UNDER PRESSURE

Effects, impacts, and adaptation to climate change in Latin American and Caribbean water operators

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Abbreviations

LAC	Latin America and the Caribbean
CAN	Andean Community Countries
CCB	Caribbean Group Countries
CID	Central America, Haiti, Mexico, Panama, and the Dominican Republic countries
CSC	Southern Cone Countries
DMDU	Decision Making under Deep Uncertainty
ENSO	El Niño - Southern Oscillation
EPA	Environmental Protection Agency (United States of America)
IPCC	Intergovernmental Panel on Climate Change
MRSE	Mechanisms of Payment for Ecosystem Services (by its Spanish initials)
Sunass	National Superintendence of Water and Sanitation Services (Peru)
UNDRR	United Nations Office for Disaster Risk Reduction
USD	United States Dollars

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Executive summary

Climate change has impacts on the demand and supply of water and sanitation services, but adaptation is possible.

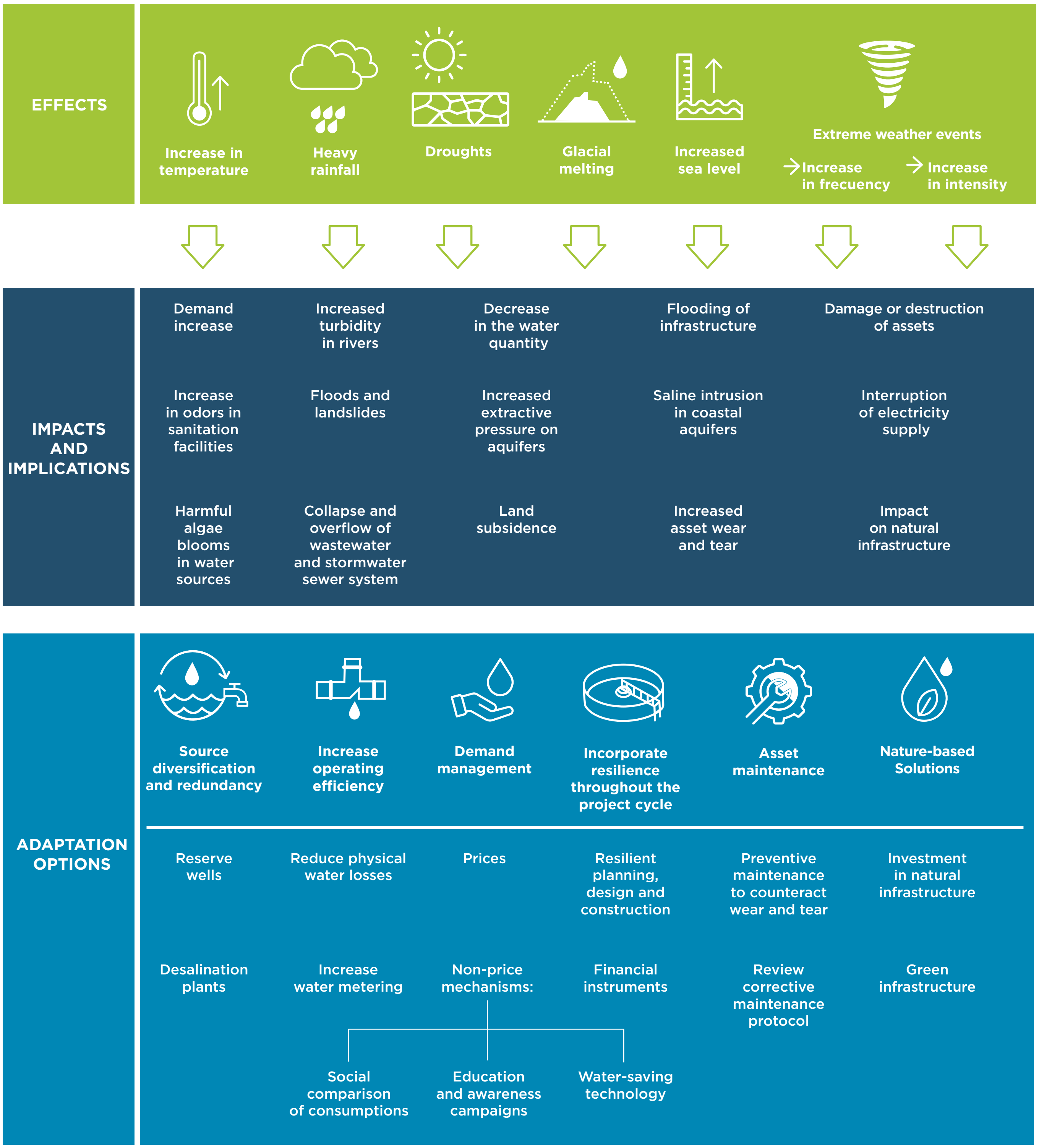
Climate change is undoubtedly one of the greatest challenges we face as a society today. Its effects include rising temperatures (which are increasing in South America even more rapidly than in the Caribbean), heavy rainfall, droughts, glacial melting , rising sea levels, and an increase in the frequency and intensity of extreme weather events. The impacts on the provision of water and sanitation services are diverse. On the demand side, an increase in population consumption is expected due to rising temperatures, which will put pressure on water sources. Demand for non-residential uses (agriculture, industry), which account for 85% of water demand in the region, will also be affected by rising temperatures and other effects of climate change.

On the supply side, climate change alters the conditions under which water service providers typically operate. Droughts reduce drinking water production in treatment plants, while heavy rains increase turbidity in rivers and can even generate landslides that damage or destroy infrastructure. As a result, operators often resort to groundwater sources; however, overexploitation of these sources can compromise water security and lead to other issues such as land subsidence. Higher temperatures increase the proliferation of harmful algae, which in turn increases water treatment costs. Rising sea levels increase the risk of infrastructure flooding and can lead to saline intrusion of coastal aquifers. Finally, extreme weather events can destroy both gray and natural infrastructure and cause interruptions in electricity, which is an important input for the water supply, affecting the continuous provision of services.

Water operators have several options for adapting to the impacts of climate change. These measures are not mutually exclusive, but, on the contrary, it is recommended that they be implemented in tandem with one another. This will allow for assets, services, and users to be resilient to the impacts of climate change. These options include diversifying sources and investing in system redundancy, increasing operational efficiency, managing demand, incorporating resilience throughout the investment project cycle, performing adequate maintenance to counteract asset wear and tear, ensuring rapid corrective maintenance, and implementing Nature-based Solutions.

Figure RE.1

Effects, impacts and adaptation options for water and sanitation services



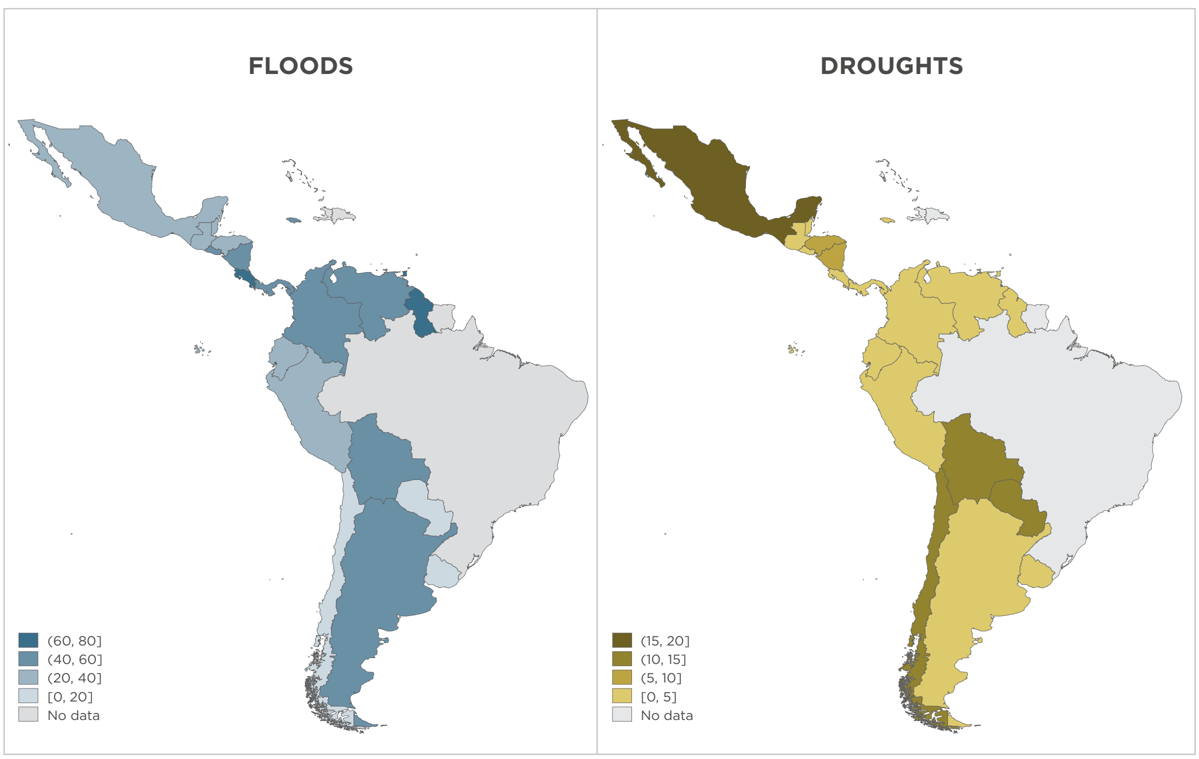
Sourse: Authors' elaboration.

Floods affect the countries of the region more than any other event; however, attention should also be paid to droughts and focused phenomena such as tornadoes and cyclones.

Floods account for 40% of the records of areas affected by events in Latin America and the Caribbean. In the countries of the Southern Cone (CSC) this percentage is 36%, in the countries of the Andean Community (CAN) it is 39%, while in the countries of the Central American Group, Haiti, Mexico, Panama, and the Dominican Republic (CID) and the Caribbean Group (CCB), the percentage reaches 41% and 64%, respectively. As can be seen in **Figure RE.2**, the percentage varies among countries, but in the vast majority of cases it is above 30%. Droughts are also increasingly recorded in some countries of the region. In particular, in Mexico 16% of the records correspond to droughts, while this percentage is 13% in Bolivia, Chile and Paraguay. There are other types of events that, although smaller in number of records, have the potential to be highly destructive and that occur in a predictable geographic pattern. For example, of the 280 geographic units affected by cyclones, 54% correspond to CID countries, while 37% correspond to CCB countries. Likewise, 59% of tornado records correspond to CID.

Figure RE.2

Floods and droughts as a percentage of total events registered in the DesInventar database



Source: Authors' elaboration with information from Desinventar.

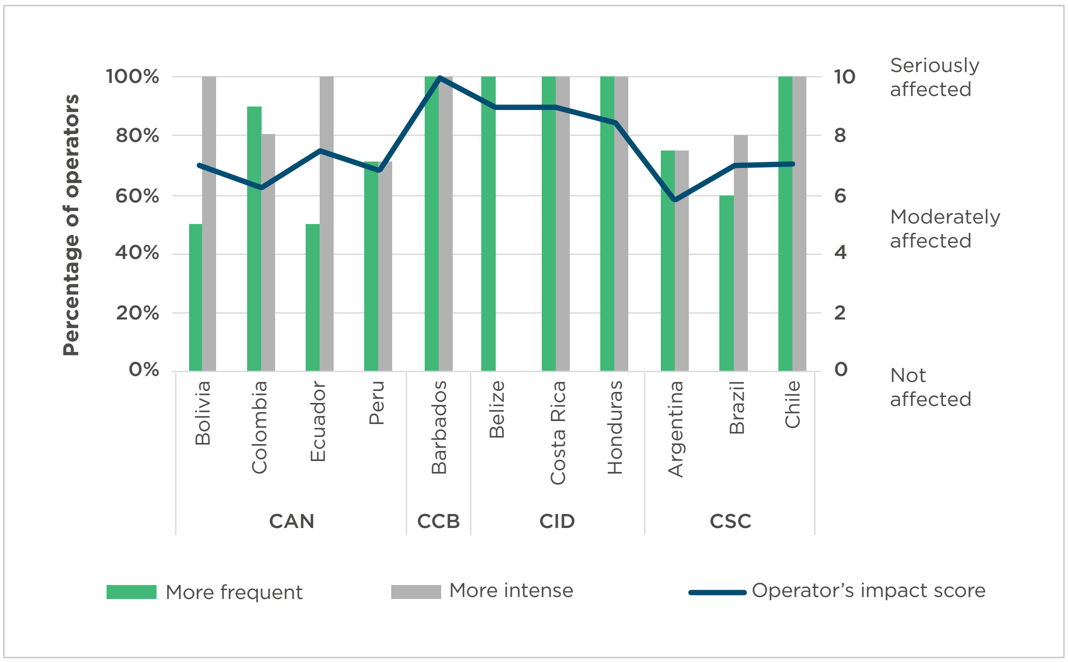
Operators in the region are affected by climate change, by increasingly frequent and intense events.

In a 2023 survey carried out by IDB of 61 water operators of different sizes in 11 countries in the region, we found that 82% perceive that extreme weather events such as droughts, heat waves, heavy rains, landslides, etc. are becoming more frequent and intense (see **Figure RE.3**).

Similarly, on a scale of 1 to 10, where 10 means that the respondent's company has been seriously affected by climate change in the last 15 years, the average score for the region is 6.9. In particular, 7 of the 61 companies surveyed (11%) reported an affectation index of 10, 4 companies (7%) an index of 9, and 15 companies (25%) an index of 8.

Figure RE.3

Frequency and intensity of extreme weather events as perceived by water operators and degree of impact on their operations



Source: IDB survey of operators in the region.

Operators report as main impacts the affectation on surface water sources and the collapse of wastewater and stormwater sewer systems due to heavy rains.

The impact on surface water sources is a reality for operators: 77% of the operators surveyed indicate that they are affected by a reduction in river flow, while 70% report an increase in the level of turbidity in surface water sources (see **Table RE.1**). In third place, 66% of the operators state that heavy rains cause the collapse of wastewater and stormwater sewer systems. Although these are the impacts most commonly reported by operators, it is important to note other impacts that could have a clearer sub-regional pattern, such as the depletion of aquifers, interruptions in electricity supply as a result of disasters, and damage to infrastructure due to hurricanes, among others.

