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Indicators of Climate Resilience in WASH: A Global Systematic Mapping and Gap Analysis

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Abstract

This thesis investigates the global landscape of indicators used to measure climate resilience within Water, Sanitation, and Hygiene (WASH) services through a systematic mapping and gap analysis. As climate change increasingly threatens water security and public health, there is an urgent need for theoretically grounded monitoring frameworks to evaluate systemic resilience across diverse contexts. This thesis develops a three-dimensional analytical framework that synthesizes Sen's capability approach, climate vulnerability theory, and institutional theory to assess indicators across socioeconomic, environmental, and institutional dimensions.

The methodology involved a systematic review of 104 indicators collected from 16 academic and policy sources published between 2017 and 2025. The results show a significant imbalance in the current indicator landscape: the environmental dimension has the highest representation, while the institutional dimension has the lowest representation. Although the WASH sector demonstrates a significant commitment to monitoring equity, inclusion, and strategic alignment, significant shortcomings were identified in accountability mechanisms, economic viability, and community agency.

The thesis concludes that current monitoring practices often prioritize technical "means" and formal "rules-on-paper" over the functional "rules-in-use" and adaptive capacity required to sustain WASH services during climate stress and shocks. To achieve the long-term targets of SDG 6, the thesis argues for a fundamental shift from static status assessments toward monitoring the adaptive efficiency of institutions and the economic resilience of users. These findings provide a theoretically grounded roadmap for developing more balanced, regionally adaptable monitoring frameworks that capture the dynamic nature of climate resilience.

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Keywords

Climate-resilient WASH, Systematic mapping, Gap analysis, Capability Approach, Climate Vulnerability Theory, Institutional Theory, Indicators, SDG 6.

List of Abbreviations

EMIS - Education Management Information Systems

GLAAS - UN-Water Global Analysis and Assessment of Sanitation and
Drinking Water

IPC - Infection Prevention and Control

IPCC - Intergovernmental Panel on Climate Change

IWRM - Integrated Water Resources Management

JMP - Joint Monitoring Program (WHO//UNICEF)

PRISMA - Preferred Reporting Items for Systematic Reviews and
Mets-Analyses

RQ - Research Question

SDG - Sustainable Development Goals

SMOSS - Safely Managed On-Site Sanitation

UNICEF - United Nations Children's Fund

WASH - Water, Sanitation, and Hygiene

WHO - World Health Organization

WinS - WASH in Schools

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1. Introduction

1.1 Climate Change, Climate Resilience and WASH

Risks and concerns associated with climate change arise from both extreme events, known as climate shocks, and more gradual, long-term effects, known as climate stress. Heatwaves, droughts, floods, storms, and wildfires are examples of extreme climate shocks that are becoming more frequent and, in some cases, more severe due to ongoing climate change (World Health Organization, 2023). When it comes to WASH services, climate change has the potential to worsen water stress and insecurity, increase the spread of waterborne infectious diseases, which may result in illness, death, service disruptions, and displacement. Climate change also has the potential to slow or reverse progress in improving WASH accessibility, increase inequality, and jeopardize the achievement of Sustainable Development Goals (SDG) targets and human rights. Threats that have already emerged will be exacerbated by long-term changes in temperatures, rainfall, and rising sea levels. In recent decades, significant water stress has been driven by pollution, overexploitation, and climate change worldwide. As a result, in research, policy, and development efforts, the WASH sector is focusing more on lowering the sensitivity or strengthening the resilience of WASH services to climate change (Kohlitz, Chong and Willetts, 2017; United Nations, 2023; World Health Organization, 2023).

People's resilience to the effects of climate change relies heavily on WASH. Climate-driven droughts and floods are extreme weather events that exacerbate problems such as pollution and water scarcity. These climate-driven issues increase public health risks by jeopardizing the security and reliability of WASH services. Recovery efforts can be made more difficult by environmental disasters, which can also strain sanitation systems, further reduce the availability and quality of water supplies, and cause long-lasting damage to WASH infrastructure (UNICEF, 2023b). Without access to essential services like WASH, people are at risk for malnourishment, illness, and water scarcity. However, according to WaterAid (2023), WASH services can increase people's climate change resilience in multiple ways. By establishing a dependable and

secure water supply, people can access clean water even during periods of drought. WASH services can also reduce the risk of environmental and water-supply contamination during floods. Expanding water storage to provide a vital reserve during times of scarcity and enable delivery when and where it is required.

Additionally, WASH can keep people healthier and better equipped to handle the problems posed by climate change. To prevent illness, WASH can also improve hygiene standards. As a result, this reduces the likelihood of secondary health emergencies and the strain on healthcare systems following flooding events, eventually strengthening community resilience (WaterAid, 2023). According to the United Nations, more than 4.2 billion people lack access to properly managed sanitation, and 2.2 billion lack access to securely managed drinking water worldwide. This problem is becoming worse due to climate change, which is causing more floods and droughts. Around 80% of wastewater worldwide returns to the environment untreated or is reused, and 70% of the world's natural wetland area has been destroyed, including many freshwater species (United Nations, 2023).

To support the development of a broader community and health resilience, WASH services and practices must be resilient to climate change (UNICEF, 2024b). WASH faces serious challenges with climate change. Droughts will reduce the amount of available water and degrade water quality. Increased floods will pollute water sources, damage ecosystems, and harm infrastructure. Floods will also cause tanks, sewers, and pit latrines to overflow, as well as the bypassing of wastewater treatment facilities and the spread of contaminated runoff from cities, businesses, and agricultural areas. The amount of water needed to maintain sufficient water intake will fluctuate as temperatures rise, potentially negatively impacting wastewater treatment systems and harming infrastructure in areas where permafrost is melting. Water shortage will be exacerbated by glacier erosion. Water quality and watershed areas will be deteriorated by wildfires. Rising sea levels and storm surges, brought on by

windstorms, will make water supplies more vulnerable to saltwater contamination (World Health Organization, 2023).

Furthermore, building health resilience to climate change, assisting society in coping with climate shocks, and promoting long-term recovery all depend on having access to WASH services. By keeping people healthy and ensuring they drink enough water as temperatures rise, they also help people cope with climate stress (World Health Organization, 2023; UNICEF, 2024b).

Societies and ecosystems are at greater risk due to rising sea levels, more frequent climate shocks, and higher global temperatures. In light of the growing effects of climate change, climate resilience is an important concept. The term “climate resilience” refers to a collection of tactics and actions intended to increase systems’ and communities’ ability to adjust to, endure, and recover from climate stress and climate shocks (Khan, Khan and Srivastava, 2024).

For developing nations, lowering their vulnerability to climate change has been a top priority in recent years for two distinct reasons. These nations' economies are largely reliant on industries and resources that are extremely vulnerable to climate stress and climate shocks. There is also a lack of resources or other essentials needed to adequately address the social and economic effects of climate change. In order to effectively address climate change within the framework of sustainable development, vulnerability and adaptability assessments must be conducted first. These evaluations will pinpoint risks and issues as well as the tactics, regulations, and measures required to address them. By addressing current vulnerabilities, future vulnerabilities resulting from climate change can be reduced (Winograd, n.d.).

People's resilience to the effects of climate change relies heavily on WASH. Pollution and water scarcity are issues exacerbated by climate change. Environmental problems put the security and reliability of WASH services at risk, thereby raising public health risks (UNICEF, 2023b). By developing climate-resilient WASH services, people's resilience to climate change increases. The impact of climate-resilient WASH on individuals is multifaceted. As a

result, this thesis has decided to focus on three dimensions, organized around three theories. Indicators will be analyzed and structured using the capability approach, climate vulnerability theory, and institutional theory.

1.2 Problem Statement

Although climate-resilient WASH services are receiving more attention, there is a lack of a comprehensive, theoretically supported summary of the indicators used to measure climate resilience in policy documents and scientific articles. It is unclear how these indicators are spread throughout the many aspects of climate resilience, including institutional, environmental, and socioeconomic aspects, and whether some aspects are well represented or underrepresented. Furthermore, it is unclear how much the indicators' focus differs across geographical settings. This could make it challenging to create fair monitoring frameworks and to methodically evaluate and compare the climate resilience of WASH services across various circumstances.

This thesis develops a three-dimensional analytical framework that includes the socioeconomic, environmental, and institutional dimensions of climate resilience in order to address this gap. Each dimension has three sub-dimensions to provide a more detailed mapping of the indicators. The socioeconomic dimension includes equality and inclusion, economic viability, and community agency; the environmental dimension addresses hazard exposure, system sensitivity, and adaptive capacity; the institutional dimension includes strategic alignment, capacity and resources, and accountability mechanisms. In addition to enabling descriptive mapping of existing indicators, this structured method allows for critical evaluation of conceptual balance and geographic differences, exposing potential gaps in current indicators.

1.3 Aim and Research Questions

A significant part of sustainable development is WASH, and the variety of services it offers supports economic growth, environmental sustainability, and poverty reduction (United Nations, 2023). The primary aim of this thesis is to investigate which indicators are used in scientific literature and policy to measure climate resilience in WASH, and how they are distributed across the three-dimensional analytical framework. The thesis also examines the geographical patterns that emerge and identifies the main shortcomings and implications for policy and practice.

Research Questions

RQ 1: Which indicators are used in scientific literature and policy to measure climate resilience in WASH?

RQ 2: How are the indicators distributed across the three-dimensional analytical framework?

RQ 3: Which geographical patterns emerge within the existing indicators?

RQ 4: What are the main shortcomings and implications for policy and practice?

1.4 Delimitations

This thesis focuses on indicators for measuring climate-resilient WASH services and is limited to peer-reviewed scientific literature and policy documents published in English from 2017 to 2026. It does not include all technical or financial performance indicators; instead, it focuses on the three dimensions of climate resilience: socioeconomic, environmental, and institutional. The thesis does not use primary data-gathering methods such as surveys or interviews; instead, it uses a systematic review to document analysis and literature reviews.

1.5 Structure of the Thesis

There are six main chapters in this thesis. In the first Chapter, the thesis background, problem statement, aim, research questions, and delimitations are presented. In Chapter 2, the literature review and theoretical framework are presented, including a summary of prior studies on climate-resilient WASH, current indicator frameworks, and the three-dimensional analytical framework used in this thesis. The research design and methods are covered in Chapter 3, along with the systematic literature review process, selection and exclusion criteria, data extraction and coding procedures, and issues of validity and reliability. The empirical findings on indicators for climate-resilient WASH services are presented in Chapter 4, along with an overview of the scientific literature and policy documents included. The findings are analyzed and discussed in Chapter 5, together with their implications for policy and practice, geographical trends, and the three-dimensional analytical framework. The thesis is finally concluded in Chapter 6, which summarizes the key findings and makes recommendations for future research and indicator development.

2. Theoretical Framework

This chapter synthesizes the three theoretical perspectives: Sen's capability approach, climate vulnerability theory, and institutional theory, into an analytic framework for examining climate-resilient WASH indicators. This synthesis acknowledges that a WASH system's resilience stems from the complex interplay among its socioeconomic outcomes, environmental conditions, and institutional foundations, rather than from an isolated analysis of any single dimension.

The socioeconomic dimension is based on the capability approach and ensures that the long-term purpose of resilience is understood not only as the survival of infrastructure but as the protection of human functionings and freedoms. The socioeconomic dimension emphasizes that a WASH system is truly resilient only if it enables all people to maintain their health and dignity during climate stress and shocks without experiencing capability deprivations. By focusing on equity

and inclusion, economic viability, and community agency, the dimension achieves this.

The environmental dimension provides the technical and contextual mechanics of resilience through the lens of climate vulnerability theory. The dimension operationalizes the relationship between hazard exposure and system sensitivity, defined by the “dose-response relationship”. By including adaptive capacity, the environmental dimension tracks the technical and environmental aspects that allow WASH services to endure and recover from climate stress and shocks. Environmental factors are seen as “conversion variables” in this dimension, which can either help or hinder the transformation of resources into valuable human achievements.

Lastly, the institutional dimension provides the enabling environment through the “rules of the game” defined by institutional theory. It distinguishes between the actual capacity, resources, and accountability mechanisms (functional “rules-in-use”) and strategic alignment (formal “rules-on-paper”). This perspective is important because it recognizes the governing frameworks needed to sustain socioeconomic and technical advancements over time. Strong institutions promote “adaptive efficiency”, which enables systems to use established feedback loops to address service disruptions and learn from climate data.

Together, these three dimensions create an analytical three-dimensional framework (summarized in Table 1) that enables systematic mapping of existing indicators. By applying this framework, the thesis can identify not only what is being monitored but also the hidden shortcomings that determine whether WASH services can truly withstand and recover from the long-term stress of a changing climate.

2.1 Sen's Capability Approach

Amartya Sen's capability approach, which focuses on what people can truly be and achieve, offers a framework for assessing social justice and human development. Many people around the world suffer from different variations of unfreedom. Access to clean water is one of the most fundamental freedoms, a basic necessity for survival. The lack of clean water limits people's capabilities, such as leading a good, long, and healthy life (Sen, 2001, pp.13–14). Amartya Sen's Capability Approach focuses on people's ability to achieve the kind of life they have reason to value. Sen argues that the most significant aspect of assessing people's well-being is recognizing what people are truly capable of. The quality of life that people can truly attain is the main focus of the capability approach. The capability approach makes a significant distinction between the means of living (resources) and the objectives of life (functionings). Infrastructure, money, and income are examples of resources. Sen suggests that these are just practically significant, even though they are crucial "general-purpose means" for gaining more freedom. They are not the final aim of growth; rather, they are merely helpful for what they enable an individual to do. The principle of functionings, which has its roots in Aristotelian philosophy, represents the different activities that people may find meaningful to do or be. These might be as simple as being well and free from preventable illnesses, or as complex as maintaining one's dignity and participating in society (Sen, 2001, pp. 24, 72–76).

Capabilities are the different combinations of functionings that an individual can do, whereas functionings are actual accomplishments. Capability is a type of "real freedom" since it emphasizes an individual's actual options, based on their social and personal circumstances. Moreover, the capability approach also makes a contrast between the "comprehensive outcome" (the process and choices involved) and the "culmination outcome" (what happens). A person who fasts, for instance, has the same functioning (being hungry) as an impoverished person who is forced to starve; however, the former holds a differing capability set since they made the decision not to eat when they could have (Sen, 2001, pp.17, 27, 75–76).

The fundamental ideas of *functionings* and *capabilities* are used to study this quality of life. Functionings are “being and doing” states, such as having access to clean water and a place to live. It is important to separate them from the means used to accomplish them. The collection of useful functionings to which an individual has effective access is referred to as capability. A person’s capability, then, is the actual freedom a person has to select from various functional combinations, or from various types of existence, that she/he has a good reason to value (Wells, n.d.). Increased independence improves people’s capacity to shape the world and to empower themselves, two aspects that are essential to the process of development (Sen, 2001, p.18). The capability approach also highlights that there is no consistent or automatic link between capabilities and resources. How well someone could turn riches into actual freedoms is determined by conversion variables. Sen identifies five factors that influence the conversion of resources into capabilities.

