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Sustainable solutions: Learning from rural and indigenous water and sanitation practices in Latin America and the Caribbean

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SUSTAINABLE SOLUTIONS:

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WITH THE COLLABORATION OF

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SIRWASH

The program for sustainable and innovative water, sanitation and hygiene services in rural areas - SIRWASH, has the technical and financial support from the Swiss Agency for Development and Cooperation (SDC), Regional Hub Lima. Its objectives are aligned with the global commitments of the United Nations 2030 Agenda to enable policy, innovation and knowledge sharing. The program also seeks to promote the necessary capacities to provide quality and sustainable services in rural communities with a particular focus on vulnerable and disadvantaged populations across four countries in Latin America and the Caribbean. The IDB is implementing the program in Bolivia, Brazil, Haiti, and Peru to close gaps in rural services (acceptability, affordability, sustainability).

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Access to safe, sufficient, and culturally appropriate water and sanitation services remains a fundamental human right and a cornerstone of dignity, health, and sustainable development. Despite global commitments under the United Nations' Sustainable Development Goal 6 (SDG 6), the Latin American and Caribbean (LAC) region continues to face persistent and deepening challenges in delivering equitable water, sanitation, and hygiene (WASH) services, particularly for rural and Indigenous communities. These inequities are driven not only by geographic isolation, limited infrastructure investment, and institutional neglect, but also by the lack of culturally relevant service models, insufficient technical support, and the weak recognition of community governance. In the face of these gaps and the limitations of conventional top-down approaches, this technical note positions the adaptive practices of rural and Indigenous communities as strategic responses.

Rooted in ancestral knowledge, community-led governance, and innovative, nature-based approaches, these practices offer critical lessons for addressing inequities, water scarcity, and environmental degradation. This report systematically examines the diverse management practices, governance models, and adaptive solutions developed by these communities, highlighting the critical interplay between traditional knowledge, local governance, and low-cost ecological innovations to address water scarcity, inequitable access, and environmental degradation.

Against this backdrop of persistent inequities, the opening section frames the paradox of water abundance and scarcity in the LAC region. Although it is endowed with significant freshwater resources, profound disparities in access persist. Urban areas have experienced incremental gains in coverage, yet rural and Indigenous populations remain disproportionately underserved. As of 2022, 53 percent of rural residents had access to safely managed drinking water,[1] compared to 81 percent in urban areas. Indigenous communities face even greater inequities, with potable water coverage at 72 percent and sanitation access at just 48 percent. These gaps are rooted in systemic barriers such as geographic isolation, limited infrastructure investment, and institutional neglect, as well as the lack of culturally appropriate solutions, limited technical assistance, and inadequate service models tailored to rural and Indigenous contexts, which together perpetuate cycles of vulnerability and exclusion.

In response to these entrenched disparities, where conventional, top-down service delivery models have often proven inadequate, subsequent sections delve into the adaptive stewardship and sanitation practices anchored in Indigenous cosmovisions and rural community governance. Through detailed case studies—including the Zapotec of Oaxaca, the comuneros of Huamantanga in Peru, and the Guarani across several countries—the report demonstrates how ancestral knowledge systems and decentralized, community-led infrastructure can sustainably manage water resources. These examples showcase the effectiveness of nature-based solutions

[1] https://washdata.org/data/household#!/

such as absorption wells, ancient canal systems (amunas), and forest conservation in enhancing groundwater recharge, water quality, and ecosystem resilience, providing replicable models for climate adaptation and water security.

Building on these adaptive models, the analysis further explores a spectrum of innovative rural water and sanitation solutions tailored to diverse environmental and socio-economic contexts. Photovoltaic water pumping systems in Ecuador, constructed wetlands in Colombia, ecological sanitation in Brazil, and rainwater harvesting in Honduras exemplify context-specific, low-cost technologies that improve service reliability and environmental sustainability. Community-based water supply organizations (CBWSOs) emerge as critical actors in managing rural water services, their effectiveness underpinned by capacity building, gender inclusion, and inter-institutional collaboration. These models highlight the importance of community engagement and local ownership in sustaining WASH systems.

In-depth fieldwork in Indigenous communities such as Santa Ana, La Guajira (Colombia), and Canaán Membrillo, Darién (Panama), demonstrates how the integration of traditional knowledge with modern technologies and participatory governance enhances resilience. These communities navigate climatic extremes, infrastructural fragility, and institutional gaps through inclusive decision-making, gender and youth engagement, and hybrid water management systems that integrate traditional knowledge and contemporary, low-cost WASH solutions. Despite notable progress, persistent challenges remain in ensuring long-term technical support, financial sustainability, and cultural acceptance of sanitation practices, especially in the face of environmental shocks and limited public sector involvement.

Drawing together these insights and lessons learned, the final section presents actionable recommendations for advancing equitable, sustainable, and resilient WASH services in rural and Indigenous contexts. Key strategies—directly responding to the structural causes of inequities such as geographic isolation, limited investment, institutional neglect, and the lack of culturally relevant solutions or technical support—include the formal recognition and integration of Indigenous and rural governance structures into national frameworks, prioritization of decentralized and locally adapted infrastructure, and development of blended financial models that combine community contributions with public and donor funding. The findings emphasize institutionalized capacity building, blending technical training with the transmission of ancestral knowledge, as essential for long-term system sustainability. The report also advocates for robust, community-led monitoring and adaptive management systems, strengthened policy advocacy for inclusive governance, enhanced transboundary cooperation, and the mainstreaming of ecological sanitation solutions.

Central to the findings herein is the imperative to mainstream gender-sensitive and socially inclusive approaches throughout all phases of WASH program design, implementation, and evaluation. Persistent gender inequalities, including women's disproportionate burden in water collection and their underrepresentation in decision-making, remain critical barriers to equitable service provision. Evidence underscores that active participation by women and youth in governance, technical operations, and hygiene promotion significantly enhances community ownership, accountability, and the sustainability of water and sanitation services. Addressing persistent structural and cultural barriers to participation, such as limited access to leadership roles or technical training, through targeted capacity-building and inclusive governance

mechanisms ensures that WASH programs genuinely reflect the diverse needs and priorities of all community members. By systematically embedding these inclusive practices, stakeholders across the LAC region can more effectively accelerate progress toward SDG 6, ensuring no community is left behind in securing universal access to safe, reliable, and culturally appropriate water and sanitation services.

LIST OF ACRONYMS

CBWSO	Community-based water supply organization
CENAGRAP	Center of Support for the Rural Management of Drinking Water
FPIC	Free, prior, and informed consent
GDP	Gross domestic product
JAAP	Water and sanitation management boards
JAAR	Rural aqueduct management boards
LAC	Latin America and the Caribbean
NGO	Non-governmental organization
PVPS	Photovoltaic water pumping systems
SDG	Sustainable Development Goal
SISAR	Integrated System of Rural Sanitation
WASH	Water, sanitation, and hygiene

1.
INTRODUCTION

Access to safe, sufficient, and culturally appropriate water and sanitation services is a fundamental human right, integral to dignity, health, and social stability. While this commitment underpins global development efforts, the practical realization of these rights remains elusive in many parts of the world. Universal, sustainable, and equitable access to water is not merely an ethical imperative but a cornerstone for fostering peace, prosperity, and resilience in the face of growing environmental challenges such as water scarcity, pollution, and climate extremes, as well as societal challenges including institutional neglect, geographic isolation, and persistent inequalities. Central to the United Nations' 2030 Agenda for Sustainable Development is Sustainable Development Goal 6 (SDG 6), which sets an ambitious yet essential target: achieving universal access to water and sanitation by 2030 (UNESCO, 2024). However, persistent challenges such as water scarcity, declining water quality, climate extremes, and broader concerns of water security, including the sustainable management of resources for multiple uses and protection of ecosystems, reveal the steep scale of the required effort (ISSD, 2013).

The global pursuit of SDG 6 is off track, with vast population segments, particularly in rural and least developed areas, still lacking access to essential water and sanitation services (UN Water, 2021). The challenges are particularly pronounced in the Latin American and Caribbean (LAC) region, where progress has not merely lagged but reversed in critical aspects.

While most regions have reported incremental gains in the coverage of safely managed drinking water services,[2] the LAC region, alongside Europe and North America, has shown no measurable increase in coverage. At current rates of progress, global coverage is projected to reach only 77 percent by 2030, leaving approximately 2 billion people without access to safely managed drinking water. Achieving universal access will require a sixfold acceleration globally, and even steeper increases in more vulnerable settings (i.e.,14-fold in least developed countries and 19-fold in fragile contexts) (UN Water, 2023).

In the LAC region, basic drinking water and sanitation services have seen only minimal improvements, with coverage rising from 92 to 94 percent for basic drinking water services and 86 to 88 percent for basic sanitation services between 2015 and 2022, an increase of just two percentage points for each service over seven years, or less than 1 percent per year (UNICEF and WHO, 2023). While universal access to basic services and the elimination of open defecation may still be within reach, the current trajectory remains insufficient to achieve the more ambitious targets of safely managed services, which go beyond the basic service level. Progress measurement itself remains constrained, as the Joint Monitoring Program data show that only a limited number of LAC countries currently report on safely managed drinking water and sanitation services, particularly in rural areas, where data availability is especially scarce.[3] Incremental gains suggest that structural inequities and persistent underinvestment continue to constrain outcomes. These trends underscore the need for more coordinated and adequately resourced efforts to advance equitable access across the region. Yet beyond these service

[2] A safely managed drinking water service, as defined by WHO/UNICEF, is an improved water source that is located on the user's premises, available when needed, and free from fecal and priority chemical contamination, ensuring safe and reliable access for drinking, cooking, personal hygiene, and other domestic uses. Source: https://washdata.org/monitoring/drinking-water

[3] https://washdata.org/data/household#!/table?geo0=country

coverage gaps, communities also face growing pressures related to water resource governance, including pollution, overexploitation, and ecosystem degradation. Indigenous and rural practices show that resilience lies not only in expanding access, but also in protecting the ecological foundations of water security.

The LAC region's vast water resources present a paradox. Home to 29 percent of the planet's terrestrial precipitation and two of the world's largest river basins, the LAC region boasts an annual per capita water availability of 21,300 m^3 (four times the global average) (Vasquez, Serrano, and Cestti, 2021). Yet, this abundance masks profound inequities. Over 150 million people in the region grapple with extreme water scarcity, and more than 24 million lack access to basic sanitation facilities (Vasquez, Serrano, and Cestti, 2021). Persistent structural pressures, including rapid population growth, urbanization, and fragmented water governance, continue to deepen service delivery gaps and environmental stresses, underscoring the importance of governance as a central determinant of equitable water access.

The socio-economic toll of water scarcity in LAC is significant, with repercussions that extend beyond access to water, sanitation, and hygiene (WASH) services. For instance, Colombia is expected to experience a GDP reduction of 1.56 to 2.31 percent due to the cascading effects of water shortages, including reduced agricultural productivity, employment losses, and constraints on industrial production (Vasquez, Serrano, and Cestti, 2021). Over the past four decades, droughts alone have inflicted economic losses of approximately US$24 billion across the region, underscoring the direct link between water insecurity and economic instability (Vasquez, Serrano, and Cestti, 2021). Rural and Indigenous communities, heavily reliant on agriculture and natural ecosystems, are particularly vulnerable to these climatic and economic shocks.

The contrast between the LAC region's water wealth and uneven access patterns reflects long-standing gaps in water governance, infrastructure development, investment, and institutional capacity. Although access to safely managed water services remains limited across the region, rural communities[4] continue to experience disproportionately low service levels. In 2022, only about 53 percent of the rural LAC population had access to safely managed drinking water services, compared to 80 percent in urban areas, underscoring a persistent rural–urban divide.[5]

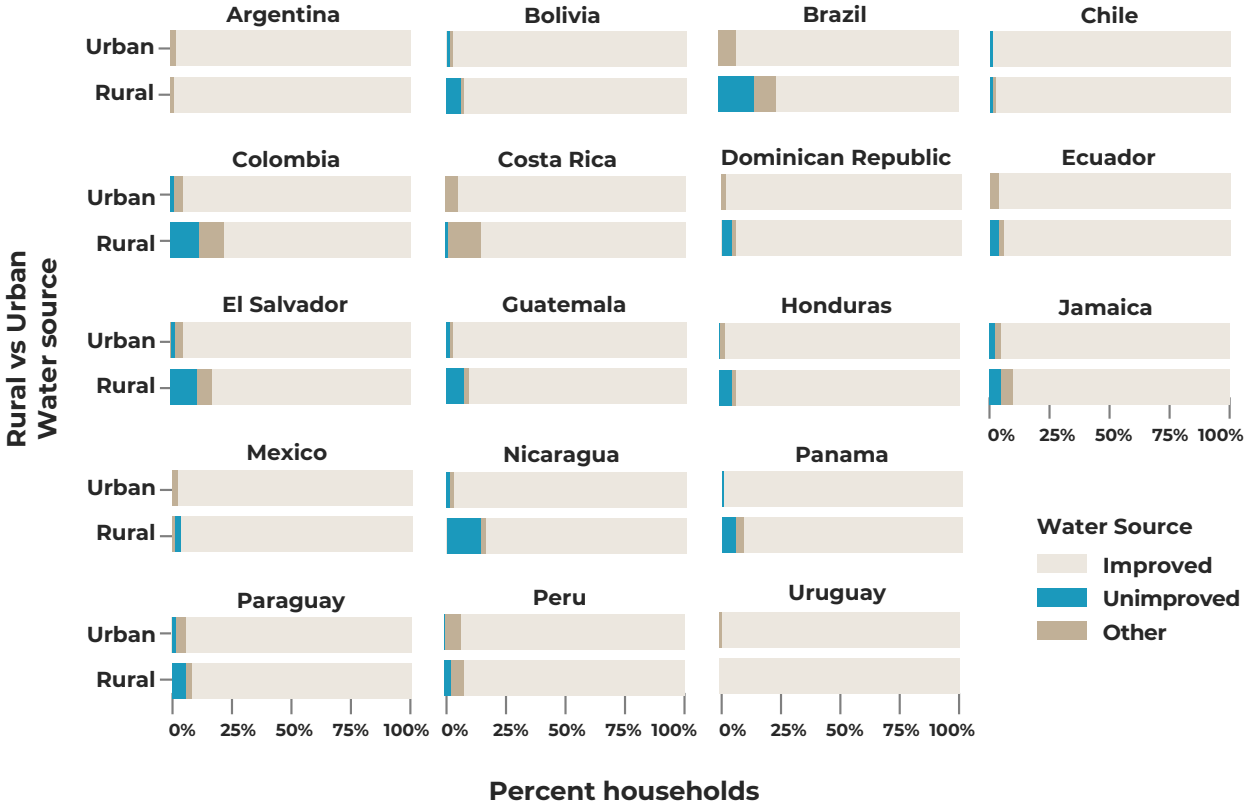
Rural communities in LAC continue to face structural barriers to accessing safe and reliable water services, reflecting deeper systemic inequalities in water governance, infrastructure investment, service delivery systems, and institutional capacity. While access to at least basic drinking water services in the region has steadily improved, reaching near-universal levels in urban areas, progress toward achieving safely managed drinking water remains uneven. Based on UNICEF and WHO (2023), as of 2022, safely managed drinking water coverage in LAC stood at 75 percent, with urban access estimated at approximately 81 percent and rural access at 53 percent, revealing a 34-percentage-point disparity (Figure 1). Although rural coverage has increased over the 2015–22 period, annual growth remains insufficient to close this gap.

[4] Rural communities are low-density populations with limited infrastructure and access to essential services, often reliant on natural resources and agriculture, and characterized by unique social dynamics and resilience despite systemic barriers and geographic isolation.

[5] https://washdata.org/data/household#!/dashboard/new

Household survey data from the AmericasBarometer (LAPOP, 2019) highlights similar inequities in access to improved water sources on premises: while 96 percent of urban households across the region report access, this figure drops to 87 percent in rural areas, with disparities exceeding 10 percentage points in countries such as Brazil, Colombia, El Salvador, and Nicaragua (Libra and Baquero, 2022). At the national level, progress remains highly uneven, while countries such as Chile and Costa Rica are approaching their 2030 targets, others have recorded growth rates as low as 0.2 to 0.5 percent per year (Vasquez, Serrano, and Cestti, 2021). This persistent divide in service coverage contributes directly to regional inequality, deepening the socio-economic vulnerability of rural populations and, in some contexts, heightening the risk of social unrest and conflict.

Figure 1. **Regional Drinking Water Coverage in Rural and Urban Areas**



Source: Libra and Baquero (2022).

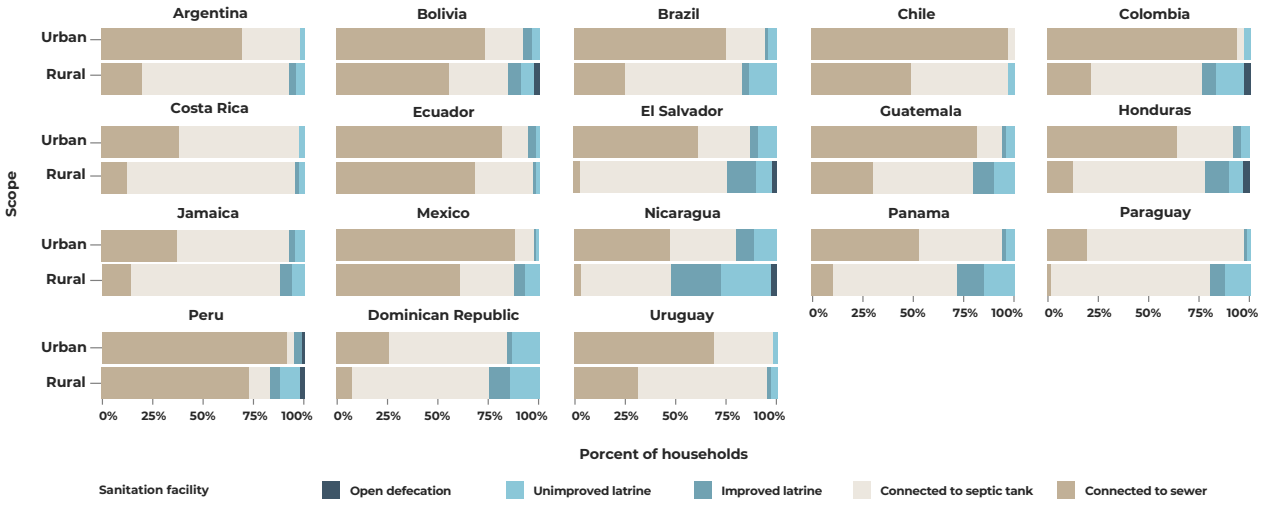
Indigenous communities,[6] often concentrated in rural and remote areas, experience limited-service coverage due to a combination of logistical barriers (e.g., geographic isolation and higher infrastructure costs) and institutional barriers (e.g., underfunded service delivery systems and limited recognition of Indigenous governance structures). In the LAC region, 72 percent of the Indigenous population has access to piped water, compared to 92 percent of the general

[6] Indigenous communities are distinct groups characterized by historical continuity with pre-colonial societies; strong ties to their ancestral territories and natural resources; unique social, economic, and political systems; and a shared commitment to preserving their cultural heritage, language, and traditions, often self-identified and recognized by their own members within non-dominant societal frameworks. Source: https://whc.unesco.org/en/glossary/275.

population;[7] however, only 48 percent of the Indigenous population has access to sewage systems, compared to 71 percent among the general population (Fan and Borja-Vega, 2024). While comprehensive regional data on safely managed services remain limited, both overall and when disaggregated by ethnicity, this constrains a full assessment of disparities at scale. These inequities not only entrench poverty and restrict socio-economic mobility but also exacerbate health burden and environmental degradation. Poorly managed sanitation pollutes water resources, diminishing their availability for other essential uses and perpetuating a cycle of inequity and vulnerability.

As with drinking water, measurement of safely managed sanitation is constrained by limited country reporting, which affects the reliability of regional estimates. Despite notable progress in urban areas, access to sanitation remains uneven and underdeveloped in rural LAC, where safely managed sanitation coverage reached approximately 46 percent as of 2022 (UNICEF and WHO, 2023). However, this estimate is based on data from only 11 of the 33 countries in the region with sufficient information to assess compliance with wastewater treatment standards (Libra and Baquero, 2022). Around 70 percent of rural residents continue to rely on rudimentary sanitation systems, and 9 percent practice open defecation, conditions that pose ongoing challenges to health and environmental sustainability (Figure 2). In Honduras, Nicaragua, and Peru, fewer than 60 percent of rural households are connected to septic tanks or sewer systems, and safe sanitation is available to only a portion of the population (Libra and Baquero, 2022).

Figure 2. **Percent of Households with Access to Different Types of Sanitation Facilities in Urban and Rural Communities**



Source: Libra and Baquero (2022).

