information and its uses in agriculture

Weather forecast and climate information not only give farmers information but it should focus on the interpretation and providing proper and effective advices which meet their needs. Weather forecasting for farmers is always focusing on the level of rainfalls and its occurrences and the temperature regarding drought period. With the help of Meteo- Rwanda, CIAT, RAB and Radio Huguka, all together we have had series of trainings conducted to different farmer promoters (FPs), using PICSA approach, were these FPs were trained on how to interpret the weather and climate data and plan their agricultural and off-farm activities based on the information fetched from weather and climate forecasting. There are various weather and climate information services that are provided by Meteo-Rwanda which can be accessed by farmers and other stakeholders, which include;

- Daily weather forecasts which outline predictions on temperature and rainfall variability to farmers on a daily basis,
- Monthly climate outlook which report temperature and rainfall variability on a monthly basis

Figure 3 provides an illustration of the rainfall variability experienced throughout the year, which serves as a foundational component for various climate information services:

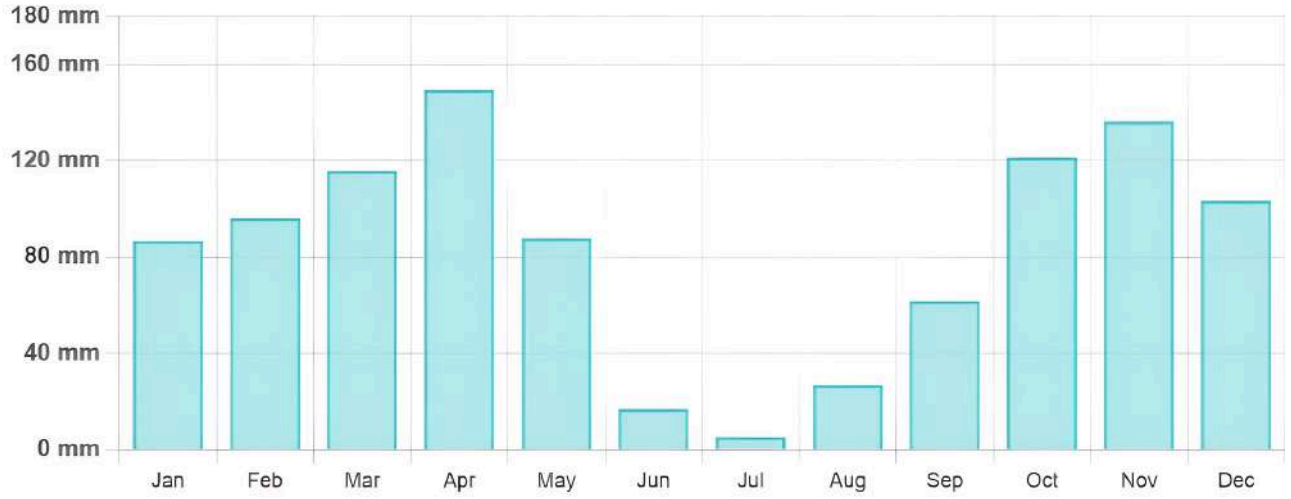

Figure 3: Rainfall variability on a monthly basis

As illustrated in Figure 3, the rainfall variability throughout the year provides the foundation for several key weather information services:

- Seasonal climate outlook which gives information on the rainfall seasons in a year. This information entails predictions on expected temperature, crop performance, rainfall onset and cessation dates and their distribution throughout the season.
- Climate alerts which are also known as early warning. The information here include floods and drought and the associated impacts based on the previous events.

The information above is vital for Rwandan farmers. While the exact number accessing weather forecasting is not fully documented, a 2024 survey published by Frontiers in Climate suggested that around 69% of 100,000 surveyed farmers access forecasts, indicating a significant increase in beneficiaries of Meteo-Rwanda services. However, many smallholder farmers combine this with indigenous/traditional knowledge. This traditional knowledge is built from observing natural indicators over time and is used for decision making in (1) Agriculture activities, (2) Medicine, (3) Food production and preservation, and (4) Soil and water management. The natural indicators these traditional practices are based on include observation of the following:

- Clouds, moon and stars,
- Behaviors of animal and insects
- Flowering ad shedding of leaves,
- Strength of the wind.

The behavior of the above natural indicators, some can related to the scientific explanations and others say that they are, grounded in a cultural narratives and community- based epistemologies. However, due to highly variable climate changes over the years, smallholders have lost confidence in indigenous forecast and hence seek scientific seasonal forecasting for climate change adaptation and mitigation. With the experience, it has shown that both scientific and traditional forecasts have their strengths and weakness, and thus the combination of both types of information are recommended to increase the adaptation and mitigation to climate change. According to the study conducted by Emmanuel Nyadzi et al, 2022, towards weather and climate services that integrate indigenous and scientific forecasts to improve forecast reliability and accepted in Ghana. They found out that, the majority of the farmers (93%) prefer the Integrated Probability Forecasting (IPF) method, as it provides a reliable forecast, requires less time and the same time resolves the contradictions arising from forecast information from different sources. Due to the effectiveness and accuracy of the IPF method, farmers already integrate the indigenous and scientific forecasts to make farming decision.

EARLY WARNING SYSTEM AND TOOL

What is an early warning system?

If we simplify for the smallholder farmers, the term early warning systems (EWS), as defined by UN, EWS, are the adaptive measures and a warning system for climate change that can be implemented, using integrated and chain of information communication to help communities prepare for hazardous climate- related events (UNEP, 2022) These chains of information communication, comprises of sensors event-detection and decision-making systems for early identification of hazards. The early warning systems are very important in the communities in these changing climate eras, because, it can work in various advantages including;

- Saves lives and jobs
- Land and infrastructures
- Support long-term sustainability
- Saving money in the long run and protect community finances
- Helps in proper planning

Early Warning Systems (EWS) are crucial for agriculture, providing farmers with timely, useful information to understand threats, prepare, and act effectively to minimize losses (Reid et al., 2009). The key elements of an early warning system are:

1. Risk knowledge
2. Monitoring and warning services
3. Dissemination and communication and
4. Response capability

These four interdependent elements form a continuous cycle necessary for effective EWS implementation, as Figure 4 illustrates the four elements of the Early Warning System below:

Risk knowledge

Deep understanding of hazard, knowing the elements at risks and who is vulnerable.

Response capabilities

Preparing evacuation centers, rescue plans, and relief goods.

Monitoring and warning

Monitoring rainfall and river levels to determine warning decisions.

Dissemination and communication

Using channels like Radio, TV, and telephone to spread warnings.

Figure 4: Four elements of the Early Warning System (EWS) as adapted by the United Nations, 2006

According to the National Institute of Statistics of Rwanda (NISR, 2020), over 76% of the population relies on subsistence agriculture. Although early warning communication channels are established across most districts and sectors, smallholder farmers still face challenges accessing and utilizing this information for effective response. Meteo Rwanda, the national institution mandated to provide accurate, timely weather and climate information and products, serves as the main source for EWS. Highly efficient and customer-focused, Meteo Rwanda channels this information, gathered from approximately 39 weather stations distributed across all four provinces and Kigali City (including low lands, high land, forest, and volcanic areas). Supplementing station data, sophisticated modern systems utilize SMS, emails, and apps to alert communities about potential flood and other risks, thereby aiding farmers and stakeholders in better preservation of their crops and livelihood.

Channels or types of Early Warning Systems

There are different early warning systems that are used to disseminate different alerts in Rwanda (United Nations Environment Programme, n.d.), some are here mentioned;

- SMS
- TV Broadcast
- Radio Data Service
- Local meetings and alerts from village level (Umudugudu)

All of these are to help people and in this case, mostly farmers, to prepare in advance for extreme weather. In Rwanda the warning network has been successful (United Nations Environment Programme, n.d.) because each day the number of SMS subscribers are increasing. More farmers are being trained to monitor and utilize rainfall data to inform agriculture activities (Nyasimi et al., 2016). Depending on the data from Meteo -Rwanda, like when the information is about high rainfall or long period of drought, then farmers are advanced to what and how? The most commonly used climate information for farmers are seasonal forecast of onset of rains, total amount of rainfall, and cessation of rains (Nyasimi et al., 2016), as summarized in the table below in **Table 1**.

Table 1: The most common used weather and climate forecasts information for farmers

Weather Forecasting information	Meaning	Farmer use
Seasonal forecast of onset of rains	The prediction of the rain season, when it likely to begin and in a specific area or region	Land preparation, which crop to plant and farm management
Total amount of rainfall	The accumulated depth of rain water over a specific area in a specified area. Measured in millimeters	planning for different agriculture system, crop selection and farm management
Cessation of rains	End of rainfall period and a transition to drier period	Agricultural planning, when to plant or harvest and water resource management

EVIDENCE OF IMPACT: Research Findings on Climate Services Effectiveness

Understanding the tangible impact of climate services is crucial for their continued adoption and improvement. Research findings from various initiatives highlight the significant benefits and successful implementation strategies, particularly in regions like Rwanda and across Sub-Saharan Africa. These findings provide evidence of how climate services empower farmers, enhance agricultural resilience, and contribute to broader development goals.

PICSA Program Results in Rwanda

Rwanda was the first country to train all district agronomists in climate services through PICSA (Participatory Integrated Climate Services for Agriculture)

The Rwanda Climate Services for Agriculture (RCSA) project reached over 1 million farmers from 2016-2020 (CGIAR, 2020)

PICSA training has been implemented across all 30 districts in Rwanda with measurable farmer adoption rates

Quantified Benefits for Farmers

Farmers using climate information services achieve 15-25% better crop yields compared to those without access (Hansen et al., 2020)

Better resourced smallholder farmers have significantly higher access and adoption rates of climate information services (Sciencedirect, 2024)

Climate services help farmers reduce production costs while maximizing agricultural yields and profits

Regional Context

- Sub-Saharan Africa faces intensified climate pressures by 2050, including higher temperatures and unpredictable precipitation patterns (IPCC, 2020)
- Climate Information Services (CIS) are crucial tools supporting proactive decision-making in agriculture across the region
- The strategic application of CIS aligns with Sustainable Development Goals, particularly poverty reduction (SDG 1), food security (SDG 2), and climate action (SDG 13)

KEY STATISTICS FOR AGRICULTURAL PLANNING

This quick-reference guide provides essential statistics for farmers and extension workers to inform local agricultural planning decisions.

Climate Change Impacts in Rwanda

- Annual minimum temperature increase: +0.76°C per decade (Challinor et al., 2007)
- Annual mean temperature increase: +0.48°C per decade (Challinor et al., 2007)
- Largest seasonal increase: +0.86°C per decade (June-August) (Challinor et al., 2007)
- Expected reduction in rural household consumption by 2050: 5-10% (Challinor et al., 2007)

Farmer Awareness and Adoption

- 85% of farmers acknowledge climate change is occurring (National Institute of Statistics of Rwanda, 2020)
- 54% observe temperature increases in their farming areas (National Institute of Statistics of Rwanda, 2020)
- 37% note rainfall pattern changes (National Institute of Statistics of Rwanda, 2020)
- 93% prefer Integrated Probability Forecasting (IPF) methods when available (National Institute of Statistics of Rwanda, 2020)

Regional Agriculture Context

- 70% of smallholder farmers in Africa depend on rainfed farming systems
- Agriculture accounts for 25% of Rwanda's GDP
- Over 80% of Rwanda's population depends on agriculture for livelihoods
- Agriculture accounts for 40% of GDP across East African Countries

Climate Services Reach

- Over 1 million farmers reached through Rwanda's climate services program (2016-2020) (Clarkson et al., 2020)
- All 30 districts in Rwanda have trained agronomists in climate services
- Daily SMS subscriber numbers continue increasing for weather information

These are the most used weather information that farmers use to adjust their farm decisions (Clarkson et al., 2020). The most important decisions farmer takes when receiving the weather information regarding their agricultural activities are;

1. The decision whether to farm or not (in a particular season)
2. Which crop to grow depending on the amount of rainfall in that season (Crop and variety selection)
3. Which farming system to apply (e.g, Intercropping or monocropping)
4. Timing of land preparation
5. Time of planting
6. The use of organic and inorganic fertilizers.

Figure 5 shows farmers consulting weather data to make informed decisions about their agricultural activities.

Figure 5: Farmers consult weather data to make informed decisions about crop selection, planting times, and overall farm management.

A study conducted by PISCA confirmed that bean farmers who used weather information before planting achieved significantly higher yields (1300 kg/ha) than those who did not (800 kg/ha) (Clarkson et al., 2020). This gap demonstrates the value of planning based on information. Climate information and advisories are useful tools for boosting farmer confidence and guiding agricultural activities toward sustainable production amid climate change. For this to be realized, climate information services must be accessible, accurate, and relevant for effective decision-making.

SEASONAL WEATHER FORECASTING WITH CROP SELECTION

Crop behavior

Different crops will always need different type of soils, different types and amount of water, and different type and amounts of nutrients. The amount of water required by crop, is dependent on the growing season and the climate where it is grown. Take a good example of topography in Rwanda, where you find, widely grown crop in the Northern and Western Province is dominantly Irish potatoes, while in Eastern Province the dominant crop is maize (National Institute of Statistics of Rwanda, 2020). This mostly goes with the altitude of the area, amount of rains, temperature levels and soil structures of the area. Different stage of crop development will also need different amount of water. Therefore, by selecting the right crop for a given soil and climate conditions, a farmer can optimize yield and save water requirement for irrigation if needed. The importance of seasonal weather forecasting is therefore helping farmers to plan accordingly and select which crop per the amount of rainfall available in the particular season. The crop water requirement and need is mainly depending on the following;

- The climate
- The crop type and
- The growth stage.

These are the factors that influence the amount of water needed by the crop. Normally the crop water needs are typically higher in sunny, hot and windy climate and in low in cloudy cool, humid climate with little wind speed. Different crops need different amount of water due to their physiological factors. The crops like rice and sugarcane, need more water than crops like beans and wheat. Smallholders need to understand the simple crop- water requirement in a season and stages of crop growth. Because the crop doesn't need much water in all its lifespan. There are stages that need more water than other stages. For example;

> In my experience, I have observed that, a fully- grown crop will need more water than the crop that has just been planted. 50% of the crop water is needed during mid-seasonal stage, that where the crop is fully developed. And another thing is that, the maximum amount needed is when a crop reached at the end of crop development stage which is the beginning of the mid-seasonal stage.