First, personal heterogeneities refer to differences in people’s physical attributes, such as age, gender, or sickness, which cause a range of demands. For instance, a person with a disease may require more resources to combat it than someone without the disease would (Sen, 2001, p. 70). Second, environmental diversity includes factors such as temperature fluctuations, rainfall, flooding, and other climatic variables, which can influence individuals’ earnings at a given income level. The quality of life can also be changed by infectious diseases such as AIDS, cholera, and malaria. Besides diseases, pollution and other environmental problems may also affect the quality of life (Sen, 2001, p. 70). Third, variations in social climate concern the broader social and institutional context, including the availability of public services such as security and education, as well as the nature of interpersonal interactions within the community, all of which can shape living conditions and opportunities (Sen, 2001, pp. 70–71; Wells, n.d.). Fourth, differences in relational perspectives refer to the fact that, depending on traditions and norms, different societies may have different needs for the commodities that sustain established behavioral patterns. In a wealthy society, for instance, having the ability to “appear in public without shame” might demand greater standards of attire and other visible actions than in a poorer

society. The personal resources required to fulfill self-respect may be subject to the same contextual fluctuations. Although the problems are usually related, this is mostly an intersocietal variance rather than an interindividual variation within a particular society (Sen, 2001, p. 71). Lastly, distribution within the family concerns norms that establish, for instance, how food and medical care are distributed between parents and children, and between men and women (Wells, n.d.).

Sen has always advocated for people to focus on the fundamental freedoms that people experience in their daily lives. Sen believes that people should focus on the actual chances they have of achieving their goals, in contrast to the prominent utilitarian perspective in ethics, which focuses on utility-based measures of well-being. Accordingly, the idea of functionings, or what an individual is or can accomplish, is essential to the study of poverty or deprivation (Morris, 2009).

When it comes to analyzing poverty and inequality, the capability approach is a significant tool because it changes the emphasis from means to outcomes and opportunities.

2.1.1 Connecting Capabilities and Climate-Resilient WASH

In the context of WASH, the capability approach highlights that access to these services is about more than simply infrastructure; it is about the real freedom that enables people to live lives they value. A basic requirement for survival and a human right is having access to securely managed WASH services. WASH services are a crucial part of several significant outcomes in the capability approach. To begin with, inadequate access to clean water and sanitary facilities causes avoidable illnesses and early deaths. WASH services help people stay healthy, which is crucial for overcoming the issues posed by climate change (Sen, 2001, pp.15–17; WaterAid, 2023). Additionally, education needs “participatory freedom”, which is hindered if an individual is always battling avoidable illness. For instance, children's “real freedom” to attend school is

limited if they are sick with waterborne diseases or have to travel far to obtain water (Sen, 2001, pp.32–33, 39). Reliable WASH services are also essential for reducing poverty and promoting economic growth (United Nations, 2023). Without them, those who are supposed to be “active agents of change” are instead seen as passive recipients of aid during disasters (Sen, 2001, pp.177–178). Being able to appear in public without feeling shame is another essential functioning. For women and girls in particular, having private and secure restrooms is crucial for preserving dignity and a sense of self (Sen, 2001, pp. 71, 75).

Furthermore, climate shocks can significantly constrain capabilities, even when infrastructure is in place, by disrupting the link between resources and outcomes. Severe floods have the potential to overwhelm healthcare systems, contaminate previously clean water, and harm supply systems by releasing diseases from latrines into the environment. Even though the toilets are still there, droughts cause water scarcity, making flushing and handwashing difficult. Rising sea levels make groundwater more saline, making it unsuitable and damaging septic tanks. In these situations, the environmental conversion factor has changed, making the resource (a pump or a latrine) no longer convert into the capability (health or sanitation) (Sen, 2001, p. 70; WaterAid, 2023).

2.1.2 The Socioeconomic Dimension

In order to categorize and analyze indicators of climate-resilient WASH, this section adapts the capability approach into a socioeconomic dimension. The analysis builds on Sen’s distinction among resources, functionings, and capabilities by examining whether indicators reflect people’s real opportunities to benefit from WASH services during climate stress and shocks. In practice, this entails giving extra attention to concerns such as agency, participation, affordability, equality, and inclusion, as well as the ways that WASH services either enhance or limit people’s capabilities to sustain their own wellness (Sen, 2001; United Nations, 2023; WaterAid, 2023). The socioeconomic dimension is

divided into three sub-dimensions: equality and inclusion, economic viability, and agency and participation.

Indicators related to who could benefit from climate-resilient WASH services are addressed by the first sub-dimension, equality and inclusion, within the socioeconomic dimension. This involves whether or not accessibility and availability of services are taken into account for groups that frequently experience structural disadvantages, such as low-income families, women and girls, rural communities, and isolated regions. Therefore, indicators that specifically address social group inequalities, monitor the availability of services for those most vulnerable during climate stress and shocks, or strive to ensure “no one is left behind” will be considered features of capabilities relating to equality and inclusion (Sen, 2001).

The second sub-dimension, economic viability, surrounds economic vulnerability. From a capability standpoint, WASH services are not socioeconomically resilient if people must access them at the expense of other necessities, such as food, healthcare, or education. The impact of WASH services on people's economic freedoms under climate stress and shocks will be determined by indicators related to service costs relative to income, the presence of social protection systems, or the risk of exclusion. These indicators indicate whether people can continue to have access to clean water and sanitation facilities during droughts, floods, or poverty without compromising other aspects of their well-being (Sen, 2001; WaterAid, 2023).

The third sub-dimension of the socioeconomic dimension focuses on participation and agency. According to the capability approach, socioeconomic resilience involves both access to services and the opportunity to influence the decisions that govern them. Indicators associated with people's participation in planning processes, the presence and impact of issues and accountability systems, or the representations of marginalized communities in WASH committees or decision-making bodies will be considered as showing agency-related capabilities. Instead of being passive consumers of externally determined solutions, these indicators reveal if people may have an impact on

how climate shocks are regarded and managed within the WASH sector (Sen, 2001).

The indicators that primarily address these capability-related issues will be categorized within the socioeconomic dimension. These three sub-dimensions, equality and inclusion, economic viability, and agency and participation, will define the socioeconomic dimension. This approach keeps the coding rooted in the principles of the capability approach. Additionally, it establishes a foundation for examining whether existing climate-resilient WASH indicators prioritize some socioeconomic aspects of resilience over others and for identifying significant gaps in this dimension.

2.2 Climate Vulnerability Theory

Vulnerability is an important yet complex concept in climate research that has evolved significantly over time. Exposure, sensitivity, and adaptive capacity are three key components that define vulnerability, according to the framework of the Intergovernmental Panel on Climate Change (IPCC) and academics such as Hans-Martin Füssel (Füssel and Klein, 2006; Füssel, 2007). The term “exposure” describes how and to what extent a system is exposed to climate stress and shocks. It addresses different climate-related risks or stressors that a system experiences depending on its location and the regional signs of climate change, such as rising temperatures, floods, or droughts (Füssel and Klein, 2006; Füssel, 2007; WaterAid, 2023). On the other hand, sensitivity refers to how much a system is affected by climate stressors or shocks, both positively and negatively. It shows how exposure and impact are related in a “dose-response relationship”. For example, a region’s geography or land cover might influence how strongly it responds to threats such as storm surges (Füssel and Klein, 2006; Füssel, 2007). Furthermore, adaptive capacity is the capacity of a system to adapt to climate change, including its unpredictability and extremes, to mitigate potential harm, maximize opportunities, or address the aftermath. It is influenced by “internal” socioeconomic aspects such as financial resources, information,

technology, skills, and institutional strength (Füssel and Klein, 2006; Kelly and Adger, 2000).

It is important to highlight that vulnerability involves more than just “being at risk” or “being exposed”. Instead, it is the result of the complex interactions among these three factors over time. Vulnerability is a combined measure of the predicted overall harm, with sensitivity and adaptive capacity serving as the system’s internal dimensions and exposure serving as its outward dimension (Füssel, 2007; Kelly and Adger, 2000). Furthermore, vulnerability is a dynamic state that is always changing. For instance, a system’s “future vulnerability” depends not only on expected climate change (exposure) but also on how ongoing socioeconomic processes and prior adaptation attempts have affected its sensitivity and adaptive capacity (Füssel and Klein, 2006; Füssel, 2007; Kelly and Adger, 2000). According to this theory, a system with limited exposure may be extremely vulnerable if its internal capacity to react is severely limited, whereas a system with high exposure may remain low-vulnerable if it has low sensitivity and significant adaptive capacity (Füssel, 2007).

2.2.1 Connecting Climate Vulnerability and Climate-Resilient WASH

In the context of climate vulnerability theory and WASH, exposure can be defined as the extent to which infrastructure and its users are affected by climate stressors and shocks. Geographic risks include WASH resources and users in high-risk locations, such as areas vulnerable to flooding, drought-prone areas, and coastal regions at risk from storms and sea-level rise. Systems that rely on water supplies that respond rapidly to environmental changes, such as surface water, hand-dug or shallow wells, and rainfall collection, are particularly vulnerable. For example, coastal groundwater may become more saline due to sea-level rise, rendering these primary sources ineffective (EU, 2025; Füssel and Klein, 2006; Füssel, 2007; Kelly and Adger, 2000; WaterAid, 2023).

In the context of WASH, sensitivity refers to the internal extent to which a threat negatively impacts a WASH system. The connection between a climate shock and its resulting harm to services can be identified as the “dose-response relationship” (Füssel, 2007). If a system has no storage buffers, such as tanks or reservoirs, to deal with supply disruptions, it is more sensitive. Another example is insufficient baseline water quality, pipeline erosion, and neglected infrastructure that cannot withstand physical stress (Kelly and Adger, 2000; WaterAid, 2023). Sensitivity can be seen in how easily services might deteriorate; for instance, heavy rains can transfer pathogens from latrines into water sources, and droughts may make it difficult for people to practice good hygiene, such as flushing and handwashing (WaterAid, 2023).

Finally, adaptive capacity refers to a WASH system’s, community’s, or institution’s ability to adapt to climate change to mitigate potential harm, maximize opportunities, or address the aftermath (Füssel and Klein, 2006). The ability to expand water sources, such as digging more resilient boreholes, developing climate-robust buildings that can endure climate shocks, and setting up storage systems, such as tanks, to function as a safety net during shortages, are all examples of technical and environmental capacity. To effectively restore services following a climate shock, it also requires setting up early warning systems and backup plans (WaterAid, 2023). Planning, investments, and day-to-day operations that include climate risks further improve adaptive capacity. This might mean developing emergency funds for quick repairs or monitoring groundwater and precipitation levels to guide decision-making. Although technical capacity is the main focus, it often includes an institutional component, in which institutions have the authority and resources to support these adaptive strategies in the long run (Füssel and Klein, 2006; WaterAid, 2023).

2.2.2 The Environmental Dimension

In order to organize indicators of climate-resilient WASH, this section defines the environmental dimension using the three key concepts of climate vulnerability theory. The environmental dimension is divided into three sub-dimensions: hazard exposure, system sensitivity, and adaptive capacity. These sub-dimensions reflect how environmental factors and climate impact WASH services, how vulnerable the services are under stress, and how prepared they are to adapt and react over time (Füssel and Klein, 2006; Füssel, 2007; Kelly and Adger, 2000; WaterAid, 2023).

The first sub-dimension within the environmental dimension is hazard exposure, which describes the type and extent of physical exposure to climate stressors and shocks that WASH services and the people they serve experience. Rather than addressing the internal features of WASH systems, indicators categorized within this sub-dimension represent external risks. As an example, by examining if important WASH systems are allocated in areas that are vulnerable to droughts or flooding, the level of dependence on surface water or shallow groundwater that is sensitive to climate change, or the frequency and degree of significant threats that could affect WASH services. These indicators reveal the types of climate stressors that the system is expected to experience (Füssel, 2007; Kelly and Adger, 2000; WaterAid, 2023).

The second sub-dimension is system sensitivity, which measures the extent to which a system is affected by climatic and environmental risks and reflects the resilience or vulnerability of WASH services. The emphasis is on resources, infrastructure, and technological aspects that affect the dose-response relationship. Indicators within this sub-dimension could include dependence on a single water source, insufficient storage or treatment capacity, and aged and poorly maintained infrastructure (Füssel, 2007; Kelly and Adger, 2000; WaterAid, 2023).

The third sub-dimension of the environmental dimension is adaptive capacity, which addresses the ability of WASH services and communities to quickly and

efficiently predict, process, respond to, and learn from climate stressors and shocks. In the environmental dimension, adaptive capacity is understood as specific actions and system features that enable services to operate under changing climate conditions. The existence of climate-resilient infrastructure plans, the use of early warning systems, or the implementation of initiatives that safeguard and restore water-related ecosystems are examples of indicators categorized within this sub-dimension (Füssel and Klein, 2006; Kelly and Adger, 2000; WaterAid, 2023). Instead of responding only to climate shocks after they happen, these indicators show whether WASH systems have integrated adaptability, redundancy, and protective measures that minimize vulnerability over time and enable services to be restored effectively.

2.3 Institutional Theory

Institutional theory examines how historical and social factors shape the behavior of professions, organizations, and other social institutions. It highlights the effects of both internal and external factors on institutions, taking into account how social structures and norms direct both individual and group behavior. Across a variety of social scientific fields, institutional theory proposes two primary frameworks: the organization as institution, which studies internal routines and practices, and the environment as institution, which emphasizes compliance with external forces. When individual behaviors are codified into established patterns that substantially impact interactions and operations within organizations, this process is known as institutionalization (Vadeboncoeur and Rahal, 2025).

Institutions, in terms of institutional theory, are defined as the “rules of the game”, the limits created by humans that govern opportunities and influence interpersonal relationships (North, 1990, pp.3–4). These limitations fall into two primary categories: Formal rules, which consist of policies, laws, constitutions, and regulations that provide a framework for economic and political exchange; and Informal norms, which include societal norms, practices, traditions, and unwritten standards of conduct. Formal rules can be easily changed by political

or court rulings, while informal norms are frequently deeply rooted in society and far more resistant to policy impacts (North, 1990, pp. 4–6). The “players” operating within these institutional structures are organizations. They are functional organizations, such as committees, government agencies, or service providers, composed of people united by a common aim to achieve particular goals. Because organizations are intended to make the most of the opportunities provided by the institutional structure, they frequently end up serving as the primary drivers of institutional change (North, 1990, pp. 4–5, 73).

Important ideas in this framework include path dependency, policies on paper vs. implementation, and coordination, accountability, and legitimacy. Path dependency highlights the importance of history, as a society’s existing institutions are shaped by its past, limiting its future options. Even if the present structure is ineffective, it is challenging to alter once a development path is set, as it is reinforced by self-reinforcing mechanisms, such as learning effects and coordination (North, 1990, pp. 76, 93–94; Scott, 2008). Policies on paper vs. implementation refer to the formal organizational structures and real behaviors; these are frequently separated, a phenomenon known as “ceremonial conformity” or decoupling. While their everyday activities are still regulated by local informal norms or functional realities, organizations might establish formal rules in order to gain legitimacy, appearing relevant and sensible to external observers (Scott, 2008). Coordination, Accountability, and Legitimacy refer to the effective monitoring and disciplinary procedures necessary to sustain the “character of the game” in the delivery of public services. For organizations to operate effectively, coordination abilities must be developed through frequent interaction. Long-term sustainability also depends on whether the regulations provide explicit accountability procedures and are consistent with local circumstances (North, 1990, pp. 4, 74; Ostrom, 2009).