Table RE.1
Impacts of climate change reported by operators in the region

IMPACTS	% OF OPERATORS
Reduction in river flow	**77%**
Increase in the level of turbidity of surface water sources (rivers, lakes)	**70%**
Collapse of wastewater and stormwater sewer systems due to heavy rainfall	**66%**
Unexpected changes in water demand due to temperature changes	**52%**
Reduction or depletion of the water table in aquifers	**41%**
Power supply interruptions as a result of disasters	**39%**
Landslides or avalanche damage to infrastructure	**33%**
Eutrophication (increased presence of algae) in water sources	**31%**
Increase in odors at wastewater treatment plants due to increased temperatures	**26%**
Saline intrusion of aquifers	**16%**
Increased evaporation of water stored in dams	**16%**
Reduction in springs or lakes due to glacial melting	**13%**
Destruction of infrastructure due to abnormal sea surge	**7%**
Land subsidence due to compaction of overexploited aquifers	**3%**

Source: IDB survey of operators in the region.

Operators in the region are already adapting to climate change: operational and gray infrastructure measures are the most prominent, but Nature-based Solutions are starting to gain ground.

Operators in the region tend to resort to solutions that include making investments in gray infrastructure and operational activities. Firstly, 64% of the operators surveyed have responded to the effects of climate change by increasing expenditure on water treatment chemicals (see **Table RE.2**). Furthermore, 56% report having made investments in the construction or maintenance of reserve wells, which reaffirms the importance of groundwater sources in the region as a strategy to cope with surface water variability in the context of climate change. Operators also mention installing photovoltaic renewable energy systems at pumping stations (Barbados), interconnection of supply networks and water sources (Brazil, Colombia), and the use of ultrasound equipment for algae control (Colombia), among other traditional strategies. Furthermore, although 36% of the operators surveyed stated that they have not implemented non-traditional measures to address the effects of climate change, Nature-Based Solutions have begun to be increasingly employed in the region. Thus, 43% of the operators surveyed have invested in reforesting the upper reaches of their contributing watersheds, while 30% have invested in protecting and restoring ecosystems such as lakes and wetlands.

Table RE.2

Climate change adaptation measures adopted by operators in the region

TYPES OF MEASURES	MEASURES	% OF OPERATORS
TRADITIONAL	Increased expenditure on water treatment chemicals	**64%**
	Investments in construction or maintenance of reserve wells	**56%**
	Expenditures for more continuous cleaning or de-silting of rivers	**34%**
	Investments in the construction of water diversions	**26%**
	Investments in the construction of storage dams	**21%**
NON-TRADITIONAL	(Re)afforestation of upper parts of the watershed	**43%**
	Investment in ecosystem protection or restoration (lakes, wetlands)	**30%**
	Encouragement of rainwater harvesting by users	**11%**
	Infiltration trenches	**7%**
	None of the above	**36%**

Source: IDB survey of operators in the region.

1. Introduction

Climate change is undoubtedly one of the greatest challenges we face as a society today. Since the beginning of the 20th century, global temperatures have risen steadily and, in the region, the temperature in South America is rising even more rapidly than in the Caribbean (Cavallo et al., 2023). As a result, we observe how several effects associated with this phenomenon exert a direct impact on the economic growth of countries, limit their ability to ensure food security for their inhabitants, and represent a growing threat to the integrity of cities, as they are impacted by more frequent and intense extreme weather events. In the future, climate change, population growth and urbanization are expected to put infrastructure services to the test, highlighting their current deficiencies (Cavallo et al., 2020).

Within these services, the provision of water and sanitation services is particularly affected due to climate change's close relationship with the water cycle. Not only are we seeing changes in atmospheric temperature, but precipitation patterns are also changing. In some areas, the lack of rain causes more frequent and prolonged droughts; while in others, rainfall is so intense that river flows and turbidity increase significantly, causing flooding in cities and even landslides that destroy infrastructure. Glaciers and ice sheets are melting, reducing the future availability of water for certain populations, while sea levels are rising, endangering coastal cities. The effects described above impact the activities of water operators and, ultimately, the provision of services to citizens.

This is a highly pertinent issue for Latin America and the Caribbean (LAC) because, although it is rich in water resources, the distribution of these resources does not correspond to the distribution of the population, with 35% of the region's population living in areas with medium-high or extremely high levels of water stress (Libra et al., 2022). This situation, which already hinders water supply in the region, will worsen in the coming years. We expect an increase in water demand: residential demand will increase due to population growth and rising temperatures, demand from the agricultural sector will increase due to increased evapotranspiration, while energy production, mining, and other water-intensive industries will also contribute to increased pressure on water sources. On the supply side, the reduction in water flows, the proliferation of droughts and heavy rains, and the increased frequency and intensity of weather events will test the resilience of water and sanitation systems. As will be demonstrated in this report, most water operators in the region are already experiencing the effects of climate change and are implementing some strategies to adapt to its impacts. However, policy efforts need to be redoubled to ensure resilience in the provision of water and sanitation services.

This report is structured as follows. The second section analyzes how climate change affects water and sanitation services. This includes a brief discussion about climate change as an aggravating factor in disaster risk, and a review of the impacts on the demand and supply of these services. It also includes a review of adaptation measures or strategies available to water and sanitation operators. The third section identifies the events related to climate change that affect each of the LAC countries and their prevalence. For this purpose, we use information from DesInventar, a database managed by the UNDRR (United Nations Office for Disaster Risk Reduction) containing the occurrence of events for the period 1970-2013. Finally, the fourth section presents the results of a 2023 survey that the IDB carried with water operators in the region. This survey was answered by 61 operators from 11 countries and provides information on the events that most affect them, their perception of the intensity and frequency of these events, as well as the measures they have adopted to deal with their impacts, among other aspects.

2

How does climate change affect water operators and how can they adapt to its consequences?

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2.1. A more variable and uncertain environment: climate change and disaster risk

A useful step in understanding how climate change affects the provision of water and sanitation services is to understand the factors that are part of disaster risk. Disaster risk is defined as the possibility of economic, material or human damage or loss in a given geographical area and time, based on the interaction of three components: hazard, exposure and vulnerability. Disaster is the materialization of risk. However, the absence of disaster does not imply the absence of risk (Barandiarán et al., 2019).

The hazard component refers to natural phenomena that could potentially affect the integrity of the population and its assets. These hazards include droughts, earthquakes, floods, heat waves, sea level rise, landslides and fires. Although some of these events occur independently of climate change, many of them are enhanced by its effects (see **Box 1** on the occurrence of the El Niño phenomenon in the context of climate change).

The exposure component reflects whether the population and/or its assets coincide, both in time and space, with the natural hazards described above.

The vulnerability component refers to the susceptibility to be harmed or damaged. In the case of assets, for example, it refers to the "intrinsic individual and aggregated characteristics that give them an inherent proneness (or conversely, a resistance) to suffer harm" (Barandiarán et al., 2019).

Figure 1
The Composition of Disaster and Climate Change Risk

Source: Authors' elaboration

Disaster risk is impacted by climate change, as it introduces variability and, to a large extent, uncertainty (as we do not know the future trajectory of the phenomenon) in natural hazards that we typically think of as static. As Barandiarán et al. (2019) point out, climate change can be considered as a factor modifying and even exacerbating disaster risk.

BOX 1

Niño with fever: The El Niño phenomenon in a climate change environment

The El Niño-Southern Oscillation (ENSO) occurs at irregular intervals of between two and seven years and involves phases of unusual warming (El Niño) and cooling (La Niña) of surface waters in the Pacific Ocean. The phenomenon also involves changes in atmospheric pressure and intense alterations in weather conditions[1]. ENSO is the strongest year-to-year climate variation on the planet, with consequences in the enviornment and society that are felt globally (McPhaden et al., 2021).

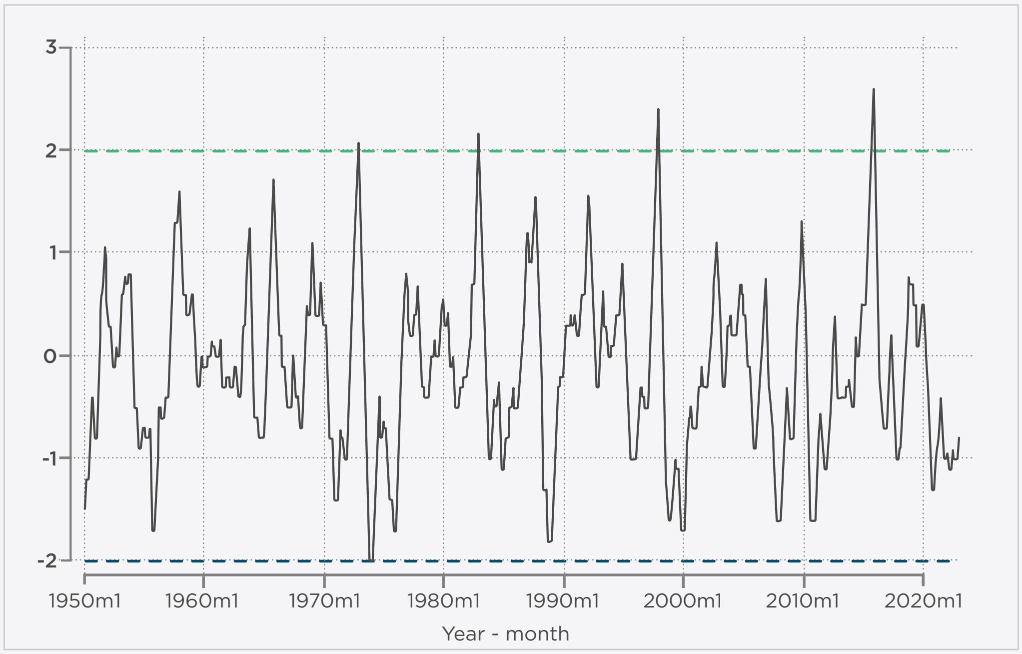
The provision of water and sanitation services is affected in different LAC countries during the occurrence of El Niño and La Niña phenomena. For example, during the 2015-2016 event, the flow of the Rimac River, Lima's main river, was reduced by 50%,[2] forcing the company to put its reserve wells into operation and reduce water pressure at night.[3] In contrast, the (Coastal) El Niño phenomenon in 2017 caused excessive rainfall that increased the turbidity level of the water sources of the largest water companies in Chile (Aguas Andinas[4]) and Peru (Sedapal[5]), having to close their water treatment plants, and putting in place emergency plans that included the use of groundwater sources and service rationing.

There is no information to conclude that climate change has had an effect on the occurrence of El Niño; however, we know that the impacts of El Niño are exacerbated by climate change (McPhaden et al., 2021). For example, Jiménez-Muñoz et al. (2016) show that the 2015-2016 El Niño, combined with the regional warming trend, was associated with unprecedented warming and a greater extent of extreme drought in the Amazon. Extreme drought, combined with high temperatures resulting from climate change, increased the occurrence of fires by 36% compared to those occurring in the previous 12 years (Aragão et al., 2018). In short, the phenomenon is happening in a warmer environment due to climate change. In the

1 https://education.nationalgeographic.org/resource/el-nino
2 https://peru21.pe/lima/fenomeno-nino-problema-agua-lima-agudizaria-febrero-208560-noticia/
3 https://www.radionacional.com.pe/informa/fenomenoelnino/fen-meno-el-ni-o-sedapal-bajar-presi-n-de-agua-en-las-noches-ante-menos-lluvia
4 https://twitter.com/aguas_andinas/status/835711645146050561
5 https://elcomercio.pe/lima/sedapal-confirmo-corte-agua-26-distritos-huaicos-161347-noticia/

last 40 years we have experienced three extreme El Niño events (1982-1983, 1997-1998, and 2015-2016) as can be seen in **Figure 2**. Recent studies show that the variance of sea surface temperatures caused by ENSO could increase by 15% by the end of the century (Cai et al., 2018), and that this would cause a doubling in the occurrence of extreme El Niño and La Niña events in response to greenhouse gas warming (Cai et al., 2014, 2015).

Figure 2
Oceanic El Niño Index (1950 - 2022)



Source: National Oceanic and Atmospheric Administration. Authors' elaboration.

2.2. Supply and demand pressures: effects and impacts of climate change

Following Hughes et al. (2021), we believe it is necessary to define the concepts of effects, impacts and implications of climate change, to ensure a clear and precise understanding of the analysis contained in the following sections of this report.

- **Effects:** The effects of climate change refer mainly to alterations in the climate and environment due to the effect of the increase in global temperature. These include changes in rainfall patterns, which manifest themselves through more frequent, intense and prolonged droughts in some cases, and storms and heavy rainfall in others. Other effects include the proliferation of heat waves, the melting of glaciers and ice sheets, rising sea levels and an increase in the frequency and intensity of extreme weather events.

- **Impacts:** Impacts are the direct (or first-order) consequences that climate change and extreme weather events have on natural and human systems. Impacts related to water and sanitation services include, for instance, the reduction in water availability, contamination of freshwater sources by saline intrusion due to sea level rise, and the collapse of wastewater and stormwater sewer systems due to heavy rains.

- **Implications:** Implications are indirect (or second-, third-, or higher-order) consequences that result from climate change impacts. They refer to environmental, social, economic and cultural changes that occur after a direct impact. Some implications could be the increase in certain diseases due to flooding and high temperatures (see **Box 2**) and the increase in water treatment costs as a result of higher turbidity in rivers. For the sake of simplicity and for the purposes of this report, considering that the implications are indirect impacts, the term impacts will also be used hereafter to refer to the implications.

Box 2

Climate change exacerbates the negative impacts of lack of infrastructure

Climate change not only has a significant impact on the operations of the companies that provide water and sanitation services but can also aggravate the negative effects that the lack of infrastructure has on public health. There is extensive literature on the relationship between lack of access to safe drinking water and several diseases such as diarrhea, skin diseases, cholera, and dengue (see Cárdenas, 2022). However, little has been documented on how extreme weather events can enhance these negative effects.

