

Reimagining North-South Research Collaborations in the Face of Global Climate Change: Strengthening the Role of ICTs in Adaptation Strategies



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ABSTRACT

The escalating impacts of global climate change and variability pose unprecedented challenges, particularly for the Global South, which bears a disproportionate burden of environmental change. The objective of this study was to examine how North–South research collaborations could strengthen climate change adaptation in developing regions by leveraging information and communication technologies (ICTs), identifying key barriers and enablers, and proposing a framework for co-designed, scalable ICT-enabled adaptation strategies that are responsive to local contexts and policy needs. Document analysis and systematic literature review were adopted as methodologies. The findings show how an ICT intervention organizes changes in communication patterns aimed at reducing climate change vulnerability and exposure. Moreover, ICTs can strengthen local capacity-building efforts, ensuring that adaptation strategies are tailored to specific contexts and are scalable and sustainable. The paper concludes that northern institutions often lead funding, data, and infrastructure, while southern partners contribute local knowledge, context, and implementation pathways. Therefore, ICT interventions must be part of the bigger and ongoing climate change adaptation agenda. The paper recommends a transition towards more collaborative, technology-driven North-South partnerships prioritizing equitable knowledge dissemination and capacity enhancement and promoting cross-cultural collaboration and capacity building to improve modelling and scenario planning. There is a need to invest in infrastructure and to use ICT for co-creation and decision support. By formalizing equitable cooperation arrangements, including co-authored intellectual property, co-led publications, shared leadership responsibilities, and transparent financial allocations, such partnerships can play a crucial role in tackling the multifaceted challenges of global climate change and fostering resilience in vulnerable regions.

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INTRODUCTION

Climate change is one of the most urgent and complex global challenges facing the world today. The scientific consensus is clear that human activities, notably the burning of fossil fuels, deforestation, and industrial practices, contribute to an increase in global temperatures, resulting in more frequent and intense weather extremes, rising sea levels, and disruptions to ecosystems and biodiversity. The Intergovernmental Panel on Climate Change (IPCC) reports that global temperatures have already

increased by approximately 1.1°C above pre-industrial levels, and this rise is expected to continue, causing widespread ecological, economic, and social consequences.¹ Climate change does not affect all regions equally, and its impacts differ worldwide. The disparity between the Global North (developed nations) and the Global South (developing nations) is particularly striking. Historically, the Global North, the most significant contributor to greenhouse gas emissions, is better equipped to manage and adapt to climate impacts owing to stronger economies, better infrastructure, and technological resources. However, they still face challenges, including extreme weather events, changing ecosystems, and rising sea levels. In contrast, the Global South, which consists mainly of lower-income nations, is far more vulnerable to the adverse effects of climate change despite contributing much less to global emissions. The vulnerability of these nations to climate change is compounded by poverty, political instability, and limited access to education and health care. Scholars such as Armitage et al. argue that North-South collaborations should be based on fairness, equity, and inclusivity principles, ensuring that both partners benefit from the exchange of knowledge and resources.² This means that the Global South should receive support and play an active role in shaping research agendas, policy recommendations, and implementing adaptation strategies.

One example of a successful North-South collaboration in climate adaptation is the “African Adaptation Initiative,” which involves partnerships between African nations, international organizations, and donor countries to enhance climate resilience across the continent.³ Information and Communication Technologies (ICTs) have become essential for climate change adaptation, particularly in vulnerable regions. ICTs enable data collection, analysis, and dissemination, which can inform decision-making and support adaptation efforts at the local, national, and regional levels. These technologies can help address critical information gaps, increase awareness of climate risks, and facilitate early warning systems that are essential for mitigating the impacts of climate change. ICTs, including satellite technology, mobile phones, and geographic information systems (GIS), have been widely adopted in climate research and adaptation projects. Satellite imagery and remote sensing technologies allow the monitoring of environmental changes such as deforestation, land degradation, and water availability, which are essential for developing early warning systems and adaptive management strategies.⁴ These technologies provide real-time data to help local governments and communities make informed decisions regarding resource management and disaster response.

In particular, mobile technology has become an invaluable tool for climate adaptation in the Global South. Mobile phones can send early warning alerts about extreme weather events such as floods or droughts, allowing communities to prepare in advance and reduce the impact of these events. Similarly, ICT platforms are increasingly being used to share information on sustainable agriculture techniques, water conservation, and biodiversity protection. North partners often prioritize high-profile topics (e.g., global climate modelling), while South partners face urgent local adaptation needs (water security, agriculture, and coastal livelihoods). Northern funders control most grants, timelines, and data access, stifling local leadership and timely decision-making.

While ICTs have the potential to significantly enhance climate adaptation efforts, challenges remain in terms of accessibility, affordability, and digital literacy, particularly in the rural and underserved areas of the Global South. Limited climate and socio-economic datasets in many southern regions and incompatible data standards hinder cross-border analysis. Scholars have highlighted that the success of ICT-based adaptation projects depends on overcoming these barriers and ensuring that technologies are appropriate for local contexts and do not exacerbate existing inequalities.⁵ Publication-centric metrics

¹ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis* (Cambridge: Cambridge University Press, 2021).

² D. Armitage, et al., “Adaptive Co-Management: Collaboration, Learning, and Multi-Level Governance,” *Environmental Management* 47, no. 4 (2011): 951–63.

³ African Development Bank, *The African Adaptation Initiative: A Transformative Approach to Strengthening Africa’s Resilience to Climate Change* (African Development Bank Group, 2018).

⁴ M. Hossain et al., “The Role of ICTs in Enhancing Climate Resilience and Adaptation in South Asia,” *Climate Policy* 20, no. 3 (2020): 297–312.

⁵ M. Kuppuswamy and D. Chawla, “Information and Communication Technology for Climate Change Adaptation in Developing Countries: A Review of Challenges and Opportunities,” *International Journal of Climate Change Strategies and Management* 7, no. 3 (2015): 295–314.

undervalue policy impacts, capacity building, and on-the-ground adaptation outcomes. This study explores how ICTs can strengthen climate change adaptation strategies through North-South collaborations and reimagine and propose new frameworks for these collaborations to better address climate challenges. Language differences and differing scientific cultures impede collaboration and dissemination among local decision makers. The objective of this study is to examine how North-South research collaborations could strengthen climate change adaptation in developing regions by leveraging information and communication technologies (ICTs), identifying key barriers and enablers, and proposing a framework for co-designed, scalable ICT-enabled adaptation strategies that are responsive to local contexts and policy needs. Specifically, this study sought to answer the following research question:

- How can ICTs enhance climate change adaptation efforts in both the Global North and South?
- What are the challenges and opportunities to strengthen North-South research partnerships in this context?

