**Building Water-Security Solutions for Pacific Island Communities**

### **Abstract**

### **Pacific Island Communities are beset with serious water security expectations. Climate change, limited freshwater resources, and various economic constraints lead to challenges, requiring creative and sustainable water security solutions for PICs. In assessing sustainable water security solutions for PICs, we emphasized the combination of traditional systems and practices with modern technology (rainwater harvesting, and decentralized or community-owned desalination utility investment). For the study we employed a mixed-methods approach to include qualitative community consultation with quantitative hydraulic modelling. Five PICs were selected (Fiji, Kiribati, Papua New Guinea, Solomon Islands, and Vanuatu). Five hundred households were included in data gathering as well as fifty key informants. Overall, 75% of rural-relied upon self-supplied water for their basic usage. If you lived in a community with recognized seasonal water shortages, you were still subjected to make due. Findings identified the advantages of community-driven rainwater harvesting systems, the distributed network modeled using EPANET also gave hope to alternatives and resilience. Suggested hybrid solutions and focus on capacity building bolstered the urgency of regional collaboration for PICs to champion action. Hybrid solutions address commitments to the Sustainable Development Goals (SDG 6) by 2030 (for universal access to water).**

# 1.Introduction

Pacific Island communities face unique challenges in achieving water security due to their remote locations, limited freshwater resources, and vulnerability to climate change impacts like rising sea levels, droughts, and extreme weather. Building water-security solutions for these communities is critical to ensuring sustainable access to safe and reliable water for drinking, agriculture, and sanitation, while preserving their cultural and environmental heritage.

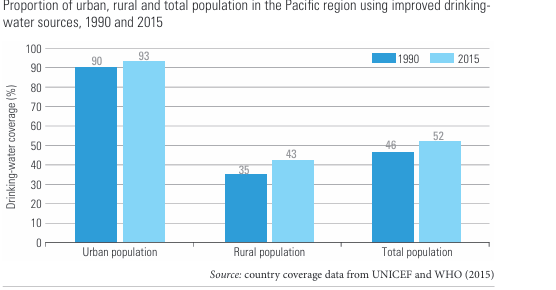
Almost one third of Earth's surface (Figure 1) contains islands which people have inhabited since 3500 years ago [1]. Several obstacles challenge Pacific Island nations when distributing water due to scarce resources combined with rising water consumption and broad climate changes[2] Pacific island countries covered in this report are: Cook Islands, the Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, the Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. These countries are part of a group of small island developing states (SIDS) globally that share similar sustainable development challenges. Approximately 10 million people are living in the Pacific region, on islands scattered across 180 million square kilometers, an area 17 times larger than Europe. Over 81% of the total population lives in rural areas (United Nations, 2014). Pacific Island Countries (PICs) collectively have the lowest rates of access to safely managed or basic drinking water and sanitation globally. They are also the least urbanized, have dynamic socioeconomic and increasing climate-linked challenges. The Pacific SIDS exist in high risk status from environmental natural hazards throughout their territory.

[3]A review on the nature of challenges impacting water distribution states that Pacific Island countries experience environmental variability and change resulting from direct human impacts such as urbanization, population growth, and changing land use and land management (e.g., deforestation and mining), as well as environmental change attributed to natural climate variability and human-induced climate change. The challenges of freshwater accessibility are not only present in small remote islands but in where water is a key driver of economic and social development while it also has a basic function in maintaining the integrity of the natural environment.  Due to its small sizes and locations of islands, many remote and rural communities in the Pacific Islands have barriers in accessing freshwater.[4] Supply side solutions alone are not adequate to address the ever-increasing demands from demographic, economic and climatic pressures that directly affect freshwater accessibility. Since water is a vital resource, it is important to find solutions to remove obstacles to its access. Thereby, recent trends indicate that many water systems essential for supporting ecosystems and increasing human populations are under significant strain. These water sources are either being contaminated by various forms of pollution, rendering them unusable, or have completely dried up. Additionally, inefficiencies and pollution across various water use sectors have exacerbated water scarcity, leading to greater water wastage[5].

The solution to freshwater issues needs comprehensive treatment because water supply conditions interact closely with both usage rates and water purity. The study underlines the requirement for an extensive strategy that performs assessments of current water resources and their projected development. The integrated approach includes stakeholder collaborations together with monitoring system improvements and water diplomatic programs to solve accessibility problems. The methodology transforms problems into prospects to create sustainable management approaches and cooperative structures which lead towards sustainable development.[6]

## 1.1 Context

Last census report



*Figure 1: Proportion of rural, urban population in the Pacific region using improved drinking water*

**Analysis of Figure 1**:

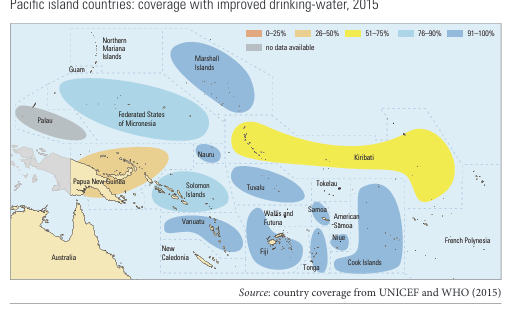
Disparities: Urban-rural differences are stark, with rural areas being perpetually under-serviced due to geographic isolation and infrastructure constraints. Fiji ranged the highest in coverage, while PNG trailed considerably with economic and governance inequality.

Self-Supply: Rainwater harvesting has been the predominant source of supply in Kiribati and rural areas of some PICs despite variability and limited storage affecting reliability.