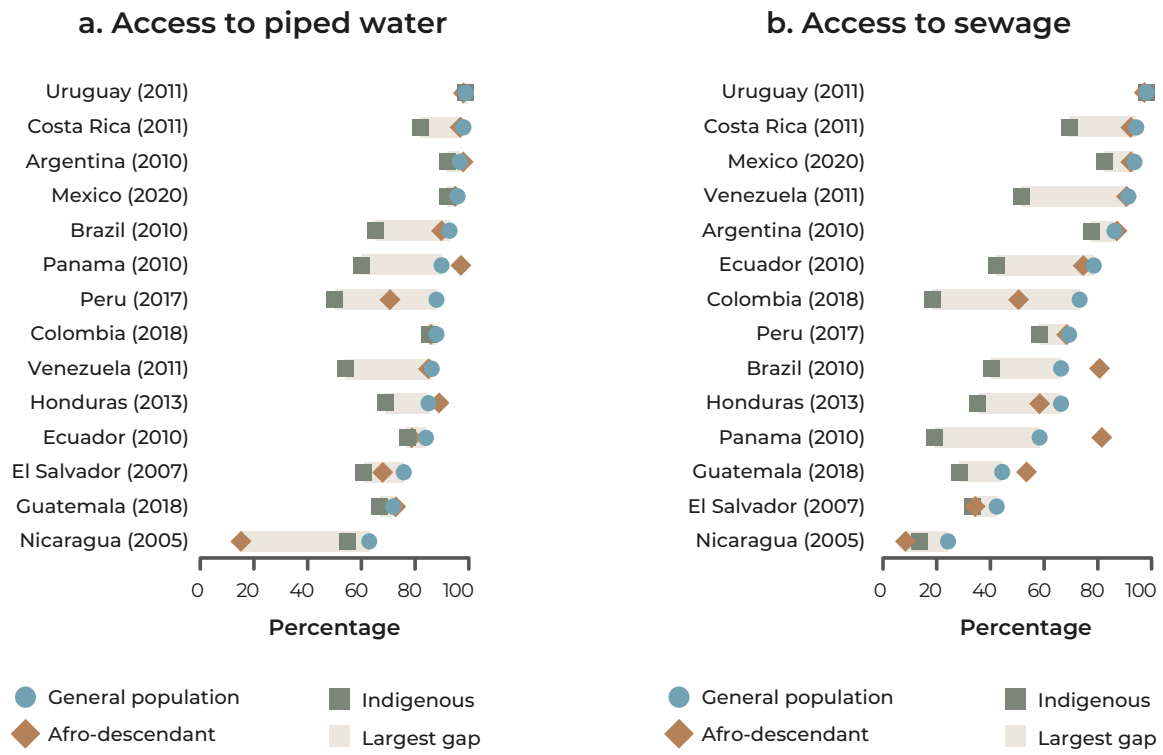
Efforts to expand rural sanitation present a significant opportunity to enhance well-being, build resilience, and promote inclusive development. While logistical and financial constraints remain, especially in remote and low-density areas, targeted investment and inclusive planning can

[7] https://washdata.org/data/household#!/dashboard/new

help ensure that no communities are left behind. The COVID-19 pandemic highlighted the need for improved service delivery and accountability, while also accelerating momentum for more transparent and equitable approaches to rural water and sanitation governance (Fan and Borja-Vega, 2024).

Indigenous water governance traditions—rooted in reciprocity, conservation, and respect for natural ecosystems—remain underrepresented in mainstream frameworks. Indigenous communities in the LAC region face significant disparities in access to safely managed water and sanitation, with potable water coverage at only 72 percent compared to 87 percent for the general population and sanitation services at a stark 48 percent versus 71 percent (Fan and Borja-Vega, 2024). These disparities are not uniform across the region but vary significantly by country, underscoring the heterogeneity of challenges faced by Indigenous populations (Figure 3). These communities rely heavily on aquatic ecosystems such as wetlands and mangroves for sustenance, including fishing and agricultural activities, yet poor water management practices have severely degraded these ecosystems, accelerating their decline (Fan and Borja-Vega, 2024). Within this context, it is useful to distinguish between complementary dimensions of Indigenous engagement with water: Indigenous knowledge, which reflects ecological and cultural understandings of water as a sentient entity; Indigenous approaches, which encompass socio-cultural traditions of stewardship; and Indigenous governance, which refers to the institutional and community-level mechanisms that operationalize these principles. Together, these dimensions provide methodologies for restoring degraded ecosystems and reshaping governance systems in ways that are both culturally grounded and ecologically sustainable.

Figure 3. **Access Gap between Indigenous and General Population Groups in Selected LAC Countries**



Source: Fan and Borja-Vega (2024).

Addressing persistent service gaps, environmental degradation, and water stress in the LAC region will require integrated solutions that combine traditional knowledge systems with contemporary technological and institutional approaches. This synthesis is crucial for addressing the immediate needs of rural and Indigenous populations and is pivotal for enhancing water security, driving sustainable development, and promoting social justice. This study aims to systematize and analyze the diverse water and sanitation management practices of rural and Indigenous communities across the LAC region, addressing challenges such as water scarcity, inequitable access, and ecosystem degradation. By documenting culturally relevant case studies and identifying actionable strategies, this effort, grounded in a comprehensive literature review and expert consultations, aims to inform the design of WASH services that prioritize equitable governance and the inclusion of traditional knowledge. Ultimately, the study aspires to pave the way for a more inclusive, sustainable, and prosperous future, ensuring that the voices and practices of marginalized communities are integral to the region's development trajectory.

2.

ADAPTIVE WATER STEWARDSHIP AND SANITATION: INDIGENOUS AND RURAL PERSPECTIVES

Water, the essence of life, has shaped human societies and their development since ancient times. Yet, how communities interact with and manage this vital resource varies significantly across regions and cultures. The dominant perspective in many societies, particularly in the West, treats water as a resource to be efficiently managed and allocated to ensure its availability and accessibility for humanity. However, this approach, while effective in many contexts, has in some cases struggled to maintain water resources within safe ecological boundaries, particularly where local engagement or ecological feedback loops are limited (Abigail and Maritza, 2024). Many current water governance systems, particularly in urban or centralized contexts, rely on top-down structures that can limit opportunities for local participation in decision-making processes (Acharibasam et al., 2023).

Addressing the complexities of the 21st century and achieving the UN's SDGs demands reimagining conventional governance practices, particularly in rural and Indigenous contexts where dispersed settlement patterns and ecological vulnerability challenge centralized models, to tackle modern WASH challenges effectively. This section examines three interrelated dimensions of Indigenous and rural water stewardship: (i) the barriers and governance challenges they face; (ii) the knowledge systems and cosmovisions that underpin their approaches; and (iii) the practices and institutional responses that sustain resilience.

While national and international efforts often emphasize closing the financing gap for safely managed water and sanitation services, Indigenous and rural communities have developed unique practices that reflect a profound connection to and understanding of the natural environment. These practices provide sustainable and adaptable solutions to contemporary WASH challenges. Rooted in communal governance and spiritual reverence for water, Indigenous water management systems embody a long-standing relationship with the land, providing practical responses to pressing issues such as climate change and infrastructural deficits.

Despite their resilience, both rural and Indigenous communities face critical barriers to accessing water and sanitation services, particularly in remote areas where state infrastructure is sparse or nonexistent. Yet, many of their practices demonstrate remarkable adaptability, leveraging centuries-old knowledge systems and an intimate understanding of local ecosystems to manage water resources in a sustainable manner. These approaches often prioritize equitable water distribution through communal governance structures, ensuring access for even the most marginalized members of their communities, as well as the protection of ecosystems that are essential to sustaining the broader water cycle.

The barriers and governance challenges faced by Indigenous and rural communities can be grouped into institutional, infrastructural, financial, logistical, and cultural dimensions, which manifest in different ways across contexts. Indigenous communities often integrate their spiritual and cultural connections to water into their governance and conservation strategies, viewing water as a sacred entity deserving of protection. Conversely, rural communities tend to focus more on practical, community-based governance models designed to sustainably and efficiently manage water and sanitation services, often in close connection with agriculture and other livelihood needs, in the face of modern challenges. To fully appreciate the contributions of each group, it is essential to examine their water and sanitation management practices separately, recognizing the unique strengths and insights they bring to address global challenges.

2.1. Indigenous Water Stewardship Practices

The development of knowledge through intuitions, concepts, and collective memory serves as a compass for individuals to navigate their environment and adapt to their surroundings. As custodians of some of the world's most biologically diverse territories, **Indigenous peoples have cultivated unique knowledge systems** over generations, deeply rooted in their cultural heritage and lived experiences. This Indigenous knowledge—encompassing ancestral, spiritual, environmental, societal, economic, political, and technological dimensions—is a vital resource for humanity, guiding interactions between human societies, the cosmos, and the natural world. Through its intrinsic moral and social responsibility toward nature, **Indigenous knowledge provides significant contributions to environmental conservation, food security, health, education, and natural resource management**, offering pathways for greater efficiency, effectiveness, and sustainability (Obeiro et al., 2022).

Indigenous cosmovisions place water at the core of existence, recognizing it as a living entity imbued with spirit, rights, and a vital role in the natural order. This perspective fosters a deep respect for water, viewing it as a sacred relative that must be honored and protected. Indigenous approaches adopt a **biocultural perspective that views water, nature, and life as inherently interconnected and interdependent**, providing valuable insights that can enhance legal, technical, and economic approaches to water governance. Grounded in natural cycles, this understanding prioritizes sustainability and biodiversity, offering complementary insights for global water management. As stewards of many of the world's most biodiverse ecosystems, Indigenous communities play a critical role in preserving natural balance through their reverence for water and ecosystem integrity (Martinez-Cruz et al, 2024).

Box 1. Cosmovision

The concept of **cosmovision** refers to Indigenous worldviews that understand water, land, and life as interconnected and inseparable. In many Indigenous traditions, water is treated as a living entity with its own spirit, rights, and protective role in sustaining life. For instance, the Zenú People in Colombia believe the world was created from a *totuma* (water container), while the Guidxiz'a (Zapotecan) community in Oaxaca venerates Shoora, a river deity embodied as a snake. Such perspectives illustrate how Indigenous governance frames water as both a life source and a guardian of cultural identity. Recognizing these cosmovisions is essential to designing WASH interventions that respect Indigenous values and ensure long-term stewardship.

Source: Martinez-Cruz et al, (2024).

The transformative power of Indigenous cosmovisions is evident in their water management practices, which seamlessly blend spiritual, ecological, and practical dimensions to address scarcity and quality challenges. Their understanding of water transcends its physical properties, deeply embedding it within their beliefs as the source of life, spiritual guidance, and protection. For instance, the Zenú People of Northern Colombia regard water as the origin of life and time, reflected in their creation story where the world emerged from a *totuma*, a water container that gave rise to fish, amphibians, trees, and humans. This narrative underscores the profound agency and life-giving power attributed to water in Indigenous worldviews, a perspective shared by many Indigenous cultures that see water, life, and energy as inseparable from the land (Martinez-Cruz et al, 2024). Similarly, the Tee Savi (Mixteco) nation in Oaxaca, Mexico developed "cajete sowing," a farming technique designed to address arid soils and insufficient rainfall. Planting drought-resistant maize seeds deep into the soil allows for access to residual moisture, ensuring sustainable food production while conserving water resources. These approaches highlight the **ingenuity of Indigenous communities in using traditional knowledge to navigate environmental challenges**, demonstrating how localized practices can offer global lessons in sustainability and resilience.

Despite their invaluable contributions, Indigenous worldviews and their deep understanding of ecological interconnectedness are often underrepresented in formal water governance. **Prevailing institutional frameworks, shaped over time by centralized and technocratic approaches, have often limited the integration of Indigenous knowledge systems and community-led practices** (Acharibasam et al., 2023). Differences in governance frameworks, particularly in how water is valued, managed, and protected, have contributed to the limited integration of Indigenous practices in formal decision-making processes. Indigenous communities in the LAC region continue to face serious threats to their water sources from mining, hydroelectric development, and large-scale agricultural expansion, often initiated without their free, prior, and informed (FPIC) consent (Martinez-Cruz et al, 2024). These interventions frequently disrupt local ecosystems and traditional water management practices, compromising both the sustainability of water resources and cultural integrity of affected communities.

Box 2. Free, Prior, and Informed Consent (FPIC)

Free, prior, and informed consent (FPIC) is a fundamental right granted to Indigenous peoples under the UN Declaration on the Rights of Indigenous Peoples, reflecting their inherent right to self-determination. FPIC empowers Indigenous communities to grant or withhold consent for projects impacting their lands, allowing them to withdraw this consent at any stage. Moreover, it ensures their active participation in the negotiation process, allowing them to influence planning, implementation, monitoring, and evaluation, thereby safeguarding their autonomy and interests.

Source: https://www.fao.org/indigenous-peoples/our-pillars/fpic/en/

Structural barriers—most prominently infrastructural, institutional, logistical, financial, and cultural—continue to hinder Indigenous communities' access to safe and potable water. These manifest in forms such as limited infrastructure, geographic isolation, and persistent gaps in institutional recognition. Yet, Indigenous peoples' intimate understanding of natural cycles enables them to adapt to even the harshest conditions. Whether managing water in the humid rainforests of the Amazon, the arid lands of sub-Saharan Africa, or the icy terrains of the Arctic, Indigenous communities demonstrate unparalleled resilience and ecological stewardship. Their practices, grounded in cultural traditions and intergenerational knowledge, **support long-term water stewardship through locally adapted techniques, community-based monitoring, and collective management of aquatic ecosystems**. By fostering collective ownership and incorporating their holistic values into water governance, Indigenous communities offer innovative solutions to contemporary challenges. These examples highlight the importance of incorporating Indigenous perspectives into global frameworks to develop inclusive, equitable, and sustainable water management systems (Martinez-Cruz et al, 2024).

The sustainable principles inherent in Indigenous water stewardship form the bedrock of tangible and innovative ancestral water and wastewater management approaches. By translating spiritual and ecological values into practical techniques, **Indigenous communities have developed systems that address immediate needs and offer enduring solutions to water resource challenges**. The following section delves into how these ancestral practices, shaped by environmental contexts and cultural traditions, remain relevant to contemporary water management strategies.

2.1.1. Ancestral Water Management Practices

Indigenous communities across the LAC region apply culturally rooted knowledge systems to manage water and natural resources in sustainable and context-specific ways. These approaches reflect a holistic understanding of the interdependence between water, ecosystems, and community well-being, guiding the development of resilient and adaptive management practices that promote sustainable development. For instance, the Guarani people of Brazil and Paraguay demonstrate forest-based water management by using natural vegetation to regulate river flow and maintain water quality. This practice underscores their deep knowledge of ecosystem dynamics and highlights the critical role of forest conservation in integrated water resource management (Martinez-Cruz et al, 2024).

Traditional knowledge serves as a cornerstone of Indigenous water management, enabling communities to meet their needs while preserving ecological balance. Oral traditions play a key role in transmitting this knowledge across generations. Elders act as knowledge keepers, sharing lessons through stories, rituals, and practices embedded in daily life. Among the Shuar of the Amazon rainforest, storytelling and ceremonial practices are employed to educate young people about the local river ecosystems, including fishing techniques and water stewardship. These methods convey both practical expertise and a strong ethic of care for water sources, reinforcing long-term protection of essential natural systems (Izah et al., 2024).

Indigenous communities are also recognized for their ability to adapt water management strategies to environmental changes. The Quechua and Aymara peoples of the high-altitude Andes have preserved and refined the Incan terrace farming techniques known as andenes.

These agricultural terraces are sophisticated water management systems that capture rainfall, prevent soil erosion, and distribute filtered water across varying altitudes (Izah et al., 2024). The andenes exhibit their resilience and ingenuity by facilitating the cultivation of a variety of commodities in difficult terrains, thereby exhibiting how Indigenous communities adapt their practices to mitigate the effects of climate change and seasonal variations.

A central feature of Indigenous water management is the understanding that water is both ecologically interconnected and spiritually significant. Among the Navajo Nation in North America, the concept of hosho, which embodies harmony, balance, and beauty, guides water management practices, emphasizing the health of the entire ecosystem over human needs alone. Similarly, Mapuche communities in Argentina and Chile hold the *Ngillatun* ceremony[8] at water sources to promote balance with nature, underscoring the view that water stewardship is both a sacred and ecological responsibility (Izah et al., 2024). These traditions reflect a broader ethic of care in which water is treated as a living part of the natural world deserving of respect and reciprocity.

Box 3. Mapuche Water Governance Councils

The Ad Mapu councils of the Mapuche people exemplify a transformative model of water management rooted in conservation and community empowerment. Anchored in participatory governance, these councils enable Mapuche communities to take an active role in decisions concerning their water resources. This inclusive framework fosters a deep sense of ownership and agency among community members, strengthening their capacity to protect and manage water sustainably. By blending traditional knowledge with contemporary governance practices, the Ad Mapu councils highlight the critical role of community-led initiatives in achieving holistic and culturally attuned water management solutions.

Source: Izah et al (2024).

Together, these diverse practices demonstrate the adaptability and contextual precision of Indigenous water management systems. Grounded in intergenerational knowledge and shaped by local ecosystems, they offer practical lessons in balancing environmental stewardship with community needs. Indigenous strategies, ranging from forest-based regulation and highland terracing to interwoven spiritual-ecological practices, can inform and enhance modern WASH efforts. The following case studies examine how Indigenous and rural communities have applied these principles in practice across the LAC region.

[8] *Ngillatun* (also spelled *Guillatún*) is the principal fertility and thanksgiving ceremony of the Mapuche people. It typically lasts 2 to 4 days and takes place in a specially designated ceremonial field centered around a *rewe* (sacred altar pole). Led by spiritual leaders such as the machi or ngenpin, the ceremony features prayers, ritual dances, animal offerings, and songs that express gratitude, seek good harvests, and reinforce community bonds and cosmic balance (Gabay, 2024).

2.1.2. Case Studies of Ancestral Water and Wastewater Management Practices

To facilitate comparison and highlight distinctive characteristics, the examples are grouped into three thematic categories: (i) governance and collective management rooted in cosmovision, (ii) social practices enhancing participation and intergenerational knowledge transfer, and (iii) context-responsive ancestral technologies tailored to environmental and livelihood realities.

Governance and Collective Management

Indigenous governance models embed water management within spiritual, cultural, and communal frameworks. Decision-making is collective, responsibilities are reinforced through assemblies and rituals, and stewardship is anchored in the recognition of water as a living relative. These approaches ensure that water governance transcends technical oversight, weaving together accountability, spirituality, and intergenerational continuity. The following cases highlight how Indigenous governance systems integrate cosmological values with practical management to sustain water resources over time.

Water Conservation Efforts in Zapotec Indigenous Communities, Oaxaca, Mexico

Community Background

The Zapotec communities of Oaxaca comprise 16 Indigenous villages situated in the drought-prone Oaxaca Valley (Map 1). These communities rely heavily on agriculture for their livelihoods and face significant challenges due to recurring droughts and diminishing water resources. Geographic isolation, limited state support, and socio-economic constraints have exacerbated these issues. In response, the Zapotec people have developed innovative, community-driven solutions deeply rooted in traditional knowledge and their connection to the land.

Map 1. **Oaxaca, Mexico**

Source: Author(s)

Key Challenges

Prolonged droughts have severely impacted the Zapotec region, reducing access to water for human consumption and agricultural irrigation. Underground aquifers, once the primary water source for these communities, have been drastically depleted. The lack of consistent rainfall and increasing strain on water resources have led to crop failures, forced migration, and economic decline in many villages. Despite these challenges, the Zapotec people have remained resilient, leveraging their communal structures and knowledge to mitigate the effects of water scarcity.

Solutions: Decentralized Water Conservation Infrastructure and Groundwater Recharge

In response to recurring droughts and the overexploitation of underground aquifers, the 16 Zapotec communities of Oaxaca mobilized through the Coordination of Peoples United for the Defense and Care of Water, and have launched over 579 decentralized water conservation projects since 2005. These include absorption wells, small dams, and water pans, each tailored

to local hydrological and ecological conditions. Absorption wells are typically 25 meters deep and strategically located beneath rooftops or along unpaved roads to capture rainwater runoff. Water percolates through layers of sand and natural filters within the well, cleansing it before it recharges the aquifer. This method has demonstrably raised water levels in nearby irrigation wells following seasonal rains. Small dams, constructed in local rivers and intermittent streams, are designed to slow the surface flow of water, promoting greater infiltration into the soil and aquifer recharge. These structures create temporary retention zones that serve as buffers during dry periods. Water pans, by contrast, are large rectangular depressions dug into the earth and lined with tarping to prevent seepage. They capture and store rainwater for later use by farmers, livestock, and wildlife. These pans also generate microclimates that contribute to environmental regeneration, attracting species such as ducks and eared doves.

