SUSTAINABLE BASINS

WATER FOR THE FUTURE

Water Security in Latin America and the Caribbean Strategy and Work Plan for the Inter-American Development Bank

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Introduction

HIGHLIGHTS:

- Latin American countries are in a **constant state of economic, social and ecological evolution (migratory phenomena, population concentration in large cities, droughts, floods, reduction of glaciers, progressive disappearance of ecosystems...).**
- These situations represent a **threat to water security (WS) throughout the region.**
- **Water security** refers to the possibility of access to **sufficient quantities of water** to meet the **diversity of water uses**, the **quality preservation** of water resources, and the due consideration of **climate change.**
- **Water security** is a **challenge** from a **social, political, and economic** point of view and has become one of the main **challenges** to be faced for **sustainable development.**
- LAC region is characterized by the **abundance of water**, although there are **great special and temporal heterogeneities** in its distribution. Moreover, the **critical dependance on the agricultural sector** and various **growing energy sectors** increase the pressure on the WS.
- The main challenges that WS strategies must face in the region include the **complex interaction between all sectors that use the resource, the region's high vulnerability to natural disasters of water origin, poor access to water and sanitation services, institutional weaknesses, and deficient water infrastructure.**
- This report presents a **detailed analysis of the water security situation** in Latin America and the Caribbean and, based on this analysis, an extensive **working plan** with an **integrated set of programs** to ensure the WS is provided.
- This document has been prepared for a wide audience, both inside and outside the IDB.

I. Introduction

The countries of the Latin America and Caribbean (LAC) region are in a state of constant changes. For several decades, **the population has been migrating to major cities**, often resorting to live in temporary and inadequate developments with limited access to quality water. Many of these cities are located on the coast and rely on small coastal basins or distant mountains for water resources. **Basin headwaters are subject to deforestation and land conversion to agriculture**. Prolonged meteorological drought events (lack of rainfall) are affecting surface flows, making **hydrological droughts** increasingly frequent and interrupting water supply to cities. On the other hand, freshwater sources, such as **tropical glaciers, are retreating quickly:** In the next two decades, most of those below 5,000 meters above sea level (m.a.s.l.) are expected to disappear. Similarly, **mountain ecosystems**, such as paramo, have been disappearing or seeing their natural storage and regulation capacity diminish. **Climate change** along with changes in land use, as a result of a rapid and unsustainable expansion of the agricultural frontier, is affecting the availability and quality of water resources, both in the short and long term, in rural and urban areas. This situation represents a **critical thread to water security throughout the region**, and places highly populated areas with an arid or semi-arid climate in a particular situation of vulnerability.

What is Water Security (WS)?

Water Security (WS) is the **capacity of a population** to safeguard the sustainable access to adequate amounts of water that is acceptable for **sustaining livelihoods, human well-being,** and **socio-economic development** for ensuring **protection against** water-borne **pollution** and **water-related disasters**, and for **preserving ecosystems in a climate of peace and political stability** (UN-Water, 2013). In this context, water security refers to the possibility of access to sufficient amounts of water to meet the **diversity of water uses**, the quality preservation of water resources, and the due consideration of climate change in: (i) water infrastructure planning, (ii) flow regulation, (iii) the management, preservation, and assessment of water ecosystem services, and (iv) flood and natural disaster risk management.

From a theoretical point of view, WS is an evolution of other concepts for water management that have been developed in recent decades. One of the most relevant efforts is **Integrated Water Resources Management (IWRM)**, defined as "a process that promotes the management and coordinated development of water, land and related resources, with an aim to maximize the social and economic well-being in an equitable manner without compromising the sustainability of ecosystems" (Global Water Partnership). In this sense, the WS and IWRM concepts have common aspects and objectives.