The institutional dimension of climate-resilient WASH in this thesis is understood through the lens of institutional theory. Focusing on how formal and informal rules, organizational structures, and governance practices influence WASH services’ capacity to anticipate, fund, and manage risks associated with climate-related risks.

2.3.1 Connecting Institutions and Climate-Resilient WASH

From an institutional theory perspective, establishing climate-resilient WASH is more of a governance issue than an engineering one. Reservoirs and boreholes are examples of physical infrastructure that offer the “means”; however, whether or not these resources successfully convert into sustainable resources for people during climate stress or shocks depends on the “rules of the game”, which are the institutions (North, 1990, pp.3–4; WaterAid, 2023). Making infrastructure resilient is only one aspect of climate-resilient WASH; another emphasizes fostering a resilient environment. This includes the formal rules and the informal norms that enable the resiliency and maintenance of services and behaviors following a climate shock (WaterAid, 2023).

The Global Acceleration Framework and SDG 6 are examples of global frameworks that offer an overview of sustainable management. However, these principles must be incorporated into local planning procedures and national leadership to achieve actual resilience. Even the most advanced policies “on paper” will not result in long-term sustainability if local “congruence”, where regulations align with local environmental and social conditions, is lacking (Ostrom, 2009; United Nations, 2023; WaterAid, 2023). Integrated Water Resources Management (IWRM), which connects WASH services to broader water security concepts, is essential for resilience. In order to address user disputes and maximize community investment, this calls for efficient coordination among historically distinct sectors, including water, health, climate, and environment (WaterAid, 2023).

Monitoring and sanctioning procedures are also essential to effective governance systems to ensure rule compliance and service quality. This also involves “learning by doing” in a resilient system, where decision-making is informed by, for example, data from groundwater and rainwater monitoring, and rules are adjusted in response to prior mistakes. When services fall short, empowered communities may demand improvements through accountability mechanisms (North, 1990, pp. 74, 81; Ostrom, 2009; WaterAid, 2023).

Furthermore, long-term funding and management that can resist dry spells and floods are necessary for sustainable WASH. This includes ensuring that service providers have the emergency finances needed for quick repairs following climate shocks and aiding local governments in creating and funding specific climate adaptation strategies (WaterAid, 2023). The quality of the institutions frequently determines how well a WASH system performs under climate shocks. An organization may adopt all the necessary climate-resilient structures on paper to gain credibility within systems that demonstrate “ceremonial conformity” or “decoupling”; however, its actual behaviors remain the same. These systems fail in the event of climate shocks because they lack the foundational informal norms and enforcement mechanisms necessary to respond (North, 1990, pp. 4, 6; Scott, 2008). On the other hand, powerful institutions may use adaptive efficiency to make up for technical errors. Decentralized decision-making and “trials and experiments” that enable adaptable and logically customized solutions are fostered by these systems. They can withstand the impacts of a climate shock and ensure that services are rapidly restored because they have redundant, resilient, and reliable systems (North, 1990, pp. 80–81; WaterAid, 2023).

2.3.2 The Institutional Dimension

The institutional dimension is defined in this section by highlighting the aspects of governance and institutions that are significant for the analysis of climate-resilient WASH indicators. According to the institutional theory, the primary focus is on how formal rules, organizational structures, and governance practices affect WASH systems' capability to anticipate, fund, and manage climate-related risks. The institutional dimension is divided into three sub-dimensions: strategic alignment, capacity and resources, and accountability mechanisms (North, 1990; WaterAid, 2023).

The first sub-dimension of the institutional dimension is strategic alignment and refers to the official commitments, duties, and goals outlined in laws, regulations, and strategies. In this context, the question is whether climate resilience in WASH is specifically acknowledged, given a clear purpose, and

included in important planning and policy documents. Examples of indicators in this dimension include the existence of national or local policies on climate-resilient WASH, the presence of climate risk variables in sector strategies, and an understanding of institutional roles and responsibilities for managing climate-related risks in the WASH sector. These indicators are considered to reflect the “rules of the game”, which specify who is in charge of what and how much climate resilience is presented as a primary goal rather than an optional one (North, 1990; United Nations, 2023; WaterAid, 2023).

The second sub-dimension is capacity and resources, which addresses organizations' ability to fulfill these responsibilities in practice, reflecting institutional strength and resource structures. To implement climate-resilient WASH, institutions must have sufficient human, technical, and financial resources, as well as relevant organizational structures and processes, even in the absence of official policies. The availability of workers and technological expertise for climate risk assessment and adaptation, the existence and effectiveness of budgetary resources or funding mechanisms related to climate-resilient WASH, or the presence of planning and coordination procedures that enable organizations to translate climate data into practical decisions are some examples of indicators within this dimension. Instead of relying on temporary programs or external assistance, these indicators assess whether institutions have the capacity and commitment to implement climate resilience over time (North, 1990; Scott, 2008; United Nations, 2023; WaterAid, 2023).

The third sub-dimension of the institutional dimension is accountability mechanisms, which involve how institutional structures promote or restrict public involvement, learning, and feedback. From an institutional standpoint, resilience involves more than just resources and directives; it also entails ensuring that various groups can participate in decision-making and that those in charge can be held accountable (North, 1990; WaterAid, 2023). Examples of indicators that fall within this sub-dimension include whether service providers must report on climate-related performance, whether monitoring and evaluation systems are in place and reflect back into decision-making, whether

communities have access to complaint mechanisms and resolution, or whether marginalized groups are represented in WASH governance structures. These indicators highlight the presence of established structures for oversight, voice, and adaptation, which can improve governance's responsiveness to fluctuating user demands and climate shocks (North, 1990; Ostrom, 2009; WaterAid, 2023).

Even if the collected data does not specifically use institutional terminology, indicators that primarily address these responsibilities will be categorized within the institutional dimension in the thesis.

2.4 Synthesizing the Three Dimensions into an Analytic Framework

This section synthesizes the three theoretical perspectives, Sen's capability approach, climate vulnerability theory, and institutional theory, into an analytic framework for examining climate-resilient WASH indicators. This synthesis is based on the understanding that a system's resilience is not determined by isolated factors but rather the product of a complex relationship between its socioeconomic outcomes, environmental contexts, and institutional foundations. By integrating these dimensions, the framework provides a deductive structure for a systematic mapping that goes beyond descriptive categorization to investigate the underlying conceptual objectives and systemic shortcomings within the sector.

This framework uses a deductive coding approach to categorize indicators, linking each identified indicator to one of the three dimensions as well as its corresponding sub-dimensions in line with its primary focus. The socioeconomic dimension, which is based on Sen's capability approach, ensures that resilience is recognized as the protection of human functionings and freedoms rather than only the survival of infrastructure. Indicators that measure whether a system allows individuals to retain their well-being during climatic stress and shocks are categorized within the socioeconomic dimension and connected to one of its

three sub-dimensions: Equity and Inclusion, Economic Viability, and Community Agency.

Furthermore, the environmental dimension, based on climate vulnerability theory, demonstrates the relationship between external hazard exposure and internal system sensitivity by providing the technical and contextual mechanics of resilience through climate vulnerability theory. Indicators are mapped into these sub-dimensions, or adaptive capacity, to monitor the technological and physical factors that enable services to withstand and recover from climate stress and shocks. Additionally, the institutional dimension provides the enabling environment by investigating the “rules of the game” defined by institutional theory. The dimension includes three sub-dimensions: strategic alignment (rules-on-paper), capacity and resources, and accountability mechanisms (rules-in-use). The perspective of institutional theory is essential to the mapping process since it identifies the governance structures required to sustain technical and socioeconomic aspects over time.

Dimension	Sub-dimension	Core concept
Socioeconomic <i>Capability Approach</i>	Equality & inclusion	Fair access across gender, age, and income groups
	Economic viability	Cost-effectiveness and financial sustainability
	Community agency	Participation, decision-making, and empowerment
Environmental <i>Climate Vulnerability Theory</i>	Hazard exposure	Climate risks
	System sensitivity	Infrastructure vulnerability to climate shocks
	Adaptive capacity	Ability to recover and adapt
Institutional <i>Institutional Theory</i>	Strategic alignment	Policy integration and planning coherence
	Capacity & resources	Technical, human, and financial capacity
	Accountability mechanisms	Monitoring, transparency, and enforcement

Table 1: Three-dimensional framework for climate-resilient WASH analysis

3. Methodology

This chapter describes the systematic review process for identifying, mapping, and evaluating indicators to measure climate resilience in WASH services. A systematic review was selected in order to ensure that the identification process remained structured, transparent, and repeatable. The research design utilizes a combination of quantitative mapping and qualitative content analysis to provide a comprehensive overview of current monitoring practices. The analytical process is guided by the three-dimensional analytical framework developed in Chapter 2, which includes socioeconomic, environmental, and institutional perspectives.

3.1 Research Design

This thesis uses a systematic review methodology to identify, map, and analyze indicators for measuring climate-resilient WASH in scientific literature and policy documents. A systematic review is a methodology for systematically searching for and synthesizing knowledge from empirical studies to inform policy and decision-making, while exploring hidden patterns and trends (Maeda et al., 2022). To address the thesis research questions, a systematic review employs organized, transparent, and repeatable techniques to identify and select available information. The method differs from conventional narrative reviews in that it uses a clear procedure for searching for, identifying, and assessing empirical evidence and is carried out in a way that is scientific and repeatable (Maeda et al., 2022).

Both quantitative mapping and qualitative content analysis are included in the review design. Indicators are identified and categorized by type, geographic scope, source, and WASH service area in the quantitative section. The qualitative part codes and examines indicators using the three-dimensional analytical framework created in Chapter 2, which includes the socioeconomic, environmental, and institutional dimensions. Instead of acting as selection filters, the theories function as a deductive coding framework, allowing for an organized examination of how current indicators approach climate resilience. The review is systematic rather than comprehensive, balancing the practical limitations of time and resources with methodological rigor. This distinction prioritizes conceptual synthesis over statistical meta-analysis while adhering to the fundamental principles of systematic review guidelines, including predetermined inclusion criteria, document search techniques, organized screening, and transparent reporting (Maeda et al., 2022).

As a master's student in development studies, I approach this thesis with a strong interest in climate resilience, WASH, and how social, environmental, and institutional factors shape access to essential services. My academic background has influenced the way I understand and analyze the topic, particularly through a focus on justice, equality, and structural vulnerability. At the same time, I

recognize that my own position shapes how I interpret the material and the theoretical frameworks used in this thesis. This thesis is therefore guided by an awareness of the perspectives, assumptions, and analytical choices that inform the research process. Rather than claiming neutrality, I aim to be transparent about the standpoint from which I approach the topic and the analytical lens through which I examine the indicators.

3.2 Review Protocol and Reporting Standards

An organized, systematic approach tailored to the scope of a master's thesis was used to conduct the review. The search method, source selection, and inclusion criteria were developed continuously in connection with the review process, rather than adhering to an officially documented review procedure. In order to narrow down the search criteria, find relevant databases, and determine which kinds of documents were most likely to include indicators related to climate-resilient WASH, initial searches were conducted. This method allowed the review's emphasis to be continually sharpened while maintaining a transparent and methodical search (Maeda et al., 2022).

The three primary phases of the review were search, screening, and analysis. Academic databases were used to find relevant scientific articles throughout the search phase. Three core concepts served as the foundation for the search terms: WASH, indicators or monitoring, and climate resilience or vulnerability. These ideas were integrated in various ways in order to capture policy-related materials and research articles that address how climate-resilient WASH can be measured or monitored. As more helpful phrases and relevant sources were available, the search approach was adjusted.

The material was initially examined by title and abstract during the screening phase, followed by full text. Documents that specifically addressed WASH in connection to climate change, climate resilience, or climate-related hazards were included. The documents that mentioned or made use of indicators, monitoring strategies, or comparable measuring techniques were also included. Documents

that addressed climate-related topics without any indicator emphasis or that touched on general WASH concerns without a climate component were not included. This made the final sample more closely matched with the goal of the thesis, which was to map and analyze indicators for climate-resilient WASH.

In the final phase of the review, the indicators identified in the selected literature were extracted and examined. Indicators were coded using the theoretical framework established in Chapter 2 after being documented in an organized manner. The analysis included theory-driven interpretation of how the indicators connect to the dimensions of the three-dimensional analytical framework: socioeconomic, environmental, and institutional, with descriptive mapping such as counting and categorizing indicators by type and geographic scope. It was possible to determine which indicators exist as well as how they are distributed across the dimensions and geographical contexts due to the combination of descriptive and interpretative research.

With the constraints of a master's thesis, the review was intended to be transparent, controlled, and repeatable. Notes on search keywords, sources, screening choices, and coding guidelines were used to document the process. The review employs a clear and methodical process that makes its phases traceable and simple to follow.

3.3 Search Strategy and Inclusion Criteria

The purpose of the literature search was to identify peer-reviewed scientific articles that provide clear definitions of indicators or measurement techniques for climate-resilient WASH. The search process included a specific set of keywords that focused on the concepts of WASH and climate resilience. (WASH OR “water, sanitation, and hygiene”) AND “climate resilient*” AND (indicator* OR monitor* OR measure* OR assess*) were combined in the primary search keywords. Different variations of the term “resilient” could be captured because of the truncation sign, and alternative WASH phrases made sure that articles with slightly different phrasing were included as well.

The search was conducted in Scopus, Web of Science, and Overton. These databases were selected because they provide users with access to a wide range of scientific and policy-related content, and, when combined, they offer a good starting point for relevant research. Overton was included to collect policy documents and other evidence-based sources related to climate-resilient WASH, while Scopus and Web of Science were used to find peer-reviewed academic literature across disciplines. Peer-reviewed academic documents from a variety of fields were gathered using Scopus and Web of Science, and Overton was added to the search to include documents that were evidence-based and focused on policy. Together, these databases provided coverage of both scientific research and policy-oriented material. The search was restricted to English-language sources.

Along with the database search, the review focused on scientific and peer-reviewed literature. The articles published in academic journals that specifically addressed indicators, measurements, or monitoring strategies linked to climate-resilient WASH were the primary focus of the final selection. Only documents that provided a clear definition or discussion of indicators or measurement frameworks were included. This criterion was crucial since the review's goal was to map multiple indicators used to measure climate resilience in WASH, in addition to identifying broader discussions on the topic. To keep the search method feasible within the limitations of a master's thesis, it was kept relatively concentrated. Instead of doing a very wide search with several phrases, the review focused on a specific set of keywords that accurately represented the goal of the thesis. This made it easier to make sure that the review's material was relevant for the following analysis of indicators and the conceptual dimensions.

3.4 Screening and Study Selection Process

To determine the review's scope and ensure that the articles selected aligned with the thesis aims, inclusion and exclusion criteria were established. These criteria were applied in accordance with a systematic review approach to determine which articles were relevant for addressing the research questions and which were not. The criteria mainly centered on topic relevancy, document type, language, as well as the existence of clear indicators or measurement techniques, since the thesis goal was to map indicators for climate-resilient WASH.