CONCEPTUAL AND THEORETICAL FRAMEWORK

Climate Change and Adaptation

Climate change adaptation refers to the process by which societies and ecosystems adjust to the impacts of climate change to minimize harm or exploit beneficial opportunities. As global temperatures rise, adaptation has become a critical focus for developed and developing countries, as they face varying degrees of climate-related challenges. Adaptation aims to increase resilience and reduce vulnerability to climate impact, including extreme weather events, shifts in agricultural productivity, water shortages, and changes in biodiversity and ecosystems. Adaptation strategies are multifaceted and can be broadly categorized as reactive **or** proactive. Reactive strategies, such as disaster relief or emergency response efforts involve responding to the effects of climate change. On the other hand, proactive strategies focus on long-term planning to anticipate and reduce potential climate impacts before they occur. These strategies are designed to increase the adaptive capacity of individuals, communities, and nations to withstand and recover from the effects of climate change.⁶

For developed countries, climate adaptation strategies often revolve around technological innovations and robust infrastructure, such as flood defenses, advanced weather forecasting systems, and climate-resilient agricultural practices. These nations also focus on enhancing their adaptive governance structures, ensuring that climate change is integrated into policy development at all levels. In the Global South, adaptation strategies tend to be more community-driven and resource based, focusing on sustainable land management, ecosystem restoration, and agricultural diversification. Given limited financial and technological resources, developing countries prioritize low-cost, locally appropriate solutions that can address immediate vulnerabilities.⁷ According to Huq et al., adaptation strategies should be framed within sustainable development, acknowledging that economic growth, poverty reduction, and climate resilience must go hand-in-hand.⁸ This integrated approach not only addresses climate change but also enhances the socioeconomic development of vulnerable populations. For example, promoting agroecology in sub-Saharan Africa can help adapt agricultural practices to changing climatic conditions while improving food security and livelihoods.

Adaptation and the Growing Risks Associated with Climate Impacts

The importance of adaptation is underscored by the growing risks associated with climate change. The Intergovernmental Panel on Climate Change (IPCC) emphasizes that without adequate adaptation measures, the adverse effects of climate change are likely to be severe, particularly in countries already facing socioeconomic challenges. Therefore, adaptation strategies must be multifaceted and integrated into short-term disaster risk management plans and long-term development policies.⁹ Adaptation

⁶ UNFCCC, “United Nations Climate Change: Annual Report 2020. United Nations Framework Convention on Climate Change, the Kyoto Protocol and the Paris Agreement,” 2020, <https://disasterlaw.ifrc.org/media/3327>.

⁷ C. Sullivan, et al., “The Role of Local Knowledge in Climate Change Adaptation in the Global South,” *Climate Policy* 18, no. 4 (2018): 502–13.

⁸ S. Huq, et al., “Adaptation to Climate Change in Developing Countries: Lessons from the Field,” *Global Environmental Change* 56 (2019): 178–90.

⁹ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis*.

strategies differ considerably between developed and developing countries because of differences in financial, technological, and institutional capacities. These differences have led to distinct approaches to adaptation, which are influenced by socioeconomic factors, governance structures, and vulnerability levels. In developed countries, adaptation tends to be technologically advanced and capital-intensive. For instance, climate-resilient infrastructure, such as sea walls and flood barriers, is commonly built in coastal regions at risk of rising sea levels. Advanced climate modelling and early warning systems predict extreme weather events and prepare communities for impacts. In Europe, climate-smart urban planning has been employed in cities such as Copenhagen and Rotterdam to ensure resilience to extreme weather through green roofs, permeable surfaces, and efficient water management systems.¹⁰ In addition, sustainable agricultural techniques, including drought-resistant crop varieties and precision irrigation, are widespread in the Global North to ensure food security amidst shifting climate patterns.¹¹

Developing countries face significant challenges in financing adaptation efforts. Many nations in the Global South rely on community-based adaptation (CBA) strategies that are less reliant on large-scale infrastructure and more focused on enhancing local resilience through knowledge sharing, resource management, and capacity building. These include initiatives such as restoring degraded ecosystems to enhance water retention in rural areas, improving early warning systems, and investing in sustainable agricultural practices to increase soil fertility and conserve water. For example, in Bangladesh, floating agricultural systems have been developed to help farmers adapt to flooding and rising sea levels.¹² Another important distinction lies in the governance and institutional frameworks. In developed countries, centralized governance structures often facilitate the implementation of adaptation strategies at the national level, where well-established legal and financial mechanisms exist to support climate change mitigation and adaptation. Conversely, in many developing countries, decentralized governance often leads to challenges in implementing large-scale climate policy. As a result, adaptation strategies are often fragmented and implemented on a smaller scale, relying on local leadership and community-based organizations to ensure their effectiveness.¹³

In Zambia, community-level adaptation projects focusing on water conservation and soil health have been highly successful because they draw on local knowledge and leadership and promote community ownership.¹⁴ However, in both regions, the necessity for collaborative solutions to address climate change has become increasingly apparent. International partnerships and North-South research collaborations are essential for bridging the resource gaps between the Global North and South. For example, the Adaptation Fund established under the UNFCCC financially supports developing countries in implementing climate adaptation projects. Such initiatives foster partnerships between developed and developing countries to ensure that resources are used effectively and solutions are tailored to local contexts.¹⁵ The concept of climate justice has emerged as a central element in global adaptation strategies. This concept advocates for the fair distribution of resources and responsibilities between the Global North and South, recognizing the historical responsibility of developed countries for most greenhouse gas emissions.

North-South Research Collaborations

Historically, North-South research collaborations have been shaped by global power imbalances stemming from colonialism, where the Global North, with its advanced scientific infrastructure, dominated the production of knowledge, whereas the Global South, rich in local and indigenous knowledge, was often relegated to the role of passive recipients. This has resulted in the marginalization

¹⁰ T. Wong, et al., "Urban Adaptation Strategies in Response to Climate Change: The Role of Infrastructure in Resilient Cities," *Urban Climate* 31 (2020): 100573.

¹¹ P. Smith, et al., "Climate Change Mitigation and Agriculture: The Role of Sustainable Agriculture Techniques in Adaptation Strategies," *Agricultural Systems* 189 (2021): 103–12.

¹² S. Khan et al., "Community-Based Adaptation to Climate Change in Bangladesh: Lessons Learned and Future Directions," *Climate and Development* 11, no. 5 (2019): 383–93.

¹³ P. Tschakert et al., "The Role of Decentralized Governance in Climate Change Adaptation: A Critical Review," *Environmental Management* 68, no. 2 (2021): 123–36.