In a practical sense, however, it is worth noting some **important differences between the WS and IWRM.** First, **the WS is a goal** that **processes such as the IWRM** strive to achieve. Thus, in practice, IWRM has been translated into a process approach (in fact, there are IWRM manuals with detailed instructions of such process), while WS focuses primarily on the goal itself, without necessarily specifying the process to achieve it. This somehow helps to identify the multiple ways to implement processes to achieve WS, depending on the specific problem, geography, climatology, institutional schemes, existent laws and regulations, and other factors. In other words, **WS is less prescriptive in terms of process than IWRM**. Finally, and this is an aspect on which this report places special emphasis, **WS focuses on water cycle management,** that is, on the **integral management of supply and demand;** while **IWRM** focuses on resource management (mainly water and land), which in practice means emphasizing the **management of water supply and demand in a fragmented manner.** For all these reasons, we can consider WS as a complement or a modernization of concepts and processes such as IWRM and other similar ones.

A Major Social, Political, and Economic Challenge

WS has progressively become one of the main challenges for sustainable development. Water resources are the main channel through which the impacts of climate change will be felt on the main drivers of growth in the world's economy: agriculture, energy, industry, and the urban sector. For example, in the agricultural sector, changes in precipitation and temperature patterns are already significantly altering the agronomic productivity, irrigation potential and comparative advantage of some nations. In regions with less reliable water supply sources, the infrastructure and services in growing cities may exacerbate the underlying scarcity, which, in turn, would limit the urban growth patterns. In the energy sector, plans to reduce greenhouse gas emissions are often based on often optimistic assumptions about sufficient water availability for massive expansion of hydropower and biofuel generation capacity: water is also needed for fossil fuel cooling and other forms of energy generation. Other WS-related consequences of climate change include potential effects on human health and changes in natural habitats, watersheds, and biodiversity. In fact, the increase in temperature produces changes not only in hydrological patterns, as mentioned above,

WS has progressively become one of the main challenges for sustainable development

but also affects the quality of the resource. Climate change, along with the eutrophication phenomena driven by waters over-enriched with nutrients, is contributing to the proliferation of cyanobacteria outbreaks (eukaryotic bacteria that is extremely dangerous to human health, with a great adaptability to higher temperatures).

WS is also a social, economic, and political problem. Long-term sustainability of water resources should be framed within the adaptation to changing climate conditions, land use, and changing population demographics. WS is an increasingly concerning subject due to the availability of this vital resource and the way to manage it to meet the challenges posed by human demand in various sectors, as well as environmental, socioeconomic, and climate change-related considerations. Water resources are often stressed by the agriculture sector, which is responsible for approximately 70% of total freshwater withdrawals worldwide (FAO, 2011a). Climate change and variability determine spatial and temporal oscillations in water availability, with an intensification of fluctuations in the hydrological cycle, leading to increased flood and drought events. This might increase competition for water among different sectors and uses, such as agriculture, but also energy generation, freshwater supply, and the environment. In the Latin American and Caribbean region, the population and per capita income keep increasing, which in turn, increase water demand, especially in rapidly growing countries. In this context, it is more evident that WS restrictions may affect other sectors (e.g. food production and energy generation), with quantifiable consequences for the overall social well-being (Bazilian et al., 2011; Miralles-Wilhelm, 2016; Perrone and Hornberger, 2014; Miralles-Wilhelm and Muñoz Castillo, 2018).

What Is the Situation in Latin America and the Caribbean?

In comparative terms, the region is characterized by the abundance of water as a whole, although with great spatial and temporal heterogeneities, as well as a critical dependence on agricultural production and diverse and growing energy sectors, which increase the pressure on WS. According to estimates by the Food and Agriculture Organization of the United Nation's (FAO), 32% of the world's renewable water resources can be found in the LAC region. However, the great spatial variability in the distribution of these resources results in striking contrasts, such as the rainfall pattern of the Amazon Basin versus the arid or semi-arid climate conditions of northern Chile, northern and central Mexico, and northeastern Brazil. The temporal dimension refers to the natural variability of the region's climate, with strong rainfall anomalies that are modulated within a range of time scales (Grimm and Saboia, 2015; Grimm and Zilli, 2009 and Mo and Schemm, 2008). **Prospective climate change with changes in the hydrological cycle and increasing water demands driven by population and economic growth impose significant challenges for the future of WS strategies in the LAC region.**

The region is characterized by the abundance of water as a whole, although with great spatial and temporal heterogeneities

In this context, WS has been acknowledged as a critical challenge for sustainable growth and social stability in the region. Given the complex interaction between the different sectors involved (water and sanitation, agriculture, energy...) it is imperative to move from traditional sectoral management approaches, where decision making and investment planning are carried out as if they were independent of each other, towards an integrated approach (e.g. the focus of the Water-Energy-Food connection) to water resources development planning and use. In addition to promote economic and resource efficiency, this integrated planning framework is important to prevent unexpected consequences and potential conflicts related to WS in the coming decades in the region (Da Silva et al. 2018; Miralles-Wilhelm, and Muñoz-Castillo, 2018).