While these nature-based solutions have significantly improved groundwater recharge and provided critical reserves during dry periods, their performance is highly dependent on seasonal rainfall. In years of extreme drought, storage and infiltration capacity decline, reducing the availability of water for human consumption and irrigation. Rather than centralized delivery systems, the infrastructure consists of decentralized assets built and maintained through collective community efforts. Construction, operation, and oversight are governed by traditional Zapotec structures, with no individual user fees. Instead, community members contribute labor and share responsibilities, reinforcing a system of reciprocity and collective stewardship that ensures long-term ownership and sustainability.

Implementation and Community Involvement

The long-term success of the Zapotec communities' water conservation efforts rests on a deeply rooted model of community-based water management, shaped by traditional governance structures that emphasize collective responsibility and communal land stewardship. From the outset, every phase of the water infrastructure projects (i.e., planning, construction, operation, and maintenance) has relied on active community participation. Community members contribute manual labor to construct and maintain the absorption wells, small dams, and water pans, while governance and oversight responsibilities are assigned through customary decision-making processes (Pelliccia, 2022). At the core of this system are general assemblies, which serve as the highest authority in communal governance. In Oaxaca, where nearly 80 percent of the land is held communally, general assemblies serve as participatory forums, with each household represented (Rojo and Rojo, 2025). Participation is mandatory, and decisions are made collectively. Through these assemblies, members are selected to perform unpaid community service roles, including the management and oversight of local water infrastructure. Water committees selected through general assemblies are tasked with overseeing infrastructure maintenance and ensuring its continued operation, with responsibilities assigned and rotated in accordance with local traditions. These positions reinforce civic engagement and prevent the concentration of decision-making authority, thereby enhancing accountability and transparency (Rojo and Rojo, 2025).

Rather than relying on individual user fees or privatized service models, the Zapotec approach to water governance is structured around reciprocal labor obligations and clearly defined communal duties. Each household is expected to contribute either through physical labor or active participation in collective oversight. This model reduces financial barriers to access while institutionalizing a shared sense of ownership over water resources (Pelliccia, 2022). The

governance framework is embedded in cultural and legal traditions that recognize communal land tenure and prioritize consensus-based management. In the absence of formal state provision, this locally governed system has maintained the functionality of decentralized infrastructure even under conditions of environmental stress.

Sustainability

The sustainability of Zapotec water conservation efforts is rooted in Indigenous governance, decentralized infrastructure, and legal recognition of water autonomy. Following decades of social mobilization, the 2021 Xnizaa decree granted 16 communities formal rights to manage their water resources (Ulloa-Calzada, 2022). This enabled direct access to public funding and technical support from institutions such as the Mexican Institute of Technology and the National Institute of Indigenous Peoples, but implementation remains entirely community-led through the Coordination of Peoples United for the Defense and Care of Water (Pelliccia, 2022).

A hybrid model that combines state co-financing with tequio (traditional communal labor) ensures financial sustainability. There are no user fees; instead, households contribute labor to construct and maintain infrastructure, which eliminates cost barriers and institutionalizes collective ownership. By 2022, over 579 water capture projects, absorption wells, water pans, and small dams had been completed, all based on low-cost, replicable designs that require minimal external inputs (Ulloa-Calzada, 2022).

Managerial sustainability is maintained through customary Zapotec governance. Community assemblies, where household participation is mandatory, assign rotating oversight roles for infrastructure maintenance. These unpaid roles are embedded in local norms of civic duty, ensuring accountability and preventing elite capture. Technical maintenance is decentralized and guided by Indigenous hydrological knowledge, including a detailed understanding of local soil absorption rates, rainfall patterns, and terrain dynamics. This knowledge informs where infrastructure is placed, when it should be used or rested during seasonal shifts, and how to ensure alignment with local ecosystems to avoid degradation or water loss. Intergenerational knowledge transfer is central to long-term viability. The Coordination of Peoples United for the Defense and Care of Water's hydrological pedagogy treats water as both a natural and cultural asset. Youth are engaged through hands-on participation, storytelling, and ritual, reinforcing water stewardship as a collective value. This locally anchored education model ensures continuity, cultivates technical competence, and sustains a deeply relational approach to resource governance (Ulloa-Calzada, 2022).

Lessons Learned

The Zapotec case demonstrates that decentralized, community-led water management can be both effective and sustainable, particularly when grounded in local knowledge and collective governance. By mobilizing traditional practices, such as *tequio* and general assemblies, the communities have ensured strong ownership, equitable access, and long-term maintenance of water infrastructure without relying on user fees. Additionally, the legal recognition of Indigenous water rights through the Xnizaa decree marked a turning point, formalizing community authority over water governance and underscoring how political advocacy and grassroots organizing are essential components of resilience in water-scarce regions.

Technical solutions tailored to local hydrology, such as absorption wells and small dams, have proven more effective and affordable than large-scale infrastructure. These low-tech, high-impact systems are not only ecologically compatible but also easily maintained by community members without external technical expertise. Furthermore, intergenerational knowledge transfer has been key to institutionalizing sustainable practices. Through participatory learning and cultural pedagogy, younger generations are equipped to uphold and adapt water governance systems, ensuring continuity in the face of environmental and political change.

Social Practices for Participation and Equity

Water stewardship among Indigenous communities is inseparable from social structures that emphasize participation, reciprocity, and equity. Knowledge is transmitted through oral traditions, cultural rituals, and community learning, ensuring that younger generations inherit both practical skills and ecological ethics. These practices foster inclusive engagement, empower marginalized voices, and align collective resource use with broader cultural values. The case studies below illustrate how Indigenous peoples strengthen participation and equity through education, ritual, and collective monitoring.

Sustainable Water Management in the Guarani Aquifer System[9]

Community Background

The Guarani people—an Indigenous group living in Argentina, Bolivia, Brazil, and Paraguay—embody the principles of forest-based water management, which are essential to the sustainability of one of the largest transboundary groundwater systems in the world: the Guarani Aquifer System (Map 2). This vast aquifer, covering approximately 1.2 million square kilometers, extends beneath Argentina. Brazil, Paraguay, and Uruguay. It serves as a critical water source for millions, providing drinking water, supporting agriculture, and maintaining regional ecosystems. For the Guarani people, whose livelihoods are deeply intertwined with the forests and waterways of the region, the aquifer represents both a vital resource and a spiritual entity.

[9] See Foster et al. (2009).

Map 2. **Guarani Aquifer System**

Source: Author(s)

Key Challenges

The Guarani Aquifer System faces mounting challenges due to unsustainable extraction, pollution, and deforestation. Rapid agricultural expansion, urbanization, and industrial activities have increased demand for water, threatening the delicate balance of this ecosystem. The degradation of natural vegetation in the recharge zones has further exacerbated these pressures, reducing the aquifer's ability to replenish itself and maintain water quality. Additionally, the aquifer's transboundary nature has presented governance challenges, requiring cooperation among the four nations sharing this resource.

Solutions: Forest-Based Water Management and Transboundary Collaboration

The Guarani people address water-related challenges through practical, a nature-based solution rooted in the conservation and restoration of natural ecosystems. Central to their strategy is the

preservation of native forests located in key aquifer recharge zones. These forests serve as vital hydrological buffers, absorbing rainfall and facilitating the gradual percolation of water into the subsurface, thereby enhancing aquifer recharge and sustaining base flows throughout the year. To maintain these functions, Guarani communities actively engage in forest protection, prevent deforestation, and promote reforestation using native species. Vegetative buffer zones along riverbanks and streams are also maintained to intercept sediments and pollutants, reduce surface runoff, and stabilize riverbanks, contributing to improved water quality and watershed resilience.

Transboundary collaboration to protect the Guarani Aquifer System has been operationalized through the support from the Global Environment Facility, the World Bank, and the Organization of American States. This initiative marked one of the first major efforts to develop a coordinated groundwater governance framework across multiple countries. Technical cooperation among Argentina, Brazil, Paraguay, and Uruguay has centered on three core areas. First, the generation and harmonization of hydrogeological data have been pursued through coordinated research efforts and the development of a shared transboundary information system, allowing for more accurate and comprehensive monitoring of the aquifer. Second, legal and institutional frameworks have been designed to support cooperative aquifer management, including principles for joint monitoring, environmental protection, and coordinated emergency response. Third, best practices in sustainable land and water use have been promoted through targeted initiatives in critical recharge zones, helping to build capacity and inform policy across national boundaries.

National-level coordination units and transnational technical working groups have brought together government agencies, academic institutions, and representatives from Indigenous and local communities to advance the cooperative management of the Guarani Aquifer System. These platforms have enabled the alignment of national water policies, establishment of common objectives for groundwater protection, and development of shared strategies for sustainable aquifer management. Stakeholder consultations in critical areas, including regions with intensive water use and sensitive recharge zones, have supported the creation of localized agreements on land-use planning, water extraction controls, and forest conservation. This collaborative governance model has strengthened institutional capacity, deepened cross-border trust, and laid the foundation for a long-term, equitable, and integrated approach to managing one of the world's largest transboundary aquifers.

Sustainability

Regional and international initiatives have complemented Indigenous efforts by fostering practical collaboration between Argentina, Brazil, Paraguay, and Uruguay. Through monitoring and mapping, scientists and local communities have utilized advanced groundwater modeling tools to identify key recharge zones and aquifer vulnerabilities, enabling targeted conservation efforts and data-driven management practices. Community-based governance in Guarani territories integrates Indigenous knowledge with modern resource management principles, ensuring locally relevant and sustainable conservation practices through active community participation. Stakeholders across the four countries have collaborated to establish sustainable use frameworks aimed at regulating water extraction and protecting recharge zones within the Guarani Aquifer System. These frameworks have been shaped through binational consultations, participatory workshops, and technical dialogues that have gathered national

water authorities—such as Argentina's Subsecretaría de Recursos Hídricos, Brazil's National Water Agency, Paraguay's Secretariat of Environment, and Uruguay's National Directorate for the Environment— as well as academic institutions, municipal officials, and local community representatives. Through these multi-level processes, the countries jointly identified aquifer vulnerabilities, defined conservation priorities, and agreed on permissible abstraction thresholds. The resulting governance arrangements laid the foundation for harmonized technical standards, coordinated monitoring systems, and equitable water allocation, key conditions for the long-term, cooperative management of this transboundary resource.

Water quality monitoring in Guarani communities is part of a broader strategy to enhance local governance and environmental stewardship. These initiatives are typically managed through partnerships between local Indigenous associations, municipal governments, and national environmental agencies, with support from international cooperation programs. Field testing kits (e.g., colorimetric strips and portable multiparameter meters) are procured using funds from donor-supported projects or national environmental programs. For example, the Guarani Aquifer System Project has facilitated the distribution of these kits as part of its capacity-building and environmental monitoring activities.

Hydrologists and environmental educators have led technical workshops to train community members. Responsibility for monitoring is shared among community volunteers, school-based environmental clubs, and local water committees, who conduct regular sampling in wells, springs, and streams. Data is reported during community assemblies and, where possible, integrated into municipal or regional water monitoring databases. This decentralized model fosters technical autonomy, reinforces Indigenous participation in resource management, and provides early warning of potential contamination. Sustainability is supported through the institutionalization of responsibilities within community structures, recurring training sessions, and the availability of replacement materials through government and non-governmental organization (NGO) support channels.

Challenges

Despite these efforts, the Guarani Aquifer System remains vulnerable to overexploitation, pollution, and governance gaps. Economic pressures for agricultural and industrial development often conflict with conservation priorities, placing additional strain on water resources. The aquifer's transboundary nature also complicates governance, requiring sustained cooperation among countries with varying economic and political interests. Moreover, the Guarani people face challenges in securing formal recognition of their land and water rights, which are critical to preserving their traditional practices and maintaining the aquifer's health.

Lessons Learned

Guarani forest-based water practices have played a critical role in maintaining aquifer recharge, improving water quality, and supporting ecological stability across one of the world's largest transboundary groundwater systems. Conservation of native vegetation in recharge zones remains essential for sustaining hydrological functions and mitigating degradation caused by deforestation and land-use change. Transboundary coordination has improved through the development of shared data systems, common monitoring protocols, and aligned legal frameworks among Argentina, Brazil, Paraguay, and Uruguay. These mechanisms have enabled

joint responses to groundwater threats and contributed to more coherent and equitable resource management.

Technical training and structured responsibilities embedded in Indigenous institutions, school programs, and water committees support local monitoring systems. National agencies and international cooperation partners provide portable kits to assist in the testing of water quality. Data is reviewed through community assemblies and integrated into municipal databases, reinforcing both autonomy and technical capacity.

Context-Responsive Ancestral Technologies

Ancestral water technologies reflect centuries of experimentation and adaptation to diverse ecological contexts. Designed to function in harmony with natural cycles, these systems are low-cost, resilient, and tailored to specific environmental challenges, such as drought, aridity, or seasonal variability. They not only ensure water availability but also reinforce cultural continuity and local sovereignty over natural resources. The following examples demonstrate how Indigenous technological ingenuity translates ecological understanding into practical solutions for contemporary water security.

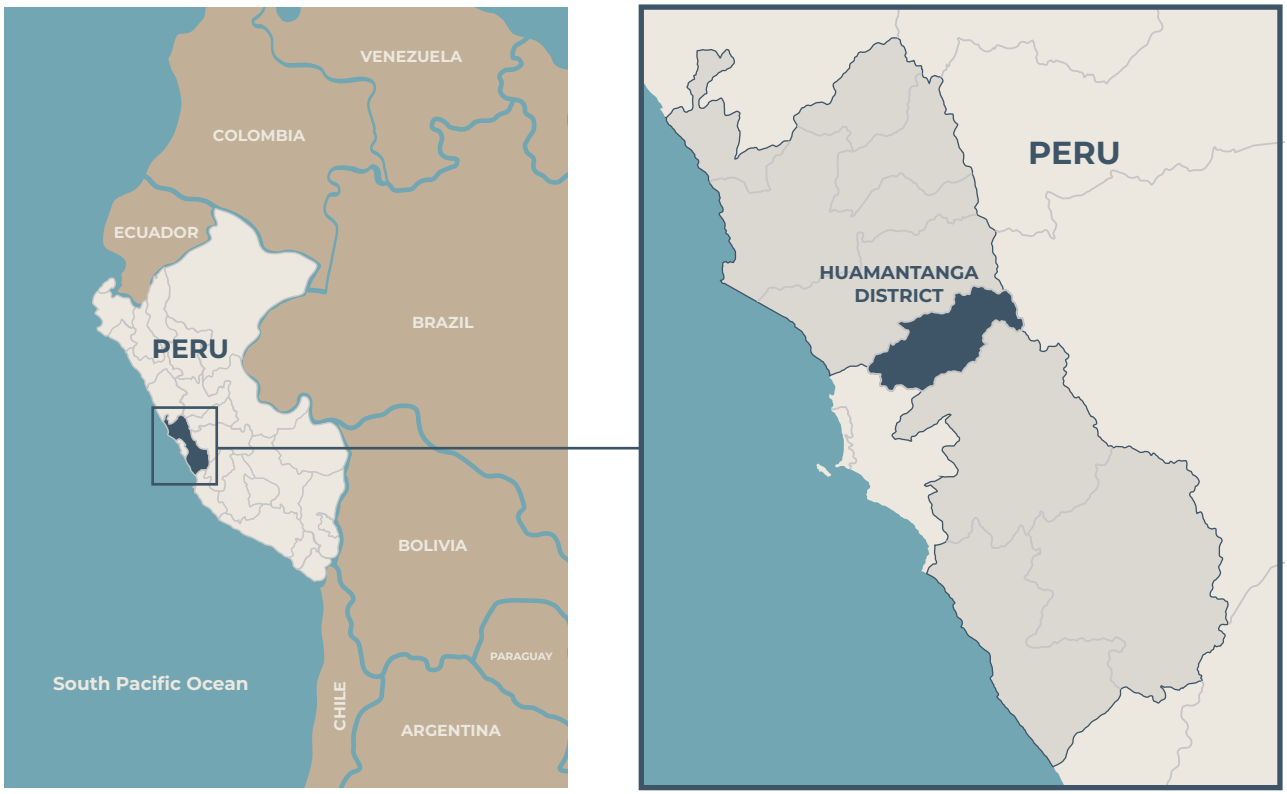
Reviving Pre-Incan Water Management Techniques in the Andes[10]

Community Background

Nestled in the highlands of Peru, the village of Huamantanga, located north of Lima, is home to the comuneros (self-identified Indigenous members of an agricultural collective that has inherited and continues to employ ancient water management practices) (Map 3). Situated within the challenging terrain of the Andean highlands, where water conservation is critical for survival, the community relies on these traditional techniques to navigate the region's seasonal precipitation and frequent droughts. Efficient water management remains essential for sustaining agricultural productivity and meeting everyday needs in this drought-prone environment.

[10] See Foster et al. (2009).

Map 3. **Huamantanga District, Peru**



Source: Author(s)

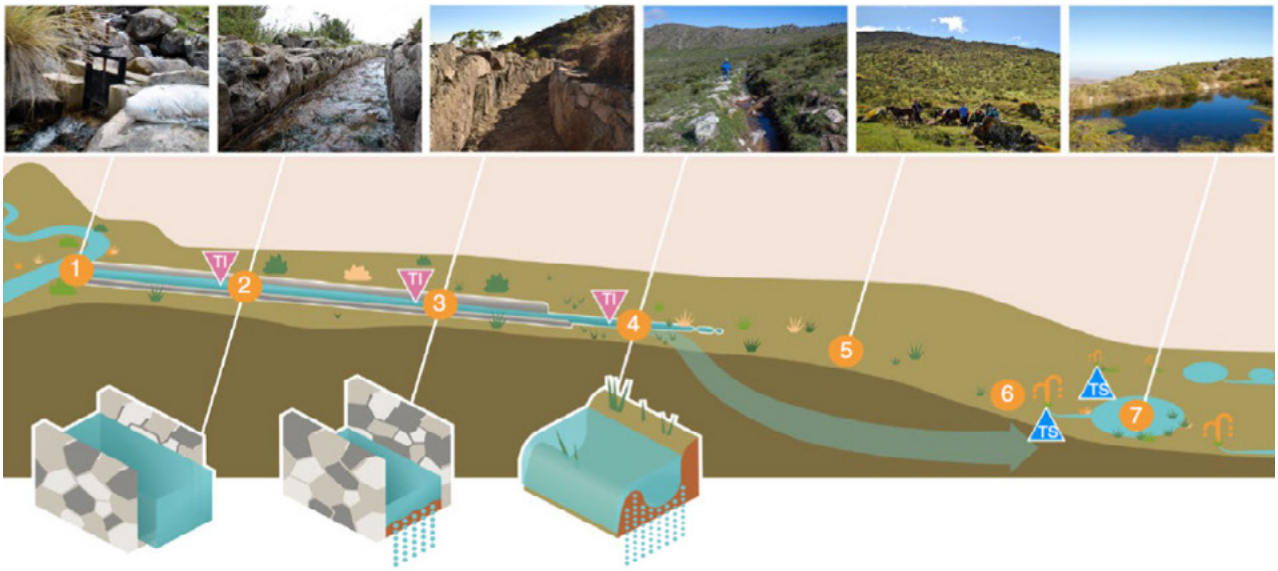
Key Challenges

Water scarcity in the Andes is compounded by the seasonal nature of rainfall and extended dry spells, leaving communities increasingly vulnerable. Climate change has exacerbated the region's challenges, leading to reduced water availability that impacts both agriculture and ecosystems. For the comuneros, whose livelihoods heavily depend on agriculture, prolonged droughts pose a significant threat to food security and economic stability. These shortages also have a cascading impact, as urban centers such as Lima rely on water sourced from Andean rivers. As drought conditions worsen, the need for sustainable, long-term water management solutions has become increasingly urgent.

Solutions: Ancient Water Canal System – The Amunas

To address these challenges, the comuneros have revived the amunas, an ancient water management system first developed by the Huari people during pre-Incan times (Figure 4). These water canals are designed to divert surplus rainfall during the wet season into natural infiltration basins situated in the highlands. The basins allow water to seep gradually through gravel and soil, recharging underground aquifers. This process ensures a steady supply of water during the dry season, as the water emerges from springs further downslope when surface water sources have dried up.

Figure 4. **Pre-Incan Water Filtration System (Amunas)**



Conceptual model of the pre-Inca infiltration enhancement system. Features of the system: diversion canals (1 and 2), infiltration canals (3 and 4), infiltration hillslopes (5), springs (6) and ponds (7). Tracer injection (TI) and sampling (TS) points are marked schematically in the diagram.

Source: Forest Trends Team (2020).

The amunas system is rooted in the principle of sowing water, effectively storing water underground and utilizing natural filtration processes to purify it. This slow percolation extends water availability, providing a lifeline for irrigation and other needs during dry months. In addition to benefiting the comuneros, the amunas also replenish rivers that supply water to Lima, underscoring their significance for both rural and urban populations.

Sustainability

Local comuneros operate and maintain the amunas system in Huamantanga through traditional communal labor, with each household contributing to the upkeep of the canals. Responsibilities are assigned and rotated through community assemblies, ensuring broad participation and reinforcing collective ownership and long-term stewardship of water resources. Maintenance involves not only routine cleaning but also ceremonial blessings, reflecting the community's deep spiritual and cultural connection to water. This intergenerational effort preserves detailed hydrological knowledge, such as which canals feed specific springs, and ensures the continued functionality of the system (Gies, 2021).