¹⁴ D. J. Gumbo et al., *Sustainable Management of Miombo Woodlands – Food Security, Nutrition and Wood Energy* (Rome: Food and Agriculture Organization of the United Nations, 2018).

¹⁵ P. Girod, "Collaborative Climate Adaptation and the Role of International Partnerships in the Global South," *Environmental Policy and Governance* 30, no. 1 (2020): 10–24.

of Southern perspectives in climate change research.¹⁶ In the earlier phases of climate research, knowledge produced in the Global North largely dictated global climate policy, with limited input from southern nations. This imbalance persisted in early climate science and policy debates, where northern institutions had better access to funding, expertise, and technology.¹⁷ However, as climate change has become an increasingly urgent global issue, there has been growing recognition of the need for more inclusive, collaborative approaches to climate research, particularly as the impacts of climate change disproportionately affect the Global South.¹⁸ The 1992 United Nations Framework Convention on Climate Change (UNFCCC) signified a critical shift, encouraging collaborative global efforts for climate action, including North-South partnerships. These collaborations have begun to focus on mitigating climate impacts and enhancing adaptation strategies for vulnerable populations in the south, where the effects of climate change are often the most severe.¹⁹

A notable example of this shift is the Intergovernmental Panel on Climate Change (IPCC), which brings together North and South researchers to develop comprehensive climate reports. This process allows for the co-production of knowledge by integrating scientific data with region-specific insights to address global and local climate issues. Furthermore, bilateral research projects funded by governments, international organizations, and non-governmental organizations (NGOs) have become key platforms for knowledge exchange. These projects increasingly emphasize the importance of Southern expertise in climate science and adaptation strategies.²⁰ In recent years, there has been a clear trend towards more equitable partnerships. For example, the African Adaptation Programme (AAP), established in 2008, is a collaborative initiative between the UNDP and African countries to strengthen climate resilience. The AAP provides a platform for local and international experts to co-design adaptation strategies, ensuring that local knowledge is central to the planning process.²¹

Enhancing adaptive capacity through knowledge exchange and co-production

Knowledge exchange and co-production are critical mechanisms that enhance the adaptive capacity in climate change research and policymaking. These approaches recognize the value of scientific and local knowledge, fostering more inclusive and contextually relevant solutions to climate change. Knowledge exchange in North-South research collaborations refers to the reciprocal transfer of information, ideas, and expertise between the Global North and the South. This approach ensures that research outputs are grounded in local realities and relevant to the needs of communities on the ground.²² For instance, the local knowledge of farmers in Sub-Saharan Africa about climate variability has significantly informed adaptive strategies in agriculture, blending local understanding with global climate models.²³ The co-production of knowledge takes this process further by involving stakeholders from the North and South throughout the research process. Co-production integrates scientific expertise with local and indigenous knowledge, thereby facilitating the development of climate adaptation strategies that are both scientifically credible and locally acceptable. As Parry et al argue, co-production enhances the relevance, effectiveness, and legitimacy of adaptation policies, ensuring that they are context-specific and participatory.²⁴

¹⁶ F. M. Chambers, "Book Review: Earth's Climate: Past and Future," *The Holocene* 12, no. 1 (January 1, 2002): 122–122, <https://doi.org/10.1177/095968360201200115>.

¹⁷ Hulme M., *Why We Disagree about Climate Change: Understanding Controversy, Inaction, and Opportunity* (Cambridge: Cambridge University Press, 2009).

¹⁸ Frank Biermann, "'Earth System Governance' as a Crosscutting Theme of Global Change Research," *Global Environmental Change* 3, no. 4 (2007): 326–37.

¹⁹ Lisa Schipper and Mark Pelling, "Disaster Risk, Climate Change and International Development: Scope for, and Challenges to, Integration," *Disasters* 30, no. 1 (March 2006): 19–38, <https://doi.org/10.1111/j.1467-9523.2006.00304.x>.

²⁰ M. Pelling et al., "The Politics of Adaptation to Climate Change: Local Community Responses and Global Policy Frameworks," *Environmental Science & Policy* 118 (2021): 143–53.

²¹ UNDP, *Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience* (Washington, DC: United Nations Development Programme (UNDP), Communications Development Incorporated, 2014).

²² W Neil Adger, Nigel W Arnell, and Emma L Tompkins, "Successful Adaptation to Climate Change across Scales," *Global Environmental Change* 15, no. 2 (2005): 77–86.

²³ John F. Morton, "The Impact of Climate Change on Smallholder and Subsistence Agriculture," *Proceedings of the National Academy of Sciences* 104, no. 50 (December 11, 2007): 19680–85, <https://doi.org/10.1073/pnas.0701855104>.

²⁴ M. L. Parry et al., *Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates* (International Institute for Environment and Development (IIED) & Grantham Institute for Climate Change, 2009).

In the context of climate change adaptation, co-production fosters adaptive capacity by empowering local communities and enhancing their ability to respond to climate change impacts. Ensor highlighted that co-production can improve resilience by ensuring that adaptation strategies are tailored to the local environment and culture.²⁵ A well-known example is the Mali Drought Adaptation Programme, which brought together local farmers, scientists, and policymakers to develop drought-tolerant crop varieties. This collaboration not only improved crop yields but also built the capacity of local farmers to adapt to increasingly unpredictable climate conditions.²⁶ Another example of co-production is the Participatory Integrated Climate Services for Agriculture (PICSA) approach, which encourages the joint development of climate services with local farmers in countries such as Kenya and Malawi. This approach blends local weather forecasting knowledge with climate science to develop more accurate and context-specific agricultural advice for farmers, thus increasing their capacity to adapt to climate variability.²⁷

The role of knowledge exchange and co-production in enhancing adaptive capacity is particularly crucial in regions such as Sub-Saharan Africa, where vulnerability to climate change is high; however, traditional adaptation strategies are often overlooked in favor of top-down, externally driven solutions.²⁸ Co-produced research builds trust between researchers and local communities, fostering more effective implementation of adaptation measures and improving long-term resilience. Co-production and knowledge exchange also facilitate social learning in which all stakeholders involved in the research and adaptation process develop a shared understanding of climate risks and solutions. This process helps to break down the divide between scientific and local knowledge, fostering collaboration and mutual respect. As Moser and Ekstrom argued, social learning in climate change research is a critical mechanism for building the adaptive capacity of vulnerable communities, enabling them to plan and implement resilience-building strategies collectively.²⁹ Collaborative networks involving researchers, policymakers, and local communities can create synergies that increase the effectiveness of adaptation strategies. For example, the Climate and Development Knowledge Network (CDKN) has facilitated knowledge sharing between countries in the Global North and South to improve climate resilience through participatory research and policy advice.³⁰ These networks provide platforms for integrating diverse perspectives, thus enabling the development of comprehensive, inclusive, and actionable climate solutions.