The lifecycle of a crop can be divided into four primary stages, each requiring a specific amount of water (Food and Agriculture Organization of the United Nations, 2022; see figure 6):

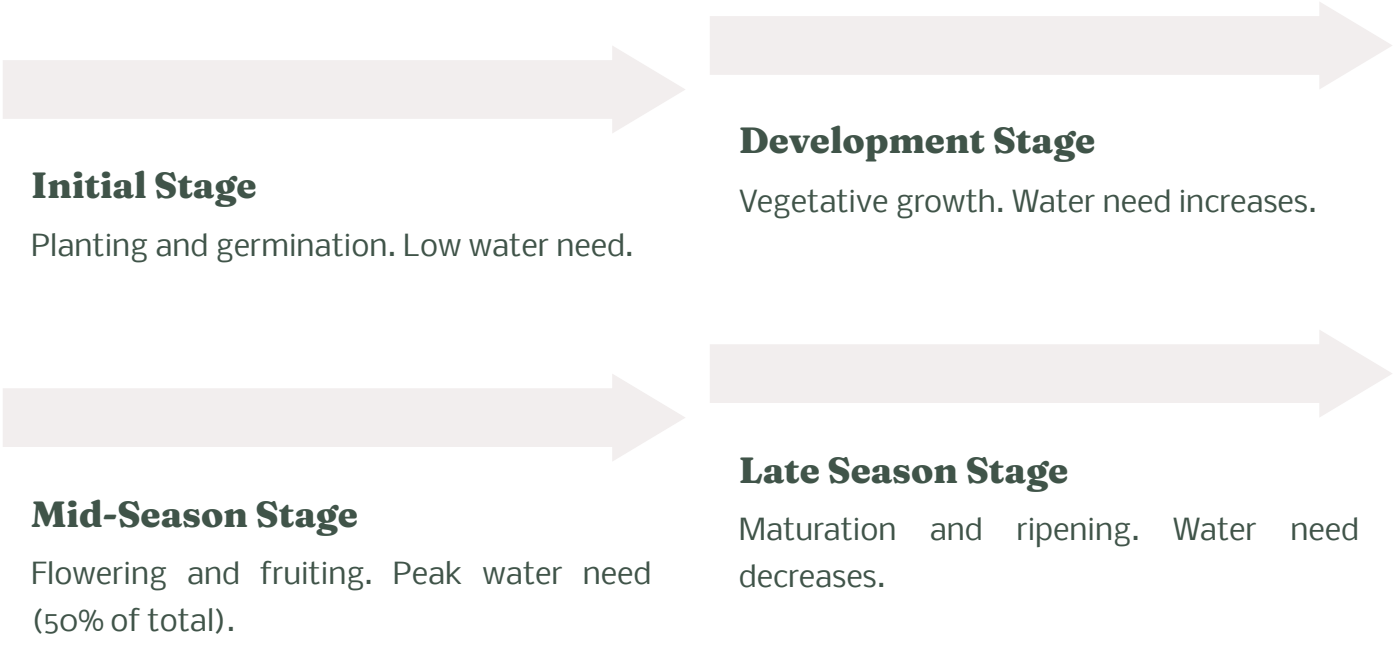

Figure 6: Growth stage of a crop. Source, FAO (1986)

The water needed for plants are usually expressed in millimeter per day (mm/day), millimeter per months (mm/month) or millimeter per season (Food and Agriculture Organization of the United Nations, 2022). This simply means, each day the crop need a water layer of 10mm over the whole area on which the crop is grown. The irrigation water can still be possible if you supply 50 mm of water every 5 days, this will be 10mm per day. The water will be stored in the root zone and gradually absorbed by crops.

When a farmer understand this, it will be easier for them to plan according to the weather forecast information for the particular season. Therefore, with the combination of weather forecast information and the crop water requirement knowledge, this will help farmers to plan and consider some factors before applying a different crop, and these are;

- Which crops to cultivate that are corresponding to the amount of rainfall in a season? If decided to select a particular crop that need more water than the amount of rainfall in a season, is there any irrigation system planned?
- Which agricultural system to be used according to the amount of rainfall received? (example if the forecasting information showed small amount of rainfall, which methods of water harvesting to used, is it mulching or cover crop or the intercropping, to keep moisture in the soil and prevent more evapotranspiration or is there any plan for having water harvesting techniques like water reservoirs in the area?).
- And if there will be more amount of rainfall than the crop water requirement, which measures are you planning to use? Is there any drainage system in your soil? Are you willing to use ridge and farrows or any other methods of draining water in the field?

The Climate Factor

Normally, crops need more water per day in a sunny and hot climate than in a cloudy and cool climate (Blain, 2013). There is a need also to consider the amount of water through percolation and evapotranspiration in order to calculate the right amount of irrigation water needed in times of drought (Food and Agriculture Organization of the United Nations, 2022). There are so many techniques that are related to climatic factor, which include mulching, tillage techniques (like zero or minimum (20- 25%) tillage), soil cover using cover crops and other soil amendments like using green manure and agroforestry, all are related to climate factors and the weather forecasting information that derive such decisions at action (Blain, 2013). With the weather forecasting and proper decision making for farmers, regarding the crop- water need to reach its full production potential under a given environment, without forgetting that for the nutrients to be absorbed into plant system, nutrients must be transported through soil solution (soil water). Therefore, the crop water requirement will mainly depend on the following factors, as illustrated in Figure 7:

- **The climate** - The crop will need more water per day during the sunny and hot climate than in cloudy and cool climate,
- **Crop type** - Different crops will need different amount of water in a season, like maize and beans require different amount of water in a season,
- **The growth stage** - Grown crops need more water than those that have been just planted.

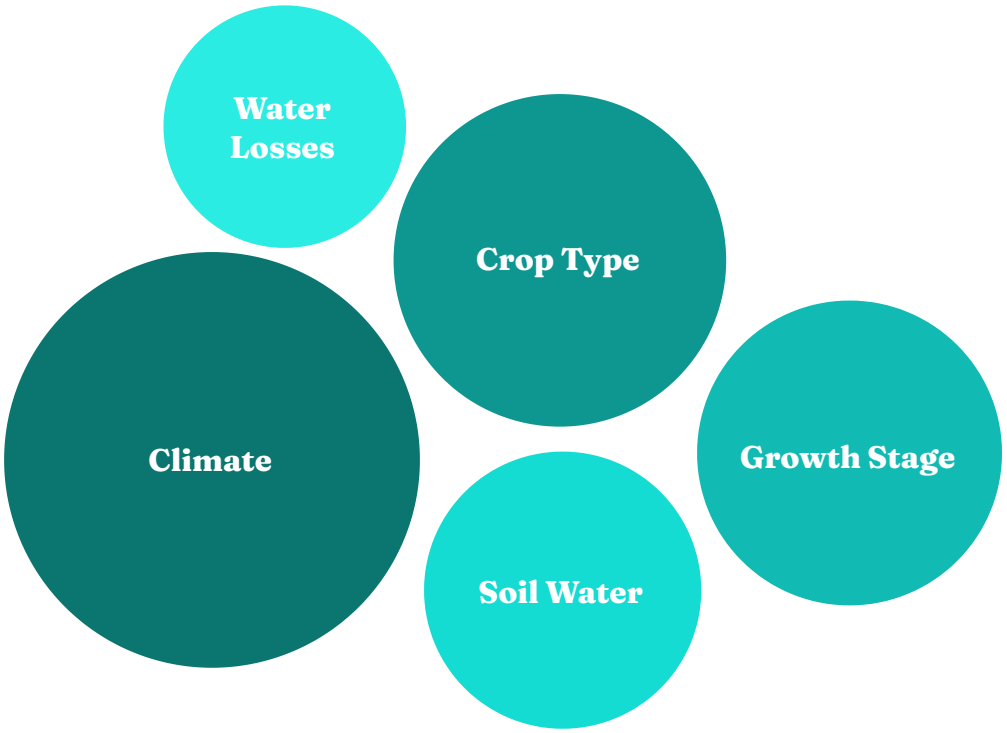

Figure 7: Key factors influencing crop water requirements.

Table 2 provides approximate seasonal water requirements for various crops commonly grown in Rwanda and similar climates.

Table 2: Approximate values of seasonal water need (FAO, 2022)

Crop	Crop water (mm/total growing period)
Banana	1200- 2200
Bean	300- 500
Cabbage	350- 500
Citrus	900- 1200
Maize	500- 800
Onion	350- 550
Peanut	500- 700
Potato	500- 700
Pea	350- 500
Rice (Paddy)	450-700
Pepper	600- 900
Soybean	450- 700
Tomato	400- 800
Sorghum/Millet	450- 650
Sunflower	600- 1000
Wheat	450- 650

SMALLHOLDER FARMERS' ADAPTATION TO WEATHER FORECASTING INFORMATION

The adaptation journey is possible

Rwanda offers accessible daily, monthly, and seasonal weather forecasting information to farmers. While the information is readily available, the challenge lies in farmer awareness and integrating this scientific knowledge with traditional prediction methods, especially as climate change necessitates such adaptation (Clarkson et al., 2020). Sector agricultural officers nationwide receive these daily, weekly, monthly, and seasonal forecasts through various channels. Smallholder farmers, individually or through cooperatives, can easily access this information from these local agronomists or directly from Meteo-Rwanda (Reid et al., 2009). With minimal training on its application, farmers can utilize this data to plan their agricultural activities effectively. Access to weather forecasting information enables various adaptation strategies, such as:

Change in cropping dates

Which corresponds with the weather forecasting information.

Change in crop varieties

Depending on the information about rainfall amount and temperature.

Use of early maturing varieties

Due to the time and period of the season.

Crop diversification

Based on the cessation of rainfall.

Soil and water management strategies

(e.g Bench Terraces, mulching, introducing agroforestry system in farming).

Fodder planting

The use of fertilizers

(Organic, Inorganic, or the combination of both).

The weather forecast does not only tell farmers the amount of rainfall or temperature level, but as well as the information on the infestation and incidence of pest and diseases (Nyasimi et al., 2016). There are some risks of pest and diseases when the rainfall is high or low and when temperature levels changes from what it used to be and take a new cause. There is no doubt to the expected outcome if farmers are using well the weather forecasting in their everyday lives, and these out comes are;

Higher crop yield

Food and water security

And hence eradicate poverty in the communities.

High income and increase in wealth

For the smallholder farmers' families.

Climate change resilient

By adapting to any given situation and having multiple ways to withstand changes.

Frequent interaction between farmers and agricultural extension agents will likely increase the access and utilization of weather forecasting information and hence enhance their agricultural productivity in a sustainable way. According to my observation some of the older farmers have monitored climate change over time and have established the traditional alternative adaptation options, and thus reducing their probability to access and utilize weather and climate information. This is not the case to young ones who are more taken to updated information. Therefore, there is a need to combine both traditional and scientific knowledge for the common development of their communities as far as sustainable agricultural production is concerned. On top of all of these, there is one aspect that farmers need to understand, and that is education, which is always a better choice to understand these issues easily. Capacity building in form of trainings, are needed for farmers as well as more on- farm researches to ensure that farmers are well trained on the hands-on. Meteo- Rwanda, RAB, and CIAT through its PICSA program have been on the forefront into this journey of training smallholder farmers on how to access and utilize weather and climate information and linking these information to the best agricultural decisions.

Adaptation benefits

The principal benefits for smallholder farmers, leveraging specific weather information, include informed farming decisions that lead to quantifiable improvements. For instance, farmers utilizing climate information services have seen **15–25% better crop yields** compared to those without access (Hansen et al., 2020). This information helps them make beneficial choices to **minimize costs and maximize agricultural yields and profits**, significantly reducing vulnerability to extreme environmental impacts. Climate services also provide evidence-based guidance for critical decisions like **crop selection, optimal planting schedules, and effective farming techniques**. Beyond enhancing crop production and income generation, weather forecasting adaptation offers several other crucial benefits within the farming sphere, such as:

Fertilizer timing

Weather forecasting will help farmers to know the best time to apply fertilizers. The soil must be neither too dry to prevent penetration of fertilizers nor too wet to the extent of runoff for maximum fertilizer effect.

Field workability

Weather forecasting will guide farmers on when to work on your farmland or not, allowing you to plan best daily schedule for your fieldwork.

Pest control

Proper weather forecast will guide you in predicting when pests may come and guide on the best time to implement pest control measures for optimum results.

Irrigation method

Weather forecasting will help you to know when to irrigate and when not to do so. Sometime you could apply irrigation and lose all the water applied through evapotranspiration.

For these benefits to fully materialize in agricultural practices, smallholder farmers must proactively identify areas requiring tactical changes to capitalize on predicted above-average rainfall or mitigate losses in below-average situations. When combined with identified key management decisions, climate and weather forecasts unlock significant value, contributing directly to several Sustainable Development Goals (SDGs), particularly those related to zero hunger, poverty eradication, and climate action.

CONFLICTS OF INTEREST

The author declares no conflict of interest

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Not Applicable

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Biogas Energy Generation Project for Sustainable Rural Development in Egypt, Qena Governorate (ENSAN AID Foundation)

CASE STUDY

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ENSAN AID Foundation, Egypt

This article is part of a special issue titled Bridging Power and Knowledge: Addressing Global Imbalances in Knowledge Systems for Sustainable Futures.

PLAIN-LANGUAGE SUMMARY

Animal Waste Challenge

Rural Egyptian communities face environmental problems from improper livestock waste disposal, leading to soil pollution, unpleasant odors, and groundwater contamination.

Biogas Solution

ENSAN Aid Foundation developed a project to convert animal waste into clean biogas energy and organic fertilizer through biogas digester units in Al-Taramsa village.