Recent hydrological research by Ochoa-Tocachi et al. (2019) provides compelling scientific validation for the amunas system, confirming its effectiveness as a nature-based solution. Using tracer techniques to monitor water flow, scientists have found that restored amunas successfully delay water movement underground for periods ranging from two weeks to eight months. This natural time-release mechanism extends water availability during the dry season, increasing early dry-season river flows by up to 33 percent and providing a critical buffer for both rural

farmers and downstream urban centers, such as Lima. The research confirms the accuracy of local hydrological knowledge, such as which canals feed specific springs, demonstrating the value of Indigenous expertise. These findings have bolstered the case for scaling amunas restoration as a resilient, cost-effective, and ecologically sound strategy for climate adaptation and water security.

Financial sustainability is supported by a collaborative funding model that combines communal labor with investments from actors such as Aquafondo, The Nature Conservancy, German Agency for International Cooperation, and private sector partners like Backus and Nestlé. As of 2021, over 22 kilometers of amunas had been restored, enhancing infiltration capacity across more than 1,500 hectares and potentially supplying over 100,000 people annually (Aquafondo, n.d.). Approximately 70 percent of project costs are allocated to local labor, directly benefiting households and stimulating the rural economy. Restoration costs, ranging from US$100 to US$150 per meter, remain significantly lower than conventional gray infrastructure. To further reinforce economic resilience, Aquafondo has introduced complementary income-generating initiatives, including bio-gardens, composting centers, and solar-powered guinea pig farms.

Environmental and social sustainability are reflected in the broad ecological and communal benefits of the system. By diverting wet-season flows into infiltration basins, the amunas recharge aquifers, reduce soil erosion, and restore native vegetation, including medicinal plants, enhancing biodiversity and landscape stability. Socially, the system thrives on traditional governance and collective action where capacity-building initiatives have equipped residents with technical skills for monitoring and maintenance (Global Water Partnership, n.d.). This model preserves cultural identity, strengthens community cohesion, and facilitates the transfer of knowledge between generations. Crucially, the initiative has influenced national water policy by demonstrating how ancestral practices, supported by modern tools and public investment, can provide sustainable responses to climate change and water insecurity.

Challenges

Despite the success of the amunas system, its reliance on rainfall limits its effectiveness during prolonged droughts. The comuneros' efforts highlight the potential of nature-based solutions in addressing water scarcity, but they also underscore the need for complementary strategies to bolster resilience to changing climatic conditions.

Lessons Learned

The revival of the amunas system in Huamantanga exemplifies how ancestral knowledge can be leveraged to address contemporary water security challenges. Using tracer techniques, hydrological studies have validated local expertise, such as understanding which canals feed specific springs, reinforcing the scientific credibility of nature-based solutions and enhancing their influence on national water policy.

Sustainability has been achieved through strong community governance, with communal labor, shared responsibilities, and cultural practices all reinforcing long-term stewardship. Responsibilities are assigned through community assemblies, and maintenance is not only practical but also ceremonial, reflecting the community's spiritual connection to water and deepening collective ownership.

Financial sustainability is supported by a blended funding model that integrates local labor contributions with external investment. Partnerships with external actors have enabled restoration at scale while channeling resources directly into the local economy. Restoration costs remain significantly lower than those of traditional gray infrastructure, and complementary livelihood initiatives, such as bio-gardens and solar-powered guinea pig farms, further bolster community resilience.

Although the system is highly effective under normal climatic conditions, its reliance on seasonal rainfall highlights the need for integrated adaptation strategies that can withstand increasingly erratic precipitation patterns. Even so, the Huamantanga experience demonstrates that when traditional practices are paired with scientific validation and sustained investment, they can provide scalable, cost-effective, and socially inclusive solutions to climate-induced water scarcity.

More broadly, the revival of the amunas illustrates how ancient practices, deeply rooted in Indigenous knowledge and tradition, can be reimagined as innovative models for climate adaptation. By combining these ancestral systems with modern scientific validation, the comuneros have created a framework with relevance not only for the Andes but for drought-prone regions worldwide.

2.2. Adaptive Rural Water and Sanitation Solutions

Rural communities in the LAC region are characterized by diverse settlement patterns, varied environmental contexts, and distinctive governance arrangements, all of which shape how water and sanitation services are provided. These features set rural service provision apart from urban systems and highlight the need for tailored approaches. In more concentrated rural areas, conventional WASH systems, such as piped networks and small-scale treatment facilities, have been implemented with varying degrees of success. In more dispersed and geographically isolated settlements, however, adapted or decentralized solutions often prove more viable and sustainable (Romano et al., 2021).

Geographic and hydrological diversity play a decisive role. Steep terrain, highly variable rainfall, and long distances between households raise construction and maintenance costs while reducing the economies of scale that centralized systems rely upon. These factors underscore why decentralized options, such as gravity-fed water systems, protected springs, and dry sanitation technologies, are often better suited to rural realities. They also explain why rural WASH strategies cannot simply replicate urban models but must instead adapt to the physical and social characteristics of each community (Romano et al., 2021).

At the same time, rural communities continue to face **persistent disparities in service quality** compared to urban areas. While urban households typically enjoy more reliable and higher-quality services, many rural communities, particularly the poorest, have significantly lower levels of access. For example, in Colombia, 82 percent of the wealthiest rural households have access to potable water, compared to 37 percent of the poorest households. These inequalities should not be viewed only as deficits but also as evidence of unique challenges for rural areas, challenges that justify the need for differentiated models of service delivery (Romano et al., 2021).

Water scarcity in rural LAC areas has also heightened social tensions over ownership and equitable use of water resources. At the same time, water quality and rural sanitation remain among the most pressing challenges. A persistent weakness is the disinfection of drinking water systems: less than 50 percent of rural communities in the region are estimated to engage in water chlorination, primarily due to the lack of infrastructure and materials required for the process. In Colombia, for instance, only 12 percent of the rural population has access to treated water, while in Peru, less than 1 percent of rural households benefit from chlorinated water (Baskovich and Flores Arias Uijtewaal, 2019).

In many rural areas, particularly those not served by formal infrastructure networks, community-based water management has become a principal mechanism for delivering basic water and sanitation services. These systems are typically managed by local water committees, which assume responsibility for daily operations, infrastructure maintenance, and, in some cases, cost recovery. While community-based water management models are formally recognized within national policy frameworks in several LAC countries (e.g., Colombia, Costa Rica, Paraguay, and Peru), practical implementation remains uneven. Data from regional monitoring platforms indicate that over 70 percent of registered rural water communities are categorized under the **lowest service sustainability index, reflecting challenges in infrastructure quality, water safety, and service continuity**. In many instances, municipal and local governments face constraints in delivering consistent technical assistance and oversight, owing to limited financial resources and staffing capacity (Baskovich and Flores Arias Uijtewaal, 2019).

As a result, despite formal policy recognition, many community-managed systems continue to function with minimal external support. This undermines service reliability, especially in regions where disinfection practices are minimal and infrastructure is subject to wear from prolonged use and insufficient maintenance. Strengthening the performance of community-based water management models will require not only their continued inclusion in regulatory frameworks but also enhanced institutional coordination, sustained investment, and tailored technical support at the local level.

Weak governance and sectoral management, characterized by limited institutional coordination, insufficient funding, and gaps in hygiene promotion programs, have hindered efforts to promote hygiene practices and behavioral changes, such as proper excreta disposal and handwashing with soap. Poor sanitation remains a **pressing public health issue**, contributing to the deaths of 580 children daily in the LAC region and facilitating the spread of diseases like intestinal worms, trachoma, and schistosomiasis. Addressing these issues could significantly improve health outcomes. For example, eliminating open defecation could reduce diarrhea-related deaths in children under five by 36 percent (PAHO, 2019).

While there has been progress in reducing **open defecation in rural areas** across LAC, critical gaps remain for vulnerable populations. In rural Haiti, 31.6 percent of the population continues to practice open defecation, and just 25.4 percent have access to at least basic sanitation services. Moreover, only 38.2 percent of rural Haitians have access to basic drinking water, underscoring a significant gap in infrastructure. In rural Bolivia, only 57.7 percent of the population uses at least basic sanitation services, while in Venezuela, the figure stands at 57.2 percent, with open defecation rates exceeding 15 percent in some rural areas. These examples illustrate the persistent rural-urban divide and the urgent need for targeted investments in WASH services for low-income, Indigenous, and geographically isolated rural communities (UNICEF and WHO, 2023).

Tracking access to safely managed sanitation services continues to pose challenges, particularly in rural regions where poorly maintained septic tanks are widespread. The **absence of reliable data** further complicates efforts to close sanitation gaps and improve health outcomes for the most affected communities. Despite these obstacles, addressing the rural sanitation crisis remains critical for achieving equitable and sustainable WASH solutions in the LAC region.

2.2.1. Community-Based Water Supply Organizations and Social Innovation in Rural WASH

Identifying the challenges rural LAC communities face is the first step toward meaningful change; equally important is recognizing the specific contexts, factors, and needs that shape service provision and adaptive capacity. Despite persistent barriers to accessing WASH services, these communities have demonstrated institutional resilience through the development of adaptive, context-specific solutions grounded in their knowledge of local ecosystems and resource conditions. A key expression of this adaptability is the role of community-based water supply organizations (CBWSOs), which serve as the primary providers of safe, potable water in rural and peri-urban areas across the Global South. Over 145,000 CBWSOs deliver water services to more than 70 million people in LAC countries.[11] These organizations operate through partnerships calibrated to their operational goals, relational networks, and territorial scope, ranging from municipal to national and transnational levels. Known as CBWSO partnerships, these alliances reflect the water operators' partnerships model, which facilitates peer-to-peer collaboration, technical exchange, and capacity development among water and sanitation providers in underserved regions. For example, in Colombia, approximately 12,000 CBWSOs serve over 11 million people, demonstrating how community-led initiatives effectively address WASH challenges through cooperation and resource sharing (Blanco-Moreno et al., 2024). The longevity and effectiveness of these organizations rely on the strength of the following key factors, which, although not uniformly present across all contexts, collectively form the foundation of operational resilience (Machado et al, 2019):

- ***Community engagement*** remains central to system sustainability. By fostering local ownership through participatory governance and direct involvement in operational decisions, CBWSOs ensure that service delivery mechanisms are closely aligned with the environmental, cultural, and social dynamics of their territories. This alignment increases compliance, reduces misuse, and enhances accountability mechanisms at the local level.

- ***Capacity building*** constitutes a critical pillar of institutional durability. CBWSOs invest in developing the technical and administrative capabilities of local personnel, thereby reducing dependency on external actors and equipping communities to perform essential functions such as routine maintenance, water quality control, tariff collection, and record-keeping. This localized competence becomes particularly relevant in areas where state support is limited or inconsistent.

- ***Inter-institutional collaboration*** contributes to service sustainability by fostering knowledge exchange and collective problem-solving. Partnerships among CBWSOs or between

[11] http://clocsas.org/

community organizations and other actors support technical strengthening, facilitate mutual learning, and promote solidarity-based management practices that align with local realities.

- *Gender inclusion* is promoted as a principle of effective community-based water governance. Including women in decision-making and operational roles is recognized as a means of strengthening accountability, improving service outcomes, and ensuring that diverse needs are represented in water management processes. Participation across genders is encouraged to enhance transparency, legitimacy, and responsiveness in governance structures.

While CBWSOs offer a foundational model for managing rural water systems, closing persistent WASH gaps requires complementary strategies that respond to the region's diverse geographical, institutional, and socio-economic conditions. In this context, social innovation has emerged as a critical mechanism for developing sustainable, context-specific solutions tailored to underserved rural populations. Unlike conventional innovations, which are typically driven by market incentives, social innovations are often initiated in response to acute social needs or systemic service failures. Their relevance lies in their capacity to mobilize local actors, harness existing community assets, and adapt to place-based constraints and opportunities. These innovations frequently leverage characteristics intrinsic to rural areas—such as land availability, community cohesion, and the presence of civil society organizations and social enterprises—to foster service delivery models that are inclusive, scalable, and institutionally embedded.

Box 4. The Integrated System of Rural Sanitation: A Collaborative Model for Sustainable Rural Water Management

The Integrated System of Rural Sanitation (SISAR), implemented in Ceará, Brazil, is a notable example of a community-based rural water management model. Its success lies in its collaborative approach, combining the efforts of local communities, public authorities, and private contractors to deliver water and sanitation services sustainably across rural areas. By 2017, SISAR operated in 1,419 communities across 146 municipalities, providing water services to over 551,500 inhabitants with an 84 percent operational efficiency rate.

A core element of SISAR's success is its management structure. By requiring each community to establish a formal organization responsible for overseeing the local water system, this model fosters a sense of accountability and ensures sustainability. Additionally, community members are responsible for appointing a local representative to manage day-to-day operations, with technical support from SISAR's staff. Once the system is operational, local technicians trained by SISAR take on maintenance, water quality control, and infrastructure management responsibilities. This approach empowers local populations to maintain their systems, reducing reliance on external entities and ensuring responsiveness to local needs.

Source: Machado et al. (2019).

Addressing persistent WASH challenges in rural LAC requires adaptive strategies that complement the CBWSO model and reflect the region's socio-economic and environmental heterogeneity. Social innovation has emerged as a vital mechanism for advancing inclusive and sustainable service delivery in underserved areas. Unlike market-driven innovation, social innovation is often catalyzed by urgent local needs (e.g., water scarcity, inadequate sanitation, geographic isolation) and is rooted in collective problem-solving, resourcefulness, and the mobilization of community assets. Rural areas, despite facing structural barriers such as limited infrastructure and institutional fragmentation, also offer unique advantages for innovation, including a stronger reliance on local actors, more accessible land for experimentation, and active networks of civil society and social enterprises. These conditions create fertile ground for place-based solutions that are both context-sensitive and institutionally embedded, strengthening the capacity of communities to respond to WASH challenges with locally appropriate and sustainable interventions (Low, 2024).

In regions lacking drinking water infrastructure, rainwater harvesting systems offer an effective and contextually appropriate solution for human consumption, particularly in areas with reliable precipitation and limited access to alternative sources. While not universally applicable, this technology has proven especially suitable in isolated or coastal areas where groundwater is saline and surface water is scarce or of poor quality. Rural communities and marginal urban areas in Honduras, as well as in neighboring Central American countries, have adopted rainwater harvesting systems in areas without access to conventional water supply infrastructure. These systems collect rainwater during downpours from zinc, asbestos, or tile roofs, channeling it through aluminum, PVC, wood, or plastic drains into covered storage units or cisterns for domestic use (OAS, n.d.).

Rural communities in specific regions of LAC, such as fog-prone coastal areas, have demonstrated remarkable adaptability through social innovations to address water scarcity. One such innovation is the use of fog catchers, which capture water from fog and clouds using mesh structures. This solution has proven effective in areas with limited access to traditional water sources, particularly in high-altitude zones where fog is prevalent. In Peru, for example, fog catchers have been implemented for various purposes, including agriculture, forestry, and ecosystem regeneration. These systems capture microscopic water droplets from the fog and direct the collected water into storage tanks for further use. Fog catchers vary in design, ranging from simple two-dimensional mesh screens to more complex cylindrical and macrodiamond collectors, each with advantages. The two-dimensional collectors are low-cost, easy to install, and self-sustaining, making them ideal for rural communities with limited resources. However, larger macrodiamond collectors have higher collection efficiency and are more resistant to adverse weather conditions, though they come at a higher cost. In addition to their agricultural uses, fog catchers have been deployed on the Peruvian coast to supplement water for human consumption, particularly in areas dependent on water carriers, known as aguateros. However, challenges such as water acidity and contamination from atmospheric pollutants mean that the collected water requires further purification before consumption. Despite these challenges, fog catchers remain an innovative and adaptive solution in select rural contexts across LAC, offering a sustainable and environmentally friendly method of water collection where climatic conditions are favorable (GEMRA, 2022).

Sustainable and decentralized sanitation solutions have become crucial components of rural WASH strategies, addressing service provision gaps while promoting environmental health

and community well-being. On-site technologies, such as ecological latrines or dry toilets, are particularly well-suited to rural contexts, where access to centralized sewerage is often limited or nonexistent. In the Peruvian Amazon, for example, flood-resilient ECOSAN latrines have been deployed to mitigate the impacts of seasonal flooding and safeguard water quality. These systems elevate sanitation infrastructure above flood levels and contain waste in sealed, composting chambers, allowing for safe reuse after an 8- to 12-month cycle. Integrated features, such as rainwater harvesting for handwashing and flushing, and banana circles for greywater filtration, further enhance the system's functionality and sustainability. By aligning with local climatic conditions and resource availability, such approaches provide context-specific, low-cost, and climate-adaptive sanitation solutions that improve public health outcomes and support circular resource use in remote and underserved communities (UNICEF, 2020).

2.2.2. Case Studies of Adaptive Rural Water and Sanitation Solutions

The following case studies illustrate adaptive solutions developed across rural LAC. To facilitate comparison and highlight distinctive rural characteristics, the solutions are grouped into three thematic categories: (i) management models that strengthen governance and community-based systems, (ii) social approaches that enhance participation, equity, and capacity, and (iii) context-responsive technologies tailored to rural environmental and livelihood contexts. Each case study demonstrates how these elements interact with rural realities to produce context-specific, scalable lessons.

Management Models

Rural communities in LAC often face institutional fragmentation, limited state presence, and weak regulatory oversight, making community-based governance central to service sustainability. Management models that empower local organizations, particularly CBWSOs, provide a framework for accountability, local ownership, and adaptive governance. These cases illustrate how rural communities strengthen management structures to overcome systemic gaps and ensure reliable WASH service delivery.

Strengthening CBWSOs in Ecuador Through the Center of Support for the Rural Management of Drinking Water[12]

Community Background

Ecuador has a long-standing tradition of community-managed water systems, particularly in rural and geographically isolated areas. These systems are often administered by water and sanitation management boards (Juntas Administradoras de Agua Potable y Alcantarillado, or JAAPs), which play a vital role in ensuring water access for populations not covered by centralized water utilities. In the province of Cañar, one of the country's most densely populated rural regions (Map 4), more than 90 JAAPs are responsible for delivering water to thousands of families. Despite their importance, JAAPs face persistent challenges related to technical capacity,

[12] See Machado et al. (2019).

financial sustainability, and organizational management. Many lack the expertise or resources to perform preventive maintenance, monitor water quality, or manage financial and administrative tasks effectively. Broader structural limitations, including limited state support and a lack of formal mechanisms for coordination or capacity-building, compound these difficulties.

Map 4. **Cañar Province, Ecuador**

Source: Author(s)

Key Challenges

The decentralized nature of water governance in Ecuador places a considerable burden on individual JAAPs, which must operate and maintain their systems with limited external assistance. Performance and service quality varies significantly across communities. Technical failures, water contamination, and financial mismanagement are common, often resulting in service interruptions and deteriorating infrastructure. Additionally, women, despite their central role in household management, remain underrepresented in the leadership of many JAAPs. These issues collectively undermine the long-term sustainability of rural water systems and hinder the achievement of equitable water governance.

Solutions: The Role of the Center of Support for the Rural Management of Drinking Water

To address these challenges, the Center of Support for the Rural Management of Drinking Water (Centro de Apoyo a la Gestión Rural del Agua Potable/CENAGRAP) was established in 2002 as a second-level association to support and coordinate JAAPs in the province of Cañar. Legally

constituted, CENAGRAP operates under a clearly defined governance structure led by an elected board of directors. This democratic structure ensures that decisions reflect the priorities and needs of member organizations.

CENAGRAP functions as a technical, administrative, and organizational support center. It organizes monthly general assemblies where JAAP representatives share operational challenges, discuss solutions, and coordinate joint initiatives. These assemblies foster peer-to-peer learning and facilitate the alignment of practices across communities. Beyond these forums, CENAGRAP provides on-demand support for urgent issues such as technical failures, infrastructure repairs, and administrative bottlenecks. Its technical team assists with water quality monitoring, disinfection protocols, accounting, and compliance with regulatory requirements.

Sustainability

CENAGRAP's operational model is built on a foundation of financial and institutional sustainability. Affiliated JAAPs pay modest monthly dues that fund the association's core functions, including routine support services. For more specialized assistance, such as major repairs, procurement of chlorine, or tailored administrative help, JAAPs may incur additional fees. This dual financing approach enables CENAGRAP to maintain a steady revenue stream while scaling its response to community needs.

Capacity-building is a cornerstone of CENAGRAP's sustainability strategy. The organization offers regular training workshops covering preventive maintenance, water disinfection, tariff setting, financial management, and governance. These sessions are included as part of membership and are open to all affiliated JAAPs. In addition to these group workshops, CENAGRAP provides individualized support and monitors progress through field visits. This blended approach addresses both general knowledge gaps and specific challenges. By embedding technical know-how within the community, CENAGRAP strengthens local autonomy and reduces dependency on external actors.