Inclusion criteria were as follows:

- WASH, or water, sanitation, and hygiene, had to be included in the articles either generally or through one or more of its various components.
- The article needed to provide a clear connection between WASH and risks associated with climate change, adaptation, vulnerability, or resilience.
- Indicators, measures, monitoring strategies, or comparable ways to assess climate-resilient WASH had to be clearly defined, described, outlined, or applied in the article.
- A peer-reviewed scientific article or policy document was required.
- The article had to be published in English.
- The article must have been published between 2017 and 2026.

The following were the exclusion criteria:

- Articles that addressed WASH without specifically mentioning climate change were not included.
- Articles that addressed climate change or climate resilience in general but lacked WASH indicators or measurement strategies were not included.
- Articles lacking a distinct indicator focus were excluded.
- Non-academic material was not included.
- Publications written in languages other than English were excluded.

4. Results: Mapping Existing Indicators

This chapter presents a systematic mapping of existing indicators for climate-resilient WASH. Relevant indicators organized across the socioeconomic, environmental, and institutional dimensions were identified from 16 sources among 54 reviewed scientific articles and policy documents.

4.1 Overview of Included Studies and Policy Documents

The selection process, demonstrated in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram (Figure 1), resulted in a final collection of 16 sources from an initial identification of 54 articles. A key finding in this identification process was the significant value of policy documents identified via Overton ($n=13$) in contrast to academic literature from Scopus ($n=1$) and Web of Science ($n=2$), as policy documents more systematically defined indicators for monitoring and assessment purposes. These 16 sources, which were released between 2017 and 2025, serve as the foundation for the 104 indicators that are examined in Chapter 5.

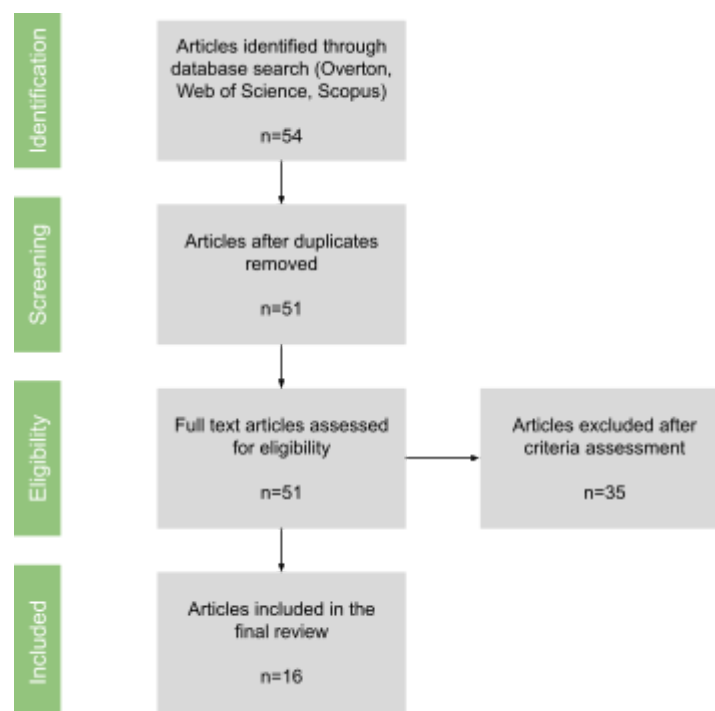


Figure 1: PRISMA Flow Diagram

4.2 Types of Indicators Used for Climate-Resilient WASH

A total of 104 indicators were collected from the 16 sources. The environmental dimension has the highest representation, with 46 indicators, followed by the socioeconomic dimension, with 35 indicators, and the institutional dimension, with 23 indicators, the least represented.

As demonstrated in Table 2, the mapping across the 9 sub-dimensions reveals that Equity and Inclusion (n=29) is the most frequent sub-dimension, while Accountability Mechanisms (n=0) is entirely unrepresented. The specific types of measurements being prioritized are further demonstrated in Figure 2, which identifies indicators that focus on access to safely managed water services (n=18) and climate hazard exposure (n=14) as the most common indicator types currently in use.

Sub-dimension	Count
Equity & inclusion	29
Strategic alignment	19
System sensitivity	18
Adaptive capacity	16
Hazard exposure	12
Capacity and resources	4
Economic viability	3
Community agency	3
Total	104

Table 2: Indicator distribution between the sub-dimensions

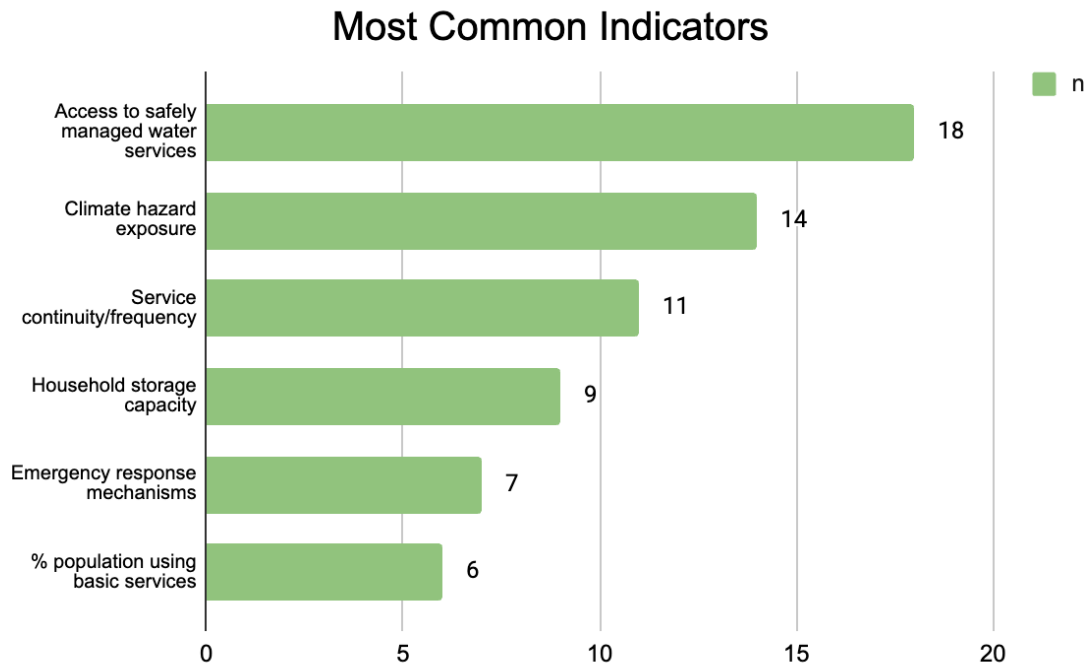


Figure 2: Most common indicator types

4.3 Indicators within the Socioeconomic Dimension

Within the socioeconomic dimension, as shown in Table 3, a total of 35 indicators were mapped and divided among the three sub-dimensions: equality and inclusion, economic viability, and community agency. The sub-dimension, equity and inclusion (n=29), has the most indicators within the socioeconomic dimension, followed by economic viability and community agency, each with three indicators. This distribution is shown in Table 3.

Sub-dimension	Count
Equity and inclusion	29
Economic viability	3
Community agency	3
Total	35

Table 3: Distribution of indicators within the socioeconomic dimension

The following section shows examples of identified indicators within the socioeconomic dimension, divided into its sub-dimensions.

Equity and Inclusion

- “Proportion of population using safely managed drinking water services” (WaterAid, 2024).
- “People benefitting from improved water infrastructure and services (sex-disaggregated, urban and rural)” (ASIAN DEVELOPMENT BANK, 2022).
- “Proportion of people having access to a water supply source” (Kumar et al., 2021).

Economic Viability

- “Total monthly water bill as a percentage of monthly income” (Kumar et al., 2021).
- “Proportion of people living in poverty” (Kumar et al., 2021).
- “People benefitting from improved water infrastructure and services (sex-disaggregated, urban and rural)” (ASIAN DEVELOPMENT BANK, 2022).

Community Agency

- “Women are empowered and represented in decision-making processes” (ASIAN DEVELOPMENT BANK, 2022).
- “The existence of water-sharing rules is deficient” (Nepal et al., 2025).
- “Perception and awareness of climate change among users” (Nepal et al., 2025).

4.4 Indicators within the Environmental Dimension

The environmental dimension contains the most indicators, with a relatively balanced distribution across its sub-dimensions: Hazard exposure, System sensitivity, and Adaptive capacity, as demonstrated in Table 4. A total of 46 indicators were mapped within the environmental dimension. System sensitivity has the most indicators (n=18), followed by Adaptive capacity (n=16) and Hazard exposure (n=12).

Sub-dimension	Count
Hazard exposure	12
System sensitivity	18
Adaptive capacity	16
Total	46

Table 4: Distribution of indicators within the environmental dimension

The following section shows examples of identified indicators within the environmental dimension, divided into its sub-dimensions.

Hazard Exposure

- “Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (exposure to unsafe WASH for all services)” (WHO, 2019).
- “Number of deaths, missing persons, and persons affected by the disaster” (WHO, 2019).
- “Climate of the regions” (Kumar et al., 2021).

System Sensitivity

- “Resilience of basic services, including health facilities” (WaterAid, 2024).
- “Percentage of water supply and sanitation technologies screened according to their suitability to withstand climate-related shocks and stresses” (UNICEF and Global Water Partnership, 2017).
- “Vulnerability of the resource to pollution or contamination” (Kumar et al., 2021).

Adaptive Capacity

- “Total annual greenhouse emissions reduction (tCO₂e per year)” (ASIAN DEVELOPMENT BANK, 2022).
- “Number of countries with over 75 percent of schools having basic drinking water, sanitation, and hygiene services” (United Nations, 2022).
- “Number of countries that have developed a climate rationale for the impact of climate change and water scarcity on WASH services” (UNICEF and WATERSPRINT, 2024).

4.5 Indicators within the Institutional Dimension

Within the institutional dimension, a total of 23 indicators were identified, which is the least represented dimension and has the most uneven distribution between the sub-dimensions: Strategic alignment, Capacity & resources, and Accountability mechanisms, as demonstrated in Table 5.

Sub-dimension	Count
Strategic alignment	19
Capacity and resources	4
Accountability mechanisms	0
Total	23

Table 5: Distribution of indicators within the institutional dimension

The following section shows examples of identified indicators within the institutional dimension, divided into its sub-dimensions.

Strategic Alignment

- “Jurisdictions (national or subnational) adopting improved policy and regulatory framework for incorporating climate resilience” (ASIAN DEVELOPMENT BANK, 2022).
- “Number of countries with national monitoring systems incorporating sustainability of WASH” (UNICEF and WATERSPRINT, 2024).

- “Existence of policy to hire private tankers for emergency water supply” (Kumar et al., 2021).

Capacity and Resources

- “Percentage of WASH staff with training and experience in climate change” (UNICEF and Global Water Partnership, 2017).
- “Participation in climate change awareness programs” (Nepal et al., 2025).
- “Provision for tanker water supply in rural areas in terms of number of tankers” (Kumar et al., 2021).

4.6 Geographical Distribution of Indicators

Different geographically patterns emerged when the 104 indicators were divided by their regional scope, as demonstrated in Table 6. The Asia-Pacific region represents the largest share of indicators, followed by the representation of Global Frameworks, Africa, and lastly the Middle East.

Country/region	Indicators
Global Frameworks	23
Asia and the Pacific	57
Africa	15
Middle East	9
Total	104

Table 6: Geographical scope of the indicators

5. Discussion

The results from Chapter 4 are analyzed and synthesized in this chapter, which uses the three-dimensional analytical framework developed in Chapter 2 to examine the state of climate-resilient WASH indicators. Through the use of the 104 identified indicators, this chapter expands beyond descriptive categorization to examine the underlying conceptual objectives and systemic shortcomings within the WASH sector. The main goal is to examine how these indicators are distributed across the socioeconomic, environmental, and institutional dimensions and to identify what these patterns reveal about the global perception of climate resilience in WASH.

In order to address the thesis research questions, this chapter is structured to first examine the landscape of the indicators, followed by examining the differing representations of the dimensions and their sub-dimensions. This chapter also explores the geographical patterns and what the implications for policy and practice are.

5.1 The Landscape of Indicators for Climate-Resilient WASH

Using an organized list of 104 indicators from 16 sources, this section summarizes the current state of indicators used to measure climate-resilient WASH. There is a significant alignment with SDG 6 frameworks, policy-driven standards that prioritize practical indicators over theoretical principles, and current monitoring gaps that could limit comprehensive system-level resilience assessment: Accountability mechanisms (n=0), Economic viability and Community agency (n=3) each, as well as Capacity and resources (n=4).

The most notable aspect of current practice is that the majority of policy documents (n=13, 81%) are from Overton. Policy documents provide indicators particularly designed for national monitoring systems, in contrast to scientific literature, which places more emphasis on theoretical conceptualization and case-study analysis. This approach can be divided into three forms.

First, SDG 6.1.1 (Proportion of population using safely managed drinking water services) and SDG 6.2.1 (Proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water) are adapted by policy frameworks to reflect aspects of climate resilience (United Nations, n.d.). The most common indicator type, “access to safely managed water services” (n=18), frequently includes resilience factors that were not included in the initial SDG definitions:

- a. Seasonal service continuity: “Percentage of population with access to water points that provide at least a 12-hour daily service all year round” (UNICEF and Global Water Partnership, 2017).
- b. Flood-resilient infrastructure: “Percentage of latrines which remain safe and functional following heavy rains and/or flooding” (UNICEF and Global Water Partnership, 2017).
- c. Emergency capacity: “Provision for tanker water supply in rural areas in terms of number of tankers” (Kumar et al., 2021).

Second, inspired by the UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) and the World Health Organization (WHO)/United Nations Children’s Fund (UNICEF) Joint Monitoring Program (JMP), policy documents regularly utilize organized monitoring methods that form the sector’s backbone (WHO, n.d.; WHO, 2025; WHO and UNICEF, 2026). This allows for an organized balance between standardized global indicators and context-specific national aspects by serving as an essential connection between national data systems and global monitoring (WHO, 2025). There are two primary methods by which this method sustains a balanced state:

- a. Through the use of a small global core of integrated SDG indicators, the approach enables systematic cross-national comparisons and helps identify inequalities, thereby informing aid provision where it is most needed (WHO, 2025).
- b. Instead of developing complex parallel systems, the framework could be connected to already existing national platforms, such as National Household Surveys or Education Management

Information Systems (EMIS), by combining this global core with regionally adapted elements (UNICEF, 2024a).

Third, disaggregation standards further improve effectiveness by highlighting climate-related risks to decision-makers. Given that women and girls suffer a disproportionate burden for household water collection, a duty that becomes increasingly difficult during climate stress and shocks, sex disaggregation, which appears in several indicators, shows a key understanding of gendered vulnerabilities (ASIAN DEVELOPMENT BANK, 2022; UNICEF, 2023a; United Nations, 2021a). This is essential to gender-responsive planning, which assures that aspects such as menstrual health and hygiene are incorporated into monitoring and service availability (UNICEF, 2024a; WHO, 2025).