Climate Vulnerability: All PICs experience climate-related vulnerabilities (e.g., mean sea-level rise, cyclones, and drought) that can threaten infrastructure resilience. Kiribati's location as an atoll, make it particularly vulnerable, while the terrain of PNG makes solutions difficult.

Funding Needs: Annual WASH expenditure (~US$230-270 million across region) is inadequate. Solomon Islands and Vanuatu, for example, would require an increased level of funding to reach SDG 6 targets for universal access by 2030.

Achieving universal access to improved drinking water is a complex task for Pacific Island countries (PICs) because of their geographic isolation, limited freshwater resources, population growth, and the impacts of climate change, including sea level rise and increased frequency and severity of extreme weather events. Improved drinking water sources refer to the WHO/UNICEF Joint Monitoring Programme (JMP) definition: piped water into dwelling, boreholes, protected wells, rainwater collection, and bottled water, as long as they are available on premises, when needed, and not contaminated. This response addresses the best available data (for the year 2025) on drinking water coverage in PICs, provides some detail about access to an improved drinking water source, addresses urban versus rural access discrepancies, describes important challenges, and includes relevant information extracted from the sources that are available. sources UNICEF and WHO.



*Figure 2: Pacific Island countries map coverage with improved drinking water. Source UNICEF and WHO*

## 1.2 Current Data on Improved Drinking Water Coverage in Pacific Island Countries

According to the WHO/UNICEF Joint Monitoring Programme (JMP) data, the access to improved drinking water sources has seen low levels of progress in Pedro Island Countries (PICs) as the percentage of the population with access improved from 46% in 1990 to 52% in 2015, short of the Millennium Development Goal (MDG) target of 73%. While it is estimated that by 2020 around 90% of the population had access to improved water sources in PICs, the percentage of rural individuals with coverage is significantly below urban individuals. Projections suggest without increased action, thousands in PICs will continue to lack safely managed water by 2030, including children, and progress will fall short of the Sustainable Development Goal (SDG) target of universal access[7].

Given that 2015 marked the end of the Millennium Development Goals (MDGs), this report can be viewed and used as a reference point and situation assessment for WASH, as well as a report to summaries the requirements of future water and sanitation development for the Pacific island countries. Ms Rhonda Robinson, Water and Sanitation Programme Deputy Director of the Pacific Community highlighted that *"While all Pacific island countries are working to provide their citizens with access to safe water and sanitation, these activities are generally not keeping pace with population growth."* The report also considered the issue of water security and safety as a key sustainable development issue for Pacific Island countries. Climate change is anticipated to have a direct impact on water resources, and therefore supplying safe drinking water and sanitation is critical to the sustainability of lives and livelihoods, economic growth, public health, environment and human rights in the small island states [8]

"This paper highlights a major challenge for us to achieve and to support the Pacific in reaching targets of the 2030 Sustainable Development Goals for universal access to improved drinking-water and sanitation facilities. Achieving these new targets will require a radical recalibration of collective effort by the Pacific and its development partners, especially in light of population projections and climate change impacts in coming years.Mr Marc Overmars, UNICEF Pacific WASH Coordinator went on to elaborate when he stated, “Climate change is one of the defining challenges of our time and it may be the greatest single threat to human health in the twenty-first century. Coordinated action from several sectors is needed to build water security and health resilience to climate change in the Pacific[8]

## 1.3 Recent Updates on Water-Security Opportunities in Island Communities

## Access to Water:

Made up of more than 25,000 islands with diverse environments, the region is home to millions of people whose lives and cultures are deeply tied to the land and ocean. Most communities live along the coasts, which are increasingly at risk from rising sea levels. This not only threatens homes and infrastructure but also harms vital marine ecosystems like coral reefs and mangroves. This damage also affects freshwater resources, as coral reefs help protect coastal freshwater supplies from saltwater contamination. The Pacific Islands are especially vulnerable to climate change because of their unique geography and ecosystems[9].

Access Statistics (2020-2024): The Pacific Community (SPC) reports that the Pacific urban population is 92% access to safe drinking water. In rural areas, the access has been reported at only 44%. The disparities are minor for some nation-states, but others remain significant throughout 2024. In Kiribati, 75% of households used improved water sources (10% desalinated, 65% rainwater), but only 40% of households have access to safely managed drinking water due to contamination risks[10].

According to Dorrevella, the Pacific Island Countries (PICs) experience major difficulties in obtaining steady access to their fundamental water supplies which consist of rainwater in addition to surface water as well as groundwater and desalinated water and imported water. Small water resources face high susceptibility to population-driven demands because of limited financial and technical capabilities in water resource management along with natural and man-made disaster impacts. Strategic Climate Change Adaptation (CCA) initiatives represent the basis for reducing climate change effects on existing development problems because tropical cyclones and droughts as well as heavy rains are increasing the frequency and severity of extreme weather disasters which damage essential water infrastructure. These heightened events will push up the expenses needed to maintain water security throughout most Pacific Islands Countries[11].

The global expansion of Pacific Islands occurred during the 19th century colonization period while Pacific traditional knowledge underwent blending with new cultural traditions from outside sources until global western knowledge replaced most traditional uses in Pacific island communities. The island groups maintain TK to different degrees while local communities keep using this traditional knowledge to handle climate variability and it could assist them in dealing with climate change [12].

Freshwater scarcity and drought are major challenges in the Pacific, made worse by the region’s limited natural water sources, such as rainwater collection systems, small underground aquifers, and, in some places, desalination plants. Changes in rainfall patterns and higher evaporation rates due to rising temperatures have caused longer dry periods, impacting both farming and access to drinking water. In places like Kiribati and Tuvalu, where freshwater is already scarce, even small drops in rainfall can create serious water shortages[13].