Dengue fever presents a particularly interesting case. The mosquitoes that transmit this disease (*Aedes aegypti*) are usually found in places that meet three conditions: **i**) relatively low altitudes—for example, in Mexico they are abundantly found below 1700 meters above sea level (Lozano-Fuentes et al., 2012)—, **ii**) warm temperatures—it has been found that around 21°C, mosquito flight is optimal (Reinhold et al, 2018)—, and **iii**) areas where there is stagnant water, either as a result of rainfall or stored in containers, a usual practice in people without access to piped water.

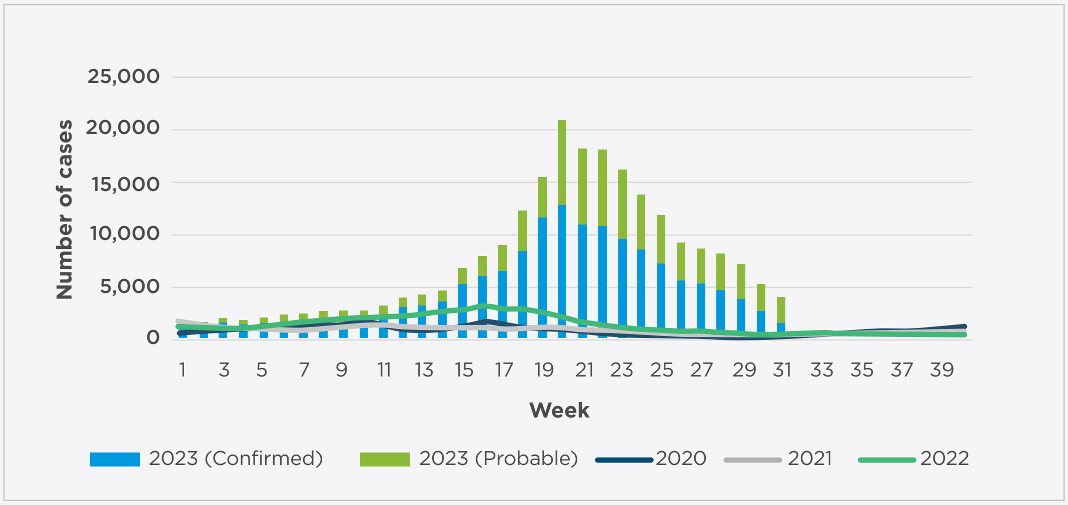
Climate change affects the proliferation of dengue because it involves an alteration of rainfall, temperature and humidity patterns. Thus, increased temperatures create favorable environments for mosquitoes in areas where they would not normally be prevalent and have an impact on their behavior[6]. In addition, certain regions experience an unusual increase in rainfall which, coupled with the absence of adequate drainage systems, generates stagnant water in the city, an ideal habitat for mosquito breeding.

In a study for Brazil, Pereda et al. (2014) examined the impact that the unusual increase in rainfall in 2008 had on dengue proliferation. In tropical cities with lower historical rainfall, such as Fortaleza and Natal, the rains increased dengue cases significantly (36% and 22%, respectively). On the other hand, in tropical cities with higher historical rainfall, such as São Luís and Teresina, the dengue rate decreased, possibly because the rains may have washed away water accumulations, reducing the number of larvae and, therefore, the mosquito population. In Curitiba, a city with a more temperate climate, increased rainfall also led to an increase in the dengue rate. The authors' simulations show that climate change will increase dengue cases in southern Brazil at a rate between 150% and 200%, depending on the temperature increase scenario.

On the other hand, Dostal et al. (2022) analyzed dengue cases reported between 2000 and 2018 in Peru and found a significant effect of temperature and the presence of the El Niño phenomenon. These results are consistent with the trend recently observed in dengue cases in this country (see **Figure 3**), in the presence of the El Niño phenomenon during 2023.

Figure 3

Number of weekly cases of dengue fever in Peru (2020 - 2023)



Source: Sala Situacional del Dengue - Ministry of Health of Peru. Accessed August 11, 2023 https://www.dge.gob.pe/sala-situacional-dengue. Authors' elaboration.

[6] Scientific studies document that warmer weather has an impact on the behavior of dengue-transmitting mosquitoes: low temperatures affect their ability to move, rendering them inactive below 10°C, while the frequency of blood-feeding is positively correlated with ambient temperature (see the literature review conducted by Reinhold et al., 2018).

2.2.1.
Impacts on demand

There are different water demands and although not all of them are met by water operators, it is important to mention the effect that climate change has on each of these demands. In many cases, limited water resources lead to competition between different uses; that is, greater consumption by one agent necessarily reduces the amount available for others. As we will see below, this tension caused by the expected increase in the different demands will be aggravated due to the effect that climate change also has on the quantity, quality and timely availability of water resources.

Impacts on residential water demand

Water treatment and distribution systems take into account the organic growth in demand due to the expected increase in population. However, in the coming years, additional increases in demand are anticipated due to climate change. Economic literature has identified that climate variables—in particular, temperature—are related to residential water demand (Dalhuisen et al, 2003; Arbués et al., 2003; Worthington et al., 2008; Sebri, 2014), which explains the seasonality that many water operators observe throughout the year. In this sense, it is expected that households will consume more water due to increased temperatures associated with climate change, and this increase in consumption may be greater in the case of households with higher socioeconomic levels (Fiorillo et al., 2021).

In the Latin America and the Caribbean region, this impact on residential water demand may be exacerbated if prices or low micro-metering do not provide users with signals that encourage them to consume rationally. In this regard, attention should be paid to the low micro-metering rates exhibited by some operators in the region. For example, the micro-metering rate in San José (Costa Rica) is 41%, while in Buenos Aires (Argentina) or Lambayeque (Peru) it is 25% and 37%, respectively (Aderasa 2021; Sunass, 2022a). In Mendoza (Argentina), only 11% of users have a meter, and only 2.5% are billed volumetrically (Toribio, 2023). An IDB study for the capital of Ecuador estimated that water consumption was reduced by 8% as a result of micro-metering (Carrillo et al., 2021), which reinforces the importance of having micro-meters to reduce excessive consumption in the context of pressure on water sources.

Impacts on non-residential water demand

Seventy-six percent of total water demand in Latin America and the Caribbean is for agricultural use, while domestic and industry demand constitutes 15% and 9%, respectively (World Bank, 2020). As in the case of residential demand, population growth brings with it increased food production and, therefore, greater water demand for agriculture. In addition, projections for the region warn that increased temperatures and reduced precipitation will significantly impact water demand in the agricultural sectors (Castellanos et al., 2022).

Climate change will also increase the scarcity risk for mining and other water-intensive industries (Caretta et al., 2022). The situation may become critical if we consider that, in the coming years, the demand for water will increase due to the exploitation of unconventional gas (shale gas) and, in the context of the energy transition, due to the extraction of critical minerals such as lithium.

Likewise, although electricity generation implies a non-consumptive use of water, it should be considered that this sector's water use may affect the availability of the resource for population use.

In Latin America and the Caribbean, about 45% of electricity generation comes from hydroelectric sources, and the percentage rises considerably for the Andean and Southern Cone countries (Lopez-Soto et al., 2022). Water is, therefore, a fundamental input for energy production in the region and is expected to be impacted by droughts, changes in the seasonality of rivers and increases in water temperature (Caretta et al., 2022). Although demand for productive purposes (electricity generation, mining, agriculture) is not usually supplied by drinking water operators, it is necessary to consider that competition between different uses, including population use, will increase as the availability of water sources decreases.

2.2.2. Impacts on supply

The effects of climate change impact the ability of operators to provide water and sanitation services through two channels. First, they affect the typical conditions under which they operate. This ranges from impacts on water sources—affecting the quantity, quality and timely availability of water resources—to affecting processes, as in the case of wastewater treatment. Secondly, extreme weather events cause the collapse, damage or even destruction of the operators' assets, jeopardizing the continuity of service provision.

Impacts on operating conditions

The rapid retreat and melting of glaciers, driven by climate change, have a significant impact on the availability of water resources. In the tropical Andes of Venezuela, Colombia, Ecuador, Peru and Bolivia, the reduction in glacial surface area during the second half of the 20th century ranges between 20% and 50% (Magrin, 2015). The Lima water company reports that glacier coverage in the Andes Mountains has been reduced from 26.6 km2 (91.7%) in 1988 to 12.2 km2 (46%) in 2013 (Sunass, 2021).

Surface sources experience significant impacts due to variations in rainfall patterns. When rainfall decreases, river flow also decreases, which in turn decreases the production of drinking water at treatment plants. On the other hand, heavy rainfall events can increase the amount of sediment carried, thus increasing turbidity in rivers. Turbidity can also be increased by the effect of forest fires, the occurrence of which increases in the context of more intense droughts (Caretta et al., 2022). Depending on the level of turbidity, this could raise drinking water treatment costs or even make the process impractical, ultimately forcing the closure of treatment plants. In March 2017, the drinking water service in Lima was interrupted for four days as heavy rains generated landslides that contaminated the city's main river (Stip et al., 2019).

Considering that water operators usually resort to wells to guarantee the provision of water services, the phenomena described above increase the extractive pressure on aquifers. Some cities in the region depend entirely on groundwater for their drinking water supply, while in others, such as Mexico City, 58% comes from these sources, and their overexploitation causes land subsidence of up to 40 centimeters per year (Solis, 2023). Subsidence can cause cracks and breaks in water supply and sewerage systems, increasing physical water losses and generating a risk of contamination.

Climate change can also affect water quality. Rising temperatures have increased the frequency, severity, and geographic distribution of harmful algal blooms in surface water sources (EPA, 2013). This issue is further exacerbated by the discharge of untreated wastewater into bodies of water, accounting for approximately 80% of the collected wastewater in the region (IANAS, 2019; World Bank, 2019). This leads to water operators having to implement additional treatment processes to ensure that the water is safe for human consumption.

Sea level rise can increase the risk of floods in infrastructure such as seawater desalination plants or wastewater treatment plants (Hughes et al., 2021). It also represents a threat to coastal aquifers, as it can contaminate them through saline intrusion. Such is the case in Jamaica and Barbados, where sea level rise will exacerbate saline intrusion caused by overexploitation of groundwater (IANAS, 2019).

Finally, higher temperatures can affect the performance of wastewater conveyance and treatment systems and cause increased odors, among other problems (Hughes et al., 2021).

Impacts on infrastructure

Water and sanitation infrastructure can fail when faced with extreme conditions that exceed the maximum parameters under which it was designed. According to the IPCC, extreme precipitation events in the region are projected to increase in magnitude and frequency. Thus, a 1.5°C increase in temperature will translate into an increase in the population affected by floods of between 100% and 200% in Colombia, Brazil and Argentina, 300% in Ecuador and 400% in Peru (Castellanos et al., 2022). Floods and landslides resulting from heavy rains can collapse, damage, or destroy water and sanitation infrastructure and increase the risk of contamination of the water supply.

The increase in the frequency and intensity of rainfall due to climate change may cause the collapse of wastewater and stormwater sewer systems. The number of floods and sewer overflows is expected to increase in the coming years, with consequent health risks (Caretta et al., 2022). In other cases, rainfall can increase the volume of water collected by the sewerage system, exceeding the installed wastewater treatment capacity and generating the discharge of insufficiently treated water into bodies of water. Likewise, rainfall can also contribute to the contamination of water sources if it generates floods that carry chemical substances.

Heavy rains and glacial melting can cause landslides that are a major threat to infrastructure in the region (Castellanos et al., 2022). In particular, they can damage or wash away drinking water catchment and treatment infrastructure. In 2017, landslides wiped out water catchment systems that a company in Chimbote (Peru) was in the process of constructing to reestablish drinking water service to more than 200,000 inhabitants[7].

On the other hand, electricity supply is an important input for water treatment and for systems for distributing drinking water and collecting wastewater via pumping. In this sense, power interruptions caused by disasters can compromise the adequate provision of water and sanitation services. In Tingo María (Peru), power outages affect the operation of pumping equipment, generating wastewater emergence in lower areas (Sedahuánuco, 2014).

Finally, in addition to gray infrastructure, natural infrastructure must be taken into account. The effects of climate change have an impact on wetlands, which cover about 20% of South America and, despite contributing to water security, are threatened mainly by human activity (Junk, 2013). On the other hand, extreme events such as hurricanes generate massive deforestation, sedimentation and siltation in river and lake basins, destroying hydrological systems and affecting downstream drinking water supply (IANAS, 2019).

Source: Aguas Andinas

[7] https://elcomercio.pe/peru/ancash/ancash-huaicos-dejan-agua-chimbote-nuevo-chimbote-408121-noticia/

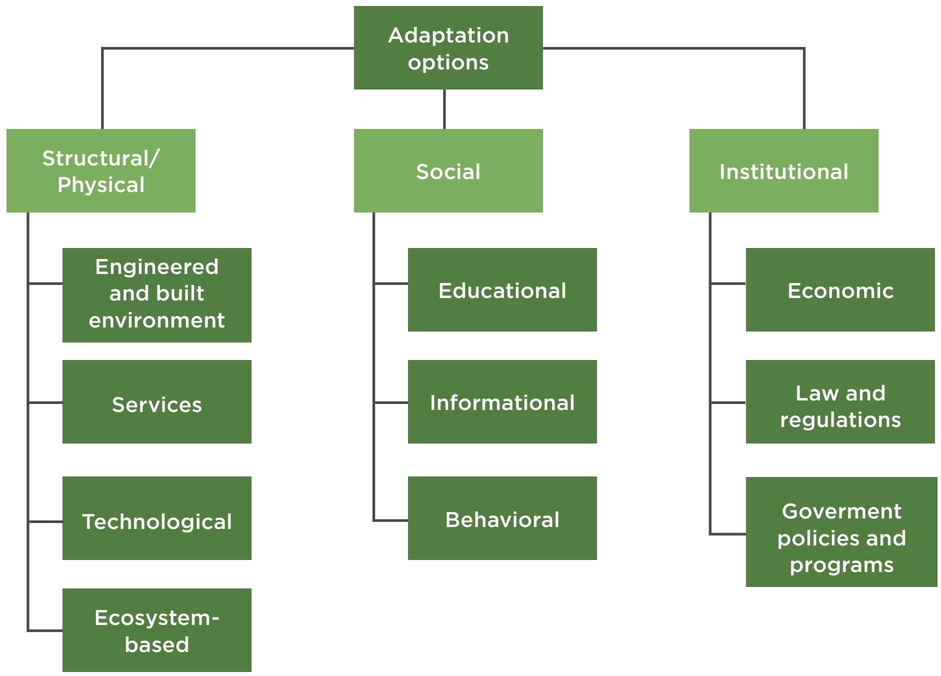
2.3. Making services more resilient: climate change adaptation measures

Adaptation to climate change is the process of adjusting to the current or expected climate and its effects, which includes reducing vulnerabilities and building the capacity of different agents and natural systems to cope with climate effects (Noble et al., 2014; Bárcena et al., 2020). In the case of infrastructure services, the focus should be on resilient infrastructure, which does not only include investment in assets but also actions to ensure the resilience of service provision and users (Hallegatte et al., 2019). Water and sanitation operators can adopt several measures to mitigate risks associated with climate change impacts. While engineering solutions are often the most common form of adaptation, there is a growing trend to adopt other types of measures that have various advantages in terms of cost, flexibility, and implementation timeframe.