Furthermore, in order to ensure that services reach individuals in the most vulnerable areas and address different exposure patterns, urban/rural and humanitarian context divisions are applied (WHO, 2025). For instance, monitoring frameworks now specifically count the number of individuals in humanitarian areas who have access to sanitary facilities and clean drinking water (UNICEF and WATERSPRINT, 2024). These divisions address recognized shortcomings in basic SDG monitoring, where regional averages sometimes fail to take into account the challenges of migration and displacement brought on by climate change and disguise significant rural and urban inequalities. This approach enables resilience and equity-focused monitoring that maintains global comparability while being aware of local conditions by going above “access only” monitoring (UNICEF, 2024a; WHO, 2025).

When combined, the present indicator landscape shows significant progress in the implementation of climate-resilient WASH through the development of global standards and specialized monitoring frameworks. By implementing climate risk management into standard practices, such as GLAAS, organizations like WHO and UNICEF have transformed the sector into a system-wide climate and health strategy (UNICEF and Global Water Partnership, 2017; UNICEF and WATERSPRINT, 2024; WHO, 2025).

However, the landscape tends to place a strong emphasis on policy presence, infrastructure dependability, and service accessibility. “Service ladders” are still given top priority in global monitoring through JMP, which monitors the change from “no service” to “safely managed” access. Even though climate resilience is included in policy “on paper”, field studies in South Asia show that the underlying changing patterns of risks are frequently ignored in favor of “quick fixes” and infrastructure-focused designs, such as elevated latrines or flood-protected wells (Nepal et al., 2025; UNICEF, 2024a; UNICEF and WATERSPRINT, 2024).

Moreover, existing practices frequently miss the larger institutional, economic, and participatory factors necessary for long-term resilience. This can be seen in three ways. First, the “institutional support and governance” section is consistently identified as the weakest link across several measures. Local governments often lack the capacity to manage disaster risks, test water quality, or provide the “backbone” for well-informed decision-making (Geremew et al., 2024; Nepal et al., 2025). Second, due to limited funds and the absence of specific budget lines for operations and maintenance, resilience is often viewed as a secondary concern. Funding remains divided and frequently depends on occasional outside assistance rather than long-term local resource mobilization (ASIAN DEVELOPMENT BANK, 2022; UNICEF, 2024a; UNICEF and WATERSPRINT, 2024). Third, although policies acknowledge participation, their actual implementation is moving slowly. Risk assessments are frequently seen as “donor-driven” requirements rather than instruments for empowering the community. In the absence of true “social capital”, such as community-led governance and local leadership, physical infrastructure is vulnerable to deterioration (UNICEF, 2024a; UNICEF and WATERSPRINT, 2024).

Even though the sector has developed the technical “means” of resilience, it has not completely operationalized the “rules of the game”, the institutional and participatory frameworks that ensure that these services can endure and recover from long-term climate stress and shocks (Scott, 2008; WaterAid, 2023).

In addition to what is being monitored, the indicator landscape also reflects what the sector considers resilient. This is significant because the collected indicators place greater emphasis on infrastructure performance, policy visibility, and service presence than on the factors that determine whether these services can truly be sustained under recurrent climate stress and shocks (WHO, 2025; UNICEF and WATERSPRINT, 2024). Rather than using a fully evolved systems approach, the indicators suggest that the sector is still defining resilience through operational indicators (Nepal et al., 2025).

5.2 Disproportionate Representation of the Three Dimensions

The distribution of the 104 indicators across the three-dimensional analytical framework of climate-resilient WASH established in Chapter 2: socioeconomic, environmental, and institutional, is examined in this section. The analysis, based on systematically organized data, reveals patterns of disproportionate representation that are informative of methodological priorities and ongoing conceptual limitations in resilience measurement. The environmental dimension is the most represented (n=46), followed by the socioeconomic dimension (n=35), and the institutional dimension is the least represented (n=23). Additional differences are shown within these sub-dimensions: Accountability mechanisms (n=0), Economic viability (n=3), Community agency (n=3), as well as Capacity and resources (n=4), which are underrepresented among the 104 indicators. Equity and inclusion (n=29), in contrast, is the sub-dimension with the most indicators. These findings indicate that while existing indicators are addressing exposure and access, there is a challenge with establishing and implementing the financial, governance, and participatory conditions required for system-level resilience.

5.2.1 The Distribution of the Socioeconomic Dimension

The socioeconomic dimension, as established in section 2.1.2, adopts Sen's capability approach to define the sub-dimensions: equity and inclusion, economic viability, and agency and participation, prioritizing actual opportunities for WASH services to perform under climate stress and shocks. There are 35 indicators mapped within the socioeconomic dimension; however, the distribution between the sub-dimensions is very uneven.

Equity and inclusion had 29 indicators and focused on structural disadvantage. Gender-based water collection burdens are addressed using sex-disaggregated indicators such as “people benefitting from improved water infrastructure and services” and “women and girls’ access during scarcity”. This is a significant part since women and girls typically carry the responsibility of collecting water, a responsibility that becomes much more difficult during climate stress and shocks (ASIAN DEVELOPMENT BANK, 2022; WHO, 2025). Addressing vulnerable groups, such as “rural school sanitation” and “refugee WASH coverage,” reflects the “no one left behind” principle by highlighting those whose access is most vulnerable (UNICEF and WATERSPRINT, 2024). The sub-dimension, equity and inclusion, aligns well with the theoretical framework, connecting both physical service availability and the prevention of capability deprivation under climate stress and shocks, a situation in which environmental hazards otherwise limit the freedom to live a valued life (Sen, 2001).

Sen's resource-functioning conversion logic is represented within the economic viability sub-dimension, which is significantly underrepresented, with only three indicators. Although there are a few indicators, “proportion of people living under poverty”, “total monthly water bill as a percentage of monthly income”, and “people benefitting from improved water infrastructure and services (sex-disaggregated; urban and rural; subsector)”, they fall short of evaluating the affordability levels during times of scarcity (ASIAN DEVELOPMENT BANK, 2022; Kumar et al., 2021). Access to water can cost impoverished urban people up to 22% of their income in extreme situations, for example, but monitoring systems rarely track how climate-related expenses compromise spending on

food, healthcare, or education (Kumar et al., 2021; UNICEF, 2023a). Because income poverty and capability deprivation are connected, with people lacking the financial resources to adjust to rising service charges, this gap challenges the fundamental idea of the capability approach, which argues that services are meaningless if they are economically restrictive (Kumar et al., 2021; Sen, 2001).

In a similar way, the socioeconomic sub-dimension agency and participation (n=3) is still in its early stages and frequently indicates a significant policy-practice gap. The percentage of countries that record high levels of real community involvement in decision-making is often low, frequently less than 40%, even though more than 70% of them have legalized systems for local involvement (UNICEF and WATERSPRINT, 2024; United Nations, n.d.). Community is often treated as a data source rather than a co-producer of resilience in current methods, such as “percentage of communities engaged and trained in climate risk assessments”. Indicators of empowerment and participation agency are required under the theoretical framework; however, there is a noticeable shortage of information about communities’ ability to influence climate responses or hold institutions responsible (Sen, 2001; UNICEF and Global Water Partnership, 2017; UNICEF and WATERSPRINT, 2024; United Nations, n.d.).

The indicators within the socioeconomic dimension demonstrate selective capability operationalization: economic freedoms and participatory agency necessary to maintain services in the face of continuous climate stress and shocks are not assessed, even though equality tracking and disaggregation are great. Monitoring systems operate at the risk of measuring only what is obvious, the presence of infrastructure, as an example, while overlooking the “rules of the game” that determine whether that infrastructure truly translates into long-term resilience for the most vulnerable. This is because they fail to capture these relational and institutional conditions (Nepal et al., 2025; North, 1990; UNICEF and WATERSPRINT, 2024).

5.2.2 The Distribution of the Environmental Dimension

The environmental dimension, as described in section 2.2.2, applies the concept of climate vulnerability through three sub-dimensions: adaptive capacity, system sensitivity, and hazard exposure (Füssel and Klein, 2006; Kelly and Adger, 2000). The findings of this dimension (n=46) are a reflection of both the overall development of environmental risk measurement methods and what is considered important in relation to climate risks and WASH vulnerability.

Hazard exposure (n=12) measures the type and extent of a system's exposure to climate change. This is measured through indicators such as “percentage of population in flood-prone areas”, “households dependent on drought-sensitive surface water”, and “WASH facilities exposed to seasonal rainfall variability”. These are in line with Füssel’s (2007) emphasis on external biophysical factors as an essential factor of vulnerability, in which hazards are characterized by their frequency, location, and intensity (Füssel, 2007; Füssel and Klein, 2006).

System sensitivity (n=18) captures the “dose-response relationship,” which is the relationship between hazard severity and system damage (Füssel, 2007). “Service interruptions from extreme weather”, the percentage of water points > 1 month/year”, and “the percentage of latrines flooded during wet season” are examples of these measurements (UNICEF and Global Water Partnership, 2017). The original SDG 6 formulations, which are sometimes referred to as “climate-blind” due to their failure to directly include climate resilience concerns or take seasonal fluctuations in service continuity into account, the 104 indicators show a significant improvement in comparison. By accounting for these seasonal fluctuations, monitoring captures the underlying vulnerability of a system, going beyond basic access (United Nations et al., 2024; WaterAid, 2024).

Adaptive capacity covers 16 indicators and focuses more on measurements such as “climate-resilient infrastructure plans implemented”, “early warning systems operational,” and “ecosystem-based protection measures” (UNICEF and Global Water Partnership, 2017; United Nations et al., 2024). Although these indicators

align with the environmental dimension of the theoretical framework, they often focus more on technical solutions, such as elevated infrastructure or backup relief boreholes, rather than on addressing the underlying social challenges (UNICEF and WATERSPRINT, 2024). The “architecture of entitlements” highlighted by Kelly and Adger (2000), which describes resilience through the social, economic, and institutional aspects that allow people to rely on resources during times of crisis, is sometimes overlooked by the emphasis on physical outputs. Furthermore, because technical interventions are frequently given higher priority over the long-term capacity development and learning required to establish true systemic resilience, current ground evaluations regularly identify institutional support and governance as the most vulnerable part in the resilience chain (Kelly and Adger, 2000; Nepal et al., 2025).

The strength of the environmental dimension is its framework alignment; indicators clearly reflect the fundamental ideas of climate vulnerability theory. However, it exposes a reactive approach: slow-onset hazards, including groundwater depletion, are underemphasized, and exposure and failure measurements take the lead over proactive adaptation.

5.2.3 The Distribution of the Institutional Dimension

The institutional dimension demonstrates a significant gap in the existing indicator landscape, with 23 indicators categorized within it, the fewest of the three dimensions. The institutional dimension is defined in section 2.3.2 and focuses on North’s (1990) institutional theory framework, in which institutions serve as the “rules of the game” that influence incentives and human interaction. The sub-dimensions within the institutional dimension are strategic alignment, capacity and resources, and accountability mechanisms. Since institutional effectiveness influences a community’s capacity to endure and advance following significant environmental and socioeconomic difficulties, its underrepresentation is a significant weakness within the indicator landscape (North, 1990; Scott, 2008).

The sub-dimension strategic alignment (n=19) has the majority of the indicators within the institutional dimension. Indicators within this sub-dimension include “the number of countries that have integrated climate resilience and Infection Prevention and Control (IPC) into their WASH in Schools (WinS) plans and strategies”, “percentage of national budget allocated and spent for WASH (as percentage of annual State budget)”, and “national WASH policies, plans and strategies that integrate climate resilience” (UNICEF, 2024a; UNICEF and Global Water Partnership, 2017; United Nations, 2021a). Although they express formal commitments, the “rules of the game” indicators often remain policy guidelines that evaluate intent rather than actual implementation. This draws attention to the policy-practice gap, which prevents climate resilience from being operationalized in system development and operation, as it is recognized on paper but often viewed as an extra or optional proposal (Scott, 2008).

The institutional dimension’s lack of indicators aligns with the policy practice gap and is especially shown in the last two sub-dimensions. Capacity and resources (n=4) include indicators such as “percentage of WASH staff with training and experience in climate change” and “participation in climate change awareness programs” (Nepal et al., 2025; UNICEF and Global Water Partnership, 2017). With just four indicators, their absence of indicators demonstrates a disregard for coordination procedures, spare parts logistics, and human resource retention, all of which are crucial for turning the plan into action. As previously stated, institutional support and governance are repeatedly identified as the weakest part in the resilience chain (Geremew et al., 2024; Nepal et al., 2025; UNICEF and WATERSPRINT, 2024). As an example, infrastructure commonly enters a “build-neglect-rehabilitate” cycle due to a severe lack of technical skills at the local level to conduct risk assessments, monitor water quality, or handle financial records (ASIAN DEVELOPMENT BANK, 2022).

Accountability mechanisms (n=0) are completely missing from the indicator landscape. Indicators that monitor performance-based outcomes, regulatory inspections, and complaint resolution are missing within the 104 indicators.

This underrepresentation exposes the marginalization of institutional theory: without responsible enforcement, funded implementation, or participatory adaptation, strong measures for environmental exposure lose significance. Current monitoring frameworks overlook the elements that determine long-term adaptive efficiency and the capacity of systems to endure and recover from repeated climate stress and shocks by focusing mainly on the “players” (organizations and infrastructure) rather than the underlying “rules of the game” (institutions) (Kumar et al., 2021; Nepal et al., 2025; North, 1990).

5.2.4 Analytical Implications of the Distribution

The distribution of indicators has five main implications. First, overrepresented sub-dimensions reflect observable outputs such as exposure levels, infrastructure access, and policy presence since they are simpler to interpret into standard indicators. On the other hand, underrepresented sub-dimensions such as economic viability, accountability, and agency rely on relational and process-based aspects that are more difficult to measure in global monitoring systems (Sen, 2001; UNICEF and Global Water Partnership, 2017).

Second, a gap between technical and systemic can be seen. The environmental dimension, as well as some aspects of the socioeconomic dimension, are better covered since they relate to physical risks, visible inequalities, and service coverage. However, the institutional dimension is still underrepresented, which could indicate that the framework is better at capturing the technical aspects of resilience than the governing institutions that actually make resilience long-lasting (Nepal et al., 2025; North, 1990; UNICEF and WATERSPRINT, 2024).

Third, the current list of indicators demonstrates a static-dynamic interaction. Instead of capturing the process of adaptation across time, the majority of indicators serve as status measurements, capturing a situation at a single moment in time. This is an issue since resilience is dynamic by nature, requiring learning, adaptation, recovery, and change in light of ongoing climate stress and shocks.

As a result, the current indicator inventory contains significantly fewer indicators that monitor patterns, recovery rates, or long-term institutional adaptability (Kelly and Adger, 2000; UNICEF and WATERSPRINT, 2024).

Fourth, the indicator list indicates that there is a possibility that formal policy adoption and operational capability may differ. Although the existence of plans, strategies, and policy commitments related to climate change could point to advancements at the paperwork level, it does not always imply that institutions have the human capacity, resources, or accountability systems necessary to carry them out. In this context, even when the implementation remains insufficient, the existence of a policy may be mistakenly taken as a sign of resilience (Scott, 2008; UNICEF and WATERSPRINT, 2024).