We Are Improving, but There is Still a Long Way to Go

Regarding water resources management, WS related best practices are beginning to appear, generally, focused on a more pragmatic application of IWRM and centered on aspects such as: (i) the integrated planning of urban drainage; (ii) the incorporation water bodies in urban environment management; and (iii) the proper management of solid waste that, beyond their impact over health and the environment, can often compromise the functioning of the stormwater and sanitary sewer system. **Despite these advances, there are still many pending challenges to achieve acceptable levels of WS in the region.** High vulnerability to natural disasters is one of the biggest challenges which often affect the populations disproportionately by income levels. Fast and unplanned urbanization in areas vulnerable to risk, **environmental degradation,** and **governance failure** are factors associated with the **increased impact of water-related natural disasters,** such as floods and droughts.

Some other challenges related to WS in the region are long-standing. Most common challenges include the **access to sanitation resources and services, institutional failures and deficiencies,** and the **provision of water infrastructure**. The built infrastructure (gray infrastructure) lacks the resilience to keep pace with the changing state of WS in LAC. Unlike this one, Nature-based Solutions (NbS) (or "green" infrastructure) do not have a limited life cycle and can support long-term sustainability of WS as long as adaptive management approaches and the efficiency of its operation and maintenance are integrated into the system design. Although NbS can often serve as stand-alone solutions, they are increasingly being included in the gray infrastructure for hybrid solutions. Recently, more attention is paid to the use of NbS for water storage and regulation (both for supply and flood control), its treatment, reutilization, and multi-purpose projects promoted by WS, food security and energy security in the fast urbanized areas of LAC. Trends point towards an increased emphasis on small scale, decentralized solutions, located close to the source of individual problems, which can be owned by the local communities involved in the projects, from conceptualization to implementation and operation.