Community Benefits

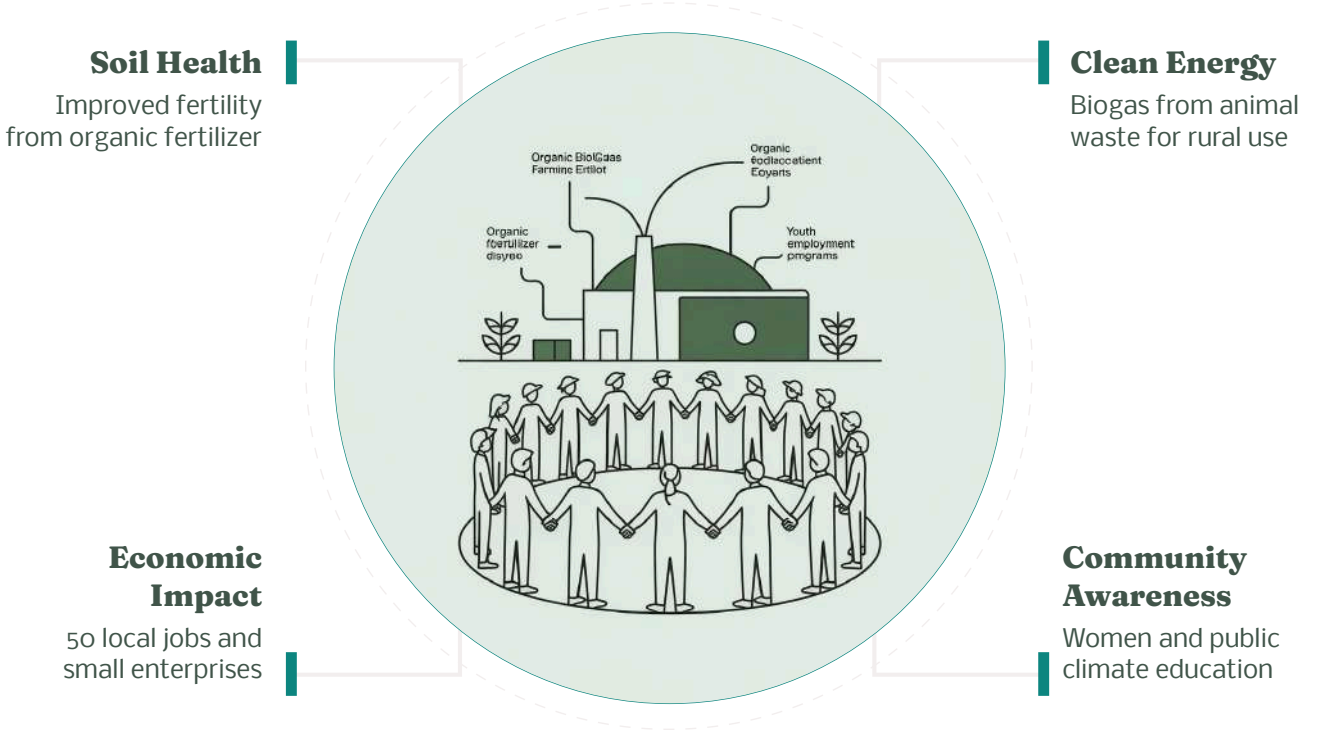
The project created 50 job opportunities for youth, improved soil fertility through organic fertilizers, and raised awareness about climate change challenges.

Sustainable Impact

This initiative demonstrates how civil society organizations can address environmental challenges while promoting economic development and community empowerment in rural Egypt.

ABSTRACT

This case study aims to highlight how the ENSAN Aid Foundation for Development has contributed to improving environmental, economic, and social sustainability in rural areas through its biogas energy generation project. It also explores the possibility of expanding the project implemented by the foundation to other similar areas in Qena Governorate in particular, and Upper Egypt in general, within the framework of ENSAN Aid's project, which aims to convert animal waste into clean energy and organic fertilizer. A mixed-method research approach was adopted, combining primary data from the field (questionnaires, focus groups, participatory assessments) conducted by ENSAN Aid, with secondary data from government reports and previous studies on bioenergy and rural development in Upper Egypt. The study concluded that: The fertility of agricultural soil increased after using organic fertilizers produced from biogas. Providing 50 job opportunities for youth in Qena Governorate, Egypt, including employment in the construction of biogas units and employment in small projects such as mushroom cultivation, recycling solid waste such as organic materials, producing organic fertilizer, and planting rooftops. Raising awareness among women and society as a whole about the challenges posed by climate change and how to address them.



Keywords: ENSAN Aid Foundation, Sustainable Development, Circular Economy, Biogas

INTRODUCTION

Livestock plays a significant and pivotal role in the global economy and food production. According to the OECD and FAO in 2017, livestock contributed approximately 40% of agricultural output in developed countries and 20% in developing countries, this sector has grown rapidly in developing countries, averaging 2.5% annually over the past two decades (Building Resilience in the Egyptian Livestock Subsector, 2025). Domestically, food security is undoubtedly one of the most important pillars of national strategic security, Livestock is an integral part of agricultural activity and one of Egypt's most important agricultural capital resources due to the contribution of its various products (primary and secondary) to agricultural production. This gives it a prominent position in the economic structure in general, and the agricultural economy in particular (GAFI, 2024).

The number of livestock (buffalo, cows, camels, sheep, and goats) reached 16.3 million in 2018, compared to 17.3 million in 2017, representing a decrease of 5.5%. The number of cattle reached 4,379,000 heads in 2018, compared to 4,387,000 heads in 2017, a decrease of 0.2%. However, the number of buffaloes reached 3,445,000 heads in 2018, compared to 3,433,000 heads in 2017 (Figure 1) (Annual Bulletin of Livestock Statistics 2019, 2019).

Figure 1: Egyptian livestock representing the significant role of cattle and buffalo in the country's agricultural economy

LIVESTOCK STATISTICS AND WASTE MANAGEMENT CHALLENGES

Table 1: Evolution of the Estimated No. of Cattle and Animals Heads During the period (2014-2018) (in thousands).

Type	2014	2015	2016	2017	2018
Cows	4762	4883	5012	4387	4379
Buffaloes	3949	3702	3437	3433	3445
Sheep	5503	3463	5556	5305	4830
Goats	4186	4046	4260	3974	3572
Camels	158	153	157	156	85

Source: (Annual Bulletin of Livestock Statistics 2019, 2019).

As illustrated in Table 1, although livestock is a source of capital and income, providing essential nutrients and additional benefits such as draught power, transportation, and organic fertilizer for soil fertilization, the increasing number of livestock has led to the production of more waste (animal manure), which leads to the spread of diseases, unpleasant odors, and groundwater pollution. However, the disposal and management of this waste is poor, resulting in serious environmental problems and significant burdens on the state. However, it could represent a hidden treasure if properly and efficiently exploited. There is an urgent need to address this problem and find scientific and practical solutions to the tragic environmental, social, and economic situation facing rural villages due to this waste and its burning. This is to preserve the environment and make communities more sustainable. This is what civil society organizations in Upper Egypt have sought to achieve, especially the ENSAN Aid Foundation, the case study we are focusing on. The Foundation aims to help rural communities achieve zero pollution, which has led to interest and support for biogas production as a renewable and environmentally sustainable resource.

BIOGAS PRODUCTION AS A MECHANISM FOR TRANSITIONING TO A CIRCULAR ECONOMY

The circular economy is based on the concept of the 3Rs (reduce, reuse, and recycle). "Reduce" refers to reducing the amount of waste in the economy, "reuse" refers to using products again as part of new products, and "recycle" refers to using the product again after processing it (Ratten, 2024). The circular economy is a way of understanding how resources are used and then reused. This means that after a product becomes waste, it is transformed into something else that can be used. This means that the relationship between production and consumption is no longer linear (that is, a product is no longer used and then discarded), but rather circular, where the product is produced, remanufactured, and then reused in a continuous cycle (Ratten, 2024).

In this context, biogas production goes through several stages (Figure 2 & 3). The process begins with hydrolysis, where large proteins, carbohydrates, and fats are converted into amino acids and long-chain fatty acids. These compounds are then converted into volatile fatty acids through acidogenesis. This is followed by secondary acidogenesis, where the volatile fatty acids are converted into acetic acid (vinegar), carbon dioxide, and hydrogen. Bacteria then consume these products to produce methane (CH_4), the main component of the biogas. This gas is highly flammable, with the methane content typically ranging from 50% to 75% (Naihma, 2017).

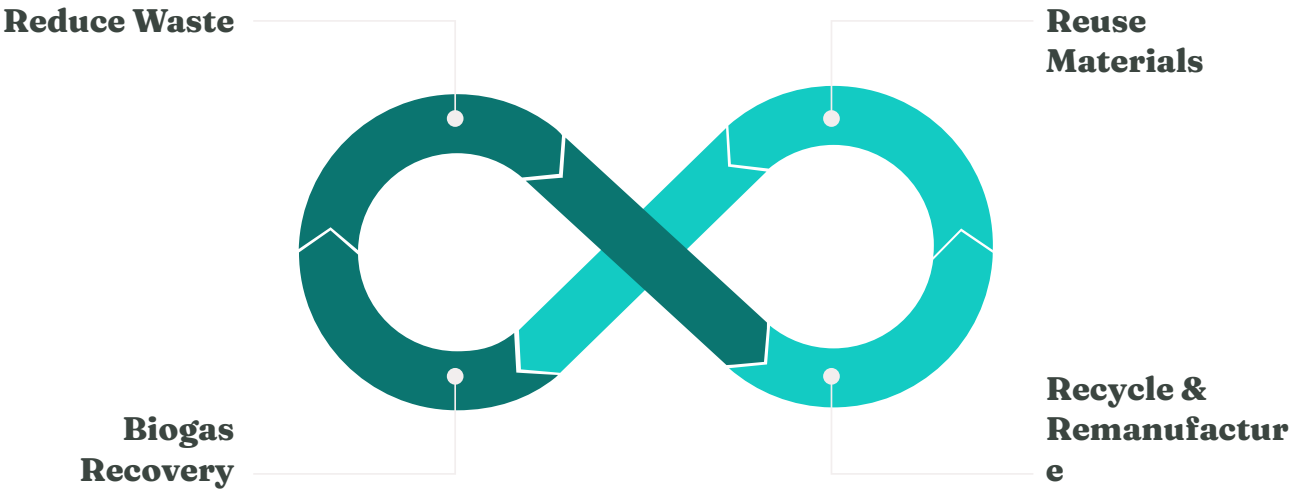


Figure 2: Production process

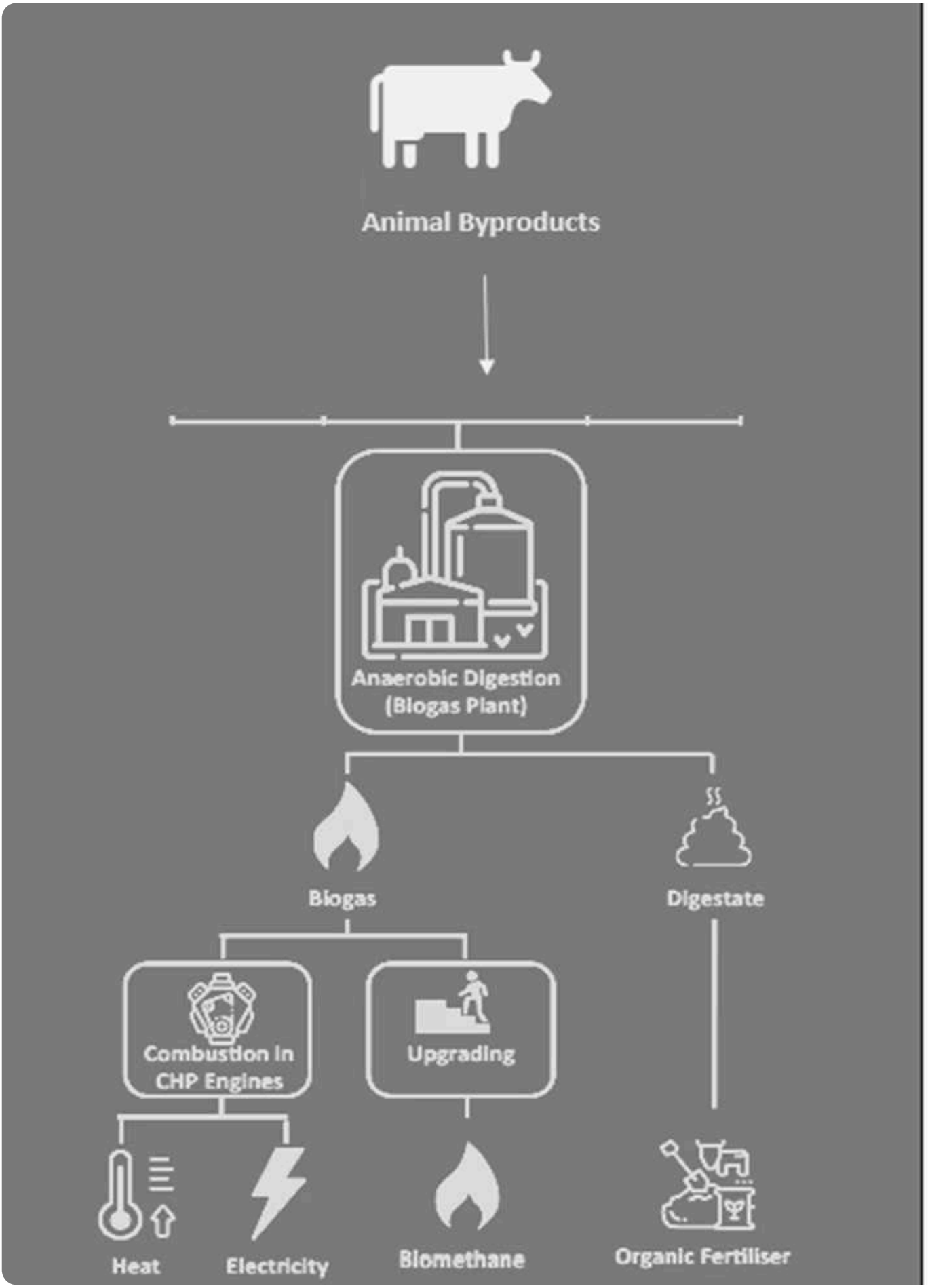


Figure 3. Biogas energy generation process

BIOGAS APPLICATIONS AND BENEFITS

01

Direct Use for Cooking and Lighting

The combustion of biogas produces lower emissions than the combustion of other biomass species, contributing to improved indoor air quality.