Lastly, the monitoring system's capacity to measure real-world resilience is limited by the information gap caused by the lack of representation of accountability and economic viability. It is challenging to assess whether WASH systems are truly user-responsive and financially sustainable over time in the absence of measurements for complaint resolution, regular tracking, maintenance finance, or affordability under climate stress and shocks. This is significant since resilience involves not just the availability of services but also their ability to be maintained, challenged, and sustained in the presence of a changing environment (Kelly and Adger, 2000; UNICEF and WATERSPRINT, 2024).

5.3 Geographical Patterns in Indicator Use

This section investigates how the indicators are distributed geographically throughout the three-dimensional analytical framework. It explores systematic patterns of under-representation and regional focus that reflect both institutional capacities for data production and variations in climate vulnerability (WHO, 2025). The indicators are categorized by the analysis into five main geographic groups: global frameworks (n=23), Asia and the Pacific island countries (n=57), Africa (n=15), and the Middle East (n=9). Despite similar climatic vulnerability across the globe, this prominent Asia-Pacific representation shows that indicator

development is more closely connected to policy infrastructure and research capability than with geographical exposure alone (UNICEF and WATERSPRINT, 2024). The distribution provides insight into framework-specific dynamics: the capability approach demonstrates geographically unequal visibility of marginalized populations; institutional theory uses variations in governance capacity to explain production differences; and climate vulnerability theory operationalizes where risks are both critical and institutionally measurable (Kelly and Adger, 2000).

5.3.1 Global Frameworks

The second-largest geographical group (n=23) comprises global frameworks, distributed somewhat evenly across the following dimensions: environmental dimension (n=10), institutional dimension (n=9), and socioeconomic dimension (n=4). These indicators, which were mainly created by UN agencies, establish the fundamental framework of climate-resilient WASH monitoring using globally comparable metrics such as “countries which have adopted innovative WinS technologies to address climate resilience to reduce the carbon footprint”, “countries use harmonized SDG-aligned indicators for drinking-water, safely managed sanitation, including Safely Managed On-Site Sanitation (SMOSS), and hygiene across households, schools and health care facilities”, and “percentage of communities which use solar powered water systems as their main source of water” (UNICEF, 2024a; UNICEF and Global Water Partnership, 2017; WHO, 2025).

Climate vulnerability theory (section 2.2.2) is significantly expressed in global hazard exposure and system sensitivity standards (Füssel, 2007). The capability approach (section 2.1.2) demonstrates structural limitations by prioritizing access above limitations to economic viability or participation privileges that differ significantly depending on the situation (Sen, 2001). Institutional theory (section 2.3.2), on the other hand, is most evident in strategic alignment indicators, which define global “rules of the game” while underspecifying the accountability and capacity mechanisms necessary for local implementation (North, 1990).

Cross-context comparison is made possible by global frameworks; however, they risk enforcing methodological standardization that obscures the reality of contextually varied resilience (North, 1990).

5.3.2 Asia and the Pacific Island Countries

The Asia and Pacific Island countries group, which is the largest group (n=57), includes indicators from the following regions: India (n=14), South Asia (n=11), Asia-Pacific (n=11), Nepal (n=8), South-East Asia (n=7), and Pacific Island countries (n=6). The distribution places greater emphasis on environmental and socioeconomic indicators than on institutional indicators. Environmental risks and equality issues are easier to measure than institutional capacity and accountability, as the region is both highly prone to climate-related WASH risks and fairly well represented in research and policy frameworks (UNICEF and WATERSPRINT, 2024).

Furthermore, regional awareness across a range of vulnerability factors is demonstrated with the help of climate vulnerability theory. Hazard exposure indicators that represent regional weather-related patterns, such as monsoons, cyclones, and drought cycles, as well as system sensitivity measurements that capture both urban service disruptions and rural infrastructure sensitivity, are demonstrations of climate vulnerability theory in the Asia-Pacific region (Kelly and Adger, 2000; UNICEF and WATERSPRINT, 2024).

When it comes to equity and inclusion, indicators that address vulnerable populations and gendered water burdens in a range of urban, rural, and small island environments demonstrate the capability approach in the Asia-Pacific region well. However, the economic aspect is limited, while a few indicators focus on the number of people living in poverty. For example, there is no systematic measurement of scarcity fees or migration expenses amongst other important aspects (Sen, 2001; Nepal et al., 2025; UNICEF and WATERSPRINT, 2024). Even in a data-rich context, institutional theory confirms governance as a

limitation by highlighting policy complexity alongside ongoing capacity shortcomings (North, 1990).

5.3.3 Africa

The Africa group consists of 15 indicators and is distributed between the following regions: Zimbabwe (n=6), Madagascar (n=4), Eastern Ethiopia (n=3), and Uganda (n=2). Several climatically vulnerable areas in Africa experience frequent cycles of drought and malnutrition, groundwater depletion, and service delivery disruptions caused by conflict, making it more difficult to provide climate-resilient WASH services.

Indicators within the African group focus more on percentages of people using basic WASH services, both at the population and community levels, and in targeted regions (United Nations, 2021a; United Nations, 2021b). From a capability approach perspective, it is clear that monitoring systems in Africa often reduce freedoms to access basic infrastructure. The indicators lack economic viability and community aspects, such as rules for water distribution during climate stress or shocks, and water costs. Even though measuring the percentage of the population using WASH services is important, it is not sufficient for long-term resilience (Sen, 2001).

Even though the primary focus of the indicators is on the use of services, there are some that relate to the environmental aspect of it. From the lens of climate vulnerability theory's concept of exposure as the type and extent to which a system is exposed to climatic variations, one indicator addresses this by measuring the "number of countries that have developed a climate rationale for the impact of climate change and water scarcity on WASH services" (Kelly and Adger, 2000; UNICEF, 2023a). Monitoring frameworks need a climate rationale to address specific external stressors communities experience; without a climate rationale, it is just a general concept. Moreover, "fencing" and "flood-proofing" are examples of infrastructure indicators that help reduce sensitivity. Because they establish the "dose-response relationship," these physical barriers regulate

the amount of damage the system experiences (the response) in the event of a flood (the dose) (Füssel, 2007; Kelly and Adger, 2000).

The formal institutional environment, in which a difference between financing and real expenditure frequently exposes “decoupling”, is operationalized by the percentage of the national budget allocated to and spent on WASH (United Nations, 2021a). Strong management and action for resilient utilities, on the other hand, monitor the “rules-in-use” and the adaptive efficiency of the “players”, assessing the localized skill development and enforcement mechanisms needed to resolve systemic obstacles under climate stress and shocks (North, 1990; Scott, 2008).

5.3.4 Middle East

The Middle East group, which includes mainly environmental indicators, has the fewest indicators within the geographical groups (n=9). Water stress, water-use efficiency, wastewater treatment, basic service resilience in health facilities, and safely managed drinking water and sanitation are the main focus within the indicators (United Nations et al., 2024; WaterAid, 2024). This reflects a geographical context in which resource management, efficiency, and water scarcity, rather than more comprehensive institutional or participatory dimensions, are the primary ways in which climate-resilient WASH is demonstrated.

This focus makes sense from the lens of climate vulnerability theory. Recurrent water stress, scarce freshwater supplies, and a strong reliance on effective water resource allocation and utilization are key features of the region (United Nations et al., 2024; WaterAid, 2024). The most significant environmental issues facing WASH systems are therefore addressed by indicators such as water stress, water-use efficiency, and the proportion of safely treated wastewater. While access is still crucial, it is framed in terms of scarcity and resource limitations rather than overall service development, as demonstrated by the prominence of indicators for securely managed drinking water and sanitation (Füssel, 2007).

The institutional dimension is reflected in only one integrated water resource management indicator, whereas the socioeconomic dimension is represented only indirectly through access-oriented SDG indicators (United Nations et al., 2024; WaterAid, 2024). The indicator set demonstrates a system where the operational and environmental aspects of water security are more visible than the governance mechanisms that sustain them.

This pattern is significant because it demonstrates that the selection of regional indicators is influenced by both the presence of climatic risk factors and how those risks are represented in monitoring and policy frameworks. Climate-resilient WASH in the Middle East is primarily understood in terms of treatment capacity, efficiency, and the management of scarcity. Because of this, the region is analytically different from the Asia-Pacific, where equity and inclusion factors are more noticeable.

5.3.5 Synthesis and Implications

Based on the analytical framework developed in Chapter 2, the geographical trends found throughout the four regional groups provide insight into the process of climate-resilient WASH development. First, when geophysical threats are both acute and observable by institutions, climate vulnerability theory shows the strongest operationalization (Kelly and Adger, 2000). Africa's limited scope underscores the difficulty of capturing broad, long-term environmental stressors such as desertification and recurrent drought cycles, whereas the Asia-Pacific region's prominence demonstrates its ability to document a variety of weather-related threats, from monsoons and cyclones to salinity intrusion (Kumar et al., 2021). This implies that there is a stronger connection between indicator production and measurement infrastructure than between vulnerability severity alone (Kelly and Adger, 2000).

Secondly, systematic differences in empirical visibility are shown using the capability approach. While equity and inclusion indicators are frequently used in Asia-Pacific contexts, where they capture gendered responsibilities and

vulnerable population access, they fall short in Africa's low representation and only make a brief appearance in indicators that focus on Middle Eastern resources (ASIAN DEVELOPMENT BANK, 2022; Sen, 2001). All regions have a significantly poor representation within the sub-dimension of economic viability, and there is no assessment of affordability standards during scarcity. Because of this geographic selection, capability deprivations are objectively invisible in particular areas where environmental stress is most likely to exacerbate them (Sen, 2001).

Third, production differences are best explained by institutional theory. From the lens of institutional theory, Africa produces uneven, service-focused measurements that overlook capacity, accountability, and adaptive implementation, whereas Asia-Pacific's policy standards and research ecosystems produce a variety of indicators across the dimensions (Nepal et al., 2025). Standardized strategic alignment indicators are one way global frameworks make up for this; however, they cannot replace region-specific documentation of the “rules-in-use” that determine resilience durability (North, 1990). This is further demonstrated in the Middle East, where, despite robust formal policy settings, technical water security is prioritized over participatory governance (United Nations et al., 2024; WaterAid, 2024).

These trends identify three methodological concerns for effective and meaningful resilience monitoring. First, regional concentration increases the risk of indicator transferability failures (UNICEF and Global Water Partnership, 2017). For instance, Asia-Pacific standards optimized for urban density and monsoon conditions may not be applicable to managing aridity in the Middle East or African water systems (Kelly and Adger, 2000). Second, although their severity, the socioeconomic vulnerabilities of under-monitored regions become overlooked, undermining equity analysis through empirical invisibility (Kelly and Adger, 2000; Sen, 2001). Third, continuous underrepresentation persists because limited institutional capacity yields the least data, thereby drawing less attention to the governance aspect most important for long-term adaptation (North, 1990).

Future indicator development should prioritize regionally relevant indicators in order to address transferability failures. Africa requires pastoralist mobility monitoring for seasonal water paths, cross-border groundwater stress indicators, and conflict-resilient service availability measurements that capture functionality during displacement (ASIAN DEVELOPMENT BANK, 2022). In addition to institutional capacity indicators, such as monitoring maintenance spending, that go beyond policy guidelines, Asia Pacific should expand beyond its accomplishments in equity and the environment to systematically evaluate economic viability shortcomings, such as tariff affordability adjusted for scarcity and migration-induced service disruptions.

Moreover, global frameworks should include regionally adaptable components that maintain SDG comparability, such as drought cycle resilience stages for African environments, drought efficiency standards for Middle Eastern systems, and monsoon seasonality levels for Asia-Pacific contexts (ASIAN DEVELOPMENT BANK, 2022; Füssel, 2007; Kelly and Adger, 2000). Most significantly, national WASH monitoring and the integration of household surveys with climate risk components are necessary to increase the ability of underrepresented regions to produce data (UNICEF and WATERSPRINT, 2024). This method ensures that the framework maintains coherence across institutional and environmental contexts by connecting the location-specific production differences revealed by the investigation. Institutions that are able to make risks systematically visible and actionable, rather than only those with the ability to measure them, are better equipped to conduct effective monitoring.

5.4 Implications for Policy and Practice

The distribution of sources highlights the policy-driven structure of current measurement practice, in which academic conceptualization is placed second to national and global monitoring systems. With 46 indicators distributed between the sub-dimensions hazard exposure (n=12), system sensitivity (n=18), and adaptive capacity (n=16), environmental indicators were the most represented dimension, according to the dimensional analysis in section 5.2. With 35

indicators, the socioeconomic dimension followed next. It was largely driven by equity and inclusion (n=29), but it faced significant limitations in terms of community agency (n=3) and economic viability (n=3). The institutional dimension was the least represented dimension with 23 indicators. Strategic alignment had the most indicators (n=19), while capacity and resources had only 4 indicators, and the accountability mechanisms sub-dimension had 0 indicators.

These dimensional differences were further demonstrated by the geographical distribution patterns analyzed in section 5.3, in which the Asia-Pacific region group had the highest indicator representation with 57 indicators. Africa had 15 indicators, and the Middle East, which was mostly focused on the United Arab Emirates, had 9. Lastly, the remaining 23 indicators were distributed within the global frameworks. The following policy and practice implications are backed up by these demonstrated patterns.

5.5.1 Operationalizing “Rules-in-use” Beyond Policy Standards

The most important demand for a measurement development is the institutional dimensions significantly low presentation, as existing indicators are effective at capturing policy objectives but frequently fall short of evaluating implementation capability or enforcement reality. Formal commitments such as “Number of countries that have developed a climate rationale for the impact of climate change and water scarcity on WASH services”, “Countries which have adopted innovative WinS technologies to address climate resilience”, and “Countries use harmonized SDG-aligned indicators for drinking-water, safely managed sanitation (including SMOSS) and hygiene across households, schools and health care facilities” are captured by the high representation of strategic alignment indicators (n=19) (UNICEF, 2023a; UNICEF, 2024a; WHO, 2025). These policy measures, however, are unable to distinguish between written adoption and operational translation, which is similar to policy practice decoupling that occurs when national strategies exist without corresponding district-level functionality. This phenomenon, which institutional theory refers to as “ceremonial conformity,” occurs when organizations develop formal rules

primarily to gain legitimacy, while their day-to-day operations remain unaffected by climate realities. According to North's institutional theory, existing indicators frequently mirror the official "rules of the game" but fall short of capturing the informal norms and enforcement mechanisms that truly govern a system's performance (North, 1990). This pattern is further supported by field studies showing that local governments are unable to enforce maintenance procedures, conduct water quality testing, or manage disaster risks, among other responsibilities.