METHODOLOGY

This study utilized data from 30 reports, journal papers, and reports on strengthening ICT's role in adaptation, framed around North–South research collaborations within the context of global climate change. The sample for this paper was derived from a strategic search using search terms such as: 'adaptation to climate change,' 'adaptive co-management,' 'Geospatial Information Systems (GIS) for climate change adaptation,' 'capacity building in crisis,' 'strengthening North South Africa,' 'North South Africa capacity building,' 'ICTs in enhancing climate resilience and adaptation,' 'Mobile phones and development,' 'Digital platforms and climate change,' 'Decentralized governance in climate change adaptation,' 'Climate Forecasting and Early Warning Systems in East Africa,' and 'Online Platforms in Enhancing Local Climate Resilience. According to Maree, a systematic literature survey technique and evaluations of publicly available documents are characterized as critical and integrative when inductive reasoning is mostly used.³¹ Document analyses and systematic literature reviews have been widely

²⁵ J Ensor, "Emerging Lessons for Community-Based Adaptation," in *Community-Based Adaptation to Climate Change: Emerging Lessons* (Practical Action Publishing, 2014), 183–97.

²⁶ Anthony Bebbington et al., "Mining and Social Movements: Struggles over Livelihood and Rural Territorial Development in the Andes," *World Development* 36, no. 12 (2008): 2888–2905.

²⁷ James Hansen et al., "Ice Melt, Sea Level Rise and Superstorms: Evidence from Paleoclimate Data, Climate Modeling, and Modern Observations That 2 °C Global Warming Could Be Dangerous," *Atmospheric Chemistry and Physics* 16, no. 6 (March 22, 2016): 3761–3812, <https://doi.org/10.5194/acp-16-3761-2016>.

²⁸ H. Reid, et al., "Community-Based Adaptation to Climate Change: An Overview," *IIED Climate Change Working Paper No. 1.*, 2009.

²⁹ Susanne C. Moser and Julia A. Ekstrom, "A Framework to Diagnose Barriers to Climate Change Adaptation," *Proceedings of the National Academy of Sciences* 107, no. 51 (December 21, 2010): 22026–31, <https://doi.org/10.1073/pnas.1007887107>.

³⁰ Climate and Development Knowledge Network, *Managing Climate Extremes and Disasters in Asia: Lessons from the SREX Report* (London: CDKN, 2013), www.cdkn.org/srex.

³¹ Kobus Maree, "Career Counselling in South African Institutions of Higher Learning in the 21st Century: Re-Discovering the Potential of Qualitative Approaches," *South African Journal of Higher Education* 26, no. 6 (January 2016), <https://doi.org/10.20853/26-4-186>.

employed in qualitative research. A systematic literature review initiated a critical discussion of the research content. Given that not all available Internet information is reliable, the researchers made every attempt to acquire papers from official sources, Web of Science, and Scopus-accredited journals. The data extraction plans included developing an extraction sheet organized by author, year, nation, setting, sample size, design, instrument, results, main findings, and restrictions. The data analysis involved the development of themes (coding lines). The emphasis of the articles is to provide reflections on such documents about ICT applications as part of Climate Change adaptation strategies in the face of Global Climate Change.

DISCUSSION

Disproportionate burden of climate-related disasters

Scholars have highlighted that while the Global North has the financial and technological means to protect itself, the Global South bears a disproportionate burden of climate-related disasters.³² The inequity in responsibility and capacity between the two regions has led to calls for a more just and equitable approach to climate adaptation and mitigation efforts.³³ In this context, the need for robust international cooperation, particularly between the Global North and South, has become increasingly critical in addressing the challenges posed by climate change. Given the challenges posed by climate change, North-South research collaboration has emerged as a vital strategy for bridging the knowledge and technology gaps between developed and developing countries. These collaborations aim to leverage the resources, expertise, and technological capabilities of the Global North, while addressing the pressing needs of the Global South regarding climate change adaptation and mitigation. Historically, research collaborations between the Global North and South have been framed within the context of development aid, in which the Global North provides financial and technical assistance to the Global South. However, contemporary collaborations have evolved to emphasize mutual learning, equity, and capacity building. According to researchers, effective North-South partnerships provide financial support and ensure that knowledge and expertise are transferred in a way that builds long-term local capacity in the Global South.³⁴

A key feature of successful North-South collaborations is the inclusion of local knowledge and expertise from the Global South in the research and decision-making processes. This approach recognizes that local communities in vulnerable regions have valuable indigenous knowledge and practical experience in managing environmental challenges. Incorporating this knowledge into climate research enhances the relevance and effectiveness of adaptation strategies, ensuring that the proposed solutions are context specific and culturally appropriate.³⁵ Moreover, local knowledge can help identify the specific risks and vulnerabilities that external researchers may overlook. Geographic Information Systems (GIS) are critical for spatial planning for climate adaptation. GIS allows for the mapping of climate hazards and vulnerabilities, enabling policymakers and local authorities to target interventions in the most affected areas. By integrating climate data with social, economic, and environmental information, GIS helps to identify risk areas, monitors the effectiveness of adaptation measures, and allocate resources more efficiently.³⁶ Furthermore, the Internet's increasing connectivity enables climate scientists, policymakers, and communities to share knowledge, experience, and best practices across borders. Online platforms and social media have become vital for disseminating climate-related information, particularly in regions with limited traditional media. These platforms facilitate global dialogue on climate change adaptation, fostering a more inclusive approach to address climate challenges.³⁷

³² Adger, Arnell, and Tompkins, "Successful Adaptation to Climate Change across Scales."

³³ M. Pelling, et al., "Disasters and Development: A Brief History of the Relationship between Development and Disaster Risk Management," *Global Environmental Change* 18, no. 4 (2008): 268–76.

³⁴ J. D. Sachs, *The Age of Sustainable Development* (Columbia University Press, 2015).

³⁵ Reid, et al., "Community-Based Adaptation to Climate Change: An Overview."

³⁶ M. Calderon, et al., "Geospatial Information Systems (GIS) for Climate Change Adaptation and Sustainable Development in Rural Areas," *Global Environmental Change* 45 (2017): 203–15.

³⁷ J. Tshand and B. Smit, "Digital Platforms and Climate Change: A Case Study of Social Media's Role in Disseminating Climate Information," *Environmental Communication* 13, no. 2 (2019): 160–75.