02

Electricity and Heat Generation

The calorific value of natural gas ranges from 50% to 70%. Burning biogas in gas generators or gas boilers can produce electricity and heat.

03

Vehicle Fuel Alternative

Biogas can be used as an alternative fuel for vehicles after being purified of impurities and modifying its properties to meet standards.

04

Natural Gas Network Integration

Purified biogas is fed into natural gas distribution networks for wider use as an alternative and sustainable energy source.

To maximize the benefits of biogas and its uses, practical solutions must be found to address the problem of waste and the management of agricultural organic waste. This problem can be attributed to several factors: Rapid population growth, Increased economic and industrial activity, Urban expansion and the spread of unregulated informal settlements, Lack of awareness and illiteracy, Absence of clear policies, and Inadequate waste management systems (Nassar et al., 2023).

CASE STUDY: ENSAN AID FOUNDATION AND ITS ROLE IN BIOGAS GENERATION IN UPPER EGYPT

ENSAN Aid implemented a biogas energy generation project in rural Egypt, specifically in Al-Taramsa village in Qena Governorate. Based on a field study conducted by the foundation in the village, focus groups revealed a pressing issue of environmental pollution. This problem is attributed to the large number of livestock in the agricultural village, where families owning these animals dispose of the waste indiscriminately, resulting in multiple environmentally harmful consequences.

ENSAN Aid relied on the following methodology to implement the biogas generation project:

Integrated Analysis

Understanding the village's production system, including the value chains of agriculture and livestock, focusing on opportunities for private sector involvement in establishing biogas units and waste recycling.

Comprehensive Assessment

Data collection on the economic, social, and environmental conditions of each household participating in the project, monitoring agricultural practices related to livestock rearing and organic waste management.

Household Resilience

Evaluating the household's ability to benefit from biogas units, generate additional income from organic compost production, and resilience to climate change and resource scarcity.

Participatory Approach

Involving farmers and youth in evaluating agricultural practices and contributing to planning environmental initiatives within the village, such as rooftop gardening and recycling.

TARGET COMMUNITY: AL-TARAMSA VILLAGE

The field sample size required to study the impact of the biogas project in Al-Taramsa–a village with a population of 33,000–was determined using approved statistical methods. The sample size was calculated at 380 individuals. This sample was subsequently distributed across the ten neighborhoods of the village according to the relative population weight of each neighborhood (as detailed in Table 2). This was carried out using a proportional stratified sampling method, ensuring accurate and fair representation of all segments of the local community.

Table 2: Number of Hamlets in the village of Tramsa in Qena Governorate in Egypt. Source: (ENSAN AID Foundation)

Hamlets	Percentage (%)	Sample Size (out of 380)
Hajer Al-Jabal	15%	58
Adhbat Al-Zahalit	14%	54
Jazirat Al-Taramsa	12%	45
Nagaa Al-Arab	9%	33
Adhbat Jad	11%	42
Nagaa Al-Sheikh Naggar	10%	38
Nagaa Al-Maghariba	7%	30
Sheikh Hassan	11%	40
Nagaa Beit Abdel Nabi	11%	40
Total	100%	380

VILLAGE CHARACTERISTICS AND PROJECT SCOPE

33K	10	8	70%
Population	**Hamlets**	**Project Duration**	**Target Girls**
55% males and 45% females	Including the mother village	Months	Of youth aged 18-29

About the target community: (Al-Taramsa Village) Its population is 33 thousand people, 55% males and 45% females. The village depends on agriculture and livestock, and a number of young people work in various professions by managing projects specific to the village and outside the village (in Qena Governorate). The mother village (Al-Taramsa) has 9 hamlets, including: 1. Hajer Al-Jabal 2- Adhbat Al-Zahalit 3- Jazirat Al-Taramsa 4- Nagaa Al-Arab 5- Adhbat Jad 6- Nagaa Al-Sheikh Naggar 7- Nagaa Al-Maghariba 8- Sheikh Hassan 9- Nagaa Beit Abdel Nabi (Figure 4).

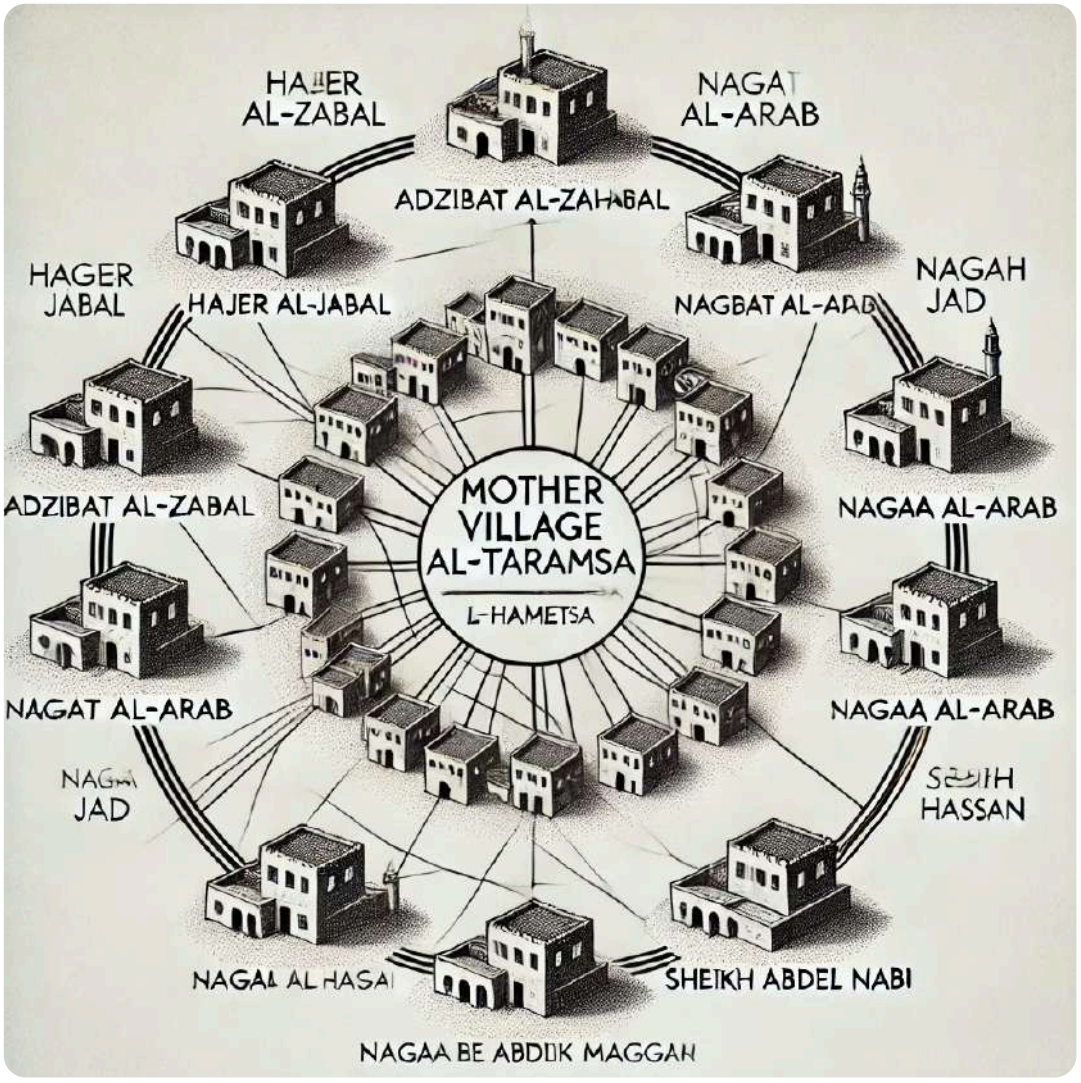


Figure 4: Map or diagram showing the layout of Al-Taramsa village and its surrounding hamlets.

Project implementation in Al-Taramseh leveraged a deep understanding of local social and economic structures. Biogas units were designed based on local knowledge of livestock waste handling, ensuring they are simple, user-friendly, and maintainable by local farmers, aligning with agricultural practices without requiring complex external support. Unit models matched community educational levels and available resources. Active involvement of diverse residents (including women and youth) in management enhanced acceptance, making local knowledge key to implementation and long-term sustainability. As an agriculture and livestock-dependent village serving as a hub for ten surrounding villages, Al-Taramseh positions this project as a scalable model for similar communities.

TARGET GROUP AND GENDER-RESPONSIVE APPROACH

Geographical scope: Al-Taramsa village in Qena Center, encompassing 10 villages. Target group: Youth aged 18-29 (70% girls, 30% boys). Seventy percent of girls in Al-Taramsa lack active community involvement, employment, and skill development opportunities. This demographic reality presents a strategic opportunity for gender-sensitive development interventions, aligning with the following objectives:

Integrating Youth into Rural Climate Action

The biogas project provides a practical training platform for youth—not only in the operation and maintenance of units, but also in resource management and recycling—thereby enhancing their role as active contributors to environmental transformation.

Economic and Social Empowerment of Girls

Project activities were specifically designed to ensure the participation of girls and young women through training on household biogas unit operations, environmental awareness sessions, and capacity building in life skills and decision-making.

Gender-Responsive Climate Action

Targeting this group ensures that climate response strategies are comprehensive and equitable, recognizing women's distinct roles in household management, energy consumption, and waste handling.

Contributing to Sustainable Development Goals

The project directly supports the achievement of several SDGs, particularly those related to gender equality, clean energy, climate action, and inclusive economic growth.

Local partnerships include the Environmental Protection Fund, Bioenergy Foundation, and Al-Taramsa Community Development Association. Project duration: 8 months.

IDENTIFYING THE PROBLEM

Based on a field study conducted by the Ensan Aid Foundation through seven focus groups in the village of Al-Taramsa, located in Qena Governorate, Egypt–with the participation of youth, women, farmers, and representatives from governmental and non-governmental agencies (Figure 5)–the study concluded that the problem of environmental pollution stems from the abundance of livestock and the indiscriminate disposal of waste by families who own these animals. This practice leads to numerous environmental and public health issues. Considering the village's priorities and the number of individuals affected, the study identified the environmental and economic crisis as the most pressing concern, impacting approximately 90% of the community. This situation contributes to environmental degradation, the spread of disease, and high rates of unemployment among youth, which collectively undermine economic, social, and health outcomes.

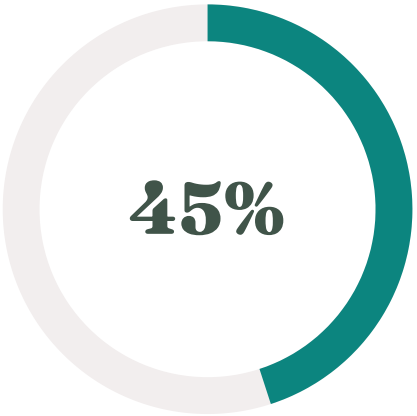
Figure 5. Youth participation in the Al-Taramsa village in the biogas generation project. Source: ENSAN Aid Foundation

Causes of the problem: Large quantities of accumulated animal waste, including solid farm materials, contribute to surface pollution, often compounded by pesticide contamination. While effective against harmful insects, pesticides severely harm soil bacteria necessary for organic matter decomposition and nutrient absorption, leading to a progressive decline in soil fertility. This reliance on chemical pest control poses a major ecological concern, as insects develop resistance and more resilient species capable of devastating crops emerge. Furthermore, chemical substances used in modern pest control contaminate food (grains, fruits, vegetables) and soil, posing significant human health risks. In Al-Taramsa, weakened soil and reduced fertility are directly linked to excessive pesticide and chemical fertilizer use; approximately 90% of village farmers rely on chemical fertilizers.

DEMOGRAPHIC ANALYSIS AND PARTICIPATION

Village Population Distribution

Males



Females

AL- Taramsa Village Gender Distribution Total Population: 33000. Source: ENSAN Aid Foundation

Youth Target Distribution

Females

Males

Youth Target (aged 18- 29) Distribution Gender. Source: ENSAN Aid Foundation

Capacity Building Participation

Females

Males

Capacity Building Participation (aged 18- 29) 50 youth: 70% Females, 30% Males. Source: ENSAN Aid Foundation

ENVIRONMENTAL AND SOCIAL IMPACTS

Furthermore, the unregulated accumulation of animal waste contributes to both visual and environmental degradation, creating significant public health risks such as respiratory issues from airborne pollutants and waterborne diseases from contaminated sources. This also imposes economic costs through increased healthcare burdens and reduced agricultural yields. Additional challenges facing the village include: The high cost and scarcity of gas cylinders, which has led many women to burn waste in traditional ovens to secure income–further exacerbating environmental pollution. Limited employment opportunities for both young men and women, leading to economic stagnation. A general lack of awareness among residents regarding the importance of waste recycling, the value of organic fertilizers, the impacts of climate change, and basic public health practices. Limited awareness among women about their role in decision-making processes and community engagement, hindering social development.

Environmental Effects

- The spread of diseases and harmful insects from the accumulation of waste
- Environmental pollution from the use of local ovens in the village
- Groundwater contamination and soil degradation
- Increased incidence of respiratory illnesses due to air pollution
- Loss of local biodiversity and ecosystem health
- Unpleasant odors impacting daily life and well-being

Social Impacts

- The lack of job opportunities for young men and women
- The absence of the role of women in society
- Limited awareness about environmental conservation
- Out-migration of youth seeking better economic prospects
- Increased strain on household incomes due to health expenditures
- Reduced community participation and social cohesion

These environmental and social challenges are deeply interconnected, forming a complex cycle of poverty and ill-health. Environmental degradation directly undermines the economic stability of the community, particularly affecting farmers and women who rely on natural resources. In turn, social issues like unemployment and lack of awareness perpetuate unsustainable practices, making it harder to address the root causes of pollution and achieve sustainable development for Al-Taramsa.