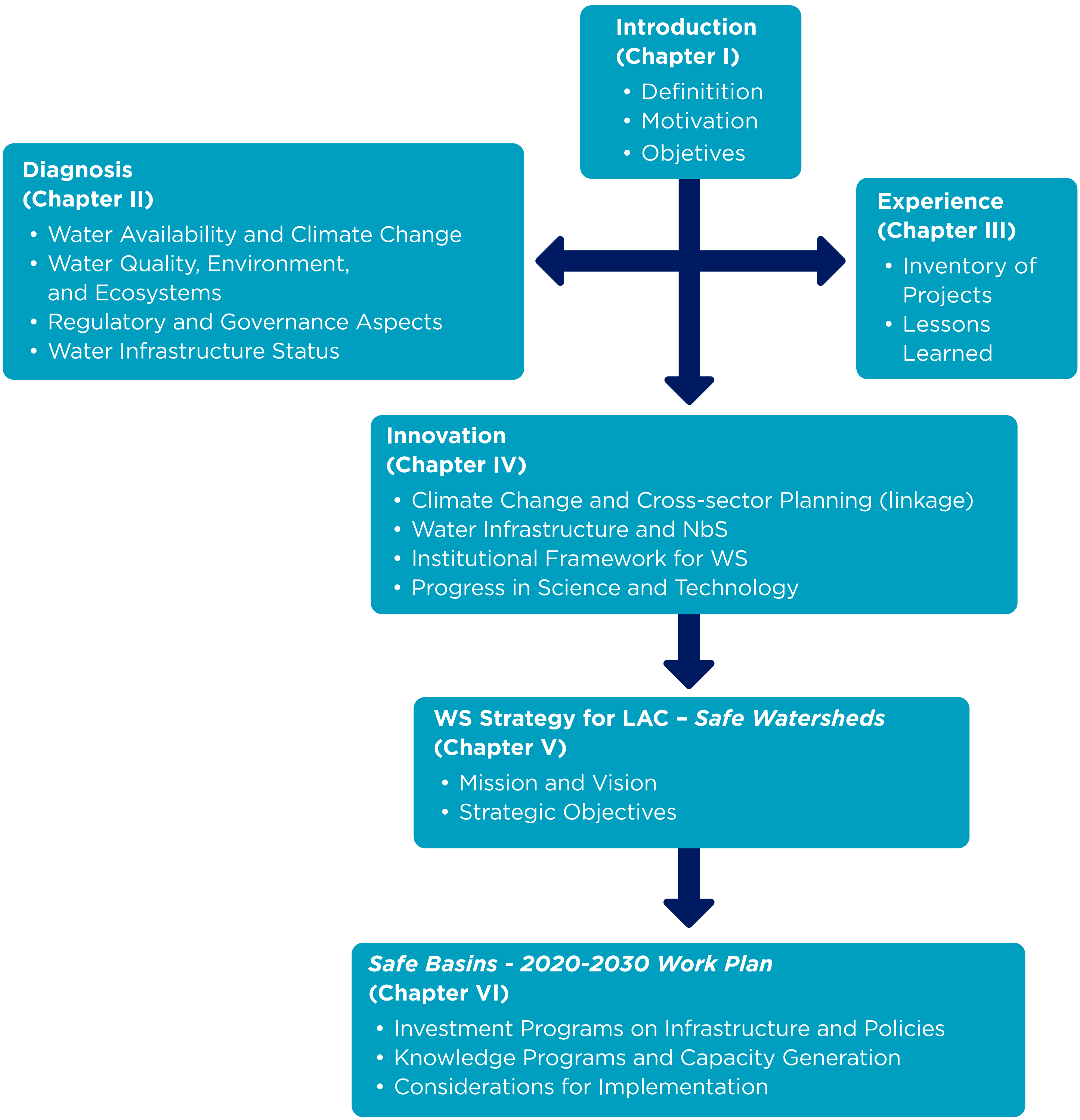
What?

The main objective of this document is to present an analysis of WS in the LAC region, which addresses issues from five complementary perspectives: **Diagnosis** of the current situation on the region (Chapter II); **History**, from the point of view of the IDB's activities on WS (Chapter III); **Prospects,** analyzing the innovation opportunities on this vitally important topic for IDB and its customers (Chapter IV); **Strategies,** which establish priority objectives for the region on WS (Chapter V); and **Proactiveness,** which outlines a work plan to advance WS in the region over the next decade, through investment programs in policies, infrastructure and knowledge (Chapter VI). The document has been prepared in consultation with several stakeholders, inside and outside the IDB, and with several stakeholders related to water security in the countries of the region. **Figure 1.1** shows the schematic logic to develop these WS perspectives in LAC.

For Whom?

This document has been prepared for a broad audience. Thus, within the IDB, it might work as guidance for planning purposes and can be used to prepare the Bank's country strategies and sectoral notes. It can also be useful as a reference for IDB's operational divisions, such as Water and Sanitation Division (WSA), and to other divisions and departments with an interest in WS issues. For readers non-related to the Bank, coming from other sectors, institutions, and organizations, this document is an extensive analysis of the challenges and opportunities that WS poses in the LAC region, considered from the particular perspective of investment program proposals by the IDB and its clients.

Figure 1.1. Flowchart of the Development of this Report, with a Synthesis of the Diagnostic (Chapter II), Historical (Chapter III), Prospective (Chapter IV), Strategical (Chapter V), and Proactive (Chapter VI) Perspectives for WS in the LAC Region.



II Current Situation of Water Security in Latin America and the Caribbean

HIGHLIGHTS:

- So far, **four major types of problems related to WS** have been identified: (i) **water balance,** represented by the **availability of water resources** and their limitations due to climate change; (ii) **water quality** and its impact on the **environment** and **ecosystems** in the climate change setting; (iii) **institutionalization of water protection and use**, represented by the water management through improved regulatory and governance mechanisms to ease the implementation of effective actions of adaptation and mitigation, and (iv) **investments on water infrastructure,** improving water access for several uses and productive activities, and reduce risks related to water excess or deficit.