There is no single way to categorize resilience measures, because the same measure can be often transversal to different categories or the implementation of an adaptation strategy involves the adoption of different measures that are interrelated (Noble et al., 2014). According to the classification presented by the IPCC in 2014, adaptation measures can be structural/physical, social and institutional (see **Figure 4**). In the particular case of water and sanitation services, structural/physical measures refer to investment in gray infrastructure, technology, and Nature-based Solutions (NbS) that allow managing the supply of water resources; social measures, meanwhile, generally refer to demand shifts that reduce pressure on the current infrastructure. Institutional measures include the application of economic instruments such as tariffs, payments for ecosystem services or the approval of infrastructure or sectoral regulations and plans that explicitly incorporate climate change adaptation criteria (see **Annex 6.1** for examples of adaptation measures for each subcategory).

Figure 4

IPCC categorization of adaptation options



Source: Authors' elaboration based on Noble et al. (2014).

In the following paragraphs, we describe some of the measures that have been adopted in countries of the region and that contribute to resilient water and sanitation services.

Diversification and redundancy in drinking water production

Conjunctive use of water sources is a practice widely used by operators to cope with climate variability. Because there are periods of higher and lower rainfall, operators often use groundwater to supplement drinking water production when surface water availability decreases, a practice used for at least 1400 years according to findings from infrastructure built by pre-Incan cultures (Ochoa-Tocachi et al., 2019). However, climate change is exacerbating climate variability, so water operators must continue to invest in the diversification of water sources.

Groundwater serves as a natural reservoir, ensuring the uninterrupted supply of drinking water services during events that impact surface water sources. These events may include droughts leading to reduced availability or landslides that raise water turbidity and damage intake infrastructure.

In Santiago de Chile, investments have been made for an amount close to USD 190 million in the period 2013-2022, which today has afforded the city 37 hours of autonomy in the event of service problems (Solis, 2023). Desalination is also an adaptation strategy. However, this technology is intensive in the use of electricity, so the use of solar energy can contribute to reducing associated emissions (Caretta et al., 2022). Chile has been strongly committed to desalination. At the time of writing this report, there are 6 desalination plants under construction and 22 in operation[8], including the Atacama plant, which provides drinking water to more than 200,000 inhabitants.[9] Another way to diversify water sources is for users to practice rainwater harvesting for certain uses, which can be promoted and financed by the authorities, as is the case in Mexico City.[10] Diversification can also be understood geographically: it is important to decentralize the production of drinking water, as this reduces the impact on the continuity of supply when certain production infrastructure is affected by extreme weather events.

Increasing operational efficiency

Reducing physical and commercial water losses is an urgent task for Latin America and the Caribbean, which will become even more pressing as climate change increases pressure on water sources. A CAF study found that the average level of non-revenue water in 26 cities in the region was around 40% (Carrera et al., 2018) with values as high as 67%. In Peru, except for the Lima utility (29%), the average non-revenue water is around 42%, reaching up to 64% in the case of one operator (Sunass, 2022a). The average non-revenue water in Caribbean countries is 46%, reaching 75% in the case of the Jamaican operator (Janson et al., 2021). Micro-metering is essential to reduce commercial water losses; however, some operators in the region have very low micro-metering rates, which has the potential to discipline consumption. According to a recent IDB study in Quito, micro-metering can reduce water consumption by 8% (Carrillo et al., 2021). Reducing the aforementioned levels of water losses in the region will require the installation of consumption meters, maintaining updated cadasters, implementation of leak detection technologies, and investment in maintenance, rehabilitation, and replacement of water distribution networks.

[8] https://blog.investchile.gob.cl/bloges/chile-plantas-desalinizadoras

[9] https://www.sepchile.cl/2022/05/30/la-primera-planta-desaladora-estatal-de-chile-es-reconocida-y-premiada-a-nivel-mundial/

[10] https://www.sedema.cdmx.gob.mx/programas/programa/cosecha-de-lluvia

Promoting demand efficiency

In Latin America and the Caribbean, 76% of water withdrawals are for agricultural purposes (World Bank, 2020). In addition, the average ratio between water requirements for irrigation and withdrawals is 36% for the region while the world average is close to 60% (CAF, 2022), which shows that there is significant room for efficiency gains. In particular, it is important to promote efficient irrigation technologies such as drip or sprinkler irrigation. However, at the level of water operators, there is also room for efficiency gains in urban demand. Demand management measures are critical to achieving long-term service reliability, as they can be more cost-effective than investments in water supply, as pointed out in the investment analysis using principles of decision-making under deep uncertainty conducted for the Lima water operator (Kalra et al., 2015). In this regard, it should be considered that daily per capita consumption in some areas of cities in the region can reach 280 liters (Lima, Peru) and up to 650 liters in Mendoza, Argentina (Gómez-Lobo et al., 2023; Toribio, 2023), well above the recommendations of the World Health Organization.

Measures to promote demand efficiency include the establishment of tariffs that encourage rational use, as well as non-price policy options such as s the promotion of water-saving technology, labeling schemes, social comparison through bills, and education programs (Ong et al., 2023). According to Low et al. (2015), Australian authorities implemented measures such as rebates and replacement programs for domestic users (showers, washing machines, toilets) and small businesses (water-saving technology) during the Millennium Drought. An adequate system of charges for surface water drainage can encourage users to implement permeable areas and gutters to channel rainwater to green areas. This would reduce both pressure on infrastructure and the risk of flooding, as well as contribute to aquifer recharge (Solis, 2023).

Incorporate resilience throughout the project life cycle

Resilience can be introduced in both existing assets and new investments. For existing infrastructure, its reinforcement, rehabilitation or retrofitting can be done with more climate information. This includes the adoption of new design standards, which may require changing the scope of the project, upgrading assets, or developing alternative use of the assets (World Bank, 2022). For new infrastructure, it should be considered that many of the risks related to climate change can be mitigated if taken into account at an early stage. At the national level, public investment systems must incorporate risk assessment for project planning, design and implementation.

For example, using decision-making principles under deep uncertainty facilitates the identification of: i) investments that will not be regretted (i.e., beneficial under any scenario), ii) investments that avoid catastrophic or high-cost outcomes, and iii) unnecessary investments (Cavallo et al., 2020). Using these decision-making principles, the water utility in Lima (Sedapal) was able to identify investments that could be removed without affecting the objective of guaranteeing water supply reliability. The exercise involved applying these principles to a wide range of future scenarios that considered different impacts on river flows and different levels of water demand in the city. The identification of these investments led to savings of over USD 600 million; that is, 25% of the investment budget initially estimated by the company (Kalra et al., 2015). In Mendoza, Argentina, the DMDU method enabled to determine that investments in storage were significantly costly and did not effectively mitigate the vulnerabilities faced by the city. On the other hand, investments in pressurized irrigation proved to be more cost-effective by reducing water demand and increasing the availability of the resource (Groves et al., 2021).

Likewise, considering resilience in design implies the appropriate site selection (taking into consideration vulnerability to flooding or sea level rise), the selection of appropriate technologies, and construction with more resistant materials, among other aspects. According to a study by Hallegatte et al. (2019) for low- and middle-income countries, the investment costs required to provide universal access to water and sanitation in these countries would increase by between 1.1% and 2.2% to make them resilient to floods, and between 5% and 9% to make them resilient to earthquakes. Likewise, estimates show that, when climate change is taken into account, the median benefit-cost ratio of making these investments increases from 2 to 4. Once the assets are built, it is a recommended adaptation measure to promote financial instruments to manage residual risk, which includes developing the insurance market and financing instruments to implement reconstruction and contingency plans promptly (Cavallo et al. 2020; CAF, 2022).

Maintenance in times of climate change

Water operators perform preventive and corrective maintenance on their assets to preserve them from deterioration due to use or extraordinary events. This is an important component to guarantee the provision of infrastructure services: it represents 32% of the investments required to close the gap in the water and sanitation sector by 2030 (Brichetti et al., 2021). Furthermore, in an analysis conducted for low- and middle-income countries, Rozenberg and Fay (2019) find that the lack of adequate maintenance reduces the useful life of assets and increases capital costs to replace them by at least 60% in the water sector. Lack of asset maintenance is a problem in LAC: 51% of operators reporting information to Aquarating stated that they do not have a maintenance and replacement plan for physical assets, based on risk analysis of failures, costs, etc. (Pastor, 2019).

Concerning preventive maintenance, the original conditions under which the infrastructure was designed may have changed drastically due to climate change. High temperatures and exposure to extreme weather conditions accelerate the wear and tear of infrastructure and can have effects on machinery and equipment. Therefore, it is necessary to update the frequency and processes of maintenance to ensure its proper functioning. In the absence of the required maintenance, climate change increases the vulnerability component of disaster risk, as it reduces the capacity of assets to withstand extreme weather events. Regarding corrective maintenance, water operators must have protocols that allow them to repair breakdowns or failures caused by extreme weather events in the shortest possible time to ensure continuity of service or minimize its interruption.

Implement Nature-based Solutions

The provision of water and sanitation services includes physical and chemical processes, such as purification and storage, which ecosystems can perform naturally. These can replace or complement the so-called gray infrastructure that water operators rely on. Nature-based solutions (NbS) comprise actions aimed at protecting, sustainably managing and restoring natural or modified ecosystems while providing additional benefits for humans and biodiversity (Cohen-Shacham et al., 2016). Within these solutions, investment in natural infrastructure seeks to preserve or restore ecosystems to benefit from their services. In the coming years, wetlands will play a fundamental role in buffering changes in the hydrological cycle, reducing their negative social, economic and ecological impacts (Junk, 2013). Therefore, it should be noted that investment in watershed protection is partially offset by the subsequent reduction in water treatment costs (Scanlon et al., 2023).

For example, in New York City, maintaining afforestation in the contributing watershed (approximately 75% of the land) will allow the city to avoid building a treatment plant that would cost between USD 8 billion and USD 10 billion (Abell et al., 2017). In São Paulo, reforestation could significantly reduce sediment and nutrient loading in water sources (Abell et al., 2017; Ozment et al., 2018), and economic losses from the 2014-2015 drought would have been reduced by 28% if NbS had been implemented (Stein Ciasca et al., 2023). In Medellín (Colombia), it has been estimated that a 10% loss of vegetation in the region would increase monthly treatment costs by USD 4.5 million (Tallis and Markham, n.d.). In Bogotá (Colombia), a natural infrastructure portfolio of USD 5.3 million could generate cost avoidance totaling USD 44.6 million over 30 years (Izquierdo-Tort et al., 2023).

An IDB study identified 156 NbS projects in the region, more than half of which have water and sanitation as the primary sectors (Ozment et al., 2021). In Peru, between 2008 and 2021, 175 investments in natural infrastructure for water security were approved totaling approximately USD 227 million, and about 58% were executed with the most significant interventions being reforestation (134), infiltration trenches (54) and pastureland enhancement (29) (Cerdán Estrada et al., 2022). For its part, green infrastructure refers to engineering interventions in urban areas that interact with gray infrastructure and provide hybrid solutions (The Nature Conservancy, 2019). While these are not usually the purview of water operators, permeable pavement, green roofs, bioretention and riparian parks are often local government interventions that reduce urban flood risk and recharge aquifers, contributing to water security (Solis, 2023).

Table 1 presents a series of adaptation measures available to water and sanitation operators and whose selection should be made based on the particular context of the company (i.e., effectiveness, flexibility, robustness to climate and social scenarios and consistency with social norms and traditions, among other criteria) (Magrin, 2015).

Table 1

Water Utility Adaptation Strategies for Climate Change

ADAPTATION ACTIONS	STRATEGIES
Construct new infrastructure	Build flood barriers to protect infrastructure
	Build infrastructure needed for aquifer storage and recovery
	Diversify options of water supply and expand current sources
	Increase water storage capacity
	Install low-head dam for saltwater wedge and freshwater pool separation
	Plan and establish an alternative or on-site power supply
	Relocate facilities to higher elevations
Increase system efficiency	Improve energy efficiency and optimization of operations
	Finance and facilitate systems to recycle water
	Practice conjunctive use
Model climate risk	Conduct extreme precipitation events analyses
	Conduct sea-level rise and storm surge modeling
	Develop models to understand potential water quality changes
	Model and monitor groundwater conditions
	Model and reduce inflow/infiltration into the sewer system
	Use hydrologic models to project runoff and future water supply
Modify land use	Acquire and manage ecosystems
	Implement green infrastructure on site and in municipalities
	Implement watershed management
	Integrate flood management and modeling into land use planning
	Study the response of nearby wetlands to storm surge events
	Update fire models and practice fire management plans
Modify water demand	Encourage and support practices to reduce water use at local power plants
	Model and reduce agricultural and irrigation water demand
	Practice water conservation and demand management

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ADAPTATION ACTIONS	STRATEGIES
Monitor operational capabilities	Conduct stress testing on wastewater treatment biological systems to assess tolerance to heat
	Manage reservoir water quality
	Monitor and inspect the integrity of existing infrastructure
	Monitor current weather conditions
	Monitor flood events and drivers
	Monitor surface water conditions
	Monitor vegetation changes in watersheds
Plan for climate change	Adopt insurance mechanisms and other financial instruments
	Conduct climate change impacts and adaptation training
	Develop coastal restoration plans
	Develop emergency response plans
	Develop energy management plans for key facilities
	Establish mutual aid agreements with neighboring utilities
	Identify and protect vulnerable facilities
	Integrate climate-related risks into capital improvement plans
	Participate in community planning and regional collaborations
	Update drought contingency plans
Repair and retrofit facilities	Implement policies and procedures for post-flood and/or post-fire repairs
	Implement saltwater intrusion barriers and aquifer recharge
	Improve pumps for backflow prevention
	Increase capacity for wastewater and stormwater collection and treatment
	Increase treatment capabilities
	Install effluent cooling systems
	Retrofit intakes to accommodate lower flow or water levels

Source: EPA (2023).