Description of the groups affected by the problem: Youth aged (18-29) 70% girls, 30% males (University graduates and intermediate qualifications).

PROJECT OBJECTIVE AND INTERVENTIONS

The project aims to provide biogas by using cattle manure to produce safe methane gas (does not cause fires or suffocation) which goes directly as clean fuel to the gas stoves in farmers' homes through clean energy in addition to producing organic fertilizer that improves the quality of agricultural soil and increases the productive capacity of the acre and provides the farmer with the financial equivalent of gas and agricultural fertilizers as an ideal way to support the Egyptian farmer economically and reduce the burden on him, and the interventions:

Establishing and Operating Biogas Units

4 biogas units (biogas) & producing new and renewable energy as a permanent and clean alternative and providing a source of high-quality municipal fertilizer.

Raising Awareness Among Girls

Through the Women and Life program, enhancing understanding of women's roles in environmental sustainability and community development.

Environmental Investment Education

Raising awareness among villagers about environmental investment and climate change challenges and opportunities.

Capacity Building for Youth

Building the capacity of youth to implement biogas units and develop skills for sustainable waste management projects.

OUTPUTS AND PROJECT RESULTS

The project aimed to provide a renewable source of biogas and high-quality organic fertilizer to improve soil properties through the establishment of four biogas units (see Figure 5 for an image of biogas delivered to homes in the village of Tramsa). It also sought to raise awareness among 250 farming families in the village of Al-Taramseh regarding animal waste recycling and environmental investment. Additionally, the project focused on empowering 50 young women by enhancing their understanding of their roles in society and building the capacity of 50 young men and women (30% male), aged 18 to 29, to implement biogas units and small-scale solid waste recycling projects throughout the project duration.

Figure 5. Biogas delivered to homes in the village of Tramsa in Qena Governorate, Egypt. Source: ENSAN Aid Foundation.

To assess the impact of awareness activities, the project utilized several direct evaluation tools, including: Pre- and post-awareness questionnaires to measure changes in participants' knowledge about the benefits of recycling and biogas. Brief interviews with families to gauge their willingness to adopt more sustainable agricultural and livelihood practices. Field observations, which indicated that a number of families began adopting waste recycling and composting practices following the awareness sessions–an encouraging sign of improved environmental awareness. Behavioral change among farmers, where those who initially resisted the implementation of biogas units at home later expressed a willingness to adopt the technology out of genuine conviction.

PROJECT ACHIEVEMENTS AND IMPACT

Table 3: Outputs and results of the biogas generation project in the village of Tramsa in Qena Governorate, Egypt. Source: ENSAN Aid Foundation

Outputs	Results
Installation of 4 biogas units	Providing a renewable energy source for beneficiary families and reducing dependence on traditional fuels such as natural gas or firewood
Serving 20 farmers in fertilizing agricultural lands and providing 4 families with renewable energy	Improving the properties of agricultural soil and increasing its fertility, which has contributed to enhanced crop quality and reduced reliance on chemical fertilizers
Production of high-quality organic fertilizer from biogas units	Increasing local community awareness of the importance of waste management and its potential to be transformed into sustainable economic resources
Education of 250 farming families on animal waste recycling and environmental investment	Building local capacities capable of implementing similar projects in the future and promoting environmental entrepreneurship among youth
Training of 50 young men and women on implementing biogas units and waste recycling projects	Enhancing the role of women in environmental and development issues and increasing their participation in community and economic activities
Education of 50 young women on the role of women in society	Empowering women to participate more actively in decision-making processes and community leadership roles

CONCLUSION

In light of the national drive towards achieving sustainable development specifically the second and ninth pillars of Egypt's Sustainable Development Strategy (MPED, 2023), which emphasize the efficient use of both traditional and renewable resources, contribution to economic growth, the achievement of social justice and poverty eradication, environmental preservation, and the development of a leading and innovative renewable energy sector and efficient resource management ENSAN Aid has implemented a pilot project to produce clean biogas in the village of Al-Taramsa in Qena Governorate. This project represents a practical application of the waste-to-energy approach by utilizing livestock waste to produce biogas, while also generating high-quality organic fertilizer that contributes to improving the quality of agricultural soil.

The following achievements have been realized: A renewable source of biogas has been provided, along with high-quality organic fertilizer to enhance soil properties, through the establishment of four biogas units. Awareness was raised among 250 farming families in the village of Al-Taramsa regarding animal waste recycling and environmental investment. In addition, 50 young women were sensitized to the role of women in society, and the capacities of 50 young men and women (70% female, 30% male) aged 18-29 were built to implement biogas units and small-scale solid waste recycling projects in the village throughout the project period. Agricultural soil fertility improved following the use of organic fertilizers produced through the biogas process. Fifty job opportunities were created for youth in Qena Governorate, including employment in the construction of biogas units and in small-scale enterprises such as mushroom cultivation, solid waste recycling (particularly organic waste), organic fertilizer production, and rooftop gardening. Community-wide awareness was raised–particularly among women–regarding the challenges of climate change and strategies for addressing them.

To ensure that the above-mentioned outcomes were achieved, several evaluation mechanisms were applied: Pre- and post-intervention surveys were conducted with participants in awareness sessions to assess changes in knowledge and attitudes regarding recycling and biogas. Focus groups were held to discuss the experiences of families and participants in integrating sustainable practices into their daily lives. A participatory evaluation was also carried out with community members to identify both achievements and challenges.

This initiative by ENSAN Aid stands as a tangible response to the social, economic, and environmental challenges facing rural communities, particularly in light of the increasing volume of organic waste.

CONFLICTS OF INTEREST

The author declares no conflict of interest

FUNDING

Not Applicable

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Sangam: Bridging Knowledge and Amplifying South Asian Youth Voices for Climate Resilience

CASE STUDY

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PLAIN-LANGUAGE SUMMARY

The "Sangam" initiative is a youth festival in South Asia designed to address climate change and related conflicts by bridging traditional wisdom with scientific understanding. It tackles the marginalization of youth voices in climate decisions, despite South Asia's 300 million young people being highly vulnerable and crucial for a sustainable future. Pakistan, a country acutely threatened by climate change with a large, engaged youth population, was chosen as the pilot location.

The festival brought together 40 young participants (15-25, equal gender balance) for dynamic workshops and storytelling. These sessions blended local experiences and traditional knowledge with scientific insights, fostering a powerful understanding and generating solutions.

The results were incredibly promising:

85%

Climate-Conflict Link Understood

Participants grasped how climate change can lead to conflict.

95%

Motivated to Share Knowledge

An inspiring percentage were motivated to share their newfound knowledge.

92.5%

Committed to Spreading Awareness

Nearly all committed to spreading what they learned in their communities.

42.5%

Pledged to Engage Many

Young leaders pledged to share knowledge with 10 to 50 individuals each.

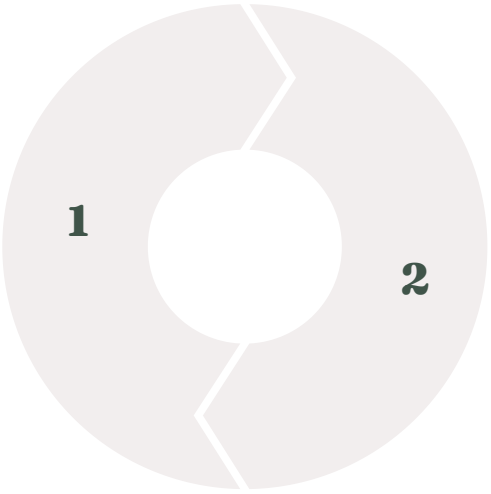
Beyond understanding, participants developed practical action plans and policy recommendations. Sangam offers a powerful, replicable model for youth-led climate action across South Asia, empowering voices and building a resilient future.

ABSTRACT

This article explores the impact of "Sangam - The Festival of Confluence," a youth-centered initiative in South Asia that bridges local and scientific knowledge to tackle climate change and climate-induced resource based and intergroup conflicts. The study employs a case study approach to explore the festival's outcomes, focusing on dialogue, cooperation, and sustainable actions. The evaluation framework assesses knowledge exchange, grassroots dissemination intentions, and policy and action engagement. Data was collected via a post-festival survey, analyzed for internal consistency using Cronbach's Alpha for key constructs –(a) knowledge and perspective exchange; (b) intentions to disseminate; and (c) formulation of action plans and policy recommendations - and supplemented by descriptive statistics and Pearson correlation analysis. Results show that the festival significantly enhanced participants' understanding of climate change and its associated conflicts. A majority expressed strong intent to disseminate the knowledge and perspectives gained, with 95% reporting motivation to share their insights. Furthermore, 90% of participants developed action plans and policy recommendations, indicating a high level of engagement. The correlation between knowledge and perspective exchange about climate induced conflicts, the perceived urgency of climate action, and understanding the importance of engagement in climate action highlights the festival's role in fostering climate resilience and peacebuilding. This article emphasizes the potential of youth-led approaches to amplify voices from the Global South in promoting climate resilience, peacebuilding, and systemic change.

Key Constructs

- Knowledge & Perspective Exchange
- Intentions to Disseminate
- Action Plans & Policy Recommendations



Key Findings

- Enhanced understanding of climate conflicts.
- 95% motivated to share insights.
- 90% developed action plans.

Keywords: Youth-led Climate Action, Knowledge Exchange for Sustainability, Climate Resilience, South Asia, Participatory Research, and Peacebuilding

INTRODUCTION

In an increasingly globalized world, climate change represents a crisis that transcends national boundaries, threatening ecosystems, livelihoods, and global stability. Its repercussions are particularly pronounced in vulnerable regions like South Asia, where geopolitical tensions, resource scarcity, and socio-economic inequalities converge (Klare, 2020; Vinke et al., 2017). The South Asian region, encompassing Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka, and the Maldives, has historically grappled with various forms of conflict. These include territorial disputes, civil wars, and geopolitical tensions, such as the enduring conflict between India and Pakistan, which claimed 81 civilian lives and displaced over 70,000 people in 2017 alone (UNICEF, 2018). Concurrently, sustainability challenges like climate change, natural resource competition, and poverty exacerbate these conflicts. Climate-induced water scarcity and resource shortages, for instance, have the potential to transform existing tensions into prolonged violence, as evidenced in contexts like Darfur, Sudan (UNEP, 2007).

Climate stress is increasingly acknowledged in South Asian policy frameworks as a driver of impacts such as livelihood insecurity, water scarcity, resource competition, and climate-induced displacement. India's National Action Plan on Climate Change (NAPCC) (2008) and Pakistan's Climate Change Policy (2021) reference these stressors. However, there is no comprehensive regional framework that explicitly links climate stress to conflict and security in a sustained, actionable, and coordinated manner. Addressing the nexus between climate change and regional conflicts is not only a pressing issue for South Asia but also a critical component of global peacebuilding and sustainability.

A Youth-Centric Crisis

In South Asia, where nearly half of the population is under 24 years of age, the implications of climate change are particularly severe. This demographic, representing the largest youth population globally until 2024 (UNICEF, 2019), is disproportionately affected by climate change (Gasparri, 2022).

The Power of Youth Voices

Young people tend to perceive climate change as an urgent crisis, driving their dedication to innovative and forward-looking solutions (Mortelliti, 2023). They have been aptly described as the "new ambassadors of scientific consensus and climate mitigation" (Eide and Kunelius, 2021).

In this context, meaningful youth participation emerges as both a prerequisite for effective climate action and a cornerstone of ambitious and equitable outcomes. Moreover, equitable and impactful climate action fosters an environment that not only addresses systemic challenges but also enhances youth well-being (Ingaruca, 2022).

South Asia's 300 million young people are uniquely positioned to lead initiatives addressing climate change and mitigating regional conflicts. As rights-bearing citizens, they have a legitimate claim to participate in actions and decision-making processes that shape their future. However, despite their critical role in achieving the Sustainable Development Goals (SDGs) and fostering positive youth development, young people often face systemic marginalization. According to the United Nations Secretary-General's policy brief, youth remain "almost invisible" in public policy and decision making processes due to barriers such as exclusion, limited capacities, and restricted accessibility (UN, 2022). Therefore, young people's potential can only be realized if they are provided with robust platforms and equipped with science-based knowledge to address these challenges effectively.

In South Asia, youth-led climate initiatives like the All-India Youth Climate Network (AIYCN) and the Nepalese Youth Climate Network (NYCN) have mobilized young people through awareness campaigns, reforestation efforts, and policy advocacy. However, there is a need for initiatives with a pioneering approach that bridge the gap between traditional knowledge and modern science while explicitly connecting climate stresses with climate-induced conflicts. Such integrative models can empower youth to not only lead climate action but also address the socio-political dimensions of environmental challenges–contributing to resilience, peacebuilding, and sustainable development rooted in local contexts.

Sangam – The Festival of Confluence: Empowering Youth for Climate Action

Sangam - The Festival of Confluence is a community-based participatory initiative empowering South Asian youth to address climate change and conflicts. What sets Sangam apart is its integration of traditional knowledge- gathered through consultations with young representatives from across the region/locality - with scientific insights, fostering a holistic approach to climate resilience. While many existing youth initiatives focus on awareness, advocacy, or specific actions like tree planting and clean-ups, Sangam explicitly links climate change with conflict resolution and peacebuilding, addressing the social tensions intensified by environmental stress. Through cultural diplomacy–employing storytelling, art, and rituals–it makes climate action emotionally resonant and rooted in local identities. Crucially, Sangam emphasizes bottom-up policy engagement through real-time interactions with policymakers, enabling youth to co-create actionable plans and policy recommendations that reflect on-the-ground realities. Emphasizing local solutions, Sangam aligns with global sustainability principles, leveraging cultural practices for sustainable resource management and conflict resolution. As highlighted by MacKay et al. (2020), localized initiatives rooted in traditional youth knowledge gain stronger community buy-in and lasting impact.