The State of North-South Research Collaborations on Climate Change

North-South research collaborations in climate change have evolved significantly over the past few decades, particularly with the increasing awareness of the disproportionate impact of climate change on the Global South. Early collaborations were often unbalanced, with northern researchers conducting studies in the south without adequate input from local communities or southern experts. This has resulted in climate change research that is primarily driven by the needs and priorities of the Global North, with limited relevance or applicability for those in the South.³⁸ Historically, such collaborations were framed through a "top-down" approach, where Northern institutions held the majority of funding, expertise, and technological resources. For example, during the 1990s and the early 2000s, global climate reports, such as those from the Intergovernmental Panel on Climate Change (IPCC), predominantly represented research and perspectives from the North.³⁹ Although important for informing global climate policy, the IPCC often fails to integrate local knowledge from affected communities in the Global South, contributing to a one-sided understanding of climate impacts. The 2000s saw a shift in this trend, driven by the realization that climate change is a global issue that requires inclusive region-specific solutions. Over time, international agreements such as the Kyoto Protocol (1997) and the Paris Agreement (2015) have emphasized the need for joint efforts in climate research and adaptation. These frameworks have opened the door to more collaborative research, integrating Southern countries' knowledge, priorities, and lived experiences.

The focus shifted towards the co-production of knowledge, whereby both Northern and Southern researchers contribute equally to the research process, ensuring that solutions are not only scientifically rigorous but also culturally and contextually appropriate funding agencies such as the Green Climate Fund (GCF), Global Environment Facility (GEF), and the World Bank, which has supported climate research partnerships between the North and South (Muñoz et al., 2020). These agencies fund joint research projects that address mitigation and adaptation challenges, ensuring that southern countries play a central role in shaping the research agenda. For instance, has funded numerous climate adaptation projects across Africa, Southeast Asia, and Latin America, focusing on enhancing the resilience of vulnerable communities.⁴⁰

International governmental organizations, such as the United Nations Framework Convention on Climate Change (UNFCCC), and regional bodies, such as the African Union (AU), have been crucial in fostering research partnerships. The IPCC continues to be a platform for North-South collaboration, particularly in working groups that involve scientists from across the globe. However, it is important to note that while these platforms have democratized the production of climate science, the financial and technical dominance of northern countries still poses challenges.⁴¹ NGOs also play a significant role in facilitating North-South collaborations, particularly in localizing climate science for adaptation. Organizations such as Oxfam, the World Wildlife Fund (WWF), and the International Institute for Environment and Development (IIED) work closely with local governments and communities in the Global South to integrate local knowledge into research and policy development. These organizations support capacity-building and promote participatory research methods, ensuring that climate adaptation strategies are grounded in local realities.⁴²

Challenges in Current Collaborations: Power Imbalances, Data Gaps, Funding Disparities, and Differing Priorities

Despite these advances, several challenges persist in North-South climate change research collaboration. These challenges include power imbalances, data gaps, funding disparities, and differing priorities between the Global North and the South.

³⁸ Kierin Mackenzie et al., "Spatio-Temporal Visualisation and Data Exploration of Traditional Ecological Knowledge/Indigenous Knowledge," *Conservation and Society* 15, no. 1 (2017): 41–58.

³⁹ Biermann, "Earth System Governance' as a Crosscutting Theme of Global Change Research."

⁴⁰ Emal Ahmad Hussainzad and Zhonghua Gou, "Climate Risk and Vulnerability Assessment in Informal Settlements of the Global South: A Critical Review," *Land* 13, no. 9 (August 25, 2024): 1357, <https://doi.org/10.3390/land13091357>.

⁴¹ Pelling, et al., "The Politics of Adaptation to Climate Change: Local Community Responses and Global Policy Frameworks."

⁴² Tamsin Ford, Ann John, and David Gunnell, "Mental Health of Children and Young People during Pandemic," *Bmj* (British Medical Journal Publishing Group, 2021).

Power Imbalances: Although North-South collaborations are more balanced than in the past, power dynamics still shape the outcomes of climate change research. Northern institutions control most of global research funding and disproportionately influence the design of international climate agreements and scientific agendas.⁴³ This can limit the voice of Southern researchers and policymakers in determining the priorities of climate change adaptation and mitigation research, sometimes resulting in recommendations that are not well-suited to local contexts.⁴⁴

Data Gaps and Disparities: A significant challenge in North-South collaborations is the lack of comprehensive, high-quality climate data from the Global South. This data gap hampers the ability of southern countries to assess climate risks and develop effective adaptation strategies. For example, limited access to reliable meteorological data, inadequate climate modelling, and scarce local-level environmental data are common issues faced by southern researchers.⁴⁵ While Northern researchers may have access to advanced technological tools and datasets, these resources are often not adequately transferred to their southern counterparts, impeding collaborative efforts.⁴⁶

Funding Disparities: Although funding agencies such as the Green Climate Fund provide financial resources for adaptation research, allocating these funds often favors large-scale projects and international institutions based in the Global North. Smaller community-driven initiatives in the Global South may struggle to secure the necessary funding, limiting their ability to implement local climate adaptation strategies. The competitive nature of global funding mechanisms can exacerbate these inequalities, as Southern researchers and organizations often lack the administrative capacity or networks to compete for these funds.⁴⁷

Differing Priorities: Research agendas often reflect the priorities of funding institutions, which are typically based in the Global North. This can create a mismatch between the climate challenges faced by southern countries and the research being conducted. For example, while adaptation to climate impacts such as droughts, floods, and sea-level rise is a critical concern for many southern countries, research funded by northern institutions may focus more on mitigation measures, such as reducing greenhouse gas emissions, or on issues that align more closely with northern interests.⁴⁸

Accessibility and Applicability of Research Outcomes in Southern Countries:

A significant issue in the North-South collaboration is the limited accessibility of research outcomes in the Global South. Climate change research often focuses on global solutions that may not be easily adapted to local conditions. As a result, research outcomes may lack practical relevance for southern communities, especially if local knowledge, needs, and socio-economic realities are not fully integrated into the research process.⁴⁹ Ensuring that research is accessible and actionable requires ongoing efforts to engage local stakeholders throughout the research process and ensure that the findings are disseminated culturally and contextually appropriately. Although North-South research collaborations on climate change have evolved significantly over the past decades, many challenges remain. Addressing power imbalances, data gaps, funding disparities, and differing priorities between the Global North and South is essential for creating more equitable and effective research partnerships. By ensuring that southern countries are

⁴³ Shivam Gupta, Mahsa Motlagh, and Jakob Rhyner, "The Digitalization Sustainability Matrix: A Participatory Research Tool for Investigating Digitainability," *Sustainability* 12, no. 21 (November 9, 2020): 9283, <https://doi.org/10.3390/su12219283>.