Over time, the association has enhanced the operational and financial performance of its members. Preventive maintenance routines have become more standardized, service interruptions have declined, and financial transparency has improved. Moreover, by uniting JAAPs under a single organizational umbrella, CENAGRAP has amplified its collective voice in provincial and national water governance discussions. Efforts to promote gender inclusion within member organizations are ongoing and have started to yield greater diversity in leadership roles.

Lessons Learned

The experience of CENAGRAP demonstrates how second-tier associations can address systemic limitations in rural water governance. By providing a platform for coordination and peer exchange, CENAGRAP helps harmonize practices across JAAPs and fosters a culture of mutual accountability. Its democratic structure, grounded in local representation, ensures that decision-making remains responsive to the priorities of its members.

Financial sustainability is supported through a pragmatic fee structure that balances regular contributions with pay-as-needed services. This model allows the association to provide consistent support without overburdening member organizations. Regular training and on-site

technical assistance equip JAAPs with the skills needed to manage their systems independently, improving service reliability and reducing the risk of infrastructure degradation.

The success of CENAGRAP illustrates the importance of institutionalizing support mechanisms that are embedded in local realities. By leveraging collective capacity and aligning support services with day-to-day challenges, the association has strengthened the resilience and sustainability of community-based water supply systems across Cañar. It offers a replicable model for other regions seeking to bridge capacity gaps and improve governance.

Social Approaches

The social fabric of rural communities, characterized by cohesion, cultural traditions, and intergenerational knowledge, provides a foundation for inclusive WASH solutions. Social approaches emphasize participation, equity, and gender inclusion, ensuring that service models reflect local needs and strengthen community legitimacy. The following examples highlight how behavioral, cultural, and social dynamics are leveraged to achieve more sustainable sanitation and hygiene outcomes.

Ecological Sanitation in Brazil's Traditional and Rural Communities[13]

Community Background

The traditional Caiçara community of Praia do Sono, located in Brazil's Angra dos Reis, Paraty and Ubatuba regions, exemplifies the intersection of cultural heritage and environmental resilience (Figure 9). Descended from Indigenous populations, African slaves, and European settlers, the Caiçara people inhabit a coastal region rich in biodiversity but limited in infrastructure. Fishing and small-scale agriculture serve as primary livelihoods. Yet, challenges related to sanitation and wastewater management persist, exacerbated by geographic isolation and vulnerability to environmental changes.

[13] See Machado et al. (2021).

Map 5. **Angra dos Reis, Paraty and Ubatuba regions, Brazil**

Source: Author(s)

Key Challenges

Praia do Sono has faced a pressing sanitation crisis due to inadequate infrastructure for managing human waste and wastewater. This situation has created serious health risks, including exposure to waterborne diseases and environmental degradation, as untreated effluents entered nearby water bodies. The community's geographic isolation, along with limited public service provision and technical capacity, makes implementing durable sanitation solutions challenging. These constraints are further compounded by seasonal climatic variability, reinforcing the need for context-specific systems capable of adapting to local environmental conditions.

Solution: Ecological Sanitation System Using Social Technologies

To tackle these challenges, the community is collaborating with local organizations, researchers, and government agencies to implement an ecological sanitation system rooted in social technology principles. This approach integrates nature-based solutions with community-driven practices to promote sustainability and health.

The sanitation system separates black water (from toilets) from gray water (household wastewater not contaminated by feces). Black water is processed using Tanks of Evapotranspiration, a sustainable solution employing sealed chambers layered with rubble, gravel, sand, and a root zone planted with vegetation. This system treats sewage and supports local agriculture by

producing nutrient-rich soil and fruit-bearing plants such as bananas. Gray water undergoes decentralized treatment and is reused to reduce water consumption (e.g., as irrigation for home gardens) and support food production. While many system components, such as gravel and rubble, are sourced locally, technical elements such as geomembranes require procurement from outside the region.

Sustainability

A defining feature of the ecological sanitation initiative in Praia do Sono is its emphasis on community ownership and sustainability. Local organizations, including the Observatory of Sustainable and Healthy Territories of Bocaina, have played a central role in the system's design and implementation by offering technical guidance and capacity-building workshops. These sessions introduce residents to the operational principles of the sanitation systems and provide support in maintenance and monitoring. This approach strengthens local knowledge and encourages long-term community engagement and shared responsibility.

The community's involvement extends beyond physical construction to decision-making and knowledge-sharing processes. Guided by the principles of participatory research and ecological awareness, the project engaged residents in workshops and discussions facilitated by local organizations and research institutions. The design of the Tanks of Evapotranspiration systems incorporated input from community members, reflecting their practical knowledge and preferences for system placement and usage.

The ecological sanitation systems are managed through a community-based model, in which residents are trained in plant upkeep and system cleaning. Collective contributions fund minor repairs and maintain basic system functionality. While this model encourages local ownership and reduces reliance on external service providers, the system's sustainability remains fragile. Key inputs, including geomembranes and other specialized components, are not available locally and must be procured externally. Their replacement requires technical expertise and funding beyond the community's immediate capacity. Although partnerships with external organizations have helped cover some of these costs, the lack of a permanent institutional support mechanism or integration into formal municipal services places the system at risk of degradation. Praia exacerbates these vulnerabilities due to Sono's remote location, which complicates the delivery of parts and technical assistance. Consequently, the long-term viability of the sanitation solution depends not only on continued community engagement but also on establishing consistent pathways for obtaining the necessary materials and support.

Lessons Learned

The ecological sanitation initiative offers valuable insights into the design and delivery of nature-based sanitation solutions in remote, traditional, and rural communities. By combining environmentally conscious technologies with participatory approaches, the community can help tailor the system to both ecological conditions and local needs. The residents' participation in training and decision making strengthens ownership and ensures alignment with the practical knowledge and available resources in the community.

The experience highlights the benefits of using locally available materials—such as gravel, rubble, and organic waste—to reduce costs and support contextual adaptation. At the same time, it

highlights the limitations of community-based models when essential components, such as geomembranes, must be sourced externally. Although external partnerships and grant support have filled some gaps, the lack of ongoing institutional involvement or integration into public service frameworks remains a barrier to long-term sustainability. Praia do Sono's geographic isolation compounds these risks by complicating access to parts and technical assistance.

While the sanitation model has proven effective in the short term, it raises concerns about long-term technical resilience. Sustaining system performance over time requires not only continued local engagement but also consistent access to technical inputs, formalized support channels, and broader institutional alignment.

Context-Responsive Technologies

Geographic dispersion, climatic variability, and limited financial resources shape the feasibility of WASH technologies in rural LAC. Appropriate technologies prioritize affordability, low maintenance, and adaptation to local environmental conditions, ensuring that solutions are both viable and resilient. The following cases showcase technological innovations tailored to rural contexts, from rainwater harvesting to renewable-energy pumping and ecological sanitation systems.

Sustainable Water Pumping in Electrically Isolated Rural Areas of Ecuador[14]

Background

In Ecuador's rural regions, where agriculture and livestock form the backbone of local livelihoods, access to water is indispensable. Over two-thirds of the economically active population in Ecuador relies on farming and livestock for sustenance and income. Yet approximately 3 percent of these communities are disconnected from the national electrical grid, leaving them without access to critical water pumping and distribution infrastructure. Traditionally, these communities have depended on internal combustion engine-driven pumps powered by subsidized fossil fuels. However, the government's gradual reduction of fuel subsidies has made these pumps increasingly costly to operate, while their environmental impact, through noise, pollution, and greenhouse gas emissions, poses significant challenges to local ecosystems. These factors have intensified the need for innovative and sustainable water pumping solutions, particularly in areas where grid connectivity remains unfeasible.

Key Challenges

The lack of reliable access to electricity in rural Ecuador has long been a barrier to agricultural productivity and clean drinking water availability. Communities face compounding challenges: high costs associated with traditional water pumping methods, environmental degradation caused by internal combustion engines, and logistical impracticality of extending the national electrical grid to low-density, geographically remote areas. Water scarcity has persisted without viable alternatives, jeopardizing household water security, agricultural yields, and livestock management.

[14] See Andrade-Cedeno et al. (2023).

As climate change exacerbates these issues, rural communities increasingly struggle to maintain their livelihoods. The reliance on fossil-fuel-driven systems not only burdens local economies but also contributes to global emissions, creating a cycle of environmental harm that further undermines the sustainability of these regions.

Solution: Photovoltaic Water Pumping System

In response to the water access challenges facing electrically isolated rural areas in Ecuador's Sierra region, photovoltaic water pumping systems (PVPS) have been introduced as a localized and sustainable solution. These systems have been implemented in select highland communities as part of pilot initiatives targeting areas with abundant solar energy and limited access to the national electricity grid. The Sierra region, characterized by high solar irradiation levels, offers optimal conditions for solar-based interventions, making PVPS a contextually appropriate alternative to fossil–fuel–driven pumps.

PVPS technology eliminates the need for diesel or gasoline, significantly reducing both operational expenditures and environmental externalities such as air pollution, noise, and greenhouse gas emissions. This shift away from fossil fuels not only lowers long-term costs for rural households but also contributes to Ecuador's broader climate and sustainability goals. Moreover, solar-based systems minimize the logistical burden of fuel transportation in remote areas, which can be both costly and unreliable. Each PVPS installation comprises two key components:

- ***Photovoltaic array***, which captures solar radiation and converts it into direct current electricity, serving as the primary energy source for the system. The use of locally abundant solar resources enhances the reliability and efficiency of water delivery in high-altitude settings.

- ***Pumping system***, which includes a centrifugal pump driven by a three-phase induction motor, regulated by a variable-speed drive equipped with maximum power point tracking. This configuration ensures optimal pump performance by continuously adjusting to variations in solar irradiance, thereby maximizing water output throughout the day.

Designed to serve both agricultural irrigation and domestic water supply, PVPS represents a practical and adaptive response to the energy access gap in off-grid Sierra communities. Although these systems are currently limited to localized pilot deployments, early evidence suggests they hold significant potential for improving water availability through a low-emission, cost-effective, and environmentally aligned solution tailored to regional conditions.

Sustainability

A hallmark of the PVPS initiative is its emphasis on community participation and training. Beneficiaries are involved in the installation process and receive training to perform basic operation—including troubleshooting and minor repairs and routine maintenance of the systems. Local technicians are also engaged to facilitate hands-on learning and familiarization with system operation. While critical components such as photovoltaic modules, centrifugal pumps, and electronic controllers are procured from specialized suppliers, local implementation strategies deliberately emphasize the use of community labor and locally available construction materials for tasks such as mounting structures, tank installation, and trench excavation. This

hybrid approach helps reduce overall project costs and fosters a sense of ownership among users. However, the long-term sustainability of these systems remains constrained by the fragility of imported components and difficulty of sourcing spare parts in remote rural settings. Limited access to technical support and supply chains for essential components presents ongoing risks to system continuity, particularly when breakdowns require specialized repairs beyond the capacity of local personnel. In such cases, external technicians and regional organizations provide critical support.

The financial model supporting PVPS operations is built on collective responsibility. While the available literature does not indicate the existence of a formal tax or service fee, the shared management of maintenance costs reflects the traditional communal ethos of rural Ecuador. CBWSOs often facilitate these arrangements, drawing on long-standing communal practices to manage shared infrastructure and coordinate maintenance responsibilities in a decentralized manner.

By leveraging local expertise and resources during deployment, the system can be tailored to the unique environmental and social conditions of rural Ecuador. However, solar panels, pumps, and electronic components are sourced from external suppliers, which poses logistical challenges. This highlights the need for strategic planning in delivering sustainable technologies to remote areas.

Lessons Learned

The deployment of PVPS in off-grid Sierra communities illustrates both the potential and complexity of delivering sustainable water infrastructure in rural contexts. These systems are well-matched to the region's solar conditions and offer a practical alternative to fuel-powered pumps by reducing long-term costs, eliminating fuel dependency, and avoiding the environmental damage associated with combustion engines. Their dual utility for irrigation and domestic supply makes them especially relevant for communities facing persistent water access challenges.

Community participation with the use of local materials and labor play a central role in implementation and cost containment. Although this hybrid approach enables deployment in remote areas, long-term sustainability remains limited by weak supply chains and insufficient access to replacement parts and technical services.

The transfer of routine maintenance and basic troubleshooting to local actors is effective, but complex repairs require external support. Without formal service fees, communities often rely on traditional models of shared responsibility to cover these expenses. CBWSOs help coordinate these efforts, drawing on local norms for managing collective infrastructure.

While the early results of PVPS implementation are promising, technical design must be accompanied by clear operational strategies, locally grounded support systems, and realistic planning around long-term system upkeep, especially in regions with fragile logistics and limited institutional presence.

Sustainable Wastewater Treatment in Rural Colombia Using Constructed Wetlands with Native Plants and Agricultural Byproducts[15]

Background

Significant challenges surround the management of domestic wastewater in the rural municipality of San Marcos, located in Sucre, Colombia (Map 6). This region, part of the Caribbean lowlands, is characterized by tropical climates and flood-prone terrains. Agriculture, particularly palm oil production, underpins local livelihoods. However, San Marcos lacks centralized wastewater treatment systems, leading to the contamination of water bodies that are essential for agriculture and daily life.

Map 6. **San Marcos, Sucre, Colombia**

Source: Author(s)

Key Challenges

The community faces a critical lack of infrastructure to treat domestic wastewater, which contains high levels of organic matter, nitrogen compounds, and harmful pathogens. The tropical climate exacerbates water pollution, allowing contaminants to spread rapidly, negatively impacting agricultural productivity, local water sources, and community health. Limited

[15] See Peralta Vega et al. (2024).

economic resources and technical expertise further complicate efforts to implement sustainable wastewater solutions.

Solutions: Constructed Wetlands Using Canna Hybrids and Palm Oil Byproducts

To address these issues, the community adopted Horizontal Subsurface Flow Constructed Wetlands, a nature-based solution designed to treat domestic wastewater effectively. This system integrates locally available materials, including Canna hybrids (ornamental plants) and oil palm fruit endocarp (carbon-rich byproduct of the community's palm oil industry), leveraging their natural filtration and bioremediation properties. Wastewater is channeled through gravel and oil palm fruit endocarp layers, which serve as filters and promote microbial activity to break down contaminants. The oil palm fruit endocarp enhances nitrogen removal by supporting microbial denitrification processes. Meanwhile, the root systems of Canna hybrids oxygenate the substrate, further improving water quality. These wetlands achieve impressive contaminant removal rates, eliminating up to 91 percent of biochemical oxygen demand, 94 percent of total suspended solids, and 75 percent of total nitrogen. The treated effluent meets Colombian environmental standards and is safe for agricultural irrigation, addressing wastewater management and water scarcity during dry seasons.

Community members' involvement during the design phase is integral to tailoring the system to local conditions. Residents work closely with technical experts, including the University of Sucre, which provide critical guidance on wetland dimensions, substrate composition, and plant selection. Field conditions, such as flood risks and soil types, are considered to ensure the wetland's effectiveness and sustainability.

Sustainability

The system's success hinges on the active participation of the San Marcos community. Residents contribute labor and materials, reinforcing their connection to the project, while academic institutions offer technical oversight and training, equipping residents with the skills to monitor water quality, clean filters, and ensure plant health. The University of Sucre has played a pivotal role in ongoing technical supervision and evaluation to optimize the system's performance. This partnership bridges gaps in expertise, empowering the community to manage the wetlands autonomously.

This approach promotes local ownership and reduces operational costs; however, sustainability is challenged by its dependence on external resources for major repairs and upgrades, including the replacement of geomembranes or the restoration of hydraulic components. In the absence of formal municipal involvement or integration into public service frameworks, long-term financing and technical support remain uncertain. This institutional gap increases the risk of service interruptions and limits the system's durability over time. Although the use of local inputs helps lower initial costs and adapt the design to local conditions, the reliance on externally sourced components complicates future maintenance. Ensuring sustainability will require expanded access to spare parts, formalization of maintenance responsibilities, and availability of mechanisms to embed these systems within broader governance or technical support structures, rather than depending on ad hoc arrangements.

Lessons Learned

The use of constructed wetlands in San Marcos demonstrates how nature-based approaches can respond to wastewater treatment challenges in rural areas with limited infrastructure. By integrating palm oil endocarp and native plant species into a horizontal subsurface flow system, the intervention adapted to local conditions and achieved high contaminant removal rates. The ability to treat domestic wastewater to standards suitable for agricultural reuse addresses both environmental and water availability concerns in a flood-prone, agriculturally dependent context.

Community involvement in implementation and routine maintenance shapes the process, reducing project costs and supporting the effective functioning of the system. Training helps to transfer basic operational knowledge, though the need for external technical support persists in cases of system failure or major repairs. The sustainability of the system remains closely tied to its institutional context. Ongoing functionality depends on access to specialized components and technical services, which are not readily available in the rural setting. The wetlands operate outside formal public service frameworks, and funding for significant maintenance relies on external partnerships. This arrangement has allowed for initial success but introduces long-term uncertainty. The use of local materials reduces initial costs, yet the reliance on externally sourced elements, such as impermeable liners and equipment, continues to pose challenges for maintenance and durability.

Rainwater Harvesting for Domestic Use in Rural Honduras[16]

Community Background

In rural areas of Honduras, particularly in the southern departments of Valle and Choluteca, many communities face persistent water insecurity (Map 7). These regions often lack centralized water infrastructure and have limited access to surface or groundwater, leaving households to rely on alternative means of securing water for domestic needs. One of the most widespread responses has been the adoption of rainwater harvesting systems, which enable families to collect and store rainfall from rooftops. These systems are typically installed by individual households using local materials and labor. Their use has expanded significantly over the past decade, especially in remote and dispersed settlements where water demand is high and conventional infrastructure is either inadequate or nonexistent.

[16] See OAS (n.d.).

Map 7. **Valle and Choluteca Regions, Honduras**

Source: Author(s)

Key Challenges

Communities in rural Honduras must navigate overlapping constraints related to water availability, quality, and access. Centralized supply systems are often absent or insufficient, prompting households to rely on rivers, shallow wells, or other sources that may be polluted or unreliable. In some cases, groundwater has been compromised by seawater intrusion, and surface water is scarce. Although rainwater harvesting can alleviate these challenges, its effectiveness depends on receiving sufficient rainfall, having an adequate roof area for collection, and having sufficient storage capacity to meet household demand during dry periods. The technology is typically deployed on an individual basis, with limited engagement from central government institutions or the private sector in promoting or scaling its use. This decentralized model can leave families vulnerable during droughts, especially those who cannot afford the initial costs of more permanent infrastructure.

Solutions

Rainwater harvesting systems used for domestic purposes in Honduras are designed to capture and store rainwater for drinking, cooking, and hygiene. These systems include a collection surface, a conveyance system, and a storage unit. Roofs made of zinc, asbestos, or tile serve as the primary collection surfaces. At the onset of the rainy season, roofs are cleaned to remove accumulated debris, and the initial rainfall is discarded to prevent contaminants from entering the storage system.

Water is conveyed from the roof to the storage unit using gutters and downspouts made from accessible materials such as PVC, aluminum, wood, or plastic. The most common form of storage is a 200-liter metal drum placed at the foot of the downspout, which can provide a family with approximately four to five days' worth of water based on a daily per-person usage of 7 liters. In households with greater needs or the means to invest in more robust infrastructure, larger cisterns with capacities of up to 9 cubic meters are built. These are particularly useful during extended dry periods. For instance, with annual rainfall of 700 mm and a roof area of 100 m^2, a family can collect an estimated 28 to 30 m^3 of water during a five-month period at 40 percent efficiency, enough to meet the dry season needs of a household of 10. The estimated cost of such storage is about US$2 per cubic meter of water.

Sustainability

The sustainability of rainwater harvesting in Honduras is linked to its ease of operation, minimal maintenance requirements, and adaptability to local conditions. For domestic systems, routine maintenance consists of cleaning the roof before the rainy season and cleaning the storage tank at the end of the season. These tasks require limited time and can be performed without specialized tools or training.

The use of locally available materials and the absence of energy requirements make the systems particularly viable in rural and off-grid areas. Furthermore, their modular nature allows households to expand their capacity incrementally as needs and resources permit. Despite these advantages, long-term sustainability can be hindered by several factors including the high initial costs of constructing large storage units, dependence on seasonal rainfall, and need for supplementary water sources during prolonged dry spells. While the collected water is generally considered safe if the system is maintained properly, it lacks essential minerals, and some users may find it unpalatable. The source material does not mention any issues related to water acidity or airborne contaminants.