01	02	03
Build Capacity	Facilitate Exchange	Promote Dissemination
Build youth capacity to address the climate-conflict nexus.	Facilitate perspective exchange across diverse backgrounds.	Promote the dissemination of insights gained to encourage action-oriented policy dialogues for sustainable peace and regional cooperation.

Conceptualization & Case Selection

Sangam - The Festival of Confluence, conceived in 2022 by nine Salzburg Global fellows, emerged from online workshops, an in-person seminar in Salzburg, and a project accelerator in Nepal. Rooted in the Asia Peace Innovators Forum, the team leveraged their South Asian heritage, experience, and regional expertise to design this impactful initiative. (See more details here: **https://www.salzburgglobal.org/multi-year-series/asia-peace-innovators-forum/pageId/11370**) Additionally, the Salzburg Global has created a video introducing the project, which can be accessed here: **https://www.youtube.com/watch?v=lR74A2OH3Jk**

Figure 1: A snapshot from the youtube video introducing the project (Video Credit: Salzburg Global)

Following the initial conceptualization, Pakistan was chosen as the pilot location due to its distinctive mix of vulnerabilities and opportunities, making it a vital testing ground for initiatives addressing climate change and climate-induced conflicts. As one of the most climate-vulnerable countries globally (Eckstein et al., 2021), Pakistan frequently experiences climate-induced disasters such as floods, droughts, and heatwaves, which compound existing socio-economic and geopolitical challenges. Moreover, Pakistan's political instability presents significant obstacles to youth engagement, despite the country's young population constituting approximately 30% of its total demographic - this population is projected to peak by 2039, with an annual growth rate of 0.9% (Javeed et al., 2022). Additionally, Pakistan's geopolitical position, sharing borders with key South Asian nations, makes it an ideal setting for fostering cross-border dialogues and collaborations on regional challenges. As a critical case study (Flyvbjerg, 2011), the successful implementation of a pilot initiative in Pakistan holds the potential to serve as a replicable model for other South Asian countries facing similar socio economic conditions and climate challenges. Aligned with Flyvbjerg typology, if such interventions prove effective in Pakistan – a complex setting marked by political instability, demographic pressures, and geopolitical tensions – it strengthens the likelihood that similar approaches could succeed in other fragile, high-risk, or transitional contexts.

Collaboration with Youth General Assembly (YGA), Pakistan

Sangam - The Festival of Confluence was piloted in Pakistan with Young General Assembly (YGA) taking the lead in co-designing and organizing the event. YGA, an autonomous organization dedicated to policy development, equitable administration, and youth empowerment, engages young people across Pakistan in public discourse on social issues. Each year, YGA recruits around 1,000 members, supported by a network of 9,000 alumni and over 1,000 active members. (Young General Assembly, n.d.)

In July 2024, YGA consulted with key young leaders from across Pakistan to co-develop the festival's agenda and activities (see figure 2). Held on 26th October 2024, Sangam centered around three key themes that were youth-driven–identified through consultations–and informed by research: (a) Understanding Climate-Induced Conflict, (b) Identifying Key Geographies and Commonalities in South Asia, and (c) Rethinking Future Actions and Policies. The festival brought together 40 youth participants, who engaged in workshops, consultations, and collaborative events designed to equip them with science-based knowledge and foster actionable conversations.

Figure 2: YGA young consultation session, held in July 2024, to gather insights from young people to co-develop the festival agenda and activities.

Emphasizing regional solidarity and cultural exchange, Sangam aimed to bridge gaps in youth participation and demonstrated how regional collaboration can effectively address shared environmental challenges like climate change. The festival highlighted the vital role of young people as agents of change, with participants actively engaging in creating solutions to climate-induced conflicts (see figure 3). For example, one youth-led group proposed a digital cross-border storytelling platform that documents lived experiences of climate migration across South Asia (from different countries), aiming to foster empathy, policy dialogue, and grassroots advocacy.

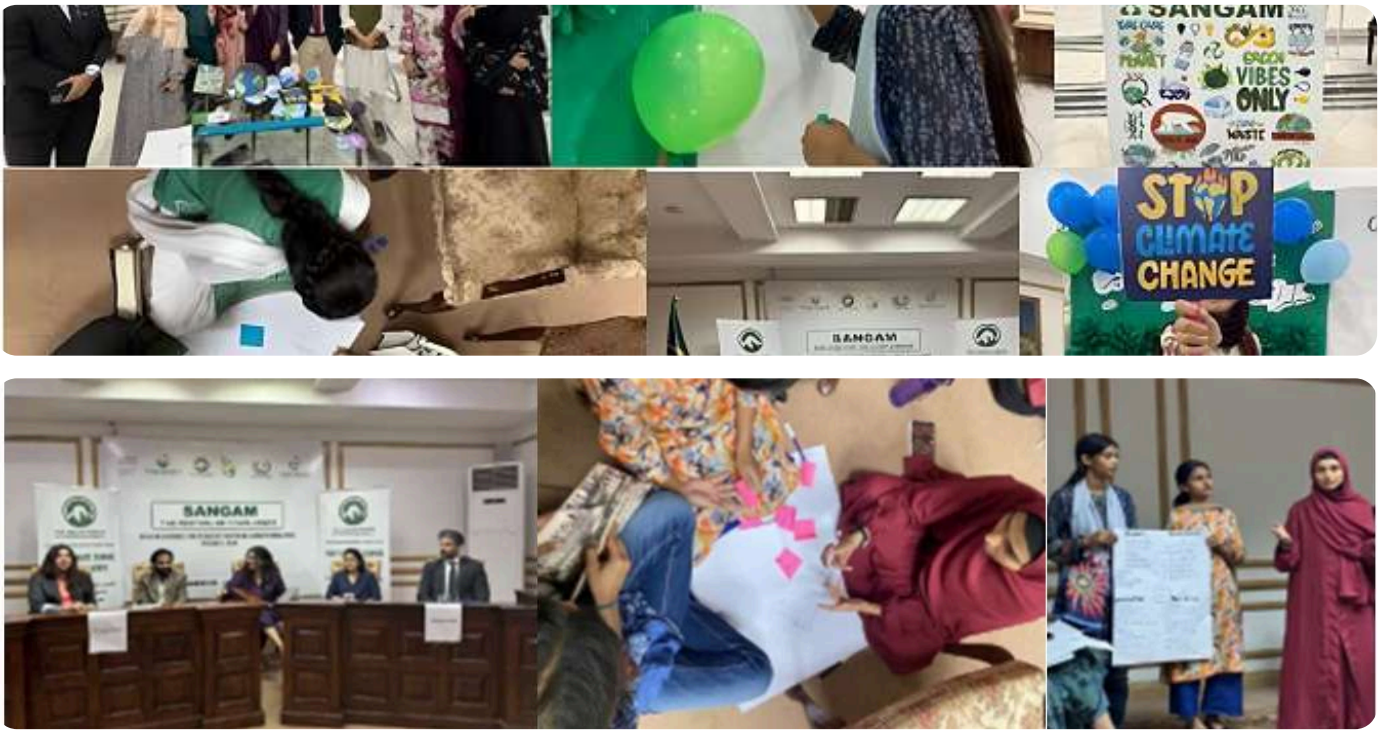


Figure 3: Pictures taken during the Sangam festival.

The in-person event was followed by online exchanges with youth organizations from Nepal and India. YGA participants shared their insights, policy recommendations, and action plans with counterparts in neighboring countries (see figure 4). This paper focuses on the impact of the in-person Sangam event in Pakistan, showcasing its role in nurturing young leaders who continue to create ripples through both local and regional initiatives. All participants belonged to the YGA network and were selected through a competitive process, during which they demonstrated their capacity and commitment to extend the festival's impact within their communities and broader youth networks across South Asia. To ensure accountability and long-term impact, each participant signed a pledge form outlining how they would apply and disseminate their learning post-festival–whether through community engagement, advocacy, or project implementation. Their fulfillment of this pledge is integrated into their year-end performance evaluation as YGA members, providing a structured mechanism to track sustained outcomes beyond the event itself.

Figure 4: Pictures taken during one of the online exchange events with counterparts in the neighboring countries.

PURPOSE

The purpose of this paper is to explore the impact of "Sangam - The Festival of Confluence" as a youth centered initiative that utilizes local knowledge integrated with scientific knowledge to capacitate young people to address climate change and climate-induced conflicts in South Asia. Following research question guided the study: Does "Sangam - The Festival of Confluence" contribute to capacitating and motivating young people to deal with climate change and climate-induced conflicts in South Asia?

METHODOLOGY

Sangam - The Festival of Confluence used a case study approach to assess its impact as a youth-centered initiative leveraging local knowledge for climate change mitigation and adaptation. The study explores the festival's outcomes, focusing on fostering dialogue, cooperation, and sustainable actions to address climate-induced conflicts in South Asia.

Evaluation Framework

The evaluation framework for Sangam - The Festival of Confluence assessed its impact on knowledge exchange, grassroots dissemination intentions, and policy engagement. To measure the effectiveness of Knowledge & Perspective Exchange, it evaluated shifts in participants' understanding of climate change and conflicts, as well as cross-regional interactions. For grassroots dissemination, the focus was on participants' intentions to share insights through youth-led initiatives, community outreach, and regional representation. The framework also measured participants' involvement in formulating policy recommendations and developing actionable plans. The indicators and items aligned with these objectives are outlined in the table 1 accompanying the framework, ensuring comprehensive evaluation of the festival's impact.

Table 1: The evaluation framework for Sangam Festival, highlighting the indicators and items aligned with its objectives.

Goal (Construct)	Indicator/s	Items	Cronbach's Alpha (scale reliability coefficient)
Awareness & Perspective Exchange	• The exchange of knowledge and perspectives on climate change, climate induced conflicts, the urgency of the issue	1. I have gained a good understanding of climate change, climate induced conflicts, and underlying causes. 2. I understand the vulnerability of various geographies to climate change and climate induced conflict. 3. I understand, taking action to deal with climate change is urgent. 4. I understand, we need to do something to deal with climate change. 5. I had a productive discussion with my group mates on climate change mitigation and climate induced conflicts. 6. I was able to gain new perspectives about climate change and climate induced conflicts during the festival.	0.76
Intentions to Disseminate	• Number of participants showing commitment to disseminate the perspectives/knowledge gained during the event • Number of beneficiaries highlighted in the dissemination pledge	7. I am motivated to disseminate the knowledge and perspectives I have gained during the festival within my community/network/organization. 8. I will disseminate the knowledge and perspectives I have gained during the festival within my community/network/organization. 9. I plan to disseminate the knowledge and perspectives I have gained during the festival among (approximately): x number of people.	0.764 (Excluding the last item which is qualitative in nature)
Formulation of Policy Recommendations and Action Plans	• Engagement in formulation of policy and/or action plan recommendations	10. My group and I have developed an action plan following the festival. 11. My group and I have developed policy recommendations following the festival.	0.77

Furthermore, Table 2 represent the projected theory of change for the Sangam festival. This theory of change outlines the pathway through which the Sangam festival fosters youth-led climate action in Pakistan and in South Asia. It illustrates how participatory activities–such as workshops, storytelling, and indigenous/local knowledge sharing–lead to increased awareness, motivation to disseminate knowledge, and the formulation of action plans. These outcomes ultimately contribute to youth-driven policy influence, regional cooperation, long-term climate resilience and peace.

Table 2: Projected theory of change for Sangam - The Festival of Confluence

Inputs/Activities	Immediate Outputs	Intermediate Outcomes	Long-term Impact
• Sangam Festival (multi-day youth event) • Participatory workshops and dialogues • Cultural exchange and storytelling • Indigenous knowledge sessions • Youth General Assembly facilitation & capacity building	• Knowledge and perspective exchange on climate change and climate-induced conflicts • Peer learning and group discussions • Exposure to localized and indigenous knowledge systems • Completion of dissemination pledges by participants	• Increased awareness and understanding of climate urgency, vulnerabilities, and regional dynamics • Strengthened motivation and intent to disseminate knowledge within local communities • Development of youth-driven policy recommendations and action plans • Formation of networks for post-event	• Youth-led climate action across South Asia • Influence of youth-informed climate policies at local and regional levels • Enhanced regional cooperation and climate peacebuilding • Long-term climate resilience through inclusive, community-driven strategies

Data Collection & Analysis

The evaluation of Sangam - The Festival of Confluence employed a post-festival survey to quantitatively assess program outcomes, ensuring alignment with its core objectives. The survey, developed using the evaluation framework, included 8 closed-ended items with a five-point Likert scale, 2 binary-scale questions, and one qualitative item. These questions captured participants' learning, experiences, and intended actions (see table 1). A random subset of 28 participants completed the survey to test reliability and internal consistency before full deployment. This step provided an opportunity to address participant queries about the survey. Reliability was evaluated using Cronbach's Alpha via STATA/SE 14.2, confirming consistency across constructs: (a) knowledge and perspective exchange ($\alpha = 0.76$), (b) intentions to disseminate ($\alpha = 0.764$), and (c) formulation of action plans and policy recommendations ($\alpha = 0.77$). Each construct exceeded the 0.7 threshold, indicating reliable measurement of participant outcomes.

The final survey was administered via Google Forms, designed to be completed in 5-7 minutes to ensure accessibility and maximize response rates. While the short survey format likely limited the depth and nuance of the data collected, this trade-off was intentional and aligned with prioritizing real-world applicability, participant engagement, and actionable insights over only experimental rigor. All 40 participants responded, providing a comprehensive dataset. The data was exported to Excel and analyzed using statistical techniques, including response distribution and correlation analysis in STATA/SE 14.2. Visualizations such as graphs and charts highlighted key trends and patterns.

- It is important to note that participants were selected using purposive sampling, with inclusion limited to individuals who attended and experienced the Sangam festival firsthand and that the survey questions were intentionally framed to capture experiences specific to the festival. This approach ensured that responses reflected direct engagement with the event's content and activities. While their contributions provide meaningful insights into the event's impact, the findings may not be generalizable beyond this specific group. Correlations in this case might reflect context-driven dynamics rather than broader trends. Furthermore, the impact evaluation is relying solely on self-reported data or participants' perspectives; therefore, it is suggested that future studies could use mixed methods–including interviews (with different stakeholders), focus groups, or observations –to triangulate findings.