⁴⁴ R. H. Moss et al., *Decision Support: Connecting Science, Risk Perception, and Decisions. Climate Change Impacts in the United States: The Third National Climate Assessment*, ed. J. M. Melillo, T. C. Richmond, and V. Yohe (U.S. Global Change Research Program, 2014), <https://data.globalchange.gov/report/nca3/chapter/decision-support>.

⁴⁵ Savin S. Chand et al., "Declining Tropical Cyclone Frequency under Global Warming," *Nature Climate Change* 12, no. 7 (July 27, 2022): 655–61, <https://doi.org/10.1038/s41558-022-01388-4>.

⁴⁶ Collin W Ahrens et al., "Plant Functional Traits Differ in Adaptability and Are Predicted to Be Differentially Affected by Climate Change," *Ecology and Evolution* 10, no. 1 (2020): 232–48.

⁴⁷ Jessica M Ayers and Saleemul Huq, "The Value of Linking Mitigation and Adaptation: A Case Study of Bangladesh," *Environmental Management* 43, no. 5 (2009): 753–64.

⁴⁸ Lea Berrang-Ford et al., "Tracking Global Climate Change Adaptation among Governments," *Nature Climate Change* 9, no. 6 (June 27, 2019): 440–49, <https://doi.org/10.1038/s41558-019-0490-0>.

⁴⁹ Huq, et al., "Adaptation to Climate Change in Developing Countries: Lessons from the Field."

recipients and co-creators of climate change research, the global community can build more inclusive, contextually relevant, and sustainable climate adaptation strategies. Continuous efforts from funding agencies, governments, and NGOs are necessary to bridge these gaps and facilitate collaborative climate science.

ICT Tools for Climate Monitoring and Early Warning Systems:

Information and Communication Technologies (ICTs) have become integral to enhancing climate monitoring and early warning systems (EWS) across regions, especially in vulnerable areas such as Africa, Asia, and Europe. These tools are essential for providing real-time data, facilitating decision-making, and improving the resilience of communities to climate-induced hazards. In Africa, ICT tools have significantly advanced early warning capabilities. The East African Community (EAC) uses the Regional Climate Outlook Forum (RCOF) to disseminate climate forecasts through mobile phones, helping farmers and local governments prepare for extreme weather events such as droughts or floods.⁵⁰ In Kenya, the Kenya Meteorological Department (KMD) leverages mobile-based platforms such as M-Farm to share weather updates and agricultural advice with farmers, thereby enhancing their ability to adapt to climate variability.⁵¹ In Asia, ICTs have been pivotal in improving early warning systems for disaster management.

In Bangladesh, an SMS-based early warning system has been implemented to alert communities to impending tropical storms and flooding. This system allows for the rapid dissemination of warnings to vulnerable populations, significantly reducing casualties during extreme events.⁵² Furthermore, India's National Remote Sensing Centre (NRSC) employs satellite data and GIS technologies to monitor and predict monsoon patterns and enhance agricultural planning and flood management.⁵³ In Europe, climate monitoring tools such as the Copernicus Climate Change Service (C3S) provide comprehensive data on temperature, precipitation, and extreme weather events across the continent. This service helps inform decision-making for urban planning, disaster management, and agricultural policies in countries such as Germany and France.⁵⁴ In addition, GIS-based systems track coastal erosion and river flooding, ensuring timely intervention in vulnerable areas. These ICT tools improve the accuracy of climate monitoring and foster collaboration between governments, communities, and international organizations to build climate resilience.

Mobile and Digital Platforms for Climate Information Dissemination:

Mobile applications, social media, and online platforms are pivotal for disseminating real-time climate information and promoting climate adaptation strategies, especially in vulnerable communities. These digital tools bridge the information gap and enable timely access to critical data, fostering more informed decision-making at the grassroots level. Mobile apps have become key to delivering localized climate forecasts and early warnings. In Kenya, the mobile app Kazi Mtaani sends climate alerts directly to users, helping farmers plan their agricultural activities around changing weather patterns.⁵⁵ Similarly, in India, the Indian Meteorological Department uses a mobile app to provide weather warnings, ensuring that rural communities are informed about extreme weather events, such as cyclones and floods.⁵⁶ These apps offer real-time climate information and provide guidance on adaptation measures, empowering communities to take proactive action.

⁵⁰ M. Ngugi, et al., "Climate Forecasting and Early Warning Systems in East Africa: A Review of ICT Tools," *Environmental Management* 65, no. 1 (2020): 45–57.

⁵¹ I. Mbiti, et al., "Leveraging ICT for Agricultural Adaptation to Climate Change: A Case Study of M-Farm in Kenya," *Environmental Research Letters* 16, no. 7 (2021): 074024.

⁵² M. Amin, et al., "Early Warning Systems and the Role of ICTs in Disaster Risk Reduction in Bangladesh," *International Journal of Disaster Risk Reduction* 47 (2020): 101514.

⁵³ S. Suryawanshi and et al., "Satellite and ICT-Based Early Warning Systems for Flood and Drought Monitoring in India," *Remote Sensing of Environment* 253 (2021): 112–55.

⁵⁴ S. Wagner, et al., "The Copernicus Climate Change Service: Supporting European Climate Adaptation," *Global Environmental Change* 70 (2021): 102358.

⁵⁵ G. Njiru, et al., "Climate Change Adaptation and the Role of Mobile Applications in Kenya," *Journal of Climate Risk and Adaptation* 12, no. 1 (2021): 87–100.

⁵⁶ S. Sharma, et al., "ICT-Based Climate Resilience and Information Systems for Rural India," *Journal of Environmental Management* 276 (2021): 111328.

Social media platforms such as Facebook and Twitter serve as powerful communication channels to reach large audiences quickly. In Ghana, local government agencies use social media to share updates on climate risks and resilience-building initiatives, thereby creating an interactive space for users to engage in climate discourse⁵⁷ In Mexico, WhatsApp groups have been used to share real-time updates on extreme weather, directly connecting vulnerable groups with governmental support and adaptation resources.⁵⁸ Furthermore, online platforms such as WeatherHub and Climanosco offer crowdsourced data to improve climate prediction and adaptation strategies. These platforms integrate weather data, community observations, and government alerts to create a collaborative space for better climate resilience.⁵⁹ These tools not only enhance the effectiveness of early warning systems but also contribute to strengthening local climate governance. Mobile and digital platforms offer dynamic solutions to disseminate climate information, empowering local communities with the knowledge necessary to adapt to climate challenges.