Lessons Learned

Rainwater harvesting provides a practical and context-appropriate solution for water supply in rural Honduras. Its decentralized nature empowers households to address water scarcity using local resources. Properly maintained systems can reduce contaminants by 80 to 90 percent, ensuring safer, more accessible water. However, the technology's effectiveness is influenced by environmental, financial, and infrastructural conditions. While low-cost barrels are widely used, their limited storage capacity poses challenges during the dry season. Larger cisterns are more effective but require upfront investment. Future efforts should focus on expanding access to rainwater harvesting by providing training, conducting demonstration projects, and establishing financial support mechanisms. The integration of low-cost purification technologies could further enhance water quality, and targeted dissemination programs would help embed the technology in broader rural development strategies.

2.3. Comparison of Community Strategies

Table 1 compares the case studies discussed herein, highlighting the community setting, country, principal WASH challenge, and solution. This overview underscores the variety of locally grounded, adaptive responses.

Table 1. **Community Strategies**

Community	Country	Key WASH challenge	Solutions
Zapotec Indigenous communities (16 villages, Oaxaca Valley)	Mexico	Prolonged droughts, aquifer depletion, and crop failures	Decentralized water conservation infrastructure (absorption wells, small dams, water pans) managed collectively through the Coordination of Peoples United for the Defense and Care of Water.
Guarani People (territories across the Guarani Aquifer)	Paraguay, Brazil, Argentina, Bolivia (the Aquifer also spans Uruguay)	Over-extraction, deforestation, pollution, and governance gaps	Forest protection and reforestation in recharge zones; transboundary aquifer cooperation
Comuneros of Huamantanga (Andean Highlands)	Peru	Seasonal water scarcity, climate-induced droughts	Revival of amunas canals for aquifer recharge through communal labor
JAAPs coordinated by CENAGRAP	Ecuador (Cañar Province)	Weak technical/ financial capacity, governance gaps	Second-level association providing technical, administrative, and training support to JAAPs
Caiçara Community of Praia do Sono	Brazil	Inadequate sanitation, wastewater contamination	Ecological sanitation (Tanks of Evapotranspiration, gray water reuse) with community participation
Electrically isolated rural communities (Sierra region)	Ecuador	Lack of electricity, costly and polluting diesel pumps	Photovoltaic water pumping system for irrigation and domestic use
Rural Municipality of San Marcos (Sucre)	Colombia	No wastewater treatment, water contamination	Constructed wetlands using native plants and agricultural byproducts
Rural households (Valle and Choluteca)	Honduras	No centralized supply, seawater intrusion, and seasonal scarcity	Household rainwater harvesting systems (roof catchment, cisterns, barrels)

3.

COMMUNITY RESILIENCE AND CULTURAL WISDOM IN PRACTICE: IN-DEPTH CASE STUDIES OF SUSTAINABLE WASH SOLUTIONS

The case studies presented herein highlight the ingenuity, resilience, and cultural depth with which Indigenous communities across the LAC region address water and sanitation challenges. Drawing on fieldwork and interviews conducted in Santa Ana, La Guajira (Colombia) and Canaán Membrillo, Darién (Panama), the analysis examines how traditional knowledge systems, communal governance models, and low-cost technological adaptations coalesce to create sustainable WASH practices. These communities are not merely recipients of development interventions but are active stewards of locally grounded solutions shaped by centuries of coexistence with their environment. These case studies document the effectiveness and replicability of Indigenous WASH practices, identify key enabling factors for success, and offer actionable insights for strengthening the resilience and equity of water governance across diverse ecological and socio-cultural settings. Together, they highlight the critical value of Indigenous leadership, gender inclusion, intergenerational knowledge transmission, and culturally responsive infrastructure in achieving sustainable WASH outcomes.

3.1. Resilience Amid Scarcity: Indigenous Water Practices in Santa Ana, La Guajira

Contextual Overview

Geographic and Environmental Context

The Indigenous community of Santa Ana is located in the Upper Guajira region of northern Colombia, within the department of La Guajira and near the border with Venezuela. The region is one of the most environmentally fragile and socioeconomically underserved in the country, marked by a semi-arid climate with prolonged droughts, intense solar radiation, scarce vegetation, and minimal rainfall. When it occurs, rainfall tends to be brief and intense, offering limited benefit for long-term water recharge or agricultural use. The arid terrain and degraded soils limit agricultural productivity, exacerbating water insecurity and directly affecting livelihoods and public health.

Santa Ana is geographically isolated. The community lies approximately 188 kilometers from Uribia and 242 kilometers from Maicao, the two nearest urban centers with more developed infrastructure and public services. The lack of reliable roads and transportation options significantly constrains mobility and hinders regular access to external support, healthcare, and state-delivered services. These conditions reinforce the community's reliance on internal social organizations, ancestral knowledge, and intermittent support from NGOs.

Water availability in Santa Ana has historically depended on surface reservoirs known as jagüeyes, hand-dug wells, and windmill-driven pumps. These traditional sources are highly susceptible to seasonal variation and often contain brackish or biologically contaminated water, especially during extended dry periods. Families have routinely walked several kilometers to access water from neighboring communities, a physically demanding task that falls disproportionately on women and girls and presents risks to personal safety. Reported health issues from consuming untreated water include diarrhea, skin rashes, and other waterborne illnesses, particularly among children and elderly residents.

To address these challenges, a solar-powered reverse osmosis desalination system was introduced in the community, offering treated water from subterranean sources. This has improved water quality and provided a more reliable source of water for domestic use. However, the system's functionality is dependent on consistent solar radiation and regular technical maintenance. Community members have developed water storage practices to manage fluctuations in supply. However, disparities in storage capacity persist, leaving some households more vulnerable during outages or repairs.

Sanitation infrastructure has also evolved. Until recently, open defecation was the dominant practice across the community, a reflection of both infrastructural gaps and cultural norms. Ecological dry latrines have since been introduced in select homes and at the local school, reducing environmental contamination and improving hygiene, particularly for children. However, the transition is incomplete. Cultural resistance, spatial constraints, and limited access to construction materials have hindered full adoption. In some areas, open defecation continues to be practiced, particularly at night, posing ongoing public health and safety risks.

Cultural frameworks are central to the community's water management and sanitation practices. Water is considered a sacred element within Wayuu cosmology, associated with both physical survival and spiritual meaning. Santa Ana's governance is matrilineal, with decision-making led by a traditional Cacique and strong roles for women in household water management and hygiene education. Women and youth are key actors in the operation and maintenance of water systems, the promotion of sanitation practices, and the transmission of traditional ecological knowledge.

Faced with overlapping environmental, infrastructural, and institutional challenges, the community of Santa Ana has developed a hybrid model of resilience that blends ancestral practices, solar-based technologies, and community-based governance. Their experience illustrates how Indigenous knowledge systems, when supported by appropriate technologies and external partnerships, can offer viable pathways for managing water scarcity and improving WASH outcomes in ecologically stressed regions.

Image 1. **Santa Ana Community**

Source: Author(s)

Demographics and Socio-economic Profile

Santa Ana is home to approximately 170 residents, organized into 47 family groups that reflect a tightly knit kinship structure. The population comprises approximately 32 young children (ages 0–5), around 37 youths, and a mix of adults and elders. Residents belong to the Wayuu Indigenous group, one of Colombia's most populous and culturally resilient Indigenous communities. Characteristic of Wayuu heritage, community identity is shaped through matrilineal clan structures, and the Wayuunaiki language remains widely spoken.

The community governance structure centers around a traditional Cacique, who represents the community in external negotiations and coordinates collective resource management and socio-economic development initiatives. Women play pivotal roles not only in family and water-related decision-making, but also in income generation and cultural transmission. Their leadership is particularly visible in the organization of weaving cooperatives and household water management systems.

Livelihood strategies in Santa Ana are diverse yet heavily dependent on environmental conditions and access to water. Pastoralism, especially goat herding, remains a central economic activity, along with artisanal weaving, which is rooted in Wayuu cultural symbolism and predominantly carried out by women. Small-scale agriculture, previously limited to the brief rainy season, has expanded significantly with the installation of a solar-powered reverse osmosis desalination system. This community-managed system purifies groundwater, enabling access to safe drinking water and allowing year-round agricultural activities. It has improved household food security, reduced health risks associated with untreated water, and enabled the community to diversify its livelihood base.

A notable innovation in Santa Ana's economic landscape is the establishment of a micro-enterprise that bottles and sells potable water to neighboring communities. Revenue generated from this enterprise is reinvested in maintaining the desalination system and addressing other local needs, thereby enhancing the community's financial autonomy and infrastructure resilience. This external-facing economic activity illustrates a shift from dependency on outside aid to a more proactive, self-sustaining model of service provision and enterprise.

Key Challenges

The Wayuu community of Santa Ana faces persistent and multifaceted barriers to water and sanitation access, shaped by its geographic isolation, climate vulnerability, and limited institutional support. Chronic drought conditions, intensified by La Guajira's semi-arid environment and prolonged dry seasons, pose the most critical challenges, disrupting agriculture, depleting pastureland, and causing livestock deaths, all of which directly undermine food security and income stability.

Until recently, water access has depended on jagüeyes, shallow wells, and windmill-operated pumps, which frequently yielded brackish or biologically contaminated water. Community members reported widespread health issues, particularly among children and elders, including diarrhea, skin infections, and other illnesses linked to unsafe water. In extreme droughts, these traditional sources would dry up entirely, forcing families to travel long distances, sometimes several kilometers, to access water from other settlements, exposing women and children to physical risks and lost time.

The installation of a community-managed solar-powered reverse osmosis desalination system has substantially improved water availability and quality. It provides a reliable source of potable water and enables new livelihood activities, such as year-round agriculture and a micro-enterprise that bottles and sells water to neighboring communities. However, the system remains vulnerable to maintenance delays, fluctuations in solar energy, and limited availability of spare parts and trained technicians. While the micro-enterprise generates revenue to support operations, the long-term sustainability of the system requires consistent technical support and external accompaniment.

Sanitation access has improved but remains incomplete. Open defecation was long the norm due to a lack of facilities. Although dry latrines have been introduced, initially at schools and later in select households, adoption has been uneven. Barriers include limited construction materials, spatial constraints, and some cultural resistance. The lack of centralized wastewater treatment further compounds hygiene challenges, especially in peripheral areas where latrine coverage remains low.

Underlying these challenges is the limited presence of state institutions. Santa Ana's geographic dispersion, harsh climate, and poor transportation infrastructure severely restrict the ability of public agencies to provide technical and administrative support. Even when services are nominally available, agencies often lack the human and financial resources to reach remote communities. As a result, the community depends heavily on internal organization and external NGO partnerships, such as the one with ZOA International, to operate critical services and build infrastructure.

These environmental, infrastructural, and institutional constraints reinforce each other, deepening the community's vulnerability. Health outcomes, educational attainment, and economic resilience are all affected by gaps in WASH services. As community members themselves note, lasting improvements depend not only on physical infrastructure but also on reliable systems of support, recognition, and sustained investment.

Traditional Knowledge and Cultural Significance

Traditional knowledge and cultural practices are deeply interwoven into the community's daily life and water stewardship, forming a crucial component of its resilience and identity. For the Wayuu, water is not merely a physical necessity, but a sacred element intrinsically tied to their spiritual beliefs, cultural continuity, and communal harmony. Traditional water management practices emphasize respect, conservation, and collective responsibility, values that have been passed down through generations. A central cultural ritual in times of water scarcity is the Kasha ceremony, where traditional drumming is used to invoke Juya, the spirit of rain. Elders and spiritual figures typically lead this ritual, underscoring the connection between nature and the divine. It also reaffirms community unity, with participation reinforcing a shared sense of responsibility during periods of hardship.

The management of traditional water sources reflects a detailed and time-tested approach. The *jagüeyes* have long served as critical water sources during the rainy season. Community members, especially elders, are knowledgeable in identifying strategic locations for these reservoirs and determining when and how they should be maintained or reinforced. Maintenance includes cleaning out accumulated sediments, reinforcing earthen embankments, and managing

vegetation to preserve water quality and reduce evaporation. Family groups typically organize these collective tasks, under the guidance of traditional authorities.

Women, as custodians of domestic water use within the matrilineal social structure, bear distinct responsibilities in water management. Their roles include collecting water from the distribution points, using jerrycans or plastic containers, often multiple times a day depending on household needs. At home, women store the water in covered containers to prevent contamination, using traditional knowledge to manage water quantity and quality for drinking, cooking, and hygiene. They also manage household latrines, ensure regular cleaning of sanitation facilities, and supervise handwashing routines, particularly for young children. Through daily practice and direct instruction, they teach younger generations how to use water judiciously, maintain sanitary conditions, and respect traditional beliefs about water as a sacred resource. Additionally, women play a crucial role in advocating for improvements in community hygiene and sanitation infrastructure, such as the adoption of dry latrines.

Traditional water purification practices also persist in Santa Ana, reflecting the community's resourcefulness in adapting to environmental constraints. *Mucuras* are still used in some households not only to store water, but to filter out impurities and maintain cool temperatures naturally. These vessels utilize the natural porosity of clay to facilitate slow filtration, while their closed structure helps prevent contamination from insects and dust. While less commonly used today due to the availability of treated water from the desalination plant, *mucuras* remain a tangible link to ancestral knowledge systems.

Community-driven WASH Practices and Solutions

In the Wayuu community of Santa Ana, traditional knowledge and modern innovation are interwoven to sustain and manage water and sanitation systems. These practices are anchored in communal collaboration, gender-inclusive governance, and culturally informed adaptation to environmental challenges. Historically, the community has relied on natural reservoirs known as *jagüeyes*, which were collectively maintained. Community members took responsibility for removing sediment and repairing embankments to preserve these resources during dry periods. While these traditional sources remain as a fallback, they have been supplemented in recent years by significant infrastructure improvements. Chief among these improvements is the installation of a reverse osmosis desalination plant powered by solar panels, which purifies groundwater and ensures more reliable access to safe drinking water during extended droughts.

This system was developed with support from ZOA International and is fully operated by trained members of the Santa Ana community. Daily operations include pump monitoring, equipment upkeep, panel maintenance, and cleaning of storage and distribution areas. While no formal user fees are currently charged for water access, the community has created a microenterprise that sells potable water and ice to surrounding settlements, generating funds for plant maintenance and minor repairs. This approach enables the system to remain functional even in the absence of external technical support. However, sustainability remains a challenge due to dependence on donor support for spare parts, logistical constraints linked to geographic isolation, and the community's limited access to public institutional support.

The local WASH committee, convened under the guidance of the traditional authority (Cacique), is responsible for overseeing operations, scheduling maintenance, and establishing protocols for

water use and conservation. The committee holds regular meetings to discuss system performance, assign responsibilities, and coordinate with external actors. Decision-making is participatory and reflects Santa Ana's strong communal ethos, reinforcing accountability and transparency in resource governance. This governance model could offer a replicable framework for other Indigenous and rural communities when adapted to local institutional and cultural contexts.

Women and youth play an essential role in sustaining water and sanitation practices. Women lead hygiene promotion and water conservation efforts, building on their established roles in household water management. They provide practical guidance on safe water storage, such as covering and regularly cleaning containers, and encourage the use of traditional methods like *mucuras* for filtration. Hygiene messages are shared informally through home visits and family instruction, fostering behavioral change across generations. Youth are trained to operate and maintain the solar-powered pumping system, perform daily checks on the equipment, and support the distribution of water to community households, ensuring technical knowledge is preserved and passed forward.

In parallel, sanitation improvements have advanced through the introduction of ecological dry latrines, particularly in the community school and selected households. These facilities, constructed with the support of ZOA International, have provided critical alternatives to open defecation, significantly contributing to improved public health and a restored sense of dignity, especially for women and girls. The school latrines have become a benchmark for hygienic sanitation, demonstrating the feasibility of safe waste management in resource-constrained settings. Community members highlighted the comfort and security these installations offer compared to previous practices. Implementation efforts have been complemented by community outreach and awareness activities, particularly through the involvement of women who educate neighbors on the hygienic use of latrines, the importance of keeping the structures clean, and basic maintenance practices such as covering waste and using ash to reduce odors and promote decomposition. Despite these efforts, adoption remains uneven due to material constraints, spatial limitations at some households, and lingering cultural preferences for open defecation, especially in peripheral areas of the community.

Impacts and Outcomes

The integration of traditional knowledge with adaptive WASH technologies has markedly enhanced health outcomes, climate resilience, and economic opportunities in Santa Ana. At the core of this transformation is the installation of a solar-powered reverse osmosis desalination plant, which extracts and treats brackish groundwater to produce safe drinking water. This facility was installed with the support of ZOA International and is managed locally under a communal governance model. Trained youth are responsible for operating and maintaining the system, including cleaning the filters, monitoring water quality, and ensuring continuous energy generation from the solar panels. The WASH committee oversees these responsibilities, which coordinates system use, tracks household distribution, and organizes repairs when needed.

The consistent supply of potable water from the desalination plant has markedly reduced the community's reliance on previously used sources, such as *jagüeyes*, hand-dug wells, and windmill-driven pumps, which were often saline, contaminated, and unreliable. Community members report fewer cases of diarrhea and skin infections, especially among children and the elderly, since the introduction of treated water. This improvement has enabled more regular

hygiene practices, allowing children to attend school more consistently, and has no longer burdened them with water collection responsibilities or illness.

While reliance on modern infrastructure has increased, some households still practice *mucuras* (traditional purification techniques). These clay vessels are valued for their practicality and cultural significance, demonstrating the community's ability to integrate ancestral knowledge with contemporary systems. Together, these measures reflect a community-led model of water governance that enhances well-being while preserving cultural continuity.

Image 2. **Desalination Plant with Solar Panels in Santa Ana**

Source: Author(s)

Sanitation conditions have advanced through the introduction of ecological dry latrines, constructed with support from ZOA International and installed in both the educational facility and selected households. These latrines have reduced open defecation, improved public health, and provided women and girls with increased safety, privacy, and dignity. Community members noted the enhanced cleanliness and odor control of these systems. Hygiene promotion efforts, led by women, include instructing families in latrine maintenance, the use of ash for decomposition and odor reduction, and the importance of handwashing and environmental cleanliness. However, adoption remains uneven due to spatial limitations and persistent cultural habits in peripheral areas.

Economic resilience has also strengthened. The community has established a microenterprise to produce and sell potable water and ice to nearby communities, generating revenue that is reinvested in plant maintenance and supporting household income. This initiative, coupled with improved water access, has facilitated year-round cultivation of small food plots, decreasing reliance on external food sources and boosting nutritional self-sufficiency.

Ultimately, the structured participation of women and youth in WASH governance, through technical roles, hygiene education, and operational oversight, has fostered a deeper collective ownership and social cohesion. Youth are trained to monitor the solar panels, inspect water quality, and ensure proper functioning of the system. Women continue to lead hygiene promotion and intergenerational knowledge transmission. These practices strengthen institutional sustainability and position the community as a model of integrated, community-led WASH management in remote and environmentally challenging regions.

Challenges and Limitations of Current Practices

Despite recent advances in infrastructure and community-driven innovation, the Santa Ana Wayuu community faces persistent challenges that threaten the long-term reliability, equity, and sustainability of its water and sanitation systems. Seasonal drought remains the most pressing constraint, exacerbated by the community's dependence on solar-powered extraction technologies. During extended periods of cloud cover, the desalination plant cannot operate at full capacity, interrupting potable water distribution and forcing residents to revert to older, less safe sources such as *jagüeyes*, hand-dug wells, and windmill-driven pumps. Although families adapt through rationing and large-capacity storage tanks, these coping mechanisms are not universally available, highlighting underlying disparities in household preparedness.

Water contamination remains a significant health concern, particularly from lagoons used for animal consumption. These open-air reservoirs are highly exposed to biological contaminants, especially during the dry season when water scarcity increases reliance on unprotected sources. Traditional purification methods persist in some households, but they are insufficient to eliminate pathogens, posing particular risks to children, the elderly, and individuals with compromised immune systems.

While the solar-powered reverse osmosis desalination system has significantly improved access to potable water, its functionality depends on consistent maintenance, spare parts, and community oversight. The microenterprise that sells potable water and ice to neighboring communities helps finance basic operational needs, but funding remains limited. Trained youth manage the system locally, yet the absence of formal technical support or backup expertise constrains their capacity. Community leaders have expressed concern that breakdowns requiring specialized repair or external inputs may result in prolonged service interruptions.

Sanitation practices, though improved by the introduction of dry ecological latrines, face uneven adoption across the community. Cultural resistance, lack of construction materials, and spatial constraints limit broader household uptake. Open defecation persists, especially in peripheral areas, exposing residents, particularly women and children, to elevated hygiene and safety risks. While the community school has become a model for safe sanitation, replicating this success at scale remains a challenge.

Underlying many of these limitations is the minimal presence of public institutions. The community receives little to no sustained engagement from municipal or departmental authorities, who are constrained by geographic dispersion, climate-related transport challenges, and limited financial and human resources. Community members report a long history of exclusion from basic public services, including water, sanitation, health, and education. This institutional vacuum limits access to technical guidance, administrative support, and investment needed to sustain and scale existing solutions.