The research adhered to ethical principles to ensure integrity and respect. Informed consent was obtained for data collection and photography, with participants clearly informed about the study, their rights, and the option to withdraw. For participants under 18 years of age, parental consent was obtained for their participation in festival, research, data collection and photography. Anonymity and confidentiality were safeguarded through secure data handling and identity anonymization. Ethical clearance was obtained from the YGA, as all participants were members of the network.

RESULTS AND DISCUSSION

Demographics

Of the 40 YGA participants, 50% were female and 50% male. Ages ranged from 15 to 25 (mean 20.7, SD = 2.07). See the Sankey diagram for a detailed gender and age breakdown (figure 5).

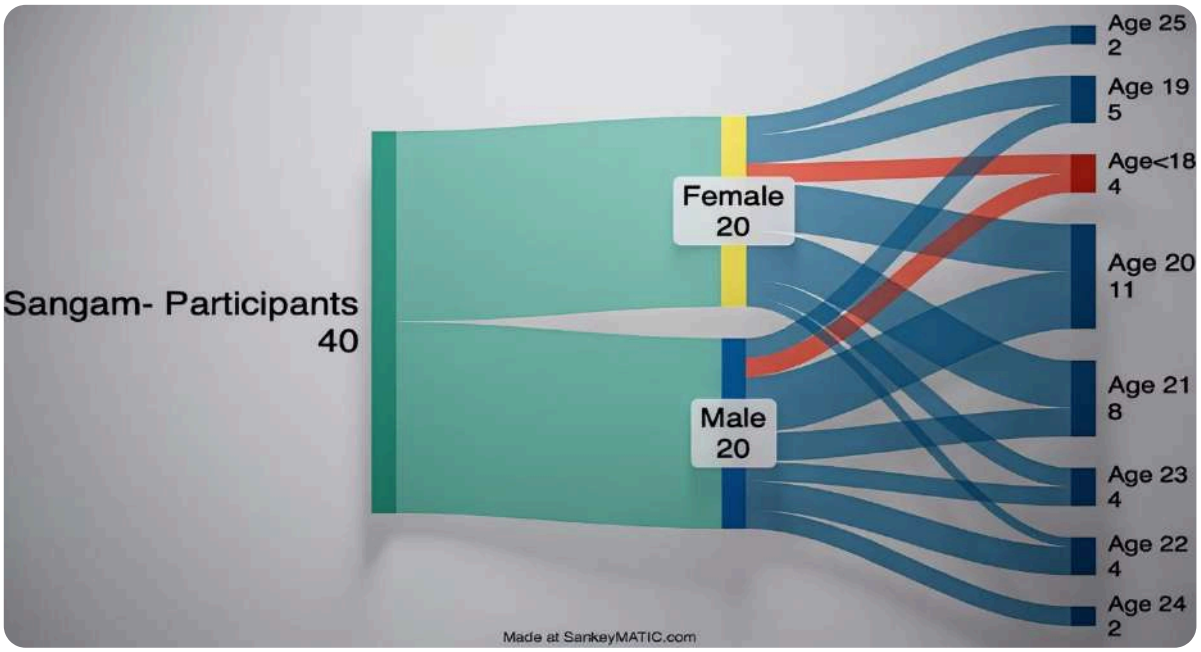


Figure 5: Sankey diagram highlighting the demography of the festival participants.

Awareness and Perspective Exchange About Climate Change and Climate Induced Conflicts

The festival significantly enhanced participants' awareness and perspectives on climate change and climate-induced conflicts. Male participants scored slightly higher (4.40) than females (4.36), reflecting a marginal gender difference (see figure 6).

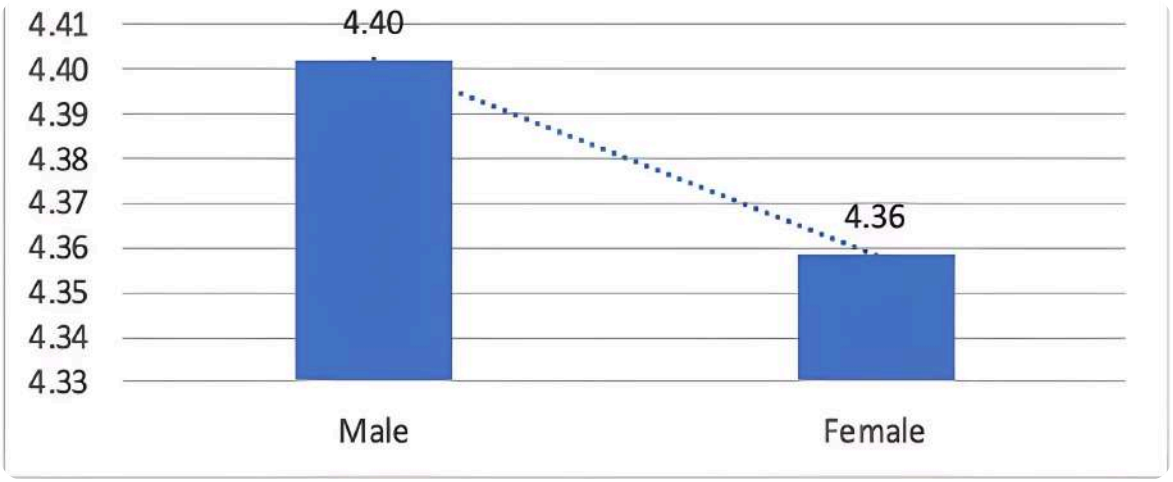


Figure 6: Average score by gender for knowledge and perspectives gained.

A substantial 85% agreed or strongly agreed they had gained a solid understanding of climate-induced conflicts and their causes (mean = 4.3, SD = 0.8) and regional vulnerabilities (mean = 4.1, SD = 0.63). Post festival, 95% acknowledged the urgency of climate action (mean = 4.4, SD = 0.8), and 97.5% emphasized its necessity (mean = 4.55, SD = 0.55). Additionally, 92.5% agreed they had gained new perspectives on climate-induced conflicts (mean = 4.37, SD = 0.63), and participants rated team discussions highly (mean = 4.5, SD = 0.64) (see figure 7).

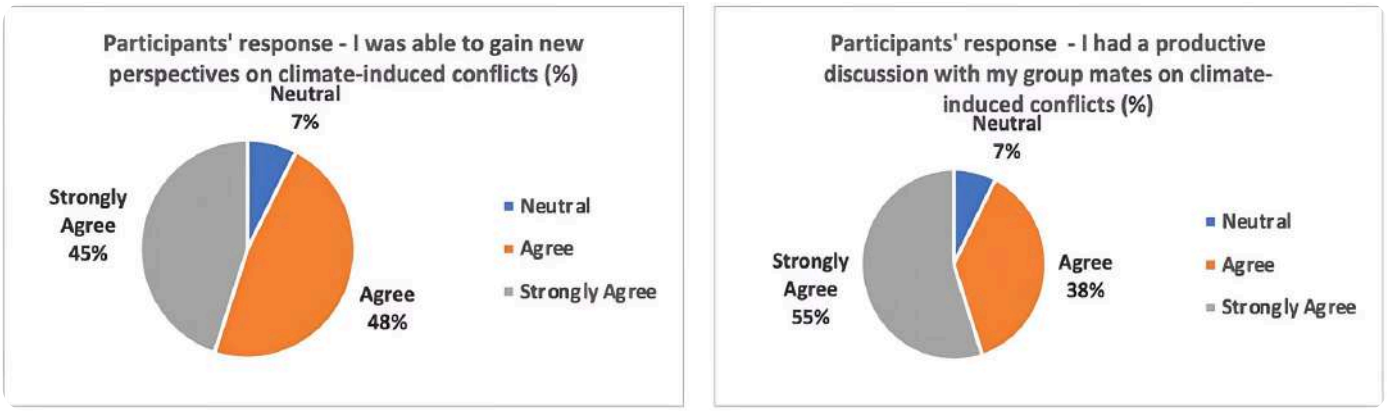


Figure 7: Participants responses about new perspectives gained and group discussion.

The standard deviation (0.6-0.8) reflects low variance, indicating consistent responses and a strong group agreement, underscoring the festival's success in fostering climate-related awareness and dialogue. A Pearson correlation analysis conducted on the Items under the Awareness and Perspective Exchange construct revealed several noteworthy relationships (see table 3). There was a moderate correlation (r = 0.6) between participants gaining a good understanding of climate-induced conflicts and gaining new perspectives on the topic (item1 and 6). Similarly, a moderate correlation (r = 0.5) was observed between participants gaining a good understanding of climate-induced conflicts and recognizing the urgency of taking action to address climate change (item 1 and 3).

Additionally, a moderate correlation (r = 0.5) was found between gaining new perspectives on climate induced conflicts and understanding the urgency of climate action (item 6 and 3). Notably, a strong correlation (r = 0.68) emerged between participants understanding the urgency of taking action to deal with climate change and recognizing the necessity of doing something about climate change (Item 3 and 4). These correlations highlight the interconnectedness of knowledge and perspective exchange about climate induced conflicts, the perceived urgency of climate action, and understanding the importance of engagement in climate action. Climate action requires behavioral change - this kind of change comes with understanding of the importance of (individual's) engagement (self-efficacy) in climate action along with knowledge (Fielding and Head, 2012) - which, the festival successfully promoted.

Table 3: Pearson correlation between various items under the awareness and perspective exchange construct

	Item-1	Item-2	Item-3	Item-4	Item-5	Item-6
Item-1	1.0					
Item-2	0.36	1.0				
Item-3	0.5	0.4	1.0			
Item-4	0.233	0.2	0.68	1.0		
Item-5	0.4	0.45	0.30	0.33	1.0	
Item-6	0.6	0.4	0.5	0.35	0.43	1.0

Intentions to Disseminate the Knowledge and Perspectives Gained

The festival significantly boosted participants' motivation to disseminate knowledge about climate change and climate-induced conflicts. Male participants scored slightly higher (4.5) than females (4.3), showing a marginal gender difference in intentions to share gained perspectives (see figure 8).

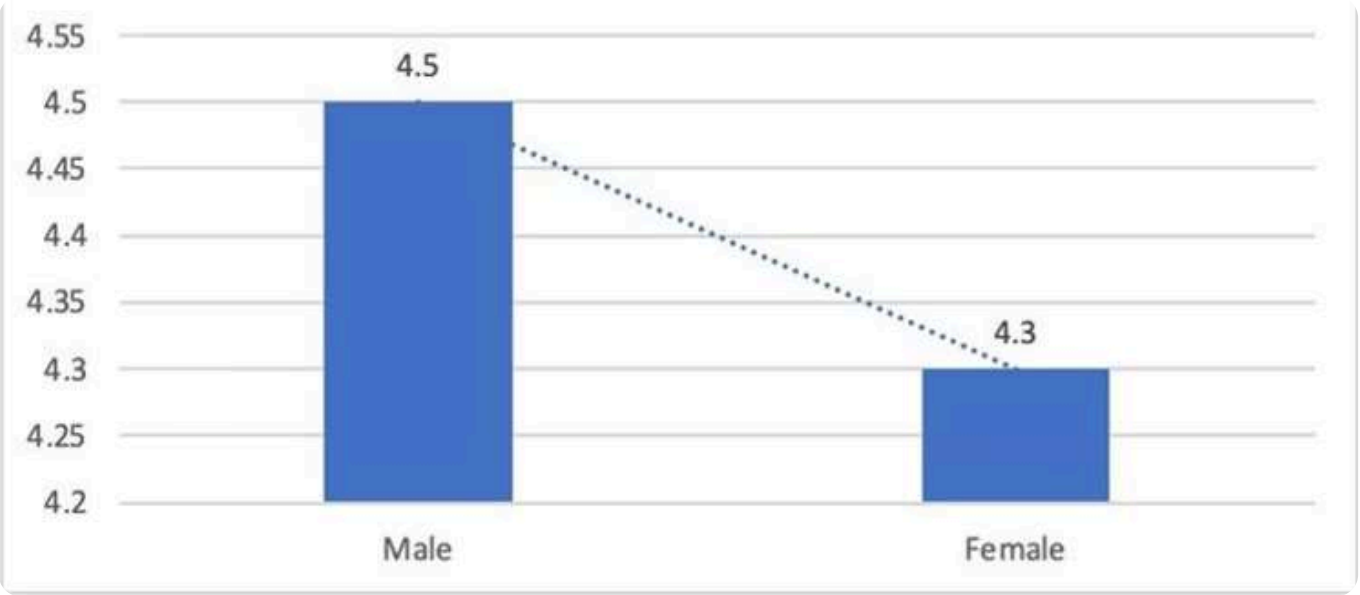


Figure 8: Average score by gender for Intentions to Disseminate

A total of 95% of participants were motivated (agreed or strongly agreed) and 92.5% expressed intent (agreed or strongly agreed) to disseminate the knowledge and perspectives gained during the festival. Following the event, participants completed a pledge form, committing to share this knowledge within their networks, organizations, and communities. Research suggests participatory knowledge transfer workshops enhance participant indentations to engage in climate action (Alif et al., 2024). The majority (42.5%) pledged to share knowledge with 10-50 people, while 20% aimed for 50-100 and over 200 individuals, and 17.5% targeted 100-200 people (see figure 9). As previously noted (section: collaboration with YGA, Pakistan), these pledges are integrated into YGA's accountability structure, monitored via periodic check-ins and year-end evaluations. Members are expected to report on progress; fulfillment contributes to their overall performance review within the YGA network. This process ensures structured tracking of long-term impact and reinforces leadership accountability.