- Regarding the **water balance**, the LAC region is one of the **areas of the planet with a greater abundance of water resources,** although the storage capacity of its basins and aquifers is progressively decreasing because of climate change. The region shows an **enormous heterogeneity in the spatial and temporal distribution of its water resources and many of the water sources of the region are threatened** due to an **inefficient management of resources.** The incidence and circumstances related to **extreme weather events** (droughts and floods) **also vary** across the region.

- **Water quality limits the availability of water resources in the region.** Water sources contamination derived from human activities (mainly wastewater disposal – with varying treatment levels -, food production, extractive and industrial activities, and electrical generation), is a problem that has been expanding in most of the countries in the region.

- Regarding the **regulatory and institutional frameworks**, there are deficiencies related mainly to inefficient regulatory frameworks, lack of capacity to implement them, weak national water authorities and basin committees, and fragmented decision-making power.

- Regarding **water infrastructure, improvements must focus** on those related to human water supply and sanitation networks, water for irrigation and food production; water for producing energy and infrastructure for tackling extreme weather events (droughts and floods). All of them show inefficiencies and potential for improvement.

II. Current Situation of Water Security in Latin America and the Caribbean

Box 2.1. WS Major Challenges in Latin AMerica and the Caribbean

The progress in efforts to achieve improvements in the availability and quality of water resources on a global scale has recently begun to translate into reference frameworks developed by several bodies (UN-Water, 2013; OECD, 2013; Global Water Partnership, 2013) to manage and achieve improvements on WS in Latin America and the Caribbean.

For example, an ECLAC's analysis (Peña, 2016) identifies **the following overall challenges of WS in LAC**:

- Population **access** to adequate levels of freshwater and sanitation.
- Water **availability** to ensure a sustainable production development and decrease conflicts related to water competition among sectors.
- The **preservation** of water bodies in a compatible state with the protection of public health and the environment.
- **Reduction of risks** related to excessive water, especially in urban areas and in those affected by hurricanes, tropical storms, and other strong perturbances.

The report concludes that in order to meet these challenges, the region must try to increase and improve its infrastructure endowment, an area in which, in recent decades, there has been a decline in the efforts made by governments, as well as to improve institutional systems. The latter show serious deficits, which tend to be accentuated by the greater development and complexity of today's societies and the intensification in the use of natural resources. The deficits observed in the sector's institutional structures are basically due to inconsistencies in their design, the inability of countries to implement regulations effectively, the weaknesses in the intervention of civil society and the failures in the operation of markets.

Another study conducted by IDB (IDB, 2012) identifies the following **challenges for WS in the region, paying more attention to climate change impacts:**

- **Poor supply, distribution, and sustainability of water sources:** Most of the Caribbean countries face water scarcity and/or restricted access to water, where the supply is lower than the demand that keeps increasing due to population growth and development. A similar situation is found in many areas of big countries such as Mexico, Brazil, Chile, and Peru. Even in countries with extensive water resources to supply their population, water is distributed in an unsustainable and unconscious way in most cases, resulting in a greater threat to water sources and their associated ecosystems due to the impacts of climate change.

- **Water pollution and water quality degradation:** While water supply problems affect a subset of countries in arid and semiarid regions, problems with poor water quality affect all countries in the region. Progressive degradation of water quality undermines ecological integrity and the very ecosystems on which the region's population depends. This is the case of the Amazon Basin and a great part of the countries in the region that have coastal areas on the Atlantic and the Pacific coasts. Some examples are the pollution caused by sewage disposal systems; the contamination of surface and groundwater caused by agricultural and industrial practices; and the salinization of aquifers near the coasts. Given that the increase in temperature, caused by climate change, becomes a multiplier of the impacts caused by environmental pollution on the quality of water sources, this becomes a particularly critical issue that is demonstrated, for example, in the increase in the frequency of the number of cases of cyanobacteria outbreaks in water bodies during the summer.