3

What climate change-related events occur in Latin America and the Caribbean and how much do they affect water and sanitation assets?

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3.1.
Characteristics of the database

DesInventar is a disaster information management system currently managed by UNDRR (United Nations Office for Disaster Risk Reduction) and supported by UNDP (United Nations Development Programme). With information from several countries for the period 1970-2013, it facilitates the analysis of trends in the occurrence of disasters and their repercussions and impacts in a systematic way. Analyzing disaster trends is important because it allows for the planning of prevention, mitigation and preparedness measures to reduce the impact of disasters on the population.

The DesInventar database is fed by the countries themselves (**Table 2** presents the LAC countries according to their availability of information) and contains data on types of events and direct and indirect effects (deaths, housing and infrastructure affected, economic sectors, etc.). The DesInventar methodology distinguishes between "events" (i.e., any socio-natural phenomenon that can be considered a threat to life, property and infrastructure) and "disaster" (i.e., the set of adverse effects caused by an event in a specific geographical unit and during a specific period).

Table 2
Countries with available information reported in the DesInventar database

SUB-REGION	COUNTRIES WITH INFORMATION	COUNTRIES WITH NO INFORMATION
Central American Countries, Haiti, Mexico, Panama and the Dominican Republic (CID)	Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Mexico, Panama	Haiti, Dominican Republic
Caribbean Group Countries (CCB)	Guyana, Jamaica, Trinidad and Tobago	Bahamas, Barbados, Suriname
Andean Group Countries (CAN)	Bolivia, Colombia, Ecuador, Peru, Venezuela	-
Southern Cone Countries (CSC)	Argentina, Chile, Paraguay, Uruguay	Brazil

Source: Authors' elaboration.

It should be noted that our analysis in the following pages includes events whose greater frequency of occurrence or intensity can be attributed to the effects of climate change.[11]

Finally, the concept of geographical units is fundamental for interpreting the data in this section. The DesInventar methodology suggests that the effects of a disaster should be disaggregated into each of the geographical units affected (the tool normally considers two levels where the first is equivalent

[11] The events reported in DesInventar not included in this analysis are: earthquakes and liquefactions, ozone, epizootics, eruptions and lahars, fires (although forest fires are included), and structural collapse. Cold wave, frost and snowstorm events are also excluded because of outliers.

to the province and the second to the municipality). In this way, the DesInventar database reports the number of "records" (also called DataCards) which does not in itself reflect the number of disasters.[12] In this sense, the same event could generate fewer or more records depending on the scale and, therefore, the number of geographical units affected.

3.2. Records of events in the region

There is a total of 141,957 records for the period 1970-2013; that is, 141,957 times in which geographic units were impacted by socio-natural phenomena that may constitute a threat to life, property and infrastructure. At the LAC level, 42% of the records correspond to floods and flash floods, with landslides being the second most common event in the region (16% of the records).

Table 3
Number of records per event and sub-region in LAC (1970-2013)

EVENT	SUB-REGION				TOTAL
	CAN	CCB	CID	CSC	
Alluvion	1,885	7	45	260	**2,197**
Avalanche	101		21	68	**190**
Coastal erosion	18		13	10	**41**
Cyclone	27	103	150		**280**
Drought	1,668	20	4,877	1,500	**8,065**
Electric storm	493	10	451	91	**1,045**
Erosion	28				**28**
Flash flood	1,520	2	1,088	99	**2,709**
Flood	24,396	1,730	23,447	7,080	**56,653**
Fog	88	3	44	481	**616**
Forest fire	7,165	2	4,724	2,220	**14,111**
Hailstorm	819	2	614	395	**1,830**
Heatwave	90	3	810	78	**981**
Landslide	14,074	401	8,566	314	**23,355**
Rainfall	3,631	67	5,460	812	**9,970**
Sedimentation	62		24	5	**91**

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[12] https://www.desinventar.net/documentation/User-Manual-Analysis-and-Query_EN.pdf

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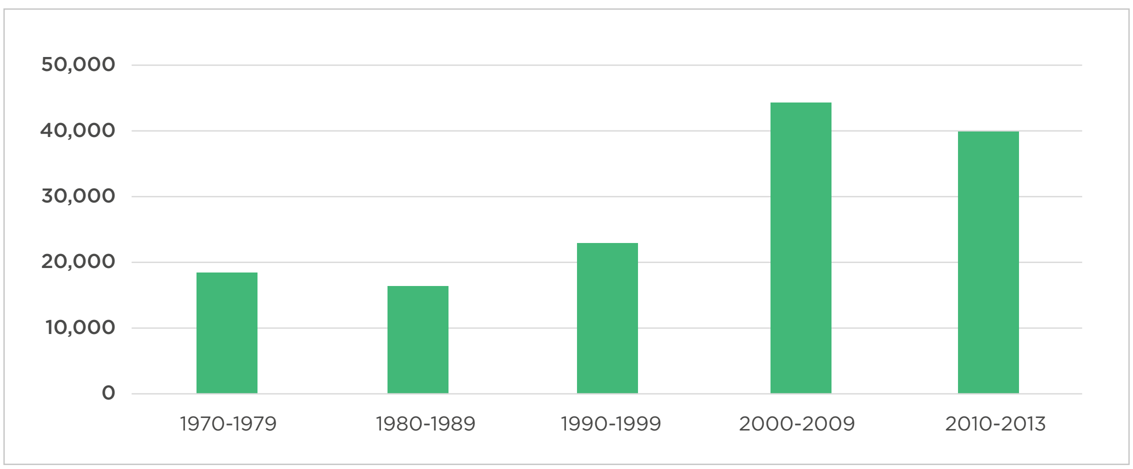
EVENT	SUB-REGION				TOTAL
	CAN	CCB	CID	CSC	
Storm	608	86	2,397	5,362	**8,453**
Surge	656	18	862	165	**1,701**
Tornado	7	2	64	36	**109**
Tsunami	10		88	6	**104**
Windstorm	4,977	258	3,291	902	**9,428**
Total	**62,323**	**2,714**	**57,036**	**19,884**	**141,957**

Source: DesInventar. Authors' elaboration.

Figure 5 shows the evolution in the number of records per decade. Although there is information only for the first four years of the decade 2010-2019, it can be anticipated that there is an increasing trend.

Figure 5
Number of records per decade



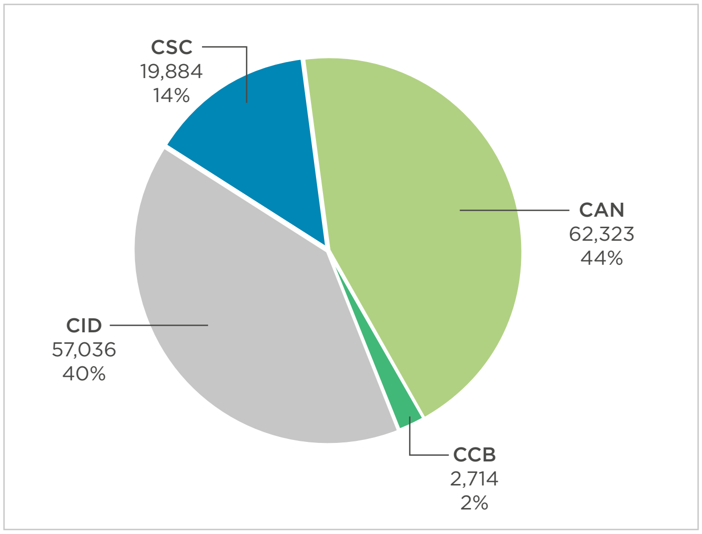
Note: No information is available for the years 2014 - 2019.

Source: DesInventar. Authors' elaboration.

On the other hand, **Figure 6** shows the number of registrations by LAC sub-regions, where it can be seen that the CAN Group countries account for 44% of the registrations, while the CID Group countries account for 40%. This is largely explained by the population and the size of the countries' territories, as can be seen in **Figure 7**.

Figure 6

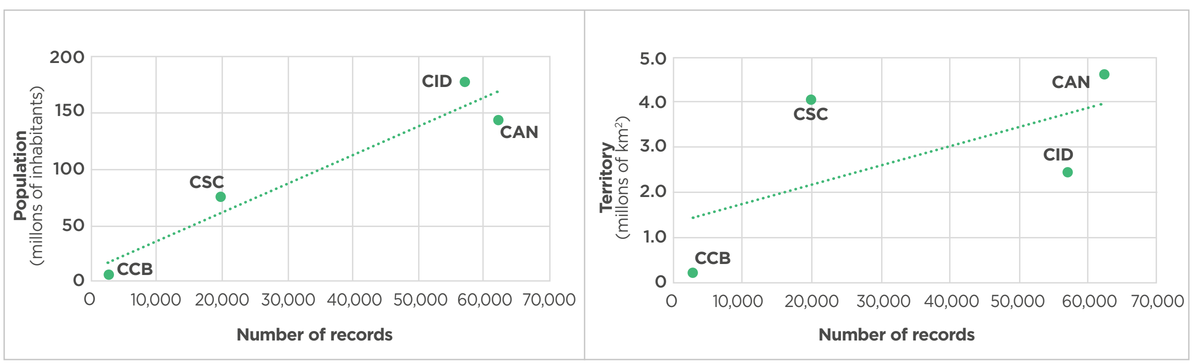
Number of records by LAC sub-region



Source: DesInventar. Authors' elaboration.

Figure 7

Relationship between the number of records and population size and area of the sub-regions



Source: DesInventar, World Development Indicators (World Bank). Authors' elaboration.

Table 4 shows that floods have generated the most records in the four LAC sub-regions, accounting for 64% of the records in the Caribbean Group countries. In the group of Andean Community countries, landslides represent the second highest number of records (23%), and in third place are forest fires (11%). In the Central American countries, landslides are also the second most recorded event (15%), followed by rains and forest fires (10% and 8%). In the Southern Cone countries, storms are the second most common event, representing 27% of the records for this sub-region, followed by forest fires (11%).

Table 4

Vertical analysis: the importance of each type of event in each sub-region in LAC (1970-2013)

EVENT	SUB-REGION			
	CAN	CCB	CID	CSC
Alluvion	3%	0.3%	0.1%	1%
Avalanche	0.2%	0%	0%	0.3%
Coastal erosion	0%	0%	0%	0.1%
Cyclone	0%	4%	0%	0%
Drought	3%	1%	9%	8%
Electric storm	1%	0.4%	1%	0%
Erosion	0%	0%	0%	0%
Flash flood	2%	0.1%	2%	0.5%
Flood	39%	64%	41%	36%
Fog	0.1%	0%	0.1%	2%
Forest fire	11%	0%	8%	11%
Hailstorm	1%	0%	1%	2%
Heatwave	0.1%	0%	1%	0%
Landslide	23%	15%	15%	2%
Rain	6%	2%	10%	4%
Sedimentation	0.1%	0%	0%	0%
Storm	1%	3%	4%	27%
Surge	1%	1%	2%	1%
Tornado	0%	0.1%	0.1%	0.2%
Tsunami	0%	0%	0.2%	0%
Windstorm	8%	10%	6%	5%
Total	**100%**	**100%**	**100%**	**100%**

Source: DesInventar. Authors' elaboration.

It is also very illustrative to review possible sub-regional concentration of particular records. Despite the high number of records in CAN (44% of the total number of records in LAC), not all events are recorded in greater frequency in this sub-region due to the meteorological conditions of the countries themselves. For example, 54% of cyclone records correspond to Central American countries and 37% to countries of the Caribbean Group. Sixty percent of the records associated with droughts are in Central America, where there are also a high number of records of heat waves, tidal waves, tornadoes, and tsunamis. For their part, 63% of storm records and 45% of snowstorm records are found in the Southern Cone countries. For more details, see **Table 5**.

Table 5

Horizontal analysis: concentration of events by sub-region (1970-2013)

EVENT	SUB-REGION			
	CAN	CCB	CID	CSC
Alluvion	86%	0%	2%	12%
Avalanche	53%	0%	11%	36%
Coastal erosion	44%	0%	32%	24%
Cyclone	10%	37%	54%	0%
Drought	21%	0%	60%	19%
Electric storm	47%	1%	43%	9%
Erosion	100%	0%	0%	0%
Flash flood	56%	0%	40%	4%
Flood	43%	3%	41%	12%
Fog	14%	0%	7%	78%
Forest fire	51%	0%	33%	16%
Hailstorm	45%	0%	37%	22%
Heatwave	9%	0%	83%	8%
Landslide	60%	2%	37%	1%
Rain	36%	1%	55%	8%
Sedimentation	68%	0%	26%	5%
Storm	7%	1%	28%	64%
Surge	39%	1%	51%	10%
Tornado	6%	2%	59%	33%
Tsunami	10%	0%	85%	6%
Windstorm	53%	3%	35%	10%
Total	**44%**	**2%**	**40%**	**14%**

Source: DesInventar. Authors' elaboration.

3.3.
Records of events affecting water and sanitation assets

The DesInventar database also includes the number of records in which it was reported that water and sanitation systems were affected.[13] The first category includes records that reported damage to the aqueduct system (water outlets, water treatment plants, aqueducts and canals which carry drinking water, and storage tanks), while the second category refers to damage to sewerage systems and wastewater treatment plants.

As can be seen in **Table 6**, floods and rains have the greatest impact on water and sanitation systems of any event. Damage to water systems in LAC was caused by floods in 42% of cases and by rains in 21% of cases. In the case of sanitation systems, these percentages are 62% and 17%, respectively. These systems are also affected by landslides (10% in water and 8% in sanitation), while droughts affect water systems (11%).