Non-governmental organizations have filled some of these gaps. ZOA International has supported the installation of dry latrines, facilitated hygiene education, and promoted inclusive community engagement. However, the durability of these efforts remains uncertain without sustained institutional support over the longer term. As one resident aptly summarized, "When the sun doesn't rise, neither does the water," a stark reminder of the community's fragile reliance on both environmental conditions and limited external support.

Replicability and Policy Implications

The Santa Ana model offers valuable insights for rural and Indigenous WASH strategies across the LAC region. Key replicable elements include the use of solar-powered systems in arid zones, engagement of traditional governance structures, and alignment of external support with community knowledge systems. To support replication, policymakers should prioritize decentralized, community-led governance; hybrid infrastructure approaches that combine renewable energy and low-tech purification; and culturally sensitive training to address sanitation barriers. Flexible maintenance and financing models are also essential for long-term viability. Importantly, the replicability of this model depends on adaptation to local contexts. Santa Ana's success was enabled by high levels of community cohesion, active participation by women and youth, and sustained partnerships with trusted NGOs, conditions that should be intentionally cultivated in other settings.

Gender and Youth Dimensions

Santa Ana highlights the pivotal role of women and youth in maintaining WASH systems. As household water managers and leaders in hygiene promotion, women have transitioned from passive users to active decision-makers. They lead community meetings, monitor water quality, and train others in sanitation practices. Despite progress, some barriers remain, including limited access to latrine materials and resistance among older generations to abandon open defecation.

Youth are increasingly seen as the custodians of future sustainability. They are responsible for monitoring solar systems, distributing water, and maintaining the infrastructure. Through participation in school-based and community-level WASH committees, they are trained in technical tasks, leadership, and accountability. Their involvement ensures knowledge continuity and embeds WASH responsibility into the social fabric of the next generation. Together, these dynamics reflect an evolving governance landscape in which inclusive participation is a valued mechanism for operational resilience and system longevity.

3.2. Adapting to Flood and Scarcity: Embera-Wounaan Water Practices in Canaán, Darién

Contextual Overview

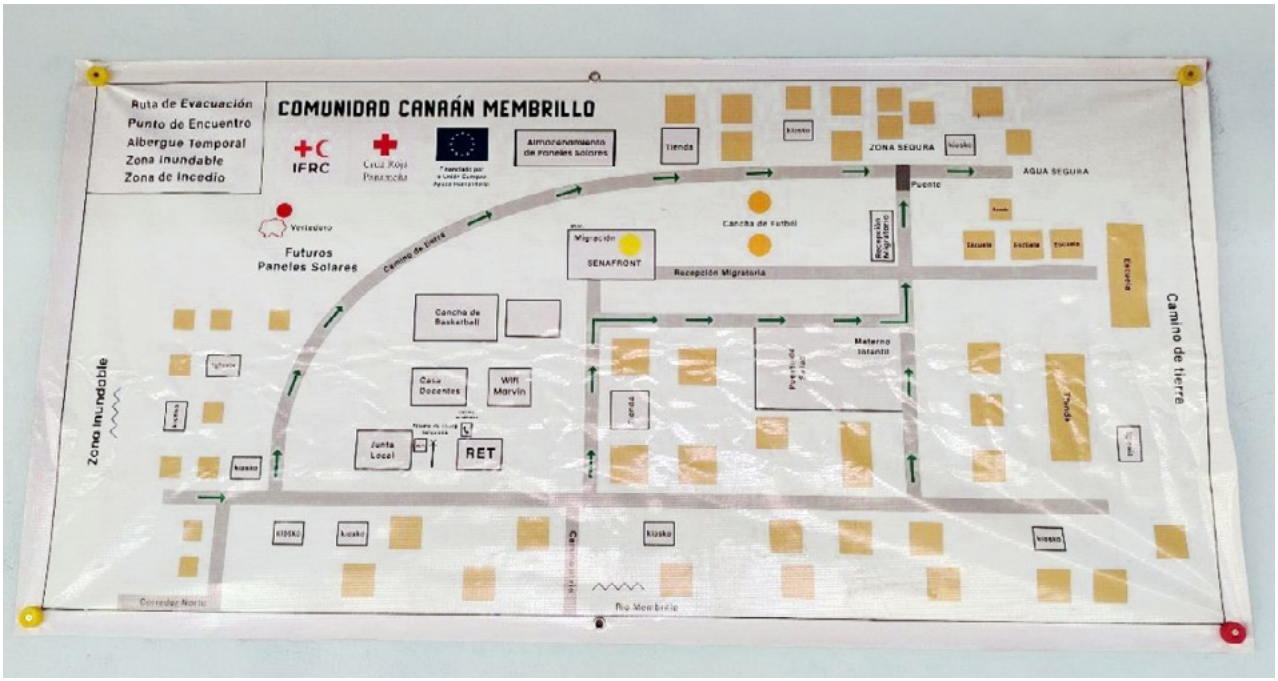
Geographic and Environmental Context

Nestled within the forested expanse of the Darién region of eastern Panama, the community of Canaán Membrillo is situated in the corregimiento of Lajas Blancas, district of Cémaco, and forms part of the Emberá-Wounaan Comarca. The surrounding environment is defined by dense

tropical forests and an abundance of rivers, most notably the nearby Membrillo River, which remains an important cultural and ecological reference point for the community. Unlike the arid plains of La Guajira, this region is marked by a humid, rainforest climate that brings both life-giving rains and destructive seasonal floods. The local ecology supports a subsistence-based lifestyle rooted in fishing, hunting, agriculture, and forest stewardship, closely tied to seasonal water cycles and the health of surrounding ecosystems.

Community members describe the forest and riverine landscape as central to their well-being and worldview. The natural environment is not merely a backdrop for economic activities but also a source of spiritual grounding and a marker of cultural identity. The abundance of unpolluted water and tranquility afforded by the forested surroundings distinguish life in Canaán from urban Panama, underscoring a sense of pride and reverence for the territory. At the same time, the community is not immune to climatic volatility. During the rainy season, the region is prone to flash floods that disrupt water infrastructure and restrict mobility, while in drier periods, limited solar exposure hampers the functionality of the community's solar-powered systems. These environmental conditions have forced the community to adapt continuously, developing informal and semi-formal strategies to secure and manage essential water resources.

Image 3. **Canaán Membrillo Community**



Source: Author(s)

Demographics and Socio-economic Profile

Canaán Membrillo is a small Indigenous settlement of approximately 410 residents distributed across 84 households. Its population structure reflects a balanced distribution across age groups, with a slight predominance of working-age adults (26–35 years), followed by youth, children, and elderly members. Gender distribution is relatively even across age categories, though traditional roles related to water collection and household management continue to fall more heavily on women. Despite its modest size, the community is marked by strong organizational cohesion, with internal governance mechanisms rooted in customary norms and collective decision-making processes.

A diversified subsistence economy shapes livelihoods in Canaán. Households engage in a mixture of agriculture, fishing, hunting, and forestry, all regulated by a community-managed plan that integrates traditional ecological knowledge. These primary activities are supplemented by small-scale commerce (e.g., kiosks and informal trade) and basic services (e.g., residential construction). While the community is connected to electricity through solar panels and backup generators, the infrastructure remains fragile and sensitive to environmental disruptions. Limited access to formal employment opportunities and minimal state presence render Canaán's economy largely self-managed and reliant on community solidarity, making maintaining water and sanitation systems a technical and social imperative.

Key Challenges

Despite its close proximity to abundant natural water sources, Canaán Membrillo faces persistent and compounding challenges in securing a consistent and safe water supply. The community's primary system, a submersible pump powered by solar panels, draws water from a shallow well and distributes it via a piped network to connected households. The system is highly vulnerable to the region's extreme seasonal variability. During the rainy season, for example, heavy floods obstruct access to the river and disrupt pumping operations. Solar panels receive insufficient sunlight due to cloud cover, undermining the energy supply needed for water extraction. These climatic constraints frequently interrupt water distribution, placing additional strain on operators and households alike.

Limited maintenance capacity and supply chain constraints further exacerbate reliance on a single, fragile water system. Essential replacement parts, such as chlorine tablets, submersible pumps, or filtration accessories, must be sourced from distant urban centers, and there is no local supplier of technical components within Darién. These logistical barriers create prolonged service outages and complicate efforts to implement system-wide upgrades. When disruptions occur, community members, especially women, often revert to traditional practices, including manually collecting water from the Membrillo River, roughly 200 meters from the village. Only about 10 percent of households still engage in this practice, but it remains a fallback option during breakdowns or shortages.

Sanitation presents a parallel set of challenges. While some households have septic systems and soak pits, communal latrines remain widely used, especially in densely populated areas. These facilities are often inadequately maintained, raising hygiene and safety concerns, especially for women who report discomfort and insecurity when using them at night. In terms of wastewater management, some homes are equipped with sanitary bathrooms connected to septic tanks

and soak pits. These systems function by separating solid waste through sedimentation and anaerobic digestion processes, offering basic greywater treatment for sinks, showers, and toilets. However, these improved systems are limited to a small number of households and were primarily built through community efforts. Economic constraints and geographic isolation make it difficult to procure construction materials locally, hindering broader adoption. As a result, many residents continue to rely on less safe communal sanitation options, increasing exposure to localized contamination, especially during floods when waste dispersal is more likely.

Traditional Knowledge and Cultural Significance

The Embera-Wounaan people of Canaán retain a deep cultural reverence for water, both a physical necessity and a spiritual element within their worldview. Elders in the community recall past traditions, particularly ceremonial dances that marked pivotal life stages, such as a girl's transition into puberty, that were closely linked to water as a symbol of purity, transformation, and vitality. Though many of these ceremonies are no longer practiced with the same frequency or public visibility, their symbolic legacy endures. Water continues to be described as "life and health" for the community, a sentiment that speaks to its material and cultural significance.

Ancestral water purification methods are still in use, blending traditional knowledge with low-tech innovation. Water is often strained through cloth, stored in buckets, and left in the sun for natural disinfection. Boiling and chlorination, introduced through training programs, have complemented these practices without displacing them. This hybridization of traditional and modern methods reflects an adaptive ethos rooted in self-reliance and openness to external knowledge.

While not always formalized in ritual, the community's cosmology emphasizes collective stewardship and intergenerational responsibility. Water is viewed as a shared resource that demands communal management. This principle underpins many of the governance practices observed in Canaán, where leadership structures blend customary decision-making with technical responsibilities, and where the care of water systems is understood as a collective moral duty. Women play a central role in the informal transmission of water-related knowledge, ensuring that household hygiene practices and conservation habits are passed on to younger generations.

Community-Driven WASH Practices and Solutions

An evolving blend of traditional practices and organized, community-led systems characterize Canaán Membrillo's approach to water and sanitation. At the core of the water supply model is the Rural Aqueduct Management Boards (Junta Administradoras de Acueducto Rural/JAAR), or the Rural Administrative Board, which manages the solar-powered submersible pump and ensures water reaches all households. Reserve tanks and PVC piping supports the system, allowing for basic piped distribution. However, recognizing the limitations of relying solely on solar power and a single water source, the community also supplements its supply through household rainwater harvesting systems. These auxiliary methods provide critical backup during periods of pump failure or low solar input.

Water is typically stored in 55-gallon drums or 5-gallon buckets. Community members have adopted rudimentary purification strategies based on guidance from NGOs and government training programs. These include sequential filtration through clean cloth, solar exposure for

natural disinfection, and, in some cases, chlorination. Notably, a small number of households also continue to rely on the nearby Membrillo River, especially when infrastructural failures disrupt access to piped water. Although this practice is declining, it underscores the fragility of current systems and importance of environmental access.

Image 4. **Community Water Well**

Source: Author(s)

Sanitation practices reflect a similarly hybrid approach. While some homes have installed septic tanks with soak pits that collect and treat greywater from showers and sinks, many still rely on communal latrines. These shared spaces, however, face chronic challenges related to hygiene, overuse, and user safety. Women in particular express concern about using latrines after dark, citing a lack of adequate lighting and security. Despite these limitations, the community has begun to explore localized wastewater solutions, including greywater filtration using septic systems and limited soak-away pits. However, geographic remoteness and economic hardship hinder the widespread implementation of more advanced or flood-resilient sanitation infrastructure.

Training provided by UNICEF and Global Brigades has played a pivotal role in enhancing community knowledge around WASH. These organizations have delivered sessions on water purification, sanitation system maintenance, and mosquito control through thermal foggers.

While most of the capacity-building efforts have targeted system operators, these trainings have laid the groundwork for broader behavioral change and have helped build a modest technical skill base within the community.

Water and Sanitation Governance

Water and sanitation governance in Canaán is organized through a locally managed administrative board under the guidance of the community's internal congress. Residents elect the board, which is charged with managing the operation and maintenance of the aqueduct system, coordinating repairs, overseeing chlorination and water quality monitoring, and collecting community payments. Decisions are made through collective assemblies, ensuring that authority remains grounded in customary norms and shared accountability. This participatory governance structure enables the community to mobilize rapidly when systems fail and adapt rules based on emerging challenges.

A key strength of this governance model is the active involvement of women, youth, and traditional leaders. Women regularly participate in system maintenance, cleaning, and awareness campaigns, taking on leadership roles in both technical tasks and broader initiatives such as fundraising and environmental education. The community's traditional leader, the Noko, also plays a pivotal role in reinforcing intergenerational responsibility. In collaboration with the congress, the Noko helped enact an internal rule requiring all youth aged 12 and older to participate in community assemblies and WASH-related activities. This culturally grounded structure has cultivated a strong sense of civic duty among younger residents and positioned traditional authority as a vital force in long-term water stewardship.

Despite these strengths, the governance system is stretched by logistical and financial constraints. The lack of a reliable supply chain for spare parts and chlorine tablets and need for technical expertise beyond the board's current capabilities hampers long-term planning. Most trainings to date have focused narrowly on water dosing and sample testing. Broader system design and maintenance knowledge remains limited to a small group of board members. Moreover, while support from international organizations has been impactful, the absence of sustained government engagement leaves the community vulnerable to future shocks and delays in emergency response.

Since 2010, the community has received support from a range of external actors. The Panamanian Red Cross and SINAPROC were among the first to provide critical supplies and capacity-building to local leaders, including foundational training on water safety and emergency preparedness. In more recent years, UNICEF and Global Brigades have extended these efforts through infrastructure upgrades, perimeter fencing, expanded reserve tank systems, and community hygiene education. These contributions have filled essential gaps in service provision. Yet, community members emphasize that ongoing technical and institutional support is still required to meet their long-term goal of uninterrupted, safe water access.

Impacts and Outcomes

Despite persistent challenges, Canaán Membrillo has made significant strides in improving water and sanitation conditions through community-led governance and practical adaptations. The introduction of a solar-powered submersible pump and a piped distribution

network has ensured intermittent access to potable water for the majority of households. This infrastructure, managed by the JAAR with oversight from the community's internal congress, has reduced dependence on untreated river water and reshaped daily routines, particularly for women and children who previously spent considerable time manually collecting water from the Membrillo River.

According to interviews, health outcomes have improved as a result of the shift away from river water and the adoption of consistent water treatment practices. Residents report fewer cases of diarrhea, stomachaches, and skin conditions, which they attribute to the chlorination of water and increased awareness of hygiene. These improvements stem in part from NGO-led training sessions on water purification techniques, such as cloth filtration, solar disinfection, and chlorine dosing, delivered by UNICEF and Global Brigades. While many households still rely on traditional purification methods as a fallback, the increasing regularity of chlorinated and piped water access has contributed to healthier household environments, especially during the dry season when untreated water sources would otherwise be in use.

Sanitation services remain uneven, but slow progress is visible. Some homes have installed septic systems and soak pits to manage greywater from showers and kitchens. Communal latrines continue to serve most of the community, particularly in higher-density areas. However, residents frequently report issues of overcrowding, poor maintenance, and insecurity, especially at night. Women are primarily responsible for cleaning latrines and guiding younger family members on hygiene routines. The phrase "sanitation management" in this context refers to these household-level tasks carried out predominantly by women. While there is no formal sanitation infrastructure management body, the involvement of women in maintaining cleanliness and promoting hygiene through informal knowledge-sharing is central to sustaining basic sanitation conditions in the community.

Youth have also been included in broader WASH governance and service activities. The Noko and community congress enacted an internal rule requiring youth aged 12 and above to participate in community meetings and support tasks such as minor repairs, chlorination, and awareness campaigns. This has helped foster intergenerational responsibility and expand the community's technical knowledge base.

In terms of financial sustainability, informal fundraising initiatives, especially sporting events, have generated modest resources used to repair water infrastructure and purchase necessary materials such as chlorine tablets. Interviewees specified that while funds are generally directed toward maintaining the existing water system, there have also been cases where collected resources were used to expand service coverage by acquiring additional piping or materials for household connections not initially reached by the network. Though limited in scale, these efforts reflect the community's proactive approach to system upkeep and incremental infrastructure development.

Challenges and Limitations of Current Practices

Despite the gains made, water and sanitation systems in Canaán Membrillo remain highly vulnerable to environmental, logistical, and institutional constraints. Seasonal flooding disrupts access to clean water and renders the solar-powered system inoperable due to inadequate sunlight. These disruptions are not isolated events but recurring patterns that expose the fragility

of the current infrastructure. During such outages, residents must rely on labor-intensive and often unsafe practices, such as retrieving river water, for basic household use.

The community's sanitation infrastructure also presents ongoing risks. Communal latrines are overburdened and inadequately maintained, posing hygiene and safety issues. Although some households have septic systems, the costs of constructing and maintaining improved latrines remain prohibitive for many families. Furthermore, the materials required to implement flood-resilient sanitation options are often unavailable locally, making external support a necessity for system upgrades.

Governance and technical capacity present additional challenges. While effective in day-to-day operations, the JAAR lacks access to consistent training, diagnostic tools, and long-term planning frameworks. The current structure relies heavily on volunteer labor and intermittent NGO support. Without expanded capacity-building efforts and institutional backing, leadership fatigue and system degradation risks remain high.

Moreover, the community still faces significant gaps in ensuring 24-hour access to water. Despite partial connectivity, residents report that water availability is inconsistent, and storage limitations at the household level exacerbate these shortfalls. Equipment failures, such as breakdowns in the pump or filtration units, can take weeks to resolve, further compounding service interruptions. These cumulative vulnerabilities illustrate that while the foundation of a sustainable WASH system exists, it is precariously balanced and urgently needs reinforcement through targeted investments and sustained partnerships.

Replicability and Policy Implications

The experience of Canaán Membrillo offers several important lessons for the design of Indigenous-led WASH interventions in remote forested regions. While the community faces significant infrastructural and environmental constraints, it has demonstrated that basic yet context-appropriate systems, anchored in community ownership and hybridized with traditional knowledge, can deliver meaningful progress in water access and sanitation management. The solar-powered submersible pump system—combined with rainwater harvesting, cloth filtration, and chlorination—illustrates how a modular, layered approach to water security can be effective in dispersed rural settlements.

The governance model in Canaán Membrillo, centered on JAAR and embedded within traditional congress structures, offers a replicable framework for community-led water management in Indigenous contexts. This model emphasizes collective decision-making, transparency, and gender-inclusive participation. Women play an active role in system maintenance and hygiene education, while youth engagement is institutionally reinforced through internal mandates requiring participation in community meetings and service activities. These practices contribute to strong local stewardship and intergenerational continuity, both of which are critical for system sustainability.

However, the limitations underscore several conditions for replicability. First, technical fragility, particularly the dependence on solar infrastructure vulnerable to seasonal variability, must be addressed through diversified energy sources or supplementary systems. Second, the logistical isolation of the Darién region highlights the need for localized supply chains and procurement

support to ensure rapid maintenance and system reliability. Third, external support must be sustained and structurally aligned with community priorities, not merely delivered through short-term interventions. While NGOs such as UNICEF and Global Brigades have contributed positively, the absence of a reliable institutional partner has left the community in a reactive posture, rather than one of long-term planning and system expansion.

From a policy perspective, Canaán reinforces the importance of integrating Indigenous knowledge into national water strategies as a legitimate technical and governance asset. The community's traditional purification methods, communal labor norms, and culturally embedded governance offer pragmatic solutions to chronic WASH challenges. Moreover, the case points to the need for differentiated public policy that recognizes the unique vulnerabilities of rainforest-based Indigenous communities, particularly in relation to climate impacts, supply chain disruptions, and access to WASH infrastructure.

The experience of Canaán Membrillo offers relevant insights for improving WASH outcomes in remote Indigenous contexts. It demonstrates that meaningful progress can be achieved through low-cost, community-managed systems anchored in local governance structures and complemented by targeted technical support. The integration of traditional knowledge, inclusive participation, and external training has enabled the community to overcome persistent logistical and environmental constraints. These results underscore the importance of sustained investment in capacity building, reliable supply chains, and long-term institutional partnerships to ensure the durability and scalability of community-led WASH solutions in similar settings.

4.