It is important that national and sub-national policymakers establish three additional indicator types to better address the concept of "rules-in-use" in institutional theory. In this theoretical context, "rules-in-use" represent the functional realities and "learning by doing" that often diverge from official "rules-on-paper" (North, 1990; Scott, 2008). First, accountability measures should assess the percentage of WASH facilities that meet national standards for operations and maintenance to address current and future climate hazards, to monitor regulatory compliance (World Health Organization et al., 2026). To maintain the "character of the game" in service delivery and assure that infrastructure continues to operate, effective monitoring and sanctioning processes are required (North, 1990; Scott, 2008). Accountability also needs to be linked to the resolution of citizen complaints, particularly in tracking how long it takes to address service interruption concerns before, during, and after climate events. By creating these feedback loops, the governance system may attain "adaptive efficiency," enabling organizations to respond to shifting customer needs and bounce back from climatic shocks more quickly (North, 1990; Ostrom, 2009; Scott, 2008; World Health Organization et al., 2026). To ensure budget usage is focused on meeting specified service restoration timelines after climate-induced hazard incidents, performance-based procedures should link financial oversight to the ratio of actual spending to identified climate adaptation costs (World Health Organization et al., 2026).

Second, indicators of capacity and resources must monitor the adequacy of human resources by assessing the percentage of staff trained in risk management and climate risk assessment (World Health Organization et al., 2026). This

change is important because technical solutions (the “means”) by themselves do not provide resilience; instead, they require the institutional capacity to translate data into actionable choices (North, 1990; Scott, 2008). To ensure compliance with operational and maintenance requirements that account for future climate risks, financial sustainability should also be tracked using the spending ratio relative to identified WASH climate adaptation costs (World Health Organization et al., 2026). The “build-neglect-rehabilitate” cycle, which is frequently caused by a lack of technical and financial skills at the local level, may be interrupted theoretically by keeping an eye on these spending ratios (ASIAN DEVELOPMENT BANK, 2022). The level of preparedness of event-specific response plans and quick restart procedures intended to sustain or restore service delivery after climate-induced hazard events should also be used as an indicator of resilience within WASH. By ensuring that environmental factors do not hinder the translation of WASH resources into real “functionings” (such as health and dignity) that people value, these indicators align with the capability approach (Sen, 2001).

Lastly, the integration of sub-national WASH plans with national adaptation plans, and the combination of budgeted climate adaptation measures for homes, schools, and healthcare facilities, should be assessed as part of implementation gap monitoring to assess strategy standardization (World Health Organization et al., 2026). From the point of view of institutional theory, this integration is necessary to guarantee that formal “rules of the game” are not just instances of “ceremonial conformity,” in which national policies exist as “rules on paper” without being converted into practical, local realities (North, 1990; Scott, 2008). Monitoring the expenditure ratio, which is the percentage of actual spending compared to identified WASH climate adaptation costs, must also be seen as an important aspect of accountability (World Health Organization et al., 2026). Keeping an eye on this ratio is essential for determining “rules-in-use”, which goes beyond paper-based commitments to assess if organizations are successfully transforming financial resources into adaptive activities as opposed to experiencing a “policy-practice decoupling” (North, 1990). Furthermore, by comparing the percentage of people living in nationally defined climate hazard zones who continue to have access to safely managed WASH services with

actual reported periods of disruption caused by climate stress or shocks, service continuity measurements should be able to differentiate policy goals from performance realities. Sen's capability approach also aligns with this distinction, which shifts the emphasis from the mere existence of infrastructure (resources) to actual accomplishments (functionings). This ensures that environmental changing factors, such as climate shocks or stress, do not hinder people from accessing the services they have a reason to value (Sen, 2001). By monitoring the direct connection between hazard severity and system function, these measurements also operationalize the "dose-response relationship" in climate vulnerability theory (Füssel, 2007).

By requiring incorporation into existing SDG-aligned yearly reporting platforms such as JMP or GLAAS, national governments may operationalize them. UNICEF and other international organizations could provide transformative technical support packages, such as observatory software and regional workshops, in order to support monitoring practices. This could help policy development into useful governance monitoring while also addressing the capacity representation gap. In order to develop "adaptive efficiency", which enables institutions to learn from data and react actively to climate stressors instead of being caught in a reactive "build-neglect-rehabilitate" cycle brought on by a lack of institutional and technical capacity, it is essential to provide such technical support (North, 1990; Scott, 2008).

5.5.2 Financial Sustainability Under Scarcity Stress

A significant shortcoming in capability measurement under climate stress or shocks is the low representation of economic viability (n=3), which is restricted to indicators such as "Total monthly water bill as a percentage of monthly income", "Proportion of people living under poverty", and sex-disaggregated access measurements (ASIAN DEVELOPMENT BANK, 2022; Kumar et al., 2021). Financial resources are only "general-purpose means" for achieving freedom, according to Sen's capability approach; however, if climate stress imposes financial burdens on WASH services, this leads to "capability

deprivation”. Environmental factors function as negative change variables in these situations, leading people to trade access to water for other necessities, such as food or medical treatment (Sen, 2001). Without financial security measures, SDG 6.1 and 6.2 “safely managed” frameworks, often repeated across sources, can be misleading.

Governments should use regulatory frameworks that allow service providers to account for the costs of being climate-resilient in tariff review submissions to develop affordability indicators. These measures should be reinforced by tracking the value and accessibility of emergency cash transfers for response and recovery after climate stress or shocks, as well as financial losses resulting from damaged WASH infrastructure (World Health Organization et al., 2026). Monitoring these losses is crucial to comprehending “dose-response relationship” and “system sensitivity”, the extent to which a certain level of climate threats causes measurable harm to service delivery (Füssel, 2007; Kelly and Adger, 2000). Furthermore, economic assessments must prioritize cost-effective climate adaptation methods in national adaptation plans to ensure long-term financial viability. This ensures that infrastructure aligns with design and construction standards that take future climate risks into consideration. Lastly, to maintain service delivery, revenue models should be monitored against the spending ratio to specified adaptation costs, while offering financial benefits for water conservation and keeping a focus on user-led investments in enhancements to the water supply (World Health Organization et al., 2026). The development of these revenue models represents a shift toward “adaptive efficiency”, in which institutional “rules of the game” are adapted to assure that systems can withstand and recover from recurring climatic stress and shocks rather than being static or reactive (North, 1990; Scott, 2008).

Because these measures cannot monitor the ratio of total spending to identified WASH climate adaptation costs, they could demonstrate how standard service indicators conceal financial risks (World Health Organization et al., 2026). Governments can handle the “resource-functioning conversion logic” by including costed policies that ensure resources such as money and infrastructure continue to be transformed into the real accomplishments, or functionings, that

people have reason to value even in the face of environmental stress or shocks (Sen, 2001). Governments may justify resilient initiatives while ensuring that resources are prioritized for people who are disproportionately affected by and vulnerable to climate change by including costed climate adaptation strategies in national policy. The essential structural opportunities for sustainable governance are provided by operationalizing regulatory frameworks that incorporate the costs of becoming climate-resilient into tariff assessments, together with implementing water-use efficiency programs (World Health Organization et al., 2026). This approach makes sure that formal regulations become functional “rules-in-use” that assess whether infrastructure actually contributes to long-term resilience for the most vulnerable, going beyond “ceremonial conformity” (North, 1990; Scott, 2008).

5.5.3 Geographical Measurement Adaptation

The Asia-Pacific region demonstrates significant capacity to monitor regional hazards such as monsoons, cyclones, and saline intrusion, as evidenced by its high representation of climate-resilient WASH indicators (n=57). This prominence suggests that indicator production is not merely a reflection of hazard sensitivity, but rather an outcome of “measurement infrastructure”, the intersection of relevant policy ecosystems, research capability, and institutional data production capacities. In this region, climate vulnerability theory is successfully operationalized by tracking specific hazard exposure and system sensitivity patterns specific to the geographical region (Kelly and Adger, 2000; UNICEF and WATERSPRINT, 2024). Policy-driven measurements, such as 12-hour daily service continuity for water stations and flood-resilient latrines that continue to operate after heavy rains, serve as examples of this (UNICEF and Global Water Partnership, 2017). Furthermore, the region has highlighted the use of emergency tanker water supplies in rural communities as a response to climate threats (Kumar et al., 2021). Although it tends to focus on reactive “means” rather than on long-term, systematic resilience, this is a technological type of adaptive capability that characterizes the region’s current progress in climate-resilient monitoring (Kelly and Adger, 2000).

In contrast, the lower presence in other regions, such as Africa (n=15) and the Middle East (n=9), indicates important geographical implications for policy and practice. Monitoring systems in Africa, for example, sometimes limit “freedom” to access basic infrastructure and lack indicators for economic viability or community-led distribution standards during times of climatic stress or shocks. This leads to a situation known as “empirical invisibility,” which undermines equity-focused policies since policymakers are unable to observe the resulting capability deprivations when regional monitoring is unable to follow scarcity-adapted water prices or the costs of migration brought on by climate change (Kelly and Adger, 2000; Sen, 2001). According to the capability approach, if water costs during scarcity cause consumers to choose between water, food, or healthcare, the service is no longer economically resilient.

Furthermore, rather than depending entirely on climate risks, institutional theory argues that imbalances in governance ability provide the most significant explanation for these output differences. Governance is the “weakest link” in the chain of resilience, where a lack of supervision and implementation leads to “ceremonial conformity”, policies that exist on paper but are unable to impact local conditions. This is demonstrated by the low representation within regions such as Africa. Future policy development should prioritize regionally relevant indicators that reflect local “rules-in-use” to close these gaps. While the Middle East should focus more on comprehensive institutional and participatory aspects, Africa needs to develop more measures to monitor seasonal water paths for migratory people and the availability of conflict-resilience services (North, 1990; Scott, 2008).

Future measurements should move beyond “on paper” policy alignment to measure “rules-in-use” by assessing institutions’ adaptive efficiency. This includes the capacity to handle customer conflicts, learn from data, and ensure that “players” (service providers) successfully implement action plans (North, 1990; Scott, 2008). To ensure services remain responsive to disruptions caused by climate stress or shocks, this may be addressed by implementing reliable procedures for handling customer complaints. In particular, this would involve

measuring how long it takes to resolve reports prior to, during, and after climatic disasters. National governments could shift focus from static status measurements to monitoring the dynamic process of adaptation by including these regionally adaptable aspects into already-existing global frameworks such as JMP or GLAAS. By ensuring that the “rules of the game” are successfully adapted to local circumstances, environmental factors such as climate stress or shocks are prevented from limiting a transformation of WASH resources into the real functionings that people value (Kelly and Adger, 2000; North, 1990; Sen, 2001).

5.5 Assessing the Usefulness of the Three-Dimensional Framework

To effectively organize and understand the 104 climate-resilient WASH indicators, this section examines the analytical utility of the three-dimensional framework: environmental (climate vulnerability theory), socioeconomic (capability approach), and institutional (institutional theory). Based on the previous analyses of the indicator landscape (5.1), dimensional distribution (5.2), and geographical patterns (5.3), the analysis indicates that the framework is effective for identifying indicator strengths, highlighting gaps, and highlighting underlying priorities in resilience monitoring. Its contributions include the ability to produce useful insights for indicator development, a clear methodology for indicator categorization, and broad theoretical coverage that goes beyond single-lens methods. The methodology, however, also highlights underlying conflicts between theoretical objectives and realistic measurability, which influence existing monitoring limitations.

6. Conclusion

The primary objective of this thesis was to present a comprehensive, theoretically supported analysis of the indicators currently used to measure climate resilience in WASH services. In relation to RQ 1, the thesis identified 104 indicators across 16 primary sources, showing that current measurement practices cover a wide range of climate-resilience aspects in both scientific literature and policy documents. Furthermore, the thesis has demonstrated an indicator landscape characterized by significant technological advancements but limited by major systemic imbalances. Through the use of a three-dimensional analytical framework that takes into account institutional, environmental, and socioeconomic factors, this thesis has methodically demonstrated where monitoring initiatives are effective and where they fall short in capturing the complexity of systemic resilience.

The indicators collected demonstrate a sector that is efficient at monitoring environmental hazards but finds it difficult to keep an eye on the economic and governance conditions required to maintain services under pressure. This answers RQ 2, as the distribution of indicators across the framework was uneven: the environmental dimension was the most represented with 44% of the mapped indicators, followed by the socioeconomic dimension with 34% and the institutional dimension with just 22%. The distribution suggests that the “rules-in-use” that define functional reality are less important than physical infrastructure and “on paper” policy consistency. An imbalance was found within these dimensions: the sub-dimension of equity and inclusion was well represented, but this was in significant contrast to the lack of accountability mechanisms indicators, and prominent disparities in institutional capacity and resources, community agency, and economic viability.

Interpreting these gaps has been made possible by the use of the three-dimensional analytical framework. Drawing on Sen’s capability approach, the thesis has demonstrated that the WASH sector is currently placing more emphasis on monitoring resources (means) than on the real functionings (achievements) that people have reasons to value, such as the presence of raised

latrines or flood-protected wells (Sen, 2001). This is important for RQ 4 because the low representation of economic viability indicators means that affordability, financial burden, and access under climate stress are not sufficiently captured in existing monitoring systems. Moreover, since economic viability indicators are underrepresented, this suggests that capability deprivations caused by climatic stress and shocks are frequently overlooked by global monitoring systems. For example, impoverished customers may be forced to choose between water and other necessities, such as food or healthcare, when climatic stress or shocks cause water scarcity and spikes in service fees. This is a critical aspect that standard access indicators fail to capture.

Additionally, the sector is in a condition of “decoupling” or “ceremonial conformity”, according to institutional theory. Although many national governments have included climate resilience into their strategic alignment through formal policies and plans, these commitments frequently remain “rules on paper” that do not affect day-to-day operations due to the lack of indicators for local enforcement, maintenance budgets, and technical staffing (North, 1990; Scott, 2008). This shows that RQ 4 is not only about missing indicators, but also about a mismatch between formal policy commitments and practical implementation. At the same time, climate vulnerability theory demonstrated that although the sector is effective at monitoring system sensitivity and hazard exposure, for example, monitoring the “dose-response relationship” between flood intensity and latrine failure, it is still mostly reactive. Instead of the adaptive capacity needed for systems to learn from data and recover dynamically from recurring climatic stresses and shocks, the present focus is still on technological “quick fixes” (Füssel, 2007; Kelly and Adger, 2000).

Regarding RQ 3, the analysis revealed clear geographical patterns in the indicator landscape. The Asia-Pacific region accounted for 55% of all indicators, indicating a large geographic imbalance in the collection of data. This significance results from a well-developed “measurement infrastructure” that includes advanced policy ecosystems and research capacities, rather than only being a reflection of the severity of the threat. In contrast, regions like Africa and the Middle East suffer from “empirical invisibility,” in which specific climatic

vulnerabilities such as pastoralist mobility, groundwater depletion, and severe aridity are not recorded by current monitoring systems. This geographical distribution demonstrates a significant risk of indicator transferability failure, in which standards developed for one area are improperly implemented in fundamentally different settings.

To address these results, this thesis makes several important recommendations for future policy and practice. First and foremost, it is important to operationalize “rules in use” by developing accountability indicators that monitor customer feedback loops and complaint-resolution timeframes before, during, and after climatic stress or shocks. Second, financial sustainability needs to be given primary concern using indicators that measure the affordability of scarcity-adjusted tariffs and ensure that local maintenance expenditures support technical solutions. Third, to ensure that monitoring maintains both local relevance and global comparability, national governments should work to include these locally adaptable aspects in current global reporting frameworks such as JMP or GLAAS. These recommendations follow directly from the shortcomings identified in RQ 4 and aim to make indicator systems more balanced, context-sensitive, and policy-relevant.