ICTs for Capacity Building and Knowledge Sharing:

Information and Communication Technologies (ICTs) have proven instrumental in capacity building and knowledge sharing, particularly in climate adaptation. These technologies enable the dissemination of essential climate information, provide platforms for training, and foster collaboration among diverse stakeholders, all of which are crucial for building resilience in vulnerable communities. Online training and webinars are the most effective ICT tools for enhancing the local capacity for climate adaptation. Platforms such as Zoom, Microsoft Teams, and Google Meet have facilitated virtual workshops and webinars, making climate adaptation training accessible to global audiences. Organizations, such as Farm Radio International, use webinars in Kenya to inform farmers about climate-resilient agricultural techniques, sustainable farming practices, and weather forecasting.⁶⁰ These platforms allow experts to share their knowledge directly with local communities, enabling farmers to integrate new adaptation strategies into their daily practice.

E-learning platforms also play a vital role in providing a structured learning environment. For example, the Climate Change Academy, an online learning initiative launched by South South North in South Africa, offers e-courses on climate change mitigation, adaptation, and sustainable development. Such platforms enable learners from different regions to access high-quality educational resources and engage with the field.⁶¹ E-learning not only allows for the delivery of critical climate knowledge but also provides flexibility, enabling participants to learn at their own pace. In addition, knowledge-sharing platforms, such as Moodle and Coursera, have allowed climate scientists, development practitioners, and local leaders to collaborate on climate solutions through online forums and collaborative projects.⁶² These platforms provide space for sharing experiences, research, and best practices, which are crucial for building a collective response to climate challenges. Thus, ICTs enable efficient, scalable, and cost-effective capacity-building efforts, ensuring that local communities have access to the knowledge and skills necessary for effective climate adaptation.

Key Challenges and Opportunities for ICT-Enabled North-South Collaboration in Technical and Infrastructure

In ICT-enabled North-South collaboration, particularly in the context of climate change adaptation, infrastructure disparities between the Global North and South present significant challenges. The Global South often faces limitations, such as insufficient broadband connectivity, unreliable electricity supply,

⁵⁷ F. Amoako and et al., "Social Media as a Tool for Climate Information Dissemination in Ghana," *Environmental Communication* 14, no. 3 (2020): 324–36.

⁵⁸ A. Salazar, et al., "WhatsApp for Early Warning Systems: An Assessment of Mobile Communication in Disaster Response in Mexico," *Disaster Risk Reduction* 10 (2021): 133–42.

⁵⁹ F. Mukhtarov, et al., "The Role of Online Platforms in Enhancing Local Climate Resilience: A Case Study of WeatherHub and Climanosco," *Climate Policy* 22, no. 4 (2022): 459–71.

⁶⁰ Peninah Munyua et al., "High Incidence of Human Brucellosis in a Rural Pastoralist Community in Kenya, 2015," *PLoS Neglected Tropical Diseases* 15, no. 2 (2021): e0009049.

⁶¹ Tim Kaiser et al., "Financial Education Affects Financial Knowledge and Downstream Behaviors" (Cambridge, MA, April 2020), <https://doi.org/10.3386/w27057>.

⁶² Rhiannon Thompson et al., "Ambient Temperature and Mental Health: A Systematic Review and Meta-Analysis," *The Lancet Planetary Health* 7, no. 7 (July 2023): e580–89, [https://doi.org/10.1016/S2542-5196\(23\)00104-3](https://doi.org/10.1016/S2542-5196(23)00104-3).

and limited access to modern technologies.⁶³ These challenges hinder the efficient deployment and adoption of ICT tools for climate-resilience projects. Rural and remote areas experience the brunt of this, where access to high-speed Internet and electricity is inconsistent, and this digital divide prevents equitable participation in global knowledge-sharing initiatives.⁶⁴ To overcome these barriers, a targeted investment in infrastructure is essential. Public-private partnerships can be crucial in improving connectivity and supporting the development of renewable energy solutions to power ICT infrastructure. Governments and international organizations must prioritize policies that increase access to broadband networks and energy-efficient technologies in underserved areas. For example, mobile networks have proven to be more resilient in low-income areas, and expanding mobile broadband could be a practical solution for bridging infrastructure gaps.⁶⁵ Additionally, low-cost, solar-powered ICT solutions can improve energy reliability in off-grid areas.⁶⁶

Cultural and Knowledge Barriers

Another challenge in North-South ICT-enabled collaboration is to overcome cultural and knowledge differences. Collaboration often involves diverse teams from different cultural, political, and socioeconomic backgrounds, resulting in miscommunication and divergent expectations. This is particularly evident in climate adaptation efforts, where local knowledge, which is deeply rooted in traditional practices, often clashes with external scientific models.⁶⁷ For instance, in many African regions, indigenous knowledge systems have been used for centuries to predict weather patterns and mitigate environmental risks; however, these are sometimes undervalued in global collaborations.⁶⁸ Furthermore, the design and implementation of ICT solutions can be problematic if they do not account for the sociocultural context of the communities they are intended to serve. A more inclusive approach to ICT development must be adopted to bridge the cultural and knowledge gaps. This includes integrating local knowledge into project design and ensuring that local communities actively participate in decision-making processes.⁶⁹ ICT solutions should be codesigned with respect to local customs and knowledge systems. Cross-cultural training and capacity-building efforts ensure that all stakeholders, from local communities to international organizations, can effectively communicate and work towards shared goals. By emphasizing participatory approaches, technology can be tailored to meet the unique needs of local populations while incorporating cutting-edge scientific knowledge.

Opportunities for innovation

Despite these challenges, ICT-enabled North-South collaborations present numerous opportunities for innovation, particularly in climate change adaptation. One significant opportunity lies in developing affordable and sustainable solutions that apply to different regional contexts. Collaborative research can lead to innovative ICT-based tools, such as mobile apps, GIS platforms, and climate data analytics, which provide communities with real-time information to enhance resilience against climate risks.⁷⁰ For example, ICT tools can help farmers in the Global South to access weather forecasts, climate-smart agriculture practices, and early warning systems that increase food security and reduce the impact of

⁶³ Kersten T. Schroeder et al., "Teaching and Learning with AI-Generated Courseware: Lessons from the Classroom," *Online Learning* 26, no. 3 (September 1, 2022), <https://doi.org/10.24059/olj.v26i3.3370>.

⁶⁴ Sophia Huyer et al., "From Vulnerability to Agency in Climate Adaptation and Mitigation," *Advancing Gender Equality through Agricultural and Environmental Research: Past, Present and Future*, 2021, 79–111.

⁶⁵ Sven Trenholm, "Challenges and Suggestions Regarding the Aesthetic Experience of Mathematics When Teaching and Learning Fully Online," *Asian Journal for Mathematics Education* 2, no. 1 (March 19, 2023): 3–15, <https://doi.org/10.1177/27527263231166415>.

⁶⁶ Lingbo Liu et al., "Elevating the RRE Framework for Geospatial Analysis with Visual Programming Platforms: An Exploration with Geospatial Analytics Extension for KNIME," *International Journal of Applied Earth Observation and Geoinformation* 130 (June 2024): 103948, <https://doi.org/10.1016/j.jag.2024.103948>.