[13] https://www.desinventar.net/documentation/Desinventar_Sendai_Data_management.pdf

Table 6

Records reporting damage to water supply and sewerage systems (1970-2013)

EVENT	WATER				SANITATION				WATER	SANITATION
	CAN	CCB	CID	CSC	CAN	CCB	CID	CSC		
Alluvion	87	2	6	34	36	3	6	6	2%	1%
Avalanche	2		1	2	1				0%	0%
Coastal erosion	1				1				0%	0%
Cyclone	1	59	12		1	59	6		1%	1%
Drought	546	15	109	115	14	1	10		11%	0%
Electric storm	7		32	2	7		2		1%	0%
Erosion									0%	0%
Flash flood	162		91	8	67		79	10	4%	2%
Flood	857	123	1,518	352	1,528	92	2,778	435	42%	62%
Fog			3						0%	0%
Forest fire	31		13	15	2		2	1	1%	0%
Hailstorm	18		21	2	41		31		1%	1%
Heatwave	8		5	21					0%	0%
Landslide	476	15	171	4	442	12	145	5	10%	8%
Rain	145	24	1,227	36	215	19	1,086	35	21%	17%
Sedimentation	6		3		1		3		0%	0%
Storm	20	29	110	168	22	25	152	256	5%	6%
Surge	8	3	6		7	3	4	2	0%	0%
Tornado			4						0%	0%
Tsunami	1			3					0%	0%
Windstorm	40		21	44	82		33	3	2%	2%
Total	**2,416**	**270**	**3,353**	**806**	**2,467**	**214**	**4,337**	**753**	**100%**	**100%**

Source: DesInventar. Authors' elaboration.

4

How does climate change affect water and sanitation operators in the region?

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4.1. Methodology and characteristics of participating operators

This section contains the results of a survey specifically designed for this study, which was answered by officials representing water and sanitation operators in Latin America and the Caribbean, preferably in charge of production or environmental management. The survey was disseminated primarily through the Water Operators' Partnership Latin America & Caribbean (WOP-LAC) networks.

To increase the scope of the survey, we also requested the support of different national associations of water companies, and we addressed direct communications to selected representative companies in all countries of Latin America and the Caribbean (see the **Acknowledgements** section). In the invitation to participate, it was suggested that the survey should preferably be answered by the department or manager in charge of water or environmental production within the company. This preference is due to the direct impact of climate change on the operations of these departments. It should be noted that the answers submitted by the interviewees do not necessarily represent the official position of the operators, but they are an important indication of the situation they are currently facing.

Information was collected for 61 water operators in the region, distributed in 11 countries, as shown below:

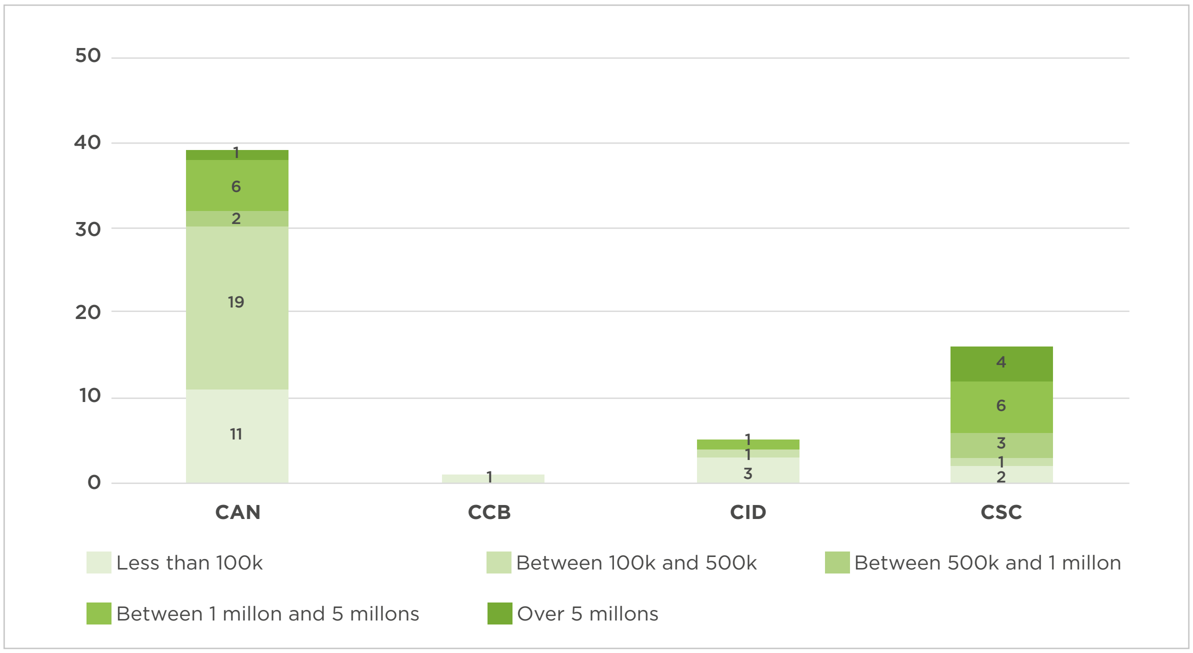
Table 7
Countries for which information is available

REGION	COUNTRY	OPERATORS
CAN	Bolivia	2
	Colombia	21
	Ecuador	2
	Peru	14
CCB	Barbados	1
CID	Belize	1
	Costa Rica	2
	Honduras	2
CSC	Argentina	4
	Brazil	5
	Chile	7

Source: Authors' elaboration based on an IDB survey of operators in the region.

Of the total sample of companies surveyed, 26% serve an area with population of less than 100 thousand inhabitants, 36% serve a population between 100 thousand and 500 thousand, 8% between 500 thousand and 1 million, 21% between 1 million and 5 million, and 8% of the companies surveyed stated that they serve populations of more than 5 million inhabitants. **Figure 8** shows a summary of operators and by size and by sub-region. The complete list of participating operators can be found in **Annex 6.2**.

Figure 8
Size of operators surveyed



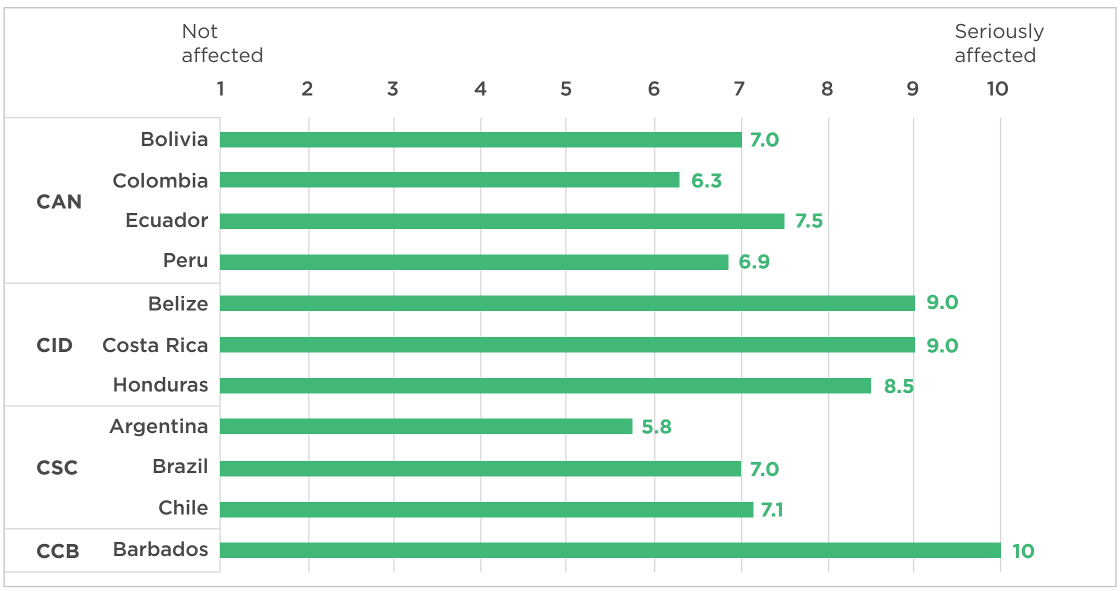
Source: Authors' elaboration based on an IDB survey of operators in the region.

4.2.
Results of the survey

Officials representing water operators were asked, on a scale of 1 to 10, how much they estimated that climate change had affected their company in the last 15 years. The average score in all countries in the sample is above 5 (moderately affected), and in some countries the average score reveals that water companies are seriously affected by the effects of climate change (see **Figure 9**). In particular, 7 of the 61 companies surveyed (11%) reported an affectation index of 10, 4 companies (7%) an index of 9, and 15 companies (25%) an index of 8.

Figure 9

Over the past 15 years, on a scale of 1 to 10, how much do you estimate that climate change has affected your company?

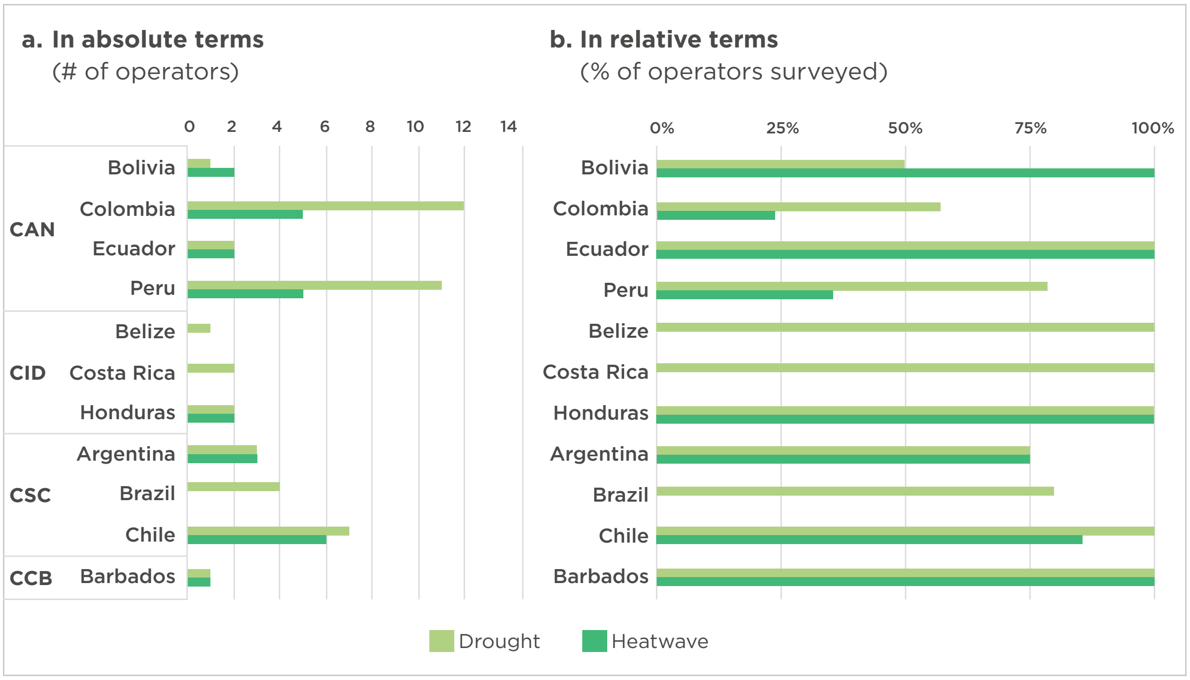


Source: Authors' elaboration based on an IDB survey of operators in the region.

The survey then asked operators about the effects of climate change that they have experienced in recent years. As can be seen in **Figure 10**, in all the countries for which information is available, there are operators that report being affected by droughts. Seventy-five percent of the operators surveyed reported having been affected by droughts, including the Barbados operator (CCB) and 100% of the operators surveyed in CID. In addition, 43% of operators surveyed in the region reported being affected by heat waves.

Figure 10

Operators affected by heat waves or droughts



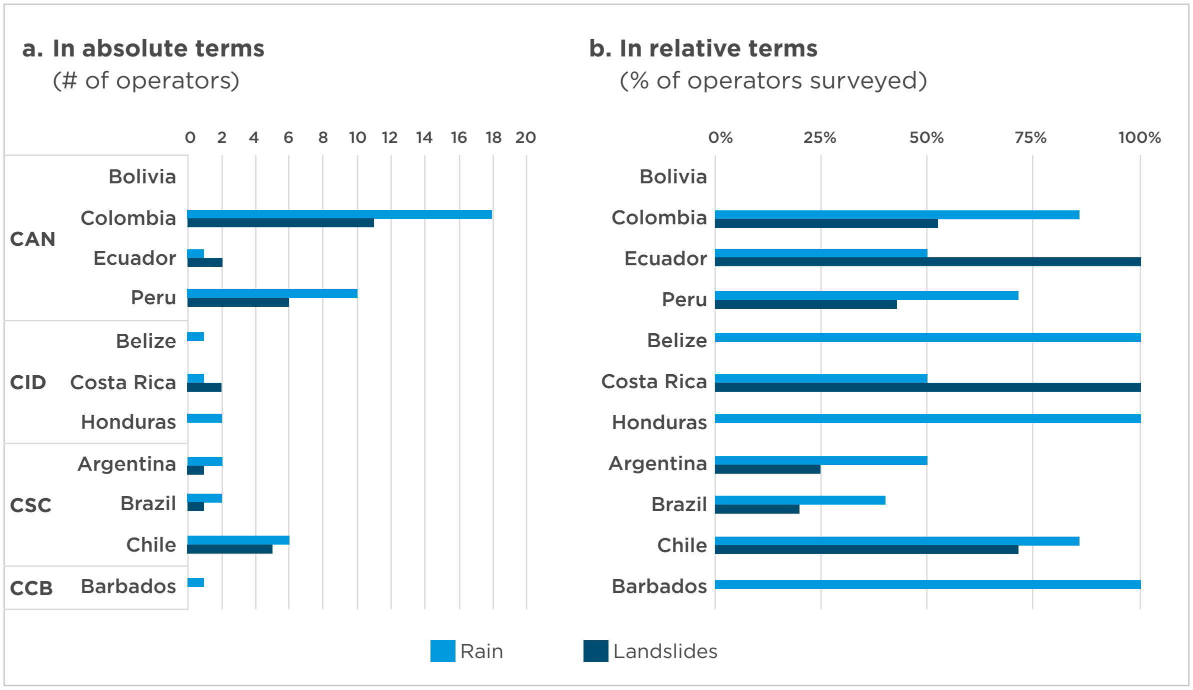
Note: Bolivia (N=2), Colombia (N=21), Ecuador (N=2), Peru (N=14), Barbados (N=1), Belize (N=1), Costa Rica (N=2), Honduras (N=2), Argentina (N=4), Brazil (N=5), Chile (N=7).