- **Impaired and inadequate infrastructure for water resources management:** From the deterioration of drainage and treatment systems to the inadequate maintenance and operation, including the design, planning, and construction of new facilities. Problems in the Amazon basin affect the entire region. Every year, heavy floods cause substantial damages and impede development. Also here, problems prevail in poor regions with high population density

(Rio de Janeiro, Nicaragua, and Haiti). Inadequate infrastructure affects less developed rural areas, which are more vulnerable to natural disasters and climate change.

- **Weak governance and institutional strengthening:** In the LAC region, water resources administrative institutions (ministries, national and local authorities) are generally inadequately managed and show consistent weaknesses in their administration. Although many countries have shown a great progress on institutional strengthening (Brazil, Mexico, Peru), it is necessary to develop proactive actions that facilitate and encourage a process of adaptation to climate change, both at the national and subnational levels.

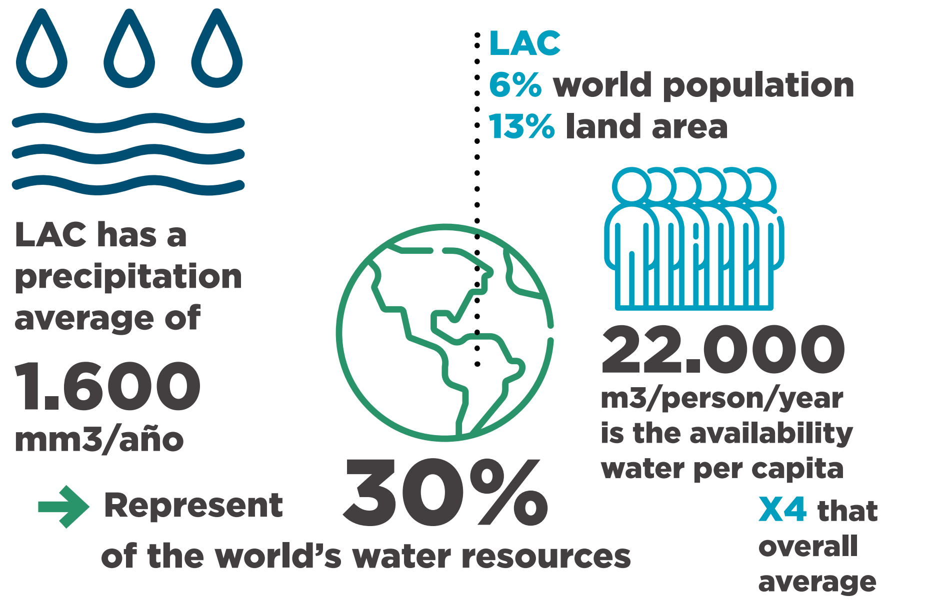
Taken as a whole, the frameworks that have been developed so far, on a global scale and for the specific case of LAC countries, focus on **four major types of problems related to WS**: (i) **water balance**, represented by the **availability of water resources and their limitations due to climate change**; (ii) **water quality** and its incidence on the **environment** and **ecosystems** in a climate change context; (iii) **institutionalization of water protection and use**, represented by water management through improved regulatory and governance mechanisms to ease the implementation of effective actions of adaptation and mitigation, and (iv) **investments in water infrastructure** that improve water access for various uses and productive activities and reduce risks related to the excess or scarcity of water.

This chapter analyzes these four groups of problems in detail as elements of the diagnosis of the current WS situation in the region.

II.1 Water Availability

Abundance of resources...

In a global context, the LAC region is one of the areas of the planet with more abundant water resources. In fact, the region has an average precipitation of 1.600 mm/year and an average runoff of 400.000 m^3/year, which represents more than 30% of the world's water resources. However, its population is equivalent to 6%, and its land surface is 13% of the world total. This means that its average per capita availability reaches approximately 22.000 m^3/person/year, **almost four times more than the global average availability**, which is 6.100 m^3/person/year. These values are even more significant when compared to those of continents such as Asia that, with an average precipitation of 650 mm/year, has an endowment of 2.500 m^3/person/year (Willaarts et al., 2014). Despite such favorable values, the region is still far from having solved the WS problems. In this regard, it is useful to review some of the main aspects related to water availability, the effects of climate change and how these interact and pose challenges for the development of the countries in the region.