Water scarcity, especially under the influence of climate change, has emerged as a critical factor for human survival and sustainable development. Rural areas face even more significant challenges as they experience water scarcity compared to urban centers, especially when confronted with droughts and other climate extremes, leading to the amplification of secondary disasters. Rural water planning should take these risks into account and develop risk response measures.[14] However, because it is difficult for managers to have an in-depth understanding of the water supply–demand relation and water utilization difficulties in each village settlement, which is seen as the most basic management unit in rural areas, the above planning generally lacks pertinence and rationality in terms of water resource allocation and the emergency management of water scarcity in rural areas.

# 2. Materials and Methods

The research for this study, Building Pacific Water Security for Pacific Island Communities, employed a qualitative literature review approach to examine water security problems among Pacific Island Countries (PICs). The authors distilled three types of sources: peer-reviewed academic literature, policy documents and documents from governments and organizations, and non-traditional NGO documents. Academic literature provided theoretical and empirical data about water security problems, while documents from governments and organizations provided a policy framework and descriptions of practical implementation. The non-traditional NGO documents provided grassroots, or community-level perspective, and identified local issues and challenges. Taken together, the sources gave a comprehensive overview of the environmental, social, and policy contexts that affect water security in PICs.[15] .

Selecting the literature involved a systematic cursor through relevant material for review purposes identified patterns, gaps, and innovation in water security; the review was able to identify comparable themes, including access, governance, water quality, and sustainability. The case studies from PICs happened to engage successful strategies and recurrent issues. In the synthesis process we assessed strengths and weaknesses of existing approaches and made sure the findings kept pace with the rapidly changing water security context in the Pacific. This qualitative approach provided an integrative view of numerous interconnected mitigating factors across different historical contexts, cultural contexts, and contemporary contexts regarding establishing water security in PICs.[16].

# 3. Literature Selection Process

This research adopts qualitative literature review methodology while using academic peer-reviewed literature alongside organizational and government documents and non-traditional NGO reports. The research method synthesizes and evaluates the existing knowledge about Pacific water security in order to perceive patterns and identify gaps alongside new developments.

The researchers studied various case examples to spot recurring strategic approaches and determining success factors. The analysis dedicated specific attention to academic works describing community-driven solutions together with policy combination approaches and infrastructure that presents resilience against climate changes. Through this systematic approach researchers gain detailed comprehension about multiple elements influencing water security challenges throughout the Pacific while having the basis for creating practical knowledge and policy suggestion frameworks.

# 4. Overview of Water Supply Distribution in the Pacific Island Country

The water service systems of Pacific Island Countries remain susceptible because these nations face large-scale operation limitations and remote distances alongside financing issues and cultural barriers along with minimal staff expertise. Water needs assessments across various locations prove to be difficult because of systemic complexity together with diverse contexts as well as the lack of objective and consistent data[17] In addition, the most yet challenging contributing factor to water loss is when climate change affecting Pacific Island Countries in ways that endanger their regional food stability. Climate change affects food security because it disrupts fisheries, agriculture and induces population movement between regions. The residents of Pacific Island Countries experience enhanced risks from natural disasters including floods, droughts and cyclones due to climate change effects[18].

Analyze existing studies, reports, and policies on water distribution in Pacific Island Nations to identify common challenges (e.g., climate change, infrastructure limitations, population growth).

Literature Review: Water Distribution Challenges in Pacific Island Nations

Water distribution in Pacific Island Nations (PINs) is a critical issue that has been extensively studied in academic research, policy reports, and development studies. This literature review synthesizes findings from existing studies to identify common challenges, including climate change, infrastructure limitations, and population growth, that hinder effective water distribution in the region. These challenges are interconnected and exacerbate water scarcity, posing significant risks to the sustainability and resilience of water systems in PINs.

The existing literature reveals that water distribution in Pacific Island Nations is hindered by a complex interplay of climate change, infrastructure limitations, population growth, and solutions. While progress has been made through regional cooperation and innovative technologies, significant gaps remain in funding, capacity building, and policy implementation. Addressing these challenges will require sustained investment, international support, and a commitment to equitable and sustainable water management practices. By building on the insights from existing studies, PINs can develop resilient water systems that ensure access to clean and reliable water for all.

# 5.Challenges to safe drinking water in the Pacific

Eventually will be emphasizing on the significant challenges associated with water distribution in Pacific Island communities and presents the methodologies and tools that can be utilized to address these challenges. It is crucial to recognize that water distribution networks are vital infrastructure, and their efficient management is fundamental to achieving sustainable societal development.*[19].* The challenges of ensuring that water is conserved and managed wisely are huge and no single agency can address them in isolation. Strengthening partnerships among stakeholders (governments, the private sector, non-governmental organizations (NGOs) and donors agencies) is the way forward.[20]

The Pacific Island regions encounter multiple essential obstacles in obtaining safe drinking water. More than one million Pacific islanders begin their day by gathering polluted water from contaminated streams alongside the struggle of locating hidden bathroom areas between sea shores and forests. The situation goes beyond basic matters of uncomfortable hardship. The lack of both safe drinking water and proper sanitation creates major health risks which primarily affect young children and acts as an essential development limitation for Pacific islands. The practice of effective handwashing, a critical weapon in our defense against diseases such as COVID 19, relies on the existence of an affordable, reliable and resilient supply of clean water[21]

In Pacific Island Countries, limited access to basic drinking water affects approximately 45% of the population, predominantly in rural areas, exacerbating health and environmental challenges due to inadequate water, sanitation, and hygiene (WASH) infrastructure [22]. High vulnerability to climate change and natural disasters, such as cyclones and droughts, leads to seawater intrusion and damaged water infrastructure, further compromising freshwater availability[23]. Governance and institutional challenges, including fragmented agency powers, minimal coordination, and insufficient funding, hinder effective water service delivery[24]. Additionally, socioeconomic and cultural factors, such as traditional land tenure systems, women’s roles in water collection, and limited financial resources, create barriers to accessing safe drinking water[25]. Addressing these issues is critical to improving water security for five million Pacific inhabitants.