⁶⁷ Christine Wamuyu Mwangi et al., "Comparing Farmers' Willingness to Pay with Costs of Clean Sweet Potato Seed Multiplication in Kenya," *Food Security* 14, no. 5 (October 17, 2022): 1279–93, <https://doi.org/10.1007/s12571-022-01293-w>.

⁶⁸ D. M. Eberhard, Gary F. S., and Charles D.F., *Ethnologue: Languages of the World*, 26th ed. (Dallas: SIL International, 2023).

⁶⁹ Ernest Dube and Edson Munsaka, "The Contribution of Indigenous Knowledge to Disaster Risk Reduction Activities in Zimbabwe: A Big Call to Practitioners," *Jamba: Journal of Disaster Risk Studies* 10, no. 1 (March 26, 2018), <https://doi.org/10.4102/jamba.v10i1.493>.

⁷⁰ Pierre-André Michaud et al., "How to Approach and Take Care of Minor Adolescents Whose Situations Raise Ethical Dilemmas? A Position Paper of the European Academy of Pediatrics," *Frontiers in Pediatrics* 11 (June 7, 2023), <https://doi.org/10.3389/fped.2023.1120324>.

climate disasters.⁷¹ Moreover, the pooling of resources and expertise in North-South collaborations can foster the development of adaptable and replicable technologies in different environments. For instance, open-source platforms can democratize access to knowledge and allow innovations to be customized for local contexts.⁷² These collaborative efforts have the potential to generate new business models and economic opportunities, mainly through the growth of the green technology industry, which addresses both climate adaptation and economic development goals. ICT-enabled North-South collaborations in climate change adaptation offer promising opportunities to leverage technology for global resilience. While infrastructure, cultural, and knowledge barriers remain significant, they can be overcome through strategic investment, inclusivity, and innovation. By fostering collaboration, respecting local knowledge, and prioritizing scalability, these efforts can lead to sustainable technology-driven solutions that help communities adapt to climate change while enhancing overall global sustainability.

RECOMMENDATIONS

1. Investment in infrastructure and the use of ICT for co-creation and decision support. To enhance the effectiveness of ICT-enabled climate adaptation strategies, investing in robust ICT infrastructure in the Global South is crucial. Public-private partnerships should focus on expanding broadband access, improving energy reliability, and ensuring that ICT tools are accessible to remote and underserved communities. Innovative solutions, such as solar-powered devices and low-cost mobile platforms, can be employed to overcome infrastructural gaps.
2. Emphasis on Local Knowledge and Inclusivity to strengthen communication and knowledge exchanges. ICT-driven adaptation strategies must incorporate local knowledge and cultural context. Facilitate regular virtual exchange programs, joint writing, and cross-institutional sabbaticals to build relationships and trust. Rather than imposing external solutions, collaborations should be designed with the active involvement of local communities to ensure that climate adaptation models are grounded in indigenous knowledge systems. Training local stakeholders in technical skills and research methodologies will further enhance the sustainability and relevance of such efforts.
3. Promote cross-cultural collaboration and capacity building to improve modelling and scenario planning. Efforts should be made to foster a better understanding and communication between the North and South teams. Promote co-developed climate-impact models that incorporate local socioeconomic pathways with transparent uncertainty communication. Cross-cultural capacity-building initiatives will help ensure that diverse knowledge systems are integrated, reducing misunderstandings and promoting mutual respect. Support local technology transfer, training-of-trainers programs, local hardware procurement, and maintenance plans to prevent dependency on northern partners. This will also contribute to the development of culturally appropriate and locally viable ICT solutions.
4. Addressing access and infrastructure gaps and encouraging Open-Source Platforms and Knowledge Sharing. Leverage cloud-based tools with offline capabilities to ensure continuity during connectivity outages. Open-source ICT platforms can democratize access to climate-adaptation technologies. By making these resources freely available and customizable for local contexts, North-South collaborations can generate scalable, low-cost solutions that can be replicated in various regions. A global knowledge-sharing network can accelerate the dissemination of best practices and innovations.
5. Monitoring, evaluating, and adapting ICT use, and ensuring governance, ethics, and equity. Formalize equitable cooperation arrangements, including co-authored intellectual property, co-led publications, shared leadership responsibilities, and transparent financial allocations. Establish ethical norms for

⁷¹ Adolfo M. García et al., "Editorial: The Unusual Suspects: Linguistic Deficits in Non-Language-Dominant Neurodegenerative Diseases," *Frontiers in Aging Neuroscience* 14 (February 16, 2022), <https://doi.org/10.3389/fnagi.2022.861041>.

⁷² Ignacio Rodríguez-Antuñano et al., "Urban Infrastructure Vulnerability to Climate-Induced Risks: A Probabilistic Modeling Approach Using Remote Sensing as a Tool in Urban Planning," *Infrastructures* 9, no. 7 (July 4, 2024): 107, <https://doi.org/10.3390/infrastructures9070107>.

data use, benefit sharing, and community permission and use community advisory boards to steer projects. Create indicators for ICT's efficacy in adaptation (data timeliness, policymakers' use, number of co-authored outputs, and policy proposal adoption). Periodically assess couple interactions to rebalance roles and correct inequalities.

CONCLUSION

This study has shown that inconsistent data standards, data gaps in the Global South, and trust deficits can slow joint analyses and upscaling of adaptation measures. As the effects of global climate change intensify, there is an urgent need for practical, equitable, and sustainable adaptation strategies. North-South research collaborations powered by Information and Communication Technologies (ICTs) hold significant promise for addressing these challenges. Northern institutions often lead funding, data, and infrastructure, while southern partners contribute to local knowledge, context, and implementation pathways. By leveraging technology, these partnerships can bridge gaps in infrastructure, knowledge, and resources, fostering innovative solutions that are scalable, inclusive, and context-sensitive. Projects that co-create research questions with southern stakeholders, policymakers, communities, and NGOs tend to produce more usable and scalable adaptation solutions. However, for these collaborations to realize their full potential, several key issues must be addressed, including technological barriers, cultural differences, and greater local engagement. Joint training, shared dashboards, and co-authored policy briefings increased the credibility and acceptability of the findings. Northern research frequently ends with demonstrations; Southern institutions' networks are critical for translating pilot results into policy and practice within local government structures. There is a need to establish regional data hubs in the Global South with defined administrations, access rules, and capacity building to ensure that local researchers can contribute and profit. Thus, investment in low-bandwidth, offline-capable data tools for rural areas is critical for improving ICT-enabled collaboration outcomes.

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