In conclusion, the WASH sector has been effective in identifying the technical requirements for climate resilience, but it has not yet completely recognized the institutional and economic underlying factors that enable such technological advancements to be sustained. Overall, this thesis answered RQ 1 by mapping the indicators currently used to measure climate-resilience in WASH, RQ 2 by demonstrating how they are distributed across the three-dimensional framework, RQ 3 by revealing geographical imbalances, and RQ 4 by identifying the main shortcomings and their implications for policy and practice. This thesis advances the discipline by offering a robust theoretical road map for more systematic and balanced monitoring. A major shift from static status indicators to measuring the adaptive efficiency of the institutions and communities that must persist, recover, and prosper despite environmental change. Future research should build upon this framework by operationalizing context-specific indicators for accountability and economic viability to ensure long-term service sustainability across diverse

geographical contexts. This is necessary in order to achieve the long-term goals of SDG 6 in an era of climatic instability.

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Appendix - Full List of Indicators

Indicator	Dimension	Reference
People with strengthened resilience to climate shocks, disasters, and other external shocks (sex-disaggregated; urban and rural)	Environmental	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Total annual greenhouse emissions reduction (tCO ₂ e per year)	Environmental	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Zones with improved [urban] environment, [climate resilience and disaster risk management]	Environmental	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
People benefiting from strengthened Environmental sustainability (no.) [sex-disaggregated]	Environmental	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Percentage of the population using basic drinking-water services	Environmental	United Nations (2021). Economic and Social Council - Country programme document Zimbabwe.
Percentage of the population using basic sanitation services	Environmental	United Nations (2021). Economic and Social Council - Country programme document Zimbabwe.
Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe WASH for all services)	Environmental	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Proportion of population using safely managed drinking water services	Environmental	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Number of deaths, missing persons and persons affected by disaster	Environmental	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Number of countries with over 80 per cent of the population using at least basic drinking water, sanitation, and hygiene services.	Environmental	United Nations (2022). Economic and Social Council - Multi-country programme document Pacific Island countries.

Number of countries with over 75 per cent of schools having basic drinking water, sanitation, and hygiene services.	Environmental	United Nations (2022). Economic and Social Council - Multi-country programme document Pacific Island countries.
Number of countries with over 75 per cent of primary health -care facilities having basic drinking water, sanitation, hygiene, waste management, and Environmental cleaning services.	Environmental	United Nations (2022). Economic and Social Council - Multi-country programme document Pacific Island countries.
Proportion of population using safely managed drinking water services	Environmental	WaterAid (2024). WaterAid's views on the UAE – Belém work programme on the UAE FGCR.
Proportion of population using safely managed sanitation services	Environmental	WaterAid (2024). WaterAid's views on the UAE – Belém work programme on the UAE FGCR.
Resilience of basic services including health facilities	Environmental	WaterAid (2024). WaterAid's views on the UAE – Belém work programme on the UAE FGCR.
Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	Environmental	United Nations, UN Water, UNICEF and Sanitation and Water for all (2024). Water and Sanitation Submission to the UAE – Belém work programme on indicators for measuring progress achieved towards the targets of the UAE Framework for Global Climate Resilience.
Change in water-use efficiency (WUE) over time	Environmental	United Nations, UN Water, UNICEF and Sanitation and Water for all (2024). Water and Sanitation Submission to the UAE – Belém work programme on indicators for measuring progress achieved towards the targets of the UAE Framework for Global Climate Resilience.
Proportion of domestic and industrial wastewater flows safely treated.	Environmental	United Nations, UN Water, UNICEF and Sanitation and Water for all (2024). Water and Sanitation Submission to the UAE – Belém work programme on indicators for measuring progress achieved towards the targets of the UAE Framework for Global Climate Resilience.
Number of countries that have developed a climate rationale for the impact of climate change and water scarcity on WASH services	Environmental	UNICEF (2023). Developing the Climate Rationale for Climate Resilient WASH Services in Uganda.

Number of people reached with at least basic hygiene services	Environmental	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of people in humanitarian context reached with appropriate drinking water services	Environmental	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of people in humanitarian contexts reached with appropriate sanitation services	Environmental	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
The number of countries that have integrated climate resilience and IPC into their WinS plans and strategies.	Environmental	UNICEF (2024). An Acceleration Framework for WASH in Schools 2024–2030.
Countries which have adopted innovative WinS technologies to address climate resilience to reduce the carbon footprint.	Environmental	UNICEF (2024). An Acceleration Framework for WASH in Schools 2024–2030.
Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services)	Environmental	WaterAid (2024). Integrating Climate Resilient Water, Sanitation and Hygiene into NAPs and NDCs Guidelines for best practice.
A concise climate-resilient WASH core (with optional national modules) is integrated into national monitoring and	Environmental	WHO (2025). WHO water, sanitation, hygiene and waste strategy 2026–2035.

JMP/GLAAS.		
Percentage of population using basic drinking water at the community level	Environmental	United Nations (2021). Economic and Social Council - Country programme document Madagascar.
Percentage of water supply and sanitation technologies screened according to their suitability to withstand climaterelated shocks and stresses	Environmental	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Percentage of households with access to a resilient latrine that does not flood during the wet season	Environmental	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Percentage of water points that have dried up for at least 1 month out of the previous 12 months	Environmental	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Percentage of new boreholes checked for yield and water quality before sign-off	Environmental	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Percentage of communities which use solar powered water systems as their main source of water	Environmental	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Does Early Warning Systems technology and associated policies and procedures (designed to predict and mitigate the impacts of climate change) account for impacts on WASH services?receive and understand warnings from early warning systems	Environmental	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Protective measures against risk of damage and inundation in place	Environmental	Geremew, A., Nijhawan, A., Mengistie, B., Mekbib, D., Flint, A. and Howard, G. (2024). Climate resilience of small-town water utilities in Eastern Ethiopia. Adrian Flint, Guy Howard, 2024

Microbial water quality testing	Environmental	Geremew, A., Nijhawan, A., Mengistie, B., Mekbib, D., Flint, A. and Howard, G. (2024). Climate resilience of small-town water utilities in Eastern Ethiopia. Adrian Flint, Guy Howard, 2024
Historic frequency of multiple natural hazard occurrences	Environmental	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha4 Prabhat Shrestha
The presence of source protection such as fencing, gabion walls, concrete structures, etc.	Environmental	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha4 Prabhat Shrestha
Intake, reservoir, and distribution networks, such as open pipes, disconnected services, and (frequently) damaged taps	Environmental	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha4 Prabhat Shrestha
Proximity of toilets to water sources	Environmental	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha4 Prabhat Shrestha
Frequency of water supply	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Capacity of domestic storage systems,	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Climate of the regions	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from

		India. Springer.
Aridity and drought proneness	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Surface and groundwater availability in the area,	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Vulnerability of the resource to pollution or contamination	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Population density	Environmental	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Jurisdictions (national or subnational) adopting improved policy and regulatory framework for incorporating climate resilience	Institutional	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Women empowered and represented in decision-making processes	Institutional	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Percentage of the population using basic hygiene services	Institutional	United Nations (2021). Economic and Social Council - Country programme document Zimbabwe.
Degree of integrated water resources management implementation (0-100)	Institutional	United Nations, UN Water, UNICEF and Sanitation and Water for all (2024). Water and Sanitation Submission to the UAE – Belém work programme on indicators for measuring progress achieved towards the targets of the UAE Framework for Global Climate Resilience.
Number of countries that have developed a climate rationale for the impact of climate change and water scarcity on WASH services	Institutional	UNICEF (2023). Developing the Climate Rationale for Climate Resilient WASH Services in Uganda.

Number of countries with national monitoring systems incorporating sustainability of WASH	Institutional	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of countries that have developed a climate rationale for the impact of climate change and water scarcity on WASH services	Institutional	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of countries integrating a humanitarian development-peace nexus approach on WASH programming through the participation of affected populations	Institutional	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
The number of countries that have integrated climate resilience and IPC into their WinS plans and strategies.	Institutional	UNICEF (2024). An Acceleration Framework for WASH in Schools 2024–2030.
The number of countries where WinS is reported with national reporting systems aligned with the JMP basic access levels.	Institutional	UNICEF (2024). An Acceleration Framework for WASH in Schools 2024–2030.
Countries use harmonized SDG-aligned indicators for drinking-water, safely managed sanitation (including SMOSS) and hygiene across households, schools and health care facilities.	Institutional	WHO (2025). WHO water, sanitation, hygiene and waste strategy 2026–2035.
Percentage of national budget allocated and spent for WASH (as percentage of annual State budget)	Institutional	United Nations (2021). Economic and Social Council - Country programme document Madagascar.

National WASH policies, plans and strategies integrate climate resilience?	Institutional	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Are climate-resilience standards in place for the construction/installation of latrines and other sanitation infrastructure?	Institutional	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Are climate-resilience standards in place for the construction/installation of water points?	Institutional	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Percentage of WASH staff with training and experience in climate change	Institutional	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Percentage of communities engaged and trained in climate risk assessments	Institutional	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Is Water Safety Planning being upgraded to account for the effects of climate change on both water quality and water quantity?	Institutional	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Strong management and action taken for resilient water utility	Institutional	Geremew, A., Nijhawan, A., Mengistie, B., Mekbib, D., Flint, A. and Howard, G. (2024). Climate resilience of small-town water utilities in Eastern Ethiopia. Adrian Flint, Guy Howard, 2024
Participation in climate change awareness programs	Institutional	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha4 Prabhat Shrestha
Existence of policy to hire private tankers for emergency water supply	Institutional	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.

Provision for tanker water supply in rural areas in terms of number of tankers	Institutional	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Disaster risk reduction measures available	Institutional	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
People with strengthened resilience to climate shocks, disasters, and other external shocks (sex-disaggregated; urban and rural)	Socioeconomic	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
People benefitting from improved water infrastructure and services [sex-disaggregated; urban and rural; subsector].	Socioeconomic	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
People benefitting from improved water infrastructure and services (no.) [sex-disaggregated; urban and rural; subsector].	Socioeconomic	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Women empowered and represented in decision-making processes	Socioeconomic	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
People benefiting from strengthened Environmental sustainability (no.) [sex-disaggregated]	Socioeconomic	ASIAN DEVELOPMENT BANK (2022). STRATEGY 2030 WATER SECTOR DIRECTIONAL GUIDE.
Percentage of the population using basic drinking-water services	Socioeconomic	United Nations (2021). Economic and Social Council - Country programme document Zimbabwe.
Percentage of the population using basic sanitation services	Socioeconomic	United Nations (2021). Economic and Social Council - Country programme document Zimbabwe.
Percentage of the population using basic hygiene services	Socioeconomic	United Nations (2021). Economic and Social Council - Country programme document Zimbabwe.

Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe WASH for all services)	Socioeconomic	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Proportion of population using safely managed drinking water services	Socioeconomic	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Proportion of population using safely managed sanitation services, including a handwashing facility with soap and water	Socioeconomic	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Number of countries reporting nationally representative data on WASH in healthcare facilities	Socioeconomic	WHO (2019). South-East Asia - Regional Plan of Action for the WHO Global Strategy on Health, Environment and Climate Change.
Number of countries with over 80 per cent of the population using at least basic drinking water, sanitation, and hygiene services.	Socioeconomic	United Nations (2022). Economic and Social Council - Multi-country programme document Pacific Island countries.
Number of countries with over 75 per cent of schools having basic drinking water, sanitation, and hygiene services.	Socioeconomic	United Nations (2022). Economic and Social Council - Multi-country programme document Pacific Island countries.
Number of countries with over 75 per cent of primary health-care facilities having basic drinking water, sanitation, hygiene, waste management, and Environmental cleaning services.	Socioeconomic	United Nations (2022). Economic and Social Council - Multi-country programme document Pacific Island countries.
Proportion of population using safely managed drinking water services	Socioeconomic	WaterAid (2024). WaterAid's views on the UAE – Belém work programme on the UAE FGCR.
Proportion of population using safely managed sanitation services	Socioeconomic	WaterAid (2024). WaterAid's views on the UAE – Belém work programme on the UAE FGCR.

Number of people reached with at least basic water that is safe and available when needed	Socioeconomic	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of schools reached with basic WASH services	Socioeconomic	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of health-care facilities reached with basic WASH services	Socioeconomic	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of people in humanitarian context reached with appropriate drinking water services	Socioeconomic	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
Number of people in humanitarian contexts reached with appropriate sanitation services	Socioeconomic	UNICEF and WATERSPRINT (2024). Compendium of Low-Carbon Climate-Resilient WASH Technologies, Recommendations for Programmatic Processes and Opportunities for Scaling-up Climate- Resilient WASH Interventions in South Asia An Assessment of Climate-Resilient WASH Services in South Asia.
The number of countries with estimates/targets for and reporting basic WASH services in schools.	Socioeconomic	UNICEF (2024). An Acceleration Framework for WASH in Schools 2024–2030.
Mortality rate attributed to unsafe water, unsafe sanitation and	Socioeconomic	WaterAid (2024). Integrating Climate Resilient Water, Sanitation and Hygiene into NAPs and NDCs Guidelines for best practice.

lack of hygiene (exposure to unsafe Water, Sanitation and Hygiene for All (WASH) services)		
Gender-responsive monitoring, including MHM, is mainstreamed and hygiene data gaps – especially in higher-income settings – narrow; regular global updates and inequality analyses inform decisions via washdata.org.	Socioeconomic	WHO (2025). WHO water, sanitation, hygiene and waste strategy 2026–2035.
Percentage of population using basic drinking water at the community level	Socioeconomic	United Nations (2021). Economic and Social Council - Country programme document Madagascar.
Percentage of population using basic sanitation services in target regions	Socioeconomic	United Nations (2021). Economic and Social Council - Country programme document Madagascar.
Percentage of population with access to water points that provide at least a 12-hour daily service all year round	Socioeconomic	UNICEF and Global Water Partnership (2017). WASH Climate Resilient Development - Monitoring and evaluation for climate resilient WASH.
Existence of water-sharing rules if deficient	Socioeconomic	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha ⁴ Prabhat Shrestha
Proportion of people who use soaps for hand washing	Socioeconomic	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal. Sujata Shrestha ⁴ Prabhat Shrestha
Perception and awareness of climate change among users	Socioeconomic	Nepal, S., Aksha, S.K., Pradhananga, S., Aryal, A., Narayan Shrestha, R., Shrestha, S. and Shrestha, P. (2025). What Does a Climate-Resilient Rural Water Supply System Look Like? An Interdisciplinary Approach to Climate Resilience Mapping in Nepal.

Proportion of people having access to water supply source	Socioeconomic	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Total monthly water bill as a percentage of monthly income	Socioeconomic	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Access to primary health services	Socioeconomic	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.
Proportion of people living under poverty	Socioeconomic	Kumar, M.D., Kabir, Y., Hemani, R. and Nitin Bassi, N. (2021). Management of Irrigation and Water Supply Under Climatic Extremes Empirical Analysis and Policy Lessons from India. Springer.