Key factors influencing the non- effectiveness of water distribution in the Pacific Islands include governance challenges, lack of national water policy, aging infrastructure, environmental challenges limited community engagement, and inadequate coordination of government and community activities in the water and sanitation sector[26]. Small dimensions and topographical features of Pacific islands present exclusive hurdles for service delivery of water and sanitation. Resources relating to drinking water remain limited across numerous countries inadequate capacity for resource management. Pressures of economic development that is, Economic progress combined with urbanization and changing climates produces simultaneous water supply deficiencies while causing flooding and deterioration of water quality along with soil degradation. Water scarcity along with flooding becomes more common because population growth and urban expansion happen simultaneously with climate changes. Effective water governance is crucial, as it encompasses transparency, participation, and sustainability, yet many PICs, such as Kiribati, lack cohesive national policies and face institutional fragmentation. The present environmental discussions and media reports about small island developing states (SIDS) warn of upcoming severe consequences due to global warming and sea-level rise. Atoll nations such as Kiribati face undeniable major difficulties among several other groups of small islands developing states. Apart from dealing with urbanization and pollution and sanitation emerging threats small island state survival depends on a fresh dedication to address evident environmental dangers. The article demonstrates how managing development impacts determines small island state survival alongside their societal future existence[27].

This paper reviews the necessity for a sustained and collaborative initiative that engages both governmental bodies and community stakeholders to tackle the intricate and diverse challenges within the water sector. It underscores the lack of a comprehensive national water policy and advocates for a strategic framework to improve governance[28].

# 6.Sustainable Solutions-Way Forward

In response to the water security challenges facing the Pacific Island Countries (PICs), this study proposed effective and sustainable solutions to enable local ownership, position local governance, and engage innovative technology, using Pacific experiences and global learning. Community engagement was a key feature of these endeavours, as demonstrated in the successful rainwater harvesting activities in Fiji, Kiribati, and Tuvalu where it established local ownership and resilience. [29, 30]. Training programs for community leaders, technicians, and engineers were implemented to build capacity for managing water infrastructure, aligning with the principles of Community-Based Resource Management (CBRM) outlined by [31]. Ligombi et al. (2025) stated that community-based resource management (CBRM), as applied to rural water supply in Tanzania, promoted sustainability by taking communities through the process of establishing governance arrangements, monitoring compliance, and resolving conflicts, while reducing reliance on external assistance[32], In PICs, community-based water committees in Tonga and Vanuatu similarly supported the management of rainwater tanks and small-scale desalination units, ensuring O&M [operations and maintenance] for the long term using local knowledge and accountability structures. Ligombi et al. (2025) stated that community-based resource management (CBRM), as applied to rural water supply in Tanzania, promoted sustainability by taking communities through the process of establishing governance arrangements, monitoring compliance, and resolving conflicts, while reducing reliance on external assistance. [32] In PICs, community-based water committees in Tonga and Vanuatu similarly supported the management of rainwater tanks and small-scale desalination units, ensuring O&M [operations and maintenance] for the long item using local knowledge and accountability structures. [29].

Water conservation programs were prioritized to reduce demand and enhance sustainability, aligning with principles of sustainable development that advocate for systems meeting present needs without compromising future resources [5, 6]. In Fiji, initiatives like drip irrigation and low-water-use technologies minimized agricultural water waste, while watershed protection in Vanuatu preserved freshwater ecosystems [33, 34]. Ligombi et al. (2025) highlighted the success of solar-powered water pumps in Tanzania, which reduced operational costs and environmental impact, offering a model for PICs [32]. Adopting similar eco-friendly technologies, such as solar-powered desalination in Tuvalu, enhanced water access while addressing climate variability [11]. These solutions required robust institutional frameworks to ensure scalability, as weak coordination often hindered progress. Institutional coordination, as discussed by Ligombi et al. (2025), underscored the need for clear roles, transparency, and stakeholder collaboration to overcome inefficiencies, a lesson applied in PICs through partnerships between governments, NGOs, and regional bodies like the Pacific Islands Development Forum (PIDF) [32, 35].

Public-Private Partnerships (PPPs) emerged as a viable strategy to address financial and technical constraints, inspired by Ligombi et al.’s (2025) findings that PPPs in Tanzania improved service delivery through private sector innovation, such as mobile payment systems for water fees [32]. In PICs, PPPs facilitated projects like the ADB-funded Suva-Nausori Water Supply Project, serving over 300,000 people in Fiji, by pooling resources and expertise [24]. However, Ligombi et al. cautioned that PPPs required clear legal frameworks to avoid regulatory ambiguities, a challenge also faced in PICs where fragmented governance impeded coordination [32]. To enhance sustainability, PICs implemented cost-recovery models, such as community-managed water tariffs in Solomon Islands, ensuring affordable access while funding infrastructure maintenance [24]. These efforts were supported by regional cooperation, with platforms like the Pacific Water and Wastewater Association fostering knowledge sharing and policy alignment to advance SDG 6 [36]. By integrating community-driven governance, sustainable technologies, and institutional coordination, PICs built resilient water systems tailored to their unique environmental and cultural contexts.