FROM KNOWLEDGE TO ACTION: RECOMMENDATIONS FOR PROGRAM DESIGN AND IMPLEMENTATION

Achieving universal access to quality, sustainable, equitable, and resilient WASH services in rural and Indigenous communities throughout the LAC region requires comprehensive, context-specific interventions that reflect the diverse ecological, social, cultural, and institutional conditions across all countries. This chapter synthesizes key insights from an extensive literature review of adaptive and ancestral WASH practices, in-field investigations in Santa Ana, La Guajira (Colombia), and Canaán, Darién (Panama), and targeted consultations with domain experts and community stakeholders. The recommendations presented in this section offer clear strategic direction, grounded in field-based evidence and case studies discussed in earlier sections. Each one outlines actionable steps for program design and implementation, with the aim of translating insights into tangible policy reforms, institutional support mechanisms, and community-level solutions. Together, they are designed to guide practical and scalable interventions that contribute to the region's WASH goals and enhance service outcomes over the long term.

To help policymakers prioritize actions, the recommendations are presented in phased blocks. Each phase builds on the previous one, moving from compliance and governance foundations to infrastructure and finance, and finally to system enablers that allow scaling. Cross-cutting measures, such as gender-sensitive inclusion, are highlighted across all phases.

4.1. Phase 0: Compliance & Early Engagement

Formal integration of Indigenous and rural governance into WASH frameworks

The formal integration of Indigenous and rural community governance structures into national and regional WASH frameworks is essential for achieving sustainable and equitable water management. Traditional governance bodies often operate without formal recognition, limiting their effectiveness in influencing policy and managing resources. Governments should therefore establish advisory councils and committees composed of respected local leaders, elders, and community representatives, granting these entities clear and explicit authority over the planning, implementation, and oversight of WASH initiatives. Legal frameworks should incorporate FPIC principles, consistent with international standards such as the UN Declaration on the Rights of Indigenous Peoples, and apply them throughout the project cycle to the greatest extent possible. Institutionalizing such structured, legally supported participatory governance mechanisms ensures that communities maintain meaningful control, enhances accountability, promotes genuine community ownership, and significantly contributes to the resilience and continuity of water and sanitation services. Effective implementation includes legislative amendments mandating regional councils, the formal institutionalization of FPIC in project approvals, and sustained administrative and technical support for these governance bodies.

To support this process, development partners (e.g., multilateral institutions, bilateral donors, philanthropic funders) should incorporate dedicated technical assistance and funding components to help countries establish or strengthen these participatory governance mechanisms. For example, institutions such as the Inter-American Development Bank, the World Bank, and UN agencies can play a catalytic role by supporting the creation of regional Indigenous water councils, promoting legal and policy harmonization, and building institutional

capacity for Indigenous organizations to engage in WASH governance. In line with the Inter-American Development Bank's Environmental and Social Policy Framework, required to ensure compliance with FPIC when financing projects in Indigenous territories, including the full documentation of these processes rather than merely promoting them. Importantly, the FPIC process must be carefully planned and implemented in a culturally appropriate manner. This consultation often requires specific timelines and iterative dialogue to ensure that Indigenous communities have the information, time, and space necessary to arrive at collective decisions, ultimately enabling genuine FPIC.

To ensure that these efforts are delivering results, development agencies and multilateral organizations supporting WASH interventions should embed monitoring mechanisms to assess the formal establishment and functionality of advisory councils, as well as their actual influence on WASH planning and implementation. Tracking the share of projects that complete and document FPIC processes, alongside the proportion of program budgets explicitly allocated to governance inclusion, will offer critical insight into compliance and impact. Additionally, regular reviews of council participation in decision-making, availability of technical support, and alignment of project outcomes with community-defined priorities can help determine whether these mechanisms are truly shifting power and ownership toward local actors. Taken together, these measures help embed culturally legitimate governance structures into formal WASH decision-making processes, fostering long-term community ownership, strengthening accountability, and advancing the equity and sustainability of water and sanitation services in Indigenous and rural areas.

4.2. Phase 1: Foundations

Institutionalized capacity building and intergenerational knowledge sharing

Institutionalizing sustained capacity-building initiatives that integrate technical training with the transmission of ancestral knowledge is essential to ensuring the long-term sustainability, resilience, and self-reliance of rural and Indigenous water and sanitation systems. In many communities, the erosion of traditional WASH-related practices, combined with limited access to technical education, weakens local capacity to maintain infrastructure, adapt to environmental stressors, and engage meaningfully in service governance. Regional experiences demonstrate that peer learning exchanges, mentorship models, and community-led training centers anchored by local technicians and Indigenous elders can effectively bridge these gaps, strengthening both system functionality and cultural continuity.

Long-term capacity-building measures should be systematically embedded into the design and implementation of externally supported WASH initiatives. Development partners can contribute by financing community-based training hubs, providing stipends for local trainers, and co-developing curricula with Indigenous knowledge holders. Development agencies and multilateral organizations can help anchor these efforts by supporting the establishment of training platforms that blend technical instruction with cultural transmission and intergenerational exchange. These hubs should serve not only as venues for technical instruction but also as repositories of traditional knowledge and platforms for intergenerational exchange.

To reinforce their effectiveness, capacity-building efforts should be embedded within formal institutional frameworks through durable partnerships with local schools, vocational institutions, Indigenous organizations, and public agencies, ensuring that training systems remain operational beyond project timelines and continue to evolve in response to community needs. Curriculum development should prioritize bilingual and intercultural formats that reflect local languages, values, and ecological conditions, while also meeting broader technical and regulatory standards. Special attention should be given to intergenerational models that recognize and support youth as both learners and future leaders, enabling them to inherit, apply, and innovate upon traditional WASH practices. These approaches help to ensure that knowledge systems are not only preserved but also continuously adapted to new challenges, ultimately fostering long-term self-reliance, local innovation, and institutional resilience in water and sanitation governance.

To evaluate the effectiveness of these capacity-building efforts, monitoring frameworks should examine both the scale and the depth of engagement across community groups. This includes tracking participation rates disaggregated by age, gender, and role; assessing the degree to which ancestral knowledge is formally integrated into training curricula; and documenting improvements in service continuity, infrastructure maintenance, and locally led troubleshooting. Special attention should be given to the participation and retention of youth and community-based trainers, as well as the long-term evolution of training programs into self-sustaining, locally managed systems that embed WASH knowledge across generations.

4.3. Phase 2: Design and Finance

Prioritization of decentralized and locally adapted WASH infrastructure

Prioritizing decentralized and locally adapted infrastructure solutions significantly enhances the resilience and sustainability of water and sanitation systems in both rural and Indigenous contexts. Standardized, one-size-fits-all approaches frequently fail to account for the diverse ecological, socio-economic, and cultural realities that define service delivery environments across the LAC region, resulting in mismatched infrastructure and limited community uptake. By embedding participatory design processes that draw on Indigenous knowledge systems and rural community expertise, infrastructure can be more appropriately tailored to local conditions, thereby improving operational relevance, user satisfaction, and long-term service continuity.

A more deliberate emphasis on locally responsive infrastructure is needed within the operational agendas of development institutions. Rather than replicating centralized service models, external partners should encourage context-sensitive infrastructure strategies grounded in community co-design and technical realism. This may involve revising project preparation protocols to incorporate participatory diagnostics, dedicating financing windows to small-scale or modular technologies, and supporting long-term community-based maintenance arrangements. Environmental resilience and affordability can be enhanced by integrating local materials and traditional design elements, especially in remote or climate-vulnerable regions. The Inter-American Development Bank, along with peer multilateral and bilateral actors, are well-positioned to test and scale community-led infrastructure innovations by supporting pilot projects that respond directly to localized challenges. These prototypes can serve as both functional solutions and policy learning tools, generating evidence for broader replication across similarly underserved geographies.

Evaluating progress requires robust tracking mechanisms across externally financed programs to measure the extent of community involvement in design, user satisfaction with installed systems, and local capacity to operate and maintain infrastructure over time. These data points will help ensure that infrastructure is delivered and sustainably operated by those it is meant to serve. When these practices are embedded into program cycles, multilateral agencies can establish inclusive and resilient infrastructure design as a foundational element of equitable WASH service delivery in rural and Indigenous areas.

Blended financial models for sustainable rural and Indigenous WASH

Establishing blended financial models that integrate contributions from rural and Indigenous communities with public investments and international support is crucial for sustaining and scaling water and sanitation services. Overreliance on single-source funding can leave programs vulnerable to resource shortages and hinder their long-term resilience, especially in remote and underserved areas. Hybrid financing approaches, co-developed with local councils, water committees, and community assemblies, promote transparent and participatory governance, ensuring that Indigenous and rural actors retain decision-making power over resource allocation, implementation priorities, and ongoing maintenance.

To facilitate broader uptake, international development partners working in the WASH sector should actively explore and support blended financing mechanisms, which must be tailored to the specific needs and capacities of rural and Indigenous communities and co-developed with local actors to ensure legitimacy and effectiveness. In this context, development institutions with regional expertise can play a catalytic role by helping design and pilot models that combine community contributions with public and donor resources. This includes offering matching funds for community contributions, providing technical assistance to support local financial planning and management, and establishing regional financial instruments that pool public, donor, and locally mobilized resources, such as household contributions, community labor, and microfinance mechanisms. They can also promote fiscal sustainability by embedding performance-based disbursement models that reward effective governance and continuity of services, and by strengthening local institutions' ability to manage and report on WASH-related budgets.

Monitoring should include not only the number of functioning blended financing arrangements but also the degree to which these mechanisms enhance local financial autonomy, improve transparency in fund allocation, and foster shared accountability between communities and external partners. Key indicators should track the proportion of externally supported WASH projects financed through multiple sources, stability and predictability of funding flows over time, and continuity of service delivery in areas where blended models have been implemented. Regular assessments of financial decision-making at the community level (e.g., the use of participatory budgeting or local audits) can further illuminate whether these approaches are strengthening institutional capacity and long-term ownership. When appropriately structured and supported, blended financing models can serve as a vital enabler of sustainable, community-driven WASH systems that reflect both local priorities and broader regional development objectives.

Institutionalizing ecological sanitation solutions

Institutionalizing ecological sanitation solutions offers a scalable and context-sensitive pathway to improving public health, environmental sustainability, and cultural relevance in rural and

Indigenous communities. Technologies such as evapotranspiration latrines, composting toilets, and constructed wetlands that use native plant species have demonstrated strong potential for safely treating wastewater in pilot settings, especially in remote or climate-stressed areas. Unlike conventional systems, these solutions are often more cost-effective, easier to maintain, and better aligned with traditional practices and ecological conditions. However, they remain underutilized due to limited institutional support, weak regulatory recognition, and fragmented financing.

Advancing the uptake of ecological sanitation within programs that international development agencies and multilateral donor organizations support requires a multi-pronged approach. Project design should prioritize these technologies in rural sanitation components, while supporting their formal inclusion in national sanitation policies, norms, and technical standards. Dedicated financing mechanisms should be established to fund construction, maintenance, and user training, particularly in areas where access to centralized systems is economically or logistically unfeasible. Development partners can accelerate adoption by supporting pilot programs, incentivizing innovation in social technologies, and partnering with municipalities, community-based organizations, and local service providers to strengthen long-term management capacity. Technical assistance should also be directed at environmental and public health agencies to develop performance monitoring systems that ensure long-term functionality and safeguard user health.

To evaluate impact, programs should monitor the number of ecological sanitation systems deployed, their operational status over time, and user satisfaction with functionality, safety, and cultural acceptability. Additional indicators might include reductions in waterborne disease incidence, decreases in untreated wastewater discharge, and improvements in soil and water quality where reuse is practiced. Where possible, attention should also be paid to community involvement in the design and maintenance of these systems, ensuring that local knowledge and preferences continue to guide implementation as ecological sanitation scales across diverse socio-ecological landscapes.

4.4. Phase 3: System Enablers

Implementing community-led monitoring and adaptive management

Implementing robust, community-led monitoring and adaptive management systems is essential to ensure that rural and Indigenous water and sanitation services remain responsive, resilient, and grounded in local realities. Centralized monitoring mechanisms often fail to detect site-specific risks or respond quickly to shifts in water quality, seasonal variation, or usage patterns, particularly in remote or environmentally sensitive areas. By equipping community members with low-cost testing kits, training them in basic hydrometeorological data collection, and creating platforms for reporting and feedback, service providers can benefit from timely, locally relevant data that inform more agile and effective decision-making. Experiences from across the LAC region demonstrate that when community monitoring is integrated into municipal water safety plans and watershed-level strategies, it enhances risk mitigation, promotes transparency, and strengthens accountability across governance levels.

Efforts to institutionalize community-led monitoring should be embedded into the core design of externally supported WASH initiatives. This entails dedicated financing for the full monitoring

lifecycle, from procuring and maintaining field-ready testing tools to co-developing culturally, linguistically, and technically appropriate training modules for Indigenous and rural users. Development institutions can support the creation of user-friendly data platforms that enable reciprocal information flows between communities and service providers, fostering two-way accountability and inclusive governance. To reinforce these efforts in highly dynamic or climate-vulnerable settings, multilateral actors may also support the operationalization of flexible protocols and contingency mechanisms, ensuring that community-led monitoring systems remain responsive to evolving environmental and service delivery conditions.

Beyond equipment and tools, institutionalization requires sustained investment in partnerships with local health offices, Indigenous associations, watershed councils, and educational institutions to deliver ongoing training, support, knowledge exchange, validate data accuracy, and reinforce credibility. These partnerships can also serve as anchors for broader capacity-building initiatives that strengthen community governance over time. To ensure long-term resilience, programs should include flexible operational protocols, contingency planning tools, and mechanisms for periodic review and adjustment of monitoring parameters. The Inter-American Development Bank can play a supporting role by embedding these adaptive measures into WASH governance frameworks, especially in regions vulnerable to climate variability and ecological disruption.

Evaluating progress will require tracking not only the number of communities actively engaged in routine monitoring but also the consistency, reliability, and usability of the data they generate. This includes assessing the frequency of data collection, quality of reporting mechanisms, and the degree to which community-generated information informs decisions at the local, municipal, and regional levels, particularly in relation to resource allocation, risk management, and service adjustments. In parallel, programs should monitor the physical durability and continued functionality of the tools and materials provided, as well as the responsiveness and effectiveness of local actions taken in response to identified risks. Finally, institutional uptake, reflected in formal recognition of community monitoring systems, their incorporation into water safety plans, and their influence on policy or investment decisions, should serve as a key benchmark for determining the long-term relevance and impact of these locally embedded adaptive management practices.

Strengthening policy advocacy and institutional inclusion

Strengthening policy advocacy and institutional inclusion is crucial to ensure that Indigenous and rural communities have a sustained and formalized voice in water and sanitation governance. Across the LAC region, these communities have historically been underrepresented in policy processes, resulting in frameworks that often overlook traditional knowledge, fail to align with local priorities, and disregard customary water-use rights. However, participatory policymaking has demonstrated transformative potential, as seen in cases where Indigenous water committees collaborated with health and environmental offices to formalize local water safety standards, or where community-developed water-use agreements were integrated into municipal and basin-level plans. These experiences demonstrate that institutional inclusion not only enhances the legitimacy and cultural relevance of water policies but also improves their operational effectiveness and social acceptance.

To support the scaling of such practices, multilateral development partners engaged in WASH programming can integrate targeted policy dialogue and institutional strengthening

components into their operations. This may include supporting the harmonization of statutory and customary water rights, financing inclusive consultation processes that reflect community-defined priorities, and facilitating the creation of participatory platforms through which Indigenous and rural representatives can engage directly with decision-makers. Multilateral development institutions can further support these efforts by applying policy-based lending and technical assistance instruments to promote institutional reforms that formalize Indigenous and rural representation across all levels of water governance and ensure that allocation frameworks are responsive to traditional practices and local socio-economic conditions.

To assess the effectiveness of these efforts, progress should be measured by the adoption of legal or regulatory provisions that guarantee Indigenous and rural representation in WASH governance, frequency and quality of inclusive policy dialogues, and degree to which traditional water-use protocols are formally incorporated into regional and national frameworks. Monitoring should also evaluate whether participatory platforms are functioning effectively by examining the consistency of community engagement, the accessibility of these platforms to marginalized groups, and their actual influence on policy and budget decisions. Additionally, attention should be paid to whether public resource allocations align with the priorities identified through inclusive consultations, particularly in historically underserved areas. By embedding these dimensions into broader institutional frameworks, external actors can help redress long-standing structural exclusions and support the development of inclusive, accountable, and resilient WASH governance ecosystems across the region.

Enhancing transboundary and regional cooperation

Enhancing transboundary and regional cooperation is essential for protecting shared water resources and managing water-related risks that span political boundaries, particularly in areas where Indigenous and rural communities depend on interconnected aquifers, rivers, or watersheds for their livelihoods and cultural practices. Despite the growing complexity of transboundary water governance, many existing agreements in the LAC region fail to incorporate customary water rights, community-based management approaches, or Indigenous stewardship principles. However, participatory coordination mechanisms—such as basin-level working groups that include Indigenous leaders, rural water user associations, and government officials—have demonstrated that cooperative solutions grounded in both traditional and technical knowledge can improve resource sustainability, reduce conflict, and build trust across jurisdictions.

Strengthening transboundary water governance in the LAC region requires sustained support for inclusive institutional mechanisms and cross-border cooperation frameworks that reflect both technical and traditional knowledge systems. This includes establishing regional dialogue platforms, facilitating equitable treaty development processes, and investing in the technical and institutional infrastructure necessary for joint resource management. Regional and international development agencies can contribute by financing shared monitoring systems, supporting capacity-building for local and national agencies on inclusive governance models, and promoting the legal recognition of traditional water-use rights in transboundary contexts. Additionally, transboundary cooperation could be embedded as a core focus within regional integration programs supported by development finance institutions, with targeted technical assistance to ensure that Indigenous and rural communities are formally represented in multi-level water governance structures.

Measuring progress should involve tracking the number of transboundary or inter-jurisdictional agreements that formally recognize Indigenous and rural water rights, frequency and effectiveness of participatory forums for joint decision-making, and extent to which shared water data informs collaborative planning. Additional indicators could include the presence of Indigenous or rural representatives in regional water governance bodies, improvements in ecosystem health or water access across borders, and evidence that local stewardship practices are reflected in regional governance strategies. Strengthening these dimensions will enhance climate resilience, reduce water-related conflict, and ensure that shared water governance reflects the diverse needs and knowledge systems of communities that depend on these resources.

Mainstreaming gender-sensitive and inclusive practices in WASH

Mainstreaming gender-sensitive and socially inclusive approaches is essential to achieving equitable, sustainable, and community-owned WASH services in rural and Indigenous contexts. Across the LAC region, women and youth frequently assume central roles in daily water management, including collecting water, managing household treatment, and maintaining basic infrastructure. However, their voices remain underrepresented in formal WASH decision-making. Field experiences demonstrate that inclusive water committees with gender and age diversity are more responsive to community needs, more trusted by users, and better able to sustain services over time. However, persistent structural and cultural barriers, such as a lack of access to leadership roles or technical training, continue to limit the full participation of marginalized groups.

Promoting inclusion within development partner–supported programs requires embedding gender- and age-responsive measures across all phases of design, implementation, and evaluation. This includes establishing requirements for equitable representation in community water governance structures; providing targeted training on leadership, negotiation, and technical skills; and incorporating inclusive participation as a condition for disbursement and program performance evaluation. Development partners can also support the creation of local mentorship programs and collaborate with civil society organizations to build long-term pathways for women and youth to enter and lead within the WASH sector. Program guidelines should ensure that training content, infrastructure design, and consultation processes are inclusive and accessible to all demographic groups, particularly those that have been historically excluded from formal governance and service delivery.

Effectiveness should be assessed by tracking the composition of local WASH committees, participation rates in training disaggregated by gender and age, and the extent to which diverse voices influence planning, budgeting, and system oversight. Monitoring should also capture qualitative shifts, such as increased confidence among participants, improved responsiveness to household needs, and enhanced social cohesion, resulting from more inclusive governance. By institutionalizing these practices, development programs can help shift WASH systems from externally driven interventions toward equitable, community-anchored services that reflect the capacities and priorities of all stakeholders.

The preceding recommendations constitute a coherent and evidence-based framework for advancing the equitable, sustainable, and rights-affirming provision of WASH services in rural and Indigenous communities across the LAC region. Grounded in the principles of participatory governance, intercultural relevance, and institutional resilience, they delineate

concrete pathways for operationalizing field-validated practices through development partner–supported interventions. Their implementation will require targeted technical and financial support, as well as regulatory alignment, cross-sectoral coordination, and the institutionalization of inclusive mechanisms at multiple levels of governance. When integrated into program design, execution, and evaluation, these measures can support development agencies and multilateral organizations in addressing structural inequities, strengthening the legitimacy and functionality of service delivery systems, and advancing the full realization of water and sanitation-related rights. In doing so, development and multilateral actors will be better positioned to contribute meaningfully to the regional achievement of SDG 6, while upholding broader commitments to social inclusion, environmental sustainability, and the rights of Indigenous peoples under international law.

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