Source: Authors' elaboration based on an IDB survey of operators in the region.

Figure 11 shows that a significant percentage of the operators surveyed reported having been affected by heavy rains and landslides. Seventy-two percent of the operators surveyed reported having been affected by heavy rains (74% in CAN and 63% in CSC), while 46% of the operators were affected by landslides (reaching 49% in CAN).

Figure 11

Operators affected by heavy rains and landslides



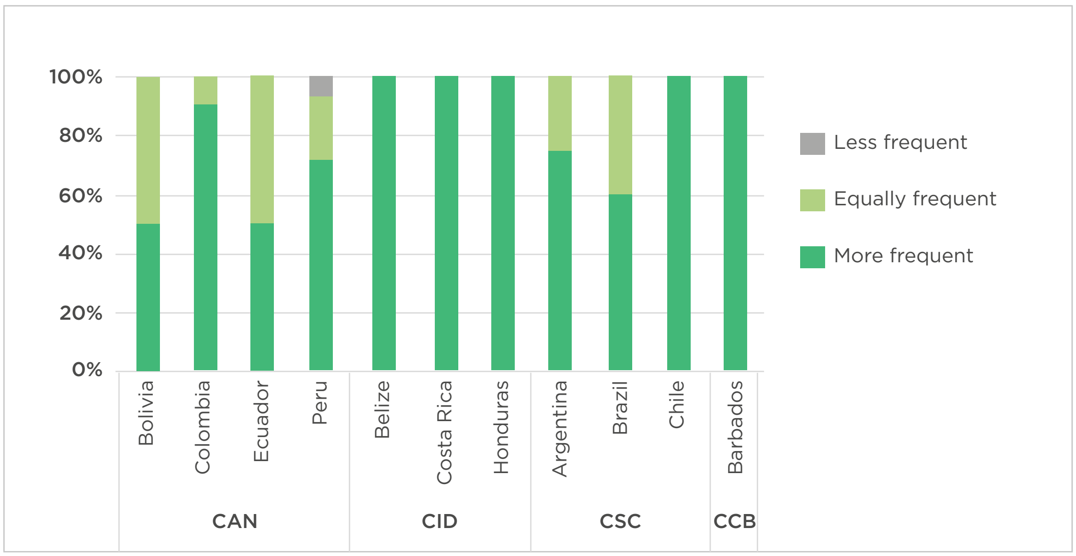
Note: Bolivia (N=2), Colombia (N=21), Ecuador (N=2), Peru (N=14), Barbados (N=1), Belize (N=1), Costa Rica (N=2), Honduras (N=2), Argentina (N=4), Brazil (N=5), Chile (N=7).

Source: Authors' elaboration based on an IDB survey of operators in the region.

The survey also asked about other types of phenomena such as tornadoes or hurricanes, frost, glacier melt, and forest fires. Although the incidence of these types of events is considerably lower, sub-regional patterns were recorded in line with what was found as a consequence of the analysis of the DesInventar database in Section 2 of this report.

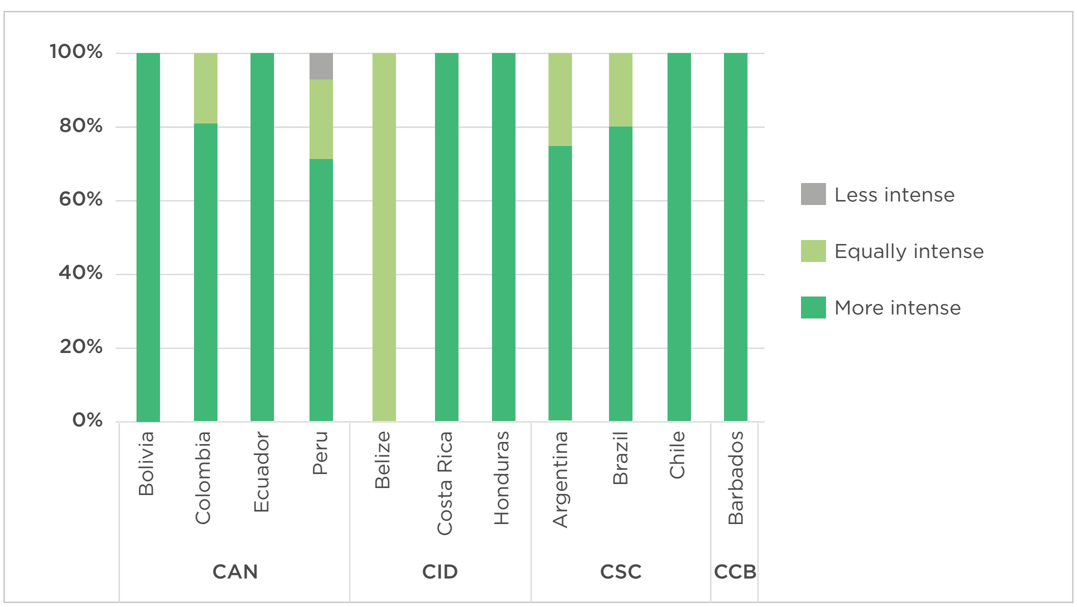
On the other hand, operators were also asked about the frequency and intensity of these phenomena in recent years. As can be seen in **Figure 12** and **Figure 13**, 82% of the operators surveyed think that extreme weather events are occurring more frequently and the same percentage also believes that they are occurring with greater intensity.

Figure 12
Do you think these events are less, equally or more frequent?



Source: Authors' elaboration based on an IDB survey of operators in the region.

Figure 13
Do you think these events are less, equally or more intense?



Source: Authors' elaboration based on an IDB survey of operators in the region.

Concerning the concrete impacts that climate change has had on the operating conditions and infrastructure of the operators surveyed (see **Table 8**), the results show that the impact on surface sources is a reality for the operators: 77% of the operators surveyed state that they are affected by a reduction in the flow of rivers, while 70% report an increase in the level of turbidity in the surface sources. In third place, 66% of the operators report that heavy rains cause the collapse of wastewater and stormwater sewer systems.

Other noteworthy impacts in the subregions include aquifer depletion and interruptions in electricity supply resulting from disasters in CCB and CID countries.

Some impacts not included in the table but reported by operators under the category "Other" include damage to infrastructure due to hurricanes (Belize), varying physical and chemical water quality (Peru), and intense water scarcity (Brazil).

Table 8
What impacts of climate change has your company experienced over the last 15 years?

IMPACTS	CAN				CCB	CID			CSC			TOTAL
	BOL	COL	ECU	PER	BRB	BLZ	CRI	HND	ARG	BRA	CHL	
Reduction in river flow	50%	67%	50%	86%	0%	100%	100%	100%	75%	100%	86%	**77%**
Increase in the turbidity level of surface sources (rivers, lakes)	50%	71%	50%	79%	0%	100%	100%	100%	50%	40%	86%	**70%**
Collapse of wastewater and stormwater sewer systems	100%	67%	100%	50%	100%	0%	100%	100%	25%	60%	86%	**66%**
Unexpected changes in water demand due to changes in temperature.	100%	29%	100%	57%	100%	0%	50%	100%	100%	40%	57%	**52%**
Lowering or depletion of the water table in aquifers	0%	19%	50%	36%	100%	100%	100%	100%	50%	20%	86%	**41%**
Power supply interruptions as a result of disasters	50%	24%	50%	29%	100%	100%	50%	100%	50%	0%	86%	**39%**
Landslides or avalanche damage to infrastructure	0%	33%	50%	50%	0%	0%	100%	50%	0%	20%	14%	**33%**
Eutrophication (increased presence of algae) in water sources	0%	24%	100%	21%	0%	0%	0%	50%	0%	60%	71%	**31%**
Increase in odors at wastewater treatment plants due to increased temperatures	100%	19%	50%	14%	100%	0%	0%	0%	25%	0%	71%	**26%**

(Continued on the next page)

Table 8 (Continued from previous page)

What impacts of climate change has your company experienced over the last 15 years?

IMPACTS	CAN				CCB	CID			CSC			TOTAL
	BOL	COL	ECU	PER	BRB	BLZ	CRI	HND	ARG	BRA	CHL	
Saline intrusion of aquifers	0%	0%	0%	21%	100%	0%	50%	0%	25%	0%	57%	**16%**
Increased evaporation of water stored in dams	50%	5%	0%	36%	0%	0%	0%	0%	0%	60%	0%	**16%**
Reduction in springs or lakes due to glacial melting	0%	0%	0%	29%	0%	0%	0%	50%	25%	0%	29%	**13%**
Destruction of infrastructure due to abnormal sea surge	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	57%	**7%**
Lans subsidence due to compaction of overexploited aquifers	0%	5%	0%	7%	0%	0%	0%	0%	0%	0%	0%	**3%**

Source: Authors' elaboration based on an IDB survey of operators in the region.

The survey also asked operators about climate change adaptation strategies. First, responses were collected on traditional measures (see **Table 9**). Almost all of the companies surveyed (92%) carry out some of these measures. Sixty-four percent of the operators surveyed have responded to the effects of climate change by increasing their purchases of chemical inputs for drinking water treatment. Fifty-six percent report having made investments in the construction or maintenance of reserve wells, which reaffirms the importance of groundwater sources in the region as a strategic natural asset in dealing with surface water variability in the context of climate change (Solís, 2023).

In Brazil, 4 of the 5 companies surveyed have invested in the construction of storage dams; while the operator in Barbados resorts to the reuse of treated wastewater and investment in desalination plants.

Some traditional adaptation measures not included in the table, but reported by operators under the category "Other" include the installation of photovoltaic renewable energy systems at pumping stations (Barbados), installation of automatic real-time groundwater quality monitoring stations (Barbados), interconnection of supply networks and water sources (Brazil, Colombia), purchase of water (Chile), construction and expansion of sources, expansion of plants, construction of ponds, renovation and replacement of pipes (Chile), ultrasound equipment for algae control (Colombia), and replacement and modernization of secondary network infrastructure, using more resistant materials -PEAD (Colombia).

Table 9
Which of the following traditional measures has your company adopted to adapt to climate change?

TRADITIONAL MEASURES	CAN				CCB	CID			CSC			TOTAL
	BOL	COL	ECU	PER	BRB	BLZ	CRI	HND	ARG	BRA	CHL	
Increased expenditure on water treatment chemicals	0%	81%	50%	71%	0%	100%	0%	100%	50%	40%	57%	**64%**
Investments in construction or maintenance of reserve wells	50%	38%	50%	29%	100%	0%	100%	50%	100%	100%	100%	**56%**
Expenditures for more continuous cleaning or de-silting of rivers	0%	29%	0%	43%	0%	100%	100%	100%	50%	20%	14%	**34%**
Investments in the construction of water diversions	0%	5%	50%	14%	0%	0%	50%	50%	50%	60%	71%	**26%**
Investments in the construction of storage dams	0%	10%	0%	14%	0%	0%	0%	0%	0%	80%	71%	**21%**
Reuse of treated wastewater	0%	0%	50%	0%	100%	0%	0%	0%	25%	0%	0%	**5%**
Investment in seawater desalination plants	0%	0%	0%	7%	100%	0%	0%	0%	0%	20%	0%	**5%**
None of the above	50%	10%	0%	14%	0%	0%	0%	0%	0%	0%	0%	**8%**

Source: Authors' elaboration based on an IDB survey of operators in the region.

Non-traditional measures (including investment in natural and green infrastructure) are less common: 36% of operators have not made any investment or adopted any strategy of this type (see **Table 10**). Forty-three percent of water operators are investing in reforestation of upper watersheds and 30% in the protection or restoration of ecosystems (lakes, wetlands, etc.). In Barbados, Ecuador, Peru, Brazil and Chile some operators report encouraging rainwater harvesting by users as a strategy to reduce demand pressure on water sources.

Some non-traditional adaptation measures not included in the table, but reported by operators under the category "Other" include investments in slope stabilization (Peru), riverbed filtration (Colombia), and awareness campaigns (Belize).

Table 10

Which of the following non-traditional measures has your company adopted to adopted to climate change?

NON-TRADITIONAL MEASURES	CAN				CCB	CID			CSC			TOTAL
	BOL	COL	ECU	PER	BRB	BLZ	CRI	HND	ARG	BRA	CHL	
(Re)afforestation of upper parts of the watershed	0%	62%	50%	21%	0%	0%	100%	100%	25%	80%	0%	**43%**
Investment in ecosystem protection or restoration (lakes, wetlands, etc.).	0%	38%	100%	29%	0%	0%	50%	0%	25%	20%	14%	**30%**
Encouraging rainwater harvesting by users	0%	0%	50%	21%	100%	0%	0%	0%	0%	20%	14%	**11%**
Infiltration trenches	0%	0%	0%	14%	0%	100%	0%	0%	0%	0%	14%	**7%**
Investments to reduce river or channel velocities to increase infiltration	0%	0%	0%	7%	0%	0%	0%	0%	0%	0%	0%	**2%**
None of the above	100%	24%	0%	43%	0%	0%	50%	0%	75%	0%	71%	**36%**

Source: Authors' elaboration based on an IDB survey of operators in the region.

The operators that reported implementing these measures (either traditional or non-traditional) were asked how they financed these measures (see **Table 11**): 45 operators (87%) stated that these were financed with resources collected from water and sanitation tariffs, 15 operators (29%) financed the measures with money transfers from some level of government, and 8 operators (15%) used resources from the collection of tariff charges specifically earmarked for these measures.

Some forms of financing not included in the table, but reported by operators under the category "Other" include direct investment by the local government (Honduras), the investor's funds (Chile), transfers via emergency decree (Costa Rica), and international loans or contributions (Argentina, Belize). There are also explicit mentions of the Inter-American Development Bank (Argentina, Barbados), the Green Climate Fund, the Caribbean Development Bank (Barbados), and Euroclima (Peru).