# 7.Enhanced coordination across all sectors

## 7.1 Incorporate Disaster Risk Reduction and Climate Adaptation

Water systems should use tough materials together with adaptive designs to develop climate-resilient infrastructure which can survive intense weather conditions such as flooding and cyclones and droughts. The development of response plans through contingency planning includes water emergency strategies along with water delivery trucks and emergency desalination units and water purification kits for disaster situations. Each community should place their water management under integrated climate adaptation planning structures. Local governments should team up with NGOs and international partners for implementing this strategy.

## 7.2 Utilize Technology and Innovation

To improve water management, integrating advanced technologies is essential. Monitoring and data collection can be significantly enhanced by deploying tools such as sensors, satellite data, and mobile applications to track water levels, quality, and usage patterns [37]. Advanced water monitoring tools—such as sensors, satellite data, and mobile apps—can track water levels, quality, and usage patterns, enabling data-driven decisions for optimized resource allocation and improved early warning systems [38]Smart water management technologies, including IoT devices and automated distribution systems, allow real-time monitoring of water flow, leak detection, and usage optimization [39]. Additionally, cloud-based platforms can centralize water data, providing stakeholders with accessible information for decision-making and policy development [40]These data-driven insights enable more efficient resource allocation and strengthen early warning systems .Smart water management can be further improved through the use of Internet of Things (IoT) devices and automated systems, which monitor real-time water flow, detect leaks, and optimize water [41]. Additionally, cloud-based platforms can support decision-making by providing centralized databases that store critical water data, facilitating access for stakeholders and informing policy development [42].

## 7.3 Ensure Financial Sustainability

A comprehensive approach must identify multiple financial sources which consist of government financial budgets combined with development aid and climate adaptation funds together with private sector investment capital. The organization needs to build financial models which enable maintenance operations for water system infrastructure. Water pricing and fee systems constitute cost recovery systems for the maintenance and expansion of water infrastructure alongside affordable basic water needs for all community members. The establishment of government and international organization and NGO and private sector alliances should develop mechanisms to exchange information along with monetary investments for major water projects.

## 7.4 Monitoring combined with evaluation of progress

Monitoring combined with evaluation of progress matters for the success of water security solutions by confirming their effectiveness and their ability to endure over time. Water security measurements require continual assessments of water qualities, water accessibility, water usage patterns along with systematic checks for water system performance across each community r[43] . Having impact evaluations provides necessary insight to measure how water security solutions influence social along with environmental and economic conditions particularly regarding improved health outcomes and increased productivity combined with resilient communities [43]Adaptive management should be used as a key strategy to enable ongoing improvements of water security plans through feedback analysis from evaluation assessments. Future undertakings will gain valuable knowledge from successful and unsuccessful implementations of schemes to achieve better planning and execution [44].

## 7..5 Enhance Cooperation Between Pacific Island Countries

The final step emphasizes the need to enhance cooperation between Pacific Island countries for managing their shared water resources while effectively responding to disasters. Different countries establish regional frameworks to defend and wisely manage transboundary water resources that include rivers and aquifers. A platform of shared knowledge that includes best practices and technical innovations and lessons learned serves to increase the successful implementation of regional solutions across different islands for overall regional resilience enhancement. Pacific communities face multiple levels of complexity when establishing water-security solutions which need combo sustainable technologies together with community involvement and governance structures backed by climate resilience projects. Below follows a step-by-step process to develop suitable water-security solutions which target Pacific Island nations along with their communities**.**

# 8. Integration of Principles

The development of water security in the Pacific Island Countries (PICs) requires specific principles to reflect the uniqueness of each nation's environmental, cultural and socio-economic characteristics with an emphasis on community and inclusion, climate resilience and sustainable resource management. The principles of community action and Indigenous engagement are paramount in this aim, tapping into Indigenous practices such as rainwater harvesting to develop local ownership and sustainability, as seen in Kiribati and the collaborative design of water infrastructure[45] .Addressing climate resilient infrastructure and technologies is an important issue, this includes projects that focus on the elevation of water storage, desalination plants, and enhanced delivery of water to rural communities as drought action which has been applied in Fiji)[33]. Sustainable resource management falls under the approaches for adapting Integrated Water Resources Management (IWRM) as it fits the Pacific, this includes watershed conservation as seen in Vanuatu to advance water demands against conservation ecosystem operations[34] .

The principle of equity is guided by access and gender inclusion towards issues on inequities between rural communities and men and women the latter to tackle opportunities for women who traditionally collect water. Other Non-Governmental Organization (NGO) work, including Oxfam Pacific's water programs in the Solomon Islands, advance woman in water governance, and of WHO/UNICE data sets rural urban access deficits[10] . Partnerships and capacity building for water security impact can be enhanced with collaboration from government, NGOs and communities, such as the UNDP's Pacific Risk Resilience Programme project, and training local community water resource managers in Tonga. The Pacific Water and Wastewater Association demonstrates as a regional network for knowledge sharing supporting programs[23] .

These principles and practices integrate water security systems in a manner suited to the context, include principles of resilience, and inclusion, but remain limited by available funding and gaps in data [36]. Future work for water security systems must build from existing or successful models, adopt new technologies such as remote sensing, while also enhancing collaborative efforts across the region towards globally advancing Sustainable Development Goal 6.