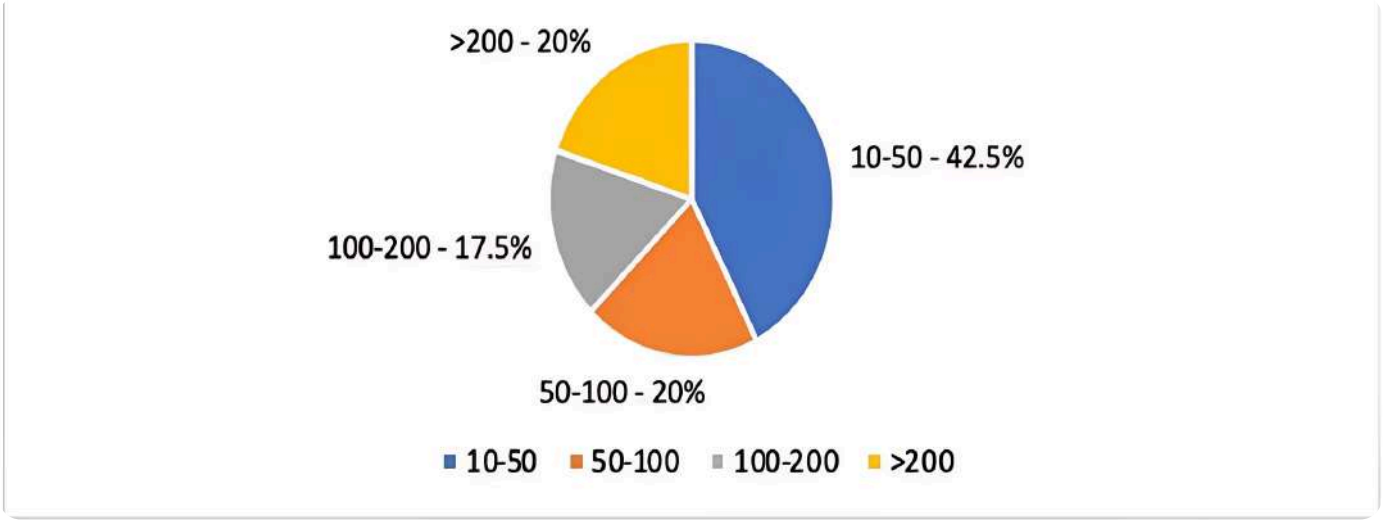


Figure 9: Percentage of participants pledging to disseminate knowledge and perspectives gained during the festival by audience size.

A Pearson correlation analysis was performed to examine the relationship between participants' motivation to disseminate the knowledge/perspectives gained and their intentions to do so. The analysis revealed a moderate correlation (r = 0.54) between participants' motivation to disseminate the knowledge (item-7) and their self-reported intentions to do so (item-8) (see table 4).

Table 4: Pearson correlation between various items under participants' motivation to disseminate the knowledge & perspectives gained construct.

	Item-7	Item-8
Item-7	1.0	
Item-8	0.54	1.0

The results indicate that the festival successfully inspired participants to not only feel motivated to disseminate knowledge but also to commit to sharing it within their wider networks. Education can increase a sense of self-efficacy, as with knowledge, young's sense of agency increases because they feel that their views are been taken seriously and they may be more likely to engage in climate mitigation (McNeill and Vaughn, 2012; De Vente et al., 2016; O'Brien et al., 2024). The correlation between motivation and intention highlights that fostering motivation in participants is crucial for translating intention into actual dissemination efforts. The varying audience reach, with the majority targeting smaller groups (10-50 people), suggests that while most participants are planning to share their learnings, the scale of dissemination may vary, potentially influenced by their individual networks or roles within their communities. Future festivals could explore ways to further increase the outreach and support participants in reaching larger audiences, ensuring a broader impact.

Formulating Policy Recommendations and Action Plans

Most participants (90%) reported having developed an action plan and policy recommendations after the festival (see figure 10). Specifically, 90% of the participants indicated that they had come up with an action plan, while the same percentage also reported creating policy recommendations. A smaller group, comprising 10% of participants, did not develop either an action plan or policy recommendations. The policy recommendations developed during the festival were presented to key decision-makers and policymakers on site and subsequently documented and circulated to relevant departments by the YGA. While the full set of recommendations was shared, key themes included the need for localized science-based, and contextual climate education, youth-inclusive governance structures, and cross-border collaboration mechanisms to address shared environmental challenges in South Asia.

Figure 10: Percentage of participants who developed action plans and policy recommendations following the Sangam festival.

This high percentage of participants developing actionable plans and policy recommendations suggests that the festival effectively empowered attendees to think critically and apply their learning in a practical context. The alignment between the creation of action plans and policy recommendations indicates that participants not only aimed to implement change at a grassroots level but also considered the larger systemic changes needed to address the issues discussed during the festival. According to De Vente et al. (2016), when participants feel confident that their views are taken seriously, they perceive their involvement in the decision-making process as impactful. This, in turn, increases their likelihood of actively engaging in the process (policy recommendations or action plan formulation). Furthermore, climate action requires stakeholders' (government and industry) willingness to change, which could be influenced by public pressure (Baldwin et al., 2022) created by young change agents. The relatively small number of participants who did not produce an action plan or policy recommendation may reflect a gap in confidence or understanding that could be addressed in future workshops through further support or guidance.

CONCLUSION

This study underscores the catalytic potential of youth-led initiatives like Sangam - The Festival of Confluence in addressing climate change and climate-induced conflicts. Most participants demonstrated a strong commitment to disseminate the knowledge and perspectives gained during the festival, with 95% expressing motivation to share their insights within their communities. The results highlight the festival's success in capacitating and motivating participants to set concrete steps toward addressing climate change and other related challenges while fostering a deeper understanding of the policy implications of their actions. Notably, 90% of attendees developed concrete action plans and policy recommendations, reflecting a high level of engagement and ownership.

- Key policy themes included the need for localized science-based, and contextual climate education, youth-inclusive governance structures, and cross-border collaboration mechanisms to address shared environmental challenges in South Asia.

By promoting knowledge exchange, actionable insights, and regional collaboration, the festival amplified voices from the Global South in promoting climate resilience, peacebuilding, and systemic change. These findings underscore the importance of such initiatives in equipping young people with the tools and perspectives necessary to tackle pressing global challenges.

Furthermore, the study highlights the need for further research into gender differences in the knowledge and perspectives gained, as well as the intentions to disseminate these perspectives and knowledge. Gender-responsive strategies that could be tested include tailored capacity-building sessions, creating safe and inclusive spaces, mentorship programs, targeted communication approaches, and addressing structural barriers openly affecting equitable participation and knowledge dissemination. Understanding these dynamics could provide valuable insights into how gender influences both the acquisition and sharing of information and perspectives about climate change and climate induced conflicts, shaping engagement strategies and knowledge transfer processes in the future (in this context).

Finally, festival like Sangam can strengthen regional cooperation by creating a shared platform for young people across South Asia to exchange knowledge, build trust, and co-develop collaborative solutions to climate-induced challenges, thereby fostering an integrated youth-led response to regional climate and peace related issues. Future festivals could enhance outreach and inclusivity by incorporating multilingual facilitation (in local languages), expanding digital access for remote young (who cannot attend in person), offering special quota for participants from underrepresented or marginalized communities or women, and building sustained pre- and post-event engagement structures such as mentorship programs, and a digital communication platform to track follow-up initiatives and exchange best practices.

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CONFLICTS OF INTEREST

There are no conflicts of interest to declare in relation to this article.

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Reflections & Emerging Pathways

Bridging Power and Knowledge: A Collective Reflection on Equity, Dialogue, and Shared Futures

Guest Editors:
Adenike Akinsemolu
Environmental Sustainability Expert, Leading Change in Education & Community Resilience

Annick Eimer
Veteran Science Journalist, Championing Global Science & Higher Education Dialogue

Sarah Iqbal
Global Health Research Manager & Knowledge Innovator, Advancing Impactful Research Dissemination

When we began this journey through the Humboldt Residency Programme 2024, we were not simply gathering to discuss sustainability or research. We came together to listen – to one another, to the Earth, and to the wisdom that lives quietly within communities and cultures across the world. We came with different stories, disciplines, and languages, yet were bound by one shared question: how can knowledge truly serve people and the planet, and not just power?

Listening as a Form of Knowing

Over the months of the Residency, we realised that listening is the first step to transformation. Listening to farmers and fishers, to healers and elders, to scientists and youth leaders – all of whom carry pieces of truth that are too often unheard. True sustainability begins when we allow these many ways of knowing to meet as equals. It asks us to slow down, to see that expertise does not only live in institutions, but in experience. It reminds us that progress is not measured by domination, but by dialogue.

Deep Listening

Moving beyond hearing words to understanding the wisdom embedded in lived experiences and traditional practices

Equal Voices

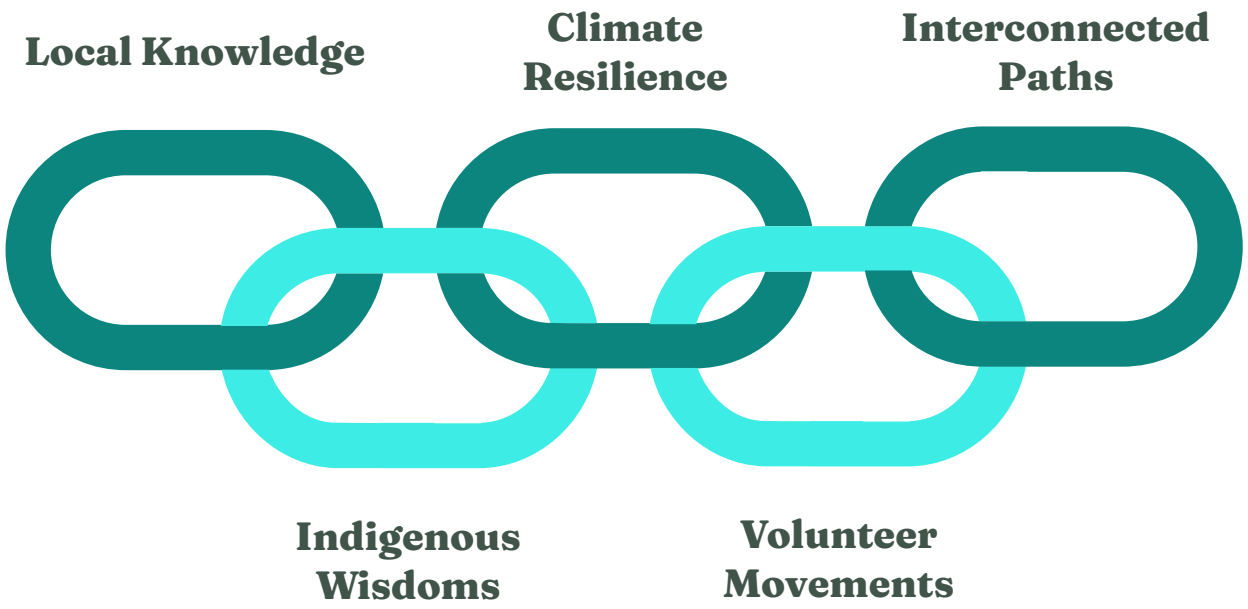
Creating spaces where academic knowledge and community wisdom hold equal weight in shaping solutions

Transformative Dialogue

Recognizing that meaningful change begins when we slow down and genuinely engage with diverse perspectives

Many Worlds, One Future

The stories in this issue – from the sacred knowledge of Arochukwu, to the shezhire genealogies of Kazakhstan, to the climate resilience of Tuvalu and the volunteer movements of Central Asia – show that the future of our planet cannot be built by one worldview alone. Each contribution carries the heartbeat of a place. Together, they form a map of interconnected wisdoms – living proof that there is no single road to sustainability. There are many roads, and they all matter. This is what it means to bridge power and knowledge: to make space for every voice, and to weave a future strong enough to hold them all.



> "Each contribution carries the heartbeat of a place. Together, they form a map of interconnected wisdoms – living proof that there is no single road to sustainability."

Innovation with a Soul

Technology and innovation are vital – but only when they carry humanity with them. As we read about weather-information systems designed for smallholder farmers, or biogas projects rooted in local cooperation, we are reminded that innovation must never erase context. Progress that forgets people is no progress at all. The most powerful tools are not just digital or mechanical; they are relational – trust, respect, empathy, and co-creation.

Human-Centered Technology

Weather-information systems designed for smallholder farmers demonstrate how innovation serves community needs

Local Cooperation

Biogas projects rooted in community partnerships show the power of collective innovation

Relational Tools

The most powerful innovations are built on trust, respect, empathy, and co-creation between communities

What We Learned

From this experience, three lessons remain with us:

1

Knowledge must be shared, not owned

Every community holds wisdom that can transform the world if given the chance to speak.

2

Collaboration is an act of courage

It means stepping out of comfort zones, unlearning hierarchies, and embracing the vulnerability of learning from others.

3

Hope is a practice

Even amid inequality and crisis, hope is the quiet force that keeps us building, imagining, and believing in better.

Reflection: These lessons emerged not from academic theory, but from the lived reality of working across cultures, disciplines, and power structures throughout our residency journey.

Other Outcomes of the Residency

A collaborative residency zine featuring brief essays, reviews, illustrations, and reflections on power and knowledge.

We Don't Talk Anymore

Tlamelo Makati's short film uses the cultural and historical significance of Afro hair braiding to explore efforts to erase traditional knowledge–and its resilience.

Between Walls and Words

In collaboration with Puneh Abdi (democ e.V.), Amie Liebowitz interviews residents of Teterow, prompting reflections on their neighbourhood and the power structures embedded in its architecture and social life.

Policy Paper: Funding Equitable Research Internationalisation

Recommendations for German research and funding organisations on fostering fair, collaborative research partnerships with low- and middle-income countries (LMICs).

Towards Shared Futures

The Humboldt Residency reminded us that knowledge is alive – it grows when nurtured, it crosses boundaries when invited, and it heals when shared. As editors and as humans, we carry deep gratitude for every author, advisor, and community represented in these pages. Each voice adds a new colour to the spectrum of understanding we need to sustain this planet.

This issue is not an ending, but a beginning – a bridge stretching from the familiar to the possible. May it inspire you, the reader, to listen more deeply, to collaborate more bravely, and to imagine more generously. Let us continue to build a world where power and knowledge walk hand in hand – not as rivals, but as partners in creating a just and sustainable future for all.

Mit Hoffnung und Solidarität,

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