Table 11

How have the implemented measures been financed?

FINANCING	CAN				CCB	CID			CSC			TOTAL
	BOL	COL	ECU	PER	BRB	BLZ	CRI	HND	ARG	BRA	CHL	
Through the collection of water and sewerage tariffs	1	12	2	11	0	1	2	2	3	4	7	**45**
Through money transfers from the national or municipal government	0	3	0	3	0	0	1	0	3	4	1	**15**
Through the collection of tariff charges specifically for these measures	0	0	1	2	0	0	1	2	1	1	0	**8**

Source: Authors' elaboration based on an IDB survey of operators in the region.

BOX 3

Peru: how do water tariffs fund climate change adaptation?

Peru adopted Law 30215 - Law on Mechanisms of Payment for Ecosystem Services (MRSE, by its initials in Spanish), a regulation that aims to promote and regulate mechanisms that facilitate the mobilization, transfer, and investment of resources in the preservation, recovery, and sustainable use of the country's diverse ecosystems. In the specific area of water and sanitation services, MRSE plays a crucial role. These mechanisms can contribute to maintaining, increasing or improving water quality, quantity and timely availability. This approach is noteworthy for its innovation, as it encourages an integrated perspective on water and sanitation services that includes both water sources and their supply basins.

Water tariffs approved by the National Superintendence of Water and Sanitation Services (Sunass) include a component to finance MRSE projects proposed by water operators. After assessing the condition of water ecosystems within their watersheds, operators prioritize conservation, restoration, and sustainable use actions. This approach ensures investment in securing both water quantity and quality, preventing potential future increases in water treatment costs or the need for higher tariff adjustments.

At the date of this report's preparation, 47 of the 50 companies nationwide have tariffs that allow them to finance MRSE projects. However, only 12 companies have advanced in the formulation, execution or completion of at least one project.[14] These include reforestation and limiting livestock grazing in Abancay, construction of basic services to prevent the discharge of sewage into water sources in Cusco, and reforestation with native trees and protection of marginal strips in Cajamarca, among others (Sunass, 2022b). The annual collection of water operators for this concept was close to USD 6.9 million[15] through MRSE tariffs (Benites Elorreaga and Gammie, 2021). However, it should be noted that in 2020 the national government temporarily authorized operators to use these funds in the framework of the public health emergency caused by COVID-19 (Emergency Decree No. 036-2020), affecting the funds available for this type of investment.

The tariffs approved by Sunass also include disaster risk management projects. Thus, 48 of the 50 companies in the country held a reserve for this type of project, with an accumulated fund of USD 10 million as of December 2021. This amount is expected to reach USD 62 million by the end of the operators' regulatory period (Sunass, 2022c).

[14] Information available at https://www.sunass.gob.pe/prestadores/empresas-prestadoras/merese/ (reviewed on August 8, 2023).

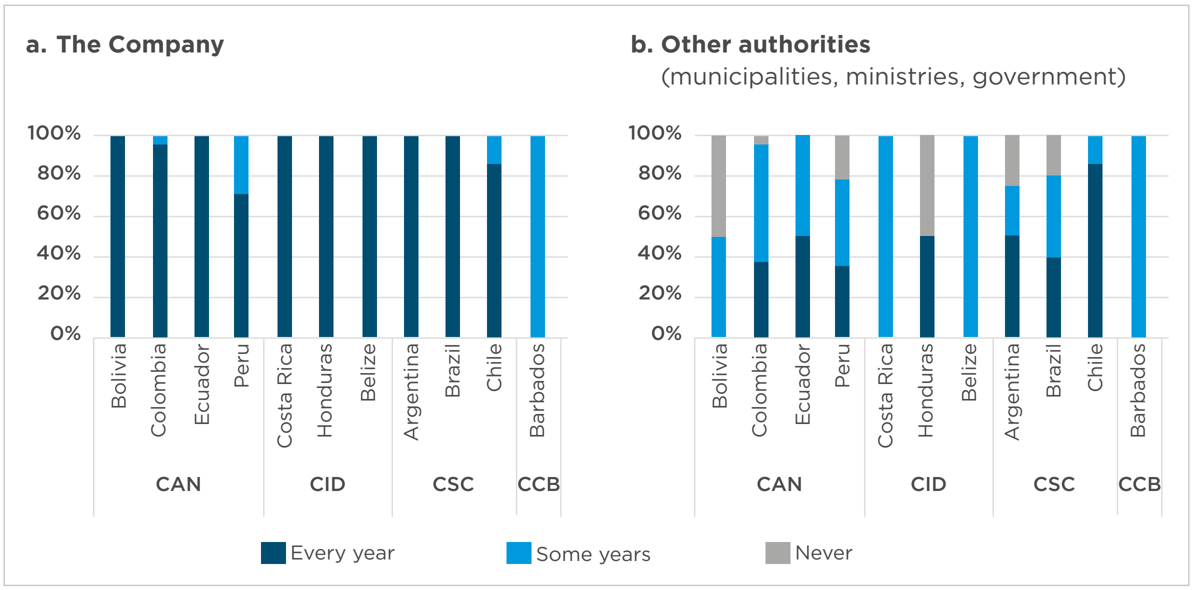
[15] Exchange rate: 1 USD = 3.70 PEN

Considering that around two-thirds of the funds collected from MRSE tariffs correspond to the company that provides services in Lima and Callao, this case deserves to be described in greater detail. In 2015, Sunass issued a tariff resolution for the 2015-2020 period, which mandated Sedapal to establish two reserve funds using the revenue generated from water and sanitation services. A first fund of 1% of annual revenues to finance MRSE and a second fund of an average of 3.6% of annual revenues to finance disaster risk management and climate change adaptation. These funds would allow to raise USD 23 million and USD 85 million, respectively, over the five years. In the case of the second fund, as specified in the corresponding tariff study, these funds could be allocated to cover the increased costs associated with the treatment of drinking water due to elevated contamination levels in the Rimac River. Additionally, they could be utilized for the procurement of chemical inputs like activated carbon and copper sulfate (Sunass, 2015).

In 2021, Sunass approved the tariffs for the period 2022-2027 and included a reserve fund for MRSE projects of approximately 0.5% of the tariff collection. This is associated with a portfolio of 29 projects (USD 18 million) aimed at recovering water generation and conservation capacity in the ecosystems of the Lima and Callao basins. In terms of disaster risk management, a reserve fund was created, allocating 0.9% of the company's annual revenues to finance an investment program of USD 27 million (Sunass, 2021).

Finally, the survey included a question on whether policies are implemented to encourage the population to use water responsibly. Eighty-nine percent of the operators stated that they carry out information campaigns every year to encourage the rational use of water. However, when asked about the authorities (such as municipalities, ministries, or the Central Government), only 41% of the operators indicated that they carry out information campaigns every year, and 46% in some years (see **Figure 14**).

Figure 14
How often does your company or any authority carry out information campaigns to encourage responsible water use?



Source: Authors' elaboration based on an IDB survey of operators in the region.

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6

Annexes

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6.1. Examples of adaptation measures in the water and sanitation sector

CATEGORY	SUB-CATEGORY	DEFINITION	EXAMPLE OF MEASURES
PHYSICAL - STRUCTURAL	Engineered and built environment	Gray infrastructure solutions are often capital-intensive, highly complex, and large-in-scale	Coastal protection structures; water storage works; stormwater and wastewater management; well drilling.
	Technology	Use of techniques and instruments (often in combination with engineering solutions). Includes modern and ancestral/indigenous technology.	Water saving technologies (including rainwater harvesting), renewable energy technologies; efficient irrigation technologies(agriculture).
	Ecosystem-based	Use of biodiversity and ecosystem services to adapt to the adverse effects of climate change.	Nature-based solutions; ecological restoration (including wetland conservation and restoration); afforestation and reforestation; mangrove conservation and replanting; reduction of forest fires; urban green infrastructure that facilitates aquifer recharge.
	Services	Implementation of social safety networks and ensuring adequate access to services.	Cleaning of drainage systems to prevent flooding; diversification of water sources.

CATEGORY	SUB-CATEGORY	DEFINITION	EXAMPLE OF MEASURES
SOCIAL	Educational	The promotion of education is a fundamental factor in the adoption of adaptation options.	Awareness raising; information campaigns; exchange of local and traditional knowledge; research networks.
	Informational	Use of information for decision-making and response to the effects of climate change.	Hazard and vulnerability mapping; early warning and response systems (including systematic monitoring and remote sensing systems); climate and scenario information; community-based adaptation plans (community-driven peri-urban neighborhood upgrading).
	Behavioral	Measures aimed at modifying people's behavior to reduce the pressure that demand exerts on the infrastructure.	Structural modifications to dwellings (e.g., to redirect rainwater for re-infiltration into the ground); water conservation practices.

CATEGORY	SUB-CATEGORY	DEFINITION	EXAMPLE OF MEASURES
INSTITUCIONAL	Economic	Use of economic instruments to promote efficient behavior, maintenance of ecosystems, and availability of resources when risks materialize.	Payments for ecosystem services; water tariffs; and disaster contingency funds.
	Laws and regulations	Approval of regulations at the local, regional, or national level to improve community resilience and safety.	Creation of protected areas; land rezoning, building standards; water regulations and agreements; laws to support disaster risk reduction.
	Government policies and programs	Development of sectoral and infrastructure plans that consider climate change adaptation and resilience criteria, as well as integrated water resources management.	National and regional adaptation plans; infrastructure plans with resilience criteria; urban improvement programs; municipal water management programs; disaster planning and preparedness; sectoral plans that include integrated water resources management; landscape and watershed management.

Source: Authors' elaboration based on Noble et al. (2014), Magrin (2015), Bárcena et al. (2020).

6.2.
List of operators which participated in the survey

SUB- REGION	COUNTRY	OPERATOR	SIZE OF POPULATION SERVED
CAN	Bolivia	Empresa Municipal de Saneamiento Básico Villazón	Less than 100k
		SAGUAPAC	Between 1 million and 5 million
	Colombia	Acuanariño	Less than 100k
		EAA de Santa Ana E.S.P. SA	Less than 100k
		Empresa Regional Aguas del Tequendama S.A. E.S.P.	Less than 100k
		EMPUSILVANIA	Less than 100k
		Triple A del Norte S.A.S. E.S.P.	Less than 100k
		Acuagyr S.A. E.S.P.	Between 100k and 500k
		Aguas de Barrancabermeja S.A. E.S.P.	Between 100k and 500k
		Aguas de Buga S.A. E.S.P.	Between 100k and 500k
		Aguas de Manizales S.A E.S.P.BIC	Between 100k and 500k
		Aquaoccidente S.A E.S.P.	Between 100k and 500k
		Centroaguas S.A. E.S.P.	Between 100k and 500k
		EMPOPASTO S. A. E.S.P.	Between 100k and 500k
		Empresa de Acueducto y LACantarillado de Pereira SAS E.S.P.	Between 100k and 500k
		Empresa de Acueducto, LACantarillado y Aseo de Yopal	Between 100k and 500k
		Veolia Aguas de Tunja	Between 100k and 500k
		Veolia Sabana	Between 100k and 500k
		ACUAVALLE S.A. E.S.P.	Between 500k and 1 million
		Aguas de Cartagena SA E.S.P.	Between 500k and 1 million
		Aguas de Cartagena	Between 1 million and 5 million
		EMCALI EICE E.S.P.	Between 1 million and 5 million
		Empresas Públicas de Medellín E.S.P. - EPM	Between 1 million and 5 million

SUB- REGION	COUNTRY	OPERATOR	SIZE OF POPULATION SERVED
CAN	Ecuador	AGUAPEN	Between 100k and 500k
		EPMAPS	Between 1 million and 5 million
	Peru	EMUSAP S.A.	Less than 100k
		EPS EMSAPA Yauli La Oroya SRL	Less than 100k
		EPS EMUSAP ABANCAY S.A.	Less than 100k
		EPS ILO S.A.	Less than 100k
		EPSSMU S.A.	Less than 100k
		EMAPA San Martín S.A.	Between 100k and 500k
		EMAPACOP S.A.	Between 100k and 500k
		EPS Aguas De Lima Norte S.A.	Between 100k and 500k
		EPS EMAPAT S.A.	Between 100k and 500k
		EPS SEDACAJ S.A.	Between 100k and 500k
		EPS SEDACUSCO S.A.	Between 100k and 500k
		EPS SEDAJULIACA SA.	Between 100k and 500k
		EPS SEDAPAR	Between 1 million and 5 million
		SEDAPAL S.A.	More than 5 million
CCB	Barbados	Barbados Water Authority	Between 100k and 500k
CID	Belize	Belize Water Services Limited	Between 100k and 500k
	Costa Rica	UNAGUAS	Less than 100k
		AyA	Between 1 million and 5 million
	Honduras	Aguas de Puerto Cortes	Less than 100k
		Unidad Municipal Desconcentrada Aguas de Siguatepeque	Less than 100k
CSC	Argentina	Cooperativa 16 de Octubre LTDA.	Less than 100k
		Obras Sanitarias Mar del Plata Sociedad de Estado	Between 500k and 1 million
		Agua y Saneamiento Mendoza - AySAM SA	Between 1 million and 5 million
		Aguas Santafesinas SA	Between 1 million and 5 million

SUB- REGION	COUNTRY	OPERATOR	SIZE OF POPULATION SERVED
CSC	Brazil	CASAN	Between 1 million and 5 million
		Companhia de Saneamento Ambiental do Distrito Federal - Caesb	Between 1 million and 5 million
		Companhia de Água e Esgoto do Ceará - CAGECE	Over 5 million
		Empresa Baiana de Águas e Saneamento - EMBASA	Over 5 million
		SABESP	Over 5 million
	Chile	FESAN Chile	Less than 100k
		Essbio S.A. - Ñuble	Between 100k and 500k
		Essbio S.A. - O'Higgins	Between 500k and 1 million
		Suralis	Between 500k and 1 million
		Essbio S.A. - Biobío	Between 1 million and 5 million
		Nuevosur	Between 1 million and 5 million
		Aguas Andinas	Over 5 million

Source: Authors' elaboration based on an IDB survey of operators in the region.

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