# 9. Results and Discussions

Using a variety of materials promotes an integrated understanding of water security as it employs both academic and practical forms of learning and is reflective of community knowledge. Academic literature is a great basis for any theoretical foundations, but the generalized focus of the literature can overlook the unique characteristics pertaining to the Pacific, such as cultural water management traditions. Government and organizational documents can be used to better appreciate the policy context that surrounds water security, but they may lack critical details around implementation challenges. NGO reports dismantle the generalizability gap of academic literature and government reports by providing specific perspectives of community-based realities but are less likely to uphold the rigor and standard of academic literature. The qualitative reviews and case studies used in the studies of the Pacific context are helpful in allowing researchers to examine specific vulnerabilities like those pertaining to islands impacted by climate change as a result of their diversity. As a result of varying methods employed, some papers lacked quantitative methods and limited measuring of water security outcomes systematically. Participatory methods are a plus because they can demonstrate community empowerment and how indigenous or local knowledge was utilised. However, participative research can also pose its own challenges in need of facilitation to adequately represent community interest and potential biases [24]Future research may strengthen the methods investigated in this domain using some of the innovations proposed by [45]such as remote-sensing technologies for monitoring water resources to promote equity and also longitudinal studies as an approach to understand longer term outcomes as a result of the many activities that support water security.

Pacific Island Countries face special vulnerabilities in their water services due to operational dimensions and funding limitations as well as cultural difficulty and administrative barriers toward technical assistance. The authors state[17] that water need assessments become complicated by the existence of regulatory complexity while situations vary widely and systematic data is difficult to obtain. A method to evaluate water services vulnerability emerged from water specialist knowledge and experiences which were collected through a documented group interaction called Delphi survey. The Delphi survey involved multiple interviews with stakeholders who included panels of experts as well as funding agencies together with local decision-makers. The Delphi process revealed important factors of vulnerability that have led to the creation of an index methodology development. The index methodology develops equivalent dimensions and variables and weight distributions through mathematical expressions comparable to the Climate Vulnerability Index. Water services in Pacific Island Countries can be assessed for their relative vulnerability through this method because variables have received quantitative measurements. The index development method shows potential for adaptation in suitable scenarios aside from its current application. Pacific Island countries and territories (PICTs) are particularly vulnerable to water-related diseases. As such, the World Health Organization (WHO) considers the cross-sectoral control of water-related diseases among the highest priority health security issues for the Western Pacific Region. The region has the lowest access to safe drinking water sources, with 41% of the population relying on surface water and other unimproved sources. Access to an improved drinking water source is higher in Fiji, with 94% of the population accessing a basic service, however, there is no published data on whether those sources are safely managed. The most recent Fiji Government estimates are that 37% of Fiji’s wastewater is disposed directly into land and marine environments and there is no available national data on the proportion of sanitation systems that are safely managed. Fiji has had over 20 reported typhoid outbreaks since 2005, a 27,000 case outbreak of dengue in 2013–2014, and multiple outbreaks of leptospirosis post-cyclone and heavy rainfall events[14]

# 10.Understanding Water Challenges in Pacific Island Countries

Pacific Islands face major development obstacles because they maintain small populations and they are geographically distant from main marketplaces and they possess limited operational capabilities[46]. Urbanization in these countries progressively grows to reinforce the need for additional urban infrastructure and services[47]. Urban service delivery problems demand solutions which national and local authorities find difficult to tackle[47]. The rising volume of diverse waste in Pacific Island Countries becomes problematic because populations increasingly reside in urban areas along with the adoption of new lifestyles[48].

The water supply problems faced by population centers of small islands stand as some of the most serious throughout the world. The restricted land space prevents the development of surface water storage facilities. The freshwater resource stands as a highly susceptible element to natural environmental processes and human-made operational activities. Frequent droughts related to ENSO limit the available freshwater reserves on restricted land territories.

Water requirements keep increasing at a time when the population expands through organic growth and as urban areas develop. Most small island nations have a scarcity of water specialists and their policies and institutions fall short while local populations take insignificant part in water resource management. The agricultural sector uses water which directly diminishes the water availability for community use.

Building sustainable long-term relationships should promote local communities to become self-reliant. Water management through Multi Agent Systems presents a solution to reduce conflicts associated with water supply. Regional organizations should create self-supportive structures which play an essential role in developing localized water solutions that belong to the islands[2].

## 10.1 Various real-life examples demonstrate water distribution problems

Suva along with other urban settings of Fiji Island has access to advanced water infrastructure although rural regions commonly use water sources that remain untainted yet insufficient. The frequency of cyclones alongside floods continuously damages water systems which presents the requirement for infrastructure that can withstand adverse weather conditions. Kiribati experiences disastrous saltwater intrusion that makes its groundwater unfit for human use so the population needs imported water and rainwater collection systems for water access. The shortage of financial resources prevents the establishment of sustainable pipelines for water distribution. The water accessibility situation in Papua New Guinea (PNG) reveals a grim picture because 60% of its population lacks access to clean water particularly affecting the rural populations due to harsh terrain and defective infrastructure. Community-owned rainwater tank projects demonstrate promising results but the country needs widespread implementation to improve water service for all citizens.

## 10.2 Kiribati: Challenges in Drought-Prone Areas

Kiribati, another low-lying atoll nation, has faced significant challenges in ensuring reliable water supply, particularly during prolonged droughts. The country’s reliance on rainwater and fragile freshwater lenses has made it highly vulnerable to climate variability.

## 10.3 Challenges in Policy and Government Framework.

**Good governance is crucial for solving water problems in small island nations, but many Pacific Island countries, like Kiribati, struggle to create effective policies. Kiribati faces some of the worst water and sanitation challenges in the world, with high child death rates from dirty water. Yet, the country still has no national water policy, laws, or long-term plans to fix these issues. Past efforts to improve water management like forming a National Committee has failed because government ministries didn’t work well together, roles were unclear, and there was little sharing of information. These committees also relied on short-term foreign funding, so they didn’t last. Right now, there’s no system to coordinate water and sanitation efforts between the government and communities, create policies, or get all government agencies working together[49]**

## **10.4 Cost Considerations in Water Safety Plan Implementation**

Water safety continues to cause substantial health risks across every income level worldwide. The World Health Organization (WHO) recommends Water Safety Plans (WSPs) as the top method for maintaining continuous safety of drinking-water supplies[50]. Research has confirmed WSP implementation produces health benefits but current data insufficiently connects expected costs to water supplier characteristics. Costs of Water Safety Plan implementation within the Western Pacific Region depend on characteristics found in drinking-water supply agencies. Implementing the Water Safety Plans among six water suppliers in the region shows that WSP implementation expenses will be minimal for established DWSAs. The wide range of implementation costs in developing DWSAs demonstrates that additional research into WSP general cost estimation may be limited in its effectiveness. Developing DWSAs face massive unpredictable costs that affect both their capital assets and their operational costs for monitoring purposes. To establish a safe water supply organization, need to enhance their capital and operational monitoring but this improvement requires future financial backing and technical support to perform effectively. Understanding all expenses related to water safety efforts proves crucial for Pacific Island countries which want to maintain stable water security programs [50].

# 11. Innovative Approaches to Water Management in Pacific Islanders

Pacific Island countries have developed multiple creative approaches to manage their water resource challenges and Chuuk State in Federated States of Micronesia exampled the creation of a non-traditional system to improve environmental analysis capabilities and water disease prevention methods in villages[51] The approach implements Geographic Information Systems (GIS) training together with basic management and environmental health education for community members at ground level and collaboration with civil society for innovative technological support. Results from this approach generate valuable information about remote and rural and least-wealthy small islands while giving direction on Western Pacific environmental management and helping with the development of worldwide outreach programs to enhance conditions in similar islands[51].

# 12. Grassroots Initiatives for Reliable and Sustainable Water Access

Developing regions now prioritizes Sustainable Rural Water Supply Schemes (RWSS) that communities run as core water infrastructure projects. Rural population access has been the main objective of these water delivery systems with their purpose to provide reliable sufficient safe drinking water. Community management operates as an established model for sustainable practices yet faces obstacles because of social, technical, institutional and financial restrictions. Community management succeeds through enhancements of external resources which need institutional backing that provides financial support alongside technical help and training together with administrative assistance to maintain long-term sustainability of RWSS. The sustainability of water supply schemes depends on community involvement throughout planning stages and implementation and maintenance period as well as water tariff setting and ownership and transparency and leadership and management activities[52].

# 12.1 Combining Indigenous and Contemporary Water Governance Methods

Traditional water risk management knowledge has been preserved by Pacific Island communities throughout multiple generations. The rising climate dangers demand Pacific Island communities to unite traditional knowledge with scientific research together with policy frameworks for creating stronger water systems. A combined approach of scientific innovation and ancestral water knowledge builds stronger defenses against freshwater shortages. “As a combined method of ancestral practices together with climate adaptation research developers can create appropriate solutions which build water security and community resilience[53].

*Fig 3. Traditional knowledge of managing water. source google image*

## 12.2 Holistic Water Governance Model for the South Pacific

Water scarcity in urban areas is putting strong pressure on water supplies which has led water managers to expand their analysis by including water governance aspects. Integrated water management emerged as a framework which demonstrates the requirement to evaluate social along with institutional and economic aspects along with technical and ecological aspects. The designated framework emphasizes social along with institutional aspects which matter for water management practices in South Pacific areas while Suva's rapid population growth demonstrates the multifaceted nature of water management challenges for Pacific Island nations. Pacific Island countries require better accounts of inter-agency communication along with community education and public engagement as well as institutional coordination of water pricing and water monitoring systems to enhance their systemic water resource management[54].

## 12.3Coordinating Water Solutions: The Vital Function of Regional Organizations

This article aims to highlight the work of South Pacific regional organizations, which play a key role in creating legal frameworks for environmental protection. Pacific nations are among the hardest hit by climate change, so leaders, businesses, and activists are working together to safeguard their islands. They’ve used discussions, workshops, and non-binding agreements ("soft law")—and more recently, enforceable legal measures ("hard law"). However, progress faces challenges due to structural and social barriers in the region. It also analyzes legal documents from national and regional organizations, as well as summit agreements and policy statements. Its goal is to: (1) raise awareness about the Pacific’s growing independence from global powers, and (2) show how grassroots efforts—led by these regional groups—offer new approaches to environmental protection. Still, the conclusion notes that Pacific island nations have a long road ahead in strengthening regional cooperation and effectively implementing these laws[55]. **By working together through regional groups such as the Pacific Islands Development Forum (PIDF), member nations can tackle shared water issues more effectively through collaboration, shared expertise, and combined resources [35].**

## 12.4 Future Directions for Sustainable Water Management

Small island nations require complete water security approaches which unite various strategies to successfully resolve their water security issues. Forecasting sustainable water management needs three core elements that is, cultural water management systems created from combining local insights and scientific data and stronger governance of water resources and improved policies and enhanced water resource control by communities. The Pacific region serves as an example to develop sustainable water management models for islands while Croatia represents a context in which this model should be created first on its islands then expanded toward coastal lands and the mainland. Islands should combine decentralized technologies and water reuse and ecological desalination planning to improve their water resource management while climate change and development pressures increase. The process toward resilience relies heavily on education because it enables citizens to gain capabilities that build resilience[53]. The combination of decentralized technologies with water reuse systems and ecological desalination methods will help islands handle their scarce water supplies when faced with growing development and climate-related challenges. The process of sustainable water management depends heavily on education because properly educated communities ensure the successful implementation of sustainable practices[56]

## 12.5 Opportunities for Improvement -Successful Water Distribution Models

Pacific Island nations face significant challenges in maintaining reliable water distribution systems due to financial constraints, aging infrastructure, and limited technical expertise. Many countries struggle to afford modern water infrastructure, such as pipelines and treatment plants, while old and poorly maintained systems lead to severe water losses—sometimes up to 50% of treated water. Fiji, despite having relatively advanced infrastructure, still loses around 40% of its water supply in urban areas like Suva due to leaks and insufficient maintenance, leaving rural communities with inconsistent access. To address these issues, increased investment in infrastructure upgrades, improved maintenance practices, and capacity-building programs are essential. International partnerships can play a key role by providing funding and technical support to help modernize water systems, reduce waste, and ensure sustainable access to clean water across the region.

## 12.6 Fiji: Integrated Water Resource Management (IWRM

Fiji has implemented Integrated Water Resource Management (IWRM) to improve its water delivery to users by managing water, land, and other resources together to improve access, quality and climate adaptation especially in rural and peri urban environments[33].Each have been initiatives, such as rainwater harvesting reservoirs for schools and health facilities, the ADB funded Suva-Nausori Water Supply Project that services over 300,000 people in urban areas, and the promotion of water conservation with Water Committees lead by the community [24]. In Tuvalu international support has provided solar-powered desalination plants to provide clean water from saltwater intruded water sources while using renewable energy, to substitute for fuel and imported products, and the trained community where the systems are located, ensures the plant will continue to be used properly and sustainably by the community[57]. These approaches simultaneously improved water security by embracing challenges that are environmental and social.

Three real-world examples demonstrate how rainwater harvesting techniques succeed in the Pacific region according to the following case studies. The Polynesian kingdom of Tonga received help from government authorities and international partners to install community-based rainwater harvesting systems because their freshwater lenses are unstable and rainfall patterns are inconsistent. The water infrastructure included little capacity rainwater tanks for residential water storage and educative training sessions run by community members to develop sustainable practices [29].. Rainwater harvesting systems were introduced to Fijian schools and health clinics to address water supply problems caused by old infrastructure coupled with climate change effects. The implementation included large storage tanks while staff received training about water quality assessment alongside tank implementation. [30]documented how this program expanded student and patient access to water while cutting down water-based illnesses and proving rainwater harvesting represents an affordable strategy for institutional storage. Tuvalu established rainwater harvesting as a core element of its climate resilience strategy because the country faces severe risks from rising seas and saltwater issues. Households and communities obtained tanks through government financial support that also used solar-desalinization systems to expand their water sources. Through this approach water security increased while local water dependence diminished and atoll nations learned about effective multiple solution strategies (Pacific Islands Forum Secretariat [PIFS], 2019). Many regional systems have proven capable of both power generation and water distribution tasks which shows the potential for water-energy integration in the area.

# 13. Conclusion

This study set out to identify and evaluate sustainable water-security solutions for Pacific Island Countries (PICs) that integrate indigenous practices with modern technologies to overcome challenges of limited freshwater supply, climate change and socioeconomic barriers. The study confirmed that 75% of the rural population in five PICs, Fiji, Kiribati, Papua New Guinea, Solomon Islands and Vanuatu were using self-supplied water, and 40% facing seasonal shortages. Community-based rainwater harvesting systems had been implemented and were successful, particularly in Kiribati and Fiji, where systems improved accessibility and reduced waterborne related diseases. Hydraulic modeling using EPANET showed the potential of distributed networks increasing resilience, especially at the rural level. In addition to capacity building and regional collaboration, the study showed that hybrid approaches combining untraditional methods (rainwater harvesting) with modern methods (i.e., solar powered desalination in Tuvalu) were a step towards expressed meaning of Sustainable Development Goal 6 (SDG 6) on "ensuring availability and sustainable management of water and sanitation for all" by 2030. Achieving SDG 6 will need an increase in investment each year beyond the current (usd 230-270 million), climate resilient infrastructure provision, and a transition to enhanced community-led governance. While this study provided key observations and insights, there were also shortcomings to our analysis. First, findings exportable beyond the five PICs may hard to generalize as literature reviews based on qualitative assessment and consultation with community groups could fail to maximize validity and reliability of knowledge across a varied Pacific region; hence the need for additional critical studies for dissemination, and significance. Second, water security outcomes from undergoing quantative assessment were limited, because some studies lacked systematic metrics. Third, we were not able to explore the long-term sustainability of methods found to be successful because, in most cases, longitudinal data was not available. These considerations and uncertainties indicate new opportunities for future research reliant on happenings within geographic locations, supported by remote sensing occurring over longer durations, which would validate and further develop the proposed ways forward with PICs. Overall this study provides a solid framework for developing "resilience-based, community-driven water systems that addresses environmental and social challenges while also advancing sustainable development" in PICs such that "communities do not need to return to traditional knowledge"[58] .

# 14.Future Research Directions

For future studies considering the water security experienced by Pacific island communities, innovative technologies such as remote sensing and inexpensive desalination should be incorporated; longitudinal studies to determine practical interventions, such as rainwater harvesting, should be undertaken, and local knowledge should be considered as part of the research process to develop community buy-in [23, 45]. Priority should also be given to ensure equitable access to water, particularly by rural and disadvantaged groups; gendered impacts are also relevant, as are strong, cooperative, regional networks such as the Pacific Water and Wastewater Association (Oxfam, 2019; SPC, 2016) for knowledge-sharing and momentum toward mobilizing resources, and support for inter- and cross-disciplinary and inter-collaboration projects, financially supported, will be crucial to achieve Sustainable Development Goal 6[59].

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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