Basins in the LAC region produce more water flow per land area than any other continent

Watersheds in the LAC region produce more water flow per land area than any other continent. The Andean Mountain range is the largest contributor to this flow (Harden, 2006). High mountain grasslands and wetlands above 3,000 meters, paramos and bofedales, have a high-water retention and regulation capacity due to their highly organic soils (Harden, 2006; Buytaert et al., 2006). However, **their historically high storage capacity is rapidly decreasing** as a combined result of two factors. On the one hand, the constant and progressive anthropogenic warming, that not only impacts water availability from tropical glaciers (Vergara et al., 2007), but also the quality of high mountain ecosystem services. On the other, the intensification of human impacts from grazing, irrigation, and mining (Rodell et al., 2018). For example, the decreased river flows with periods of intense droughts have led to the recent water scarcity in La Paz (Martínez, 2017), Lima (http://water.nature.org/waterblueprint/city/lima) and São Paulo (http://water.nature.org/waterblueprint/city/sao_paulo). Like with large metropolitan areas, also El Pantanal, the world's largest wetland, which exhibits a predictable annual flood pulse as a result of vast amounts of water leaving the Savannah to the north (Junk and da Cunha, 2018), has experienced a reduction in water flows associated with land use change to expand agricultural production.

Groundwater availability in the region's aquifers has been less studied, but recent analyses indicate a trend toward a progressive decrease in the amount of stored water and flow rates in these aquifers (Rodell et al., 2018; Lo et al., 2016).

...Uneven Distribution

On the other hand, **the region presents great heterogeneity in the spatial distribution of its water resources**. Thus, it has the most arid desert in Atacama (Chile), with practically non-existent rainfall sectors, and areas with a high-water regimen (above 2.500 mm/year). 36% of the LAC surface corresponds to areas generically classified as arid, many of which present water shortages to meet demands (UNESCO, 2010). In addition, 53% of run-off in the region is concentrated in a single river, the Amazon. The basins of the Gulf of Mexico, the South Atlantic and the Rio de la Plata, with 40% of the region's population, contain 10% of the available water resources and, in the case of Peru, 65% of the population is concentrated in areas that have 2% of their water (WWC, 2000).

...decreasing

Many water sources throughout the region are threatened

Many water sources throughout the region are threatened. This is the case in most Caribbean countries, which face water scarcity and/or lack of access to the resource, due to inefficient water resource management (combined with situations where demands generally equal or exceed supplies and there is increasing demand driven by population growth and development), which exacerbates the problems. Some countries in the region (for example, Surinam and Venezuela) continue to operate without any real separation between the water resources authority and the service provider, implying that water rights and/or use permits are given by the same institution that requests the resources. Also, there is no sufficient or updated information on drainage basins and aquifers, which limits the decision-making process on the use of water resources. Similar situations are experienced in many sectors in larger countries such as Mexico, Brazil, Chile, and Perú.

...and Poorly Managed

Even in countries with abundant water resources to supply their population, water is distributed in an unsustainable manner in most of cases, with the impacts of climate change threatening water sources even more. This will require designing adaptive water governance structures. Controversies among the use, upstream and downstream, are distributed for all the region, which suggests, in some cases, a lack of understanding and dialogue between users. That is the case of the Peruvian basins in Santa, Piura, and Tacna. In Brazil, the drought of São Paulo from 2013 to 2015 led to a discussion on a former idea to revert part of the Paraíba do Sul River to supply the megalopolis. This river supplies most of the water to the city of Rio de Janeiro and downstream suburbs, so in the event that reversal becomes effective, it is quite likely that a conflict between the two mega-cities will occur.

Projecting Water Future in LAC: What Scenario Do We Want to See?

Regarding the **relationship between WS and climate change in LAC**, the IDB recently developed a report (Miralles-Wilhelm and Muñoz-Castillo, 2018) from which we have extracted **Figure 2.1**. This shows estimates of the total annual water availability volume (sum of surface runoff and underwater) with three hydroclimatic simulation models, under the climate change scenarios RCP4.5 (moderate) and RCP6.0 (severe). This can be assumed as the total water availability for the basins and aquifers of the entire region under two possible future scenarios.

Two key outcomes can be found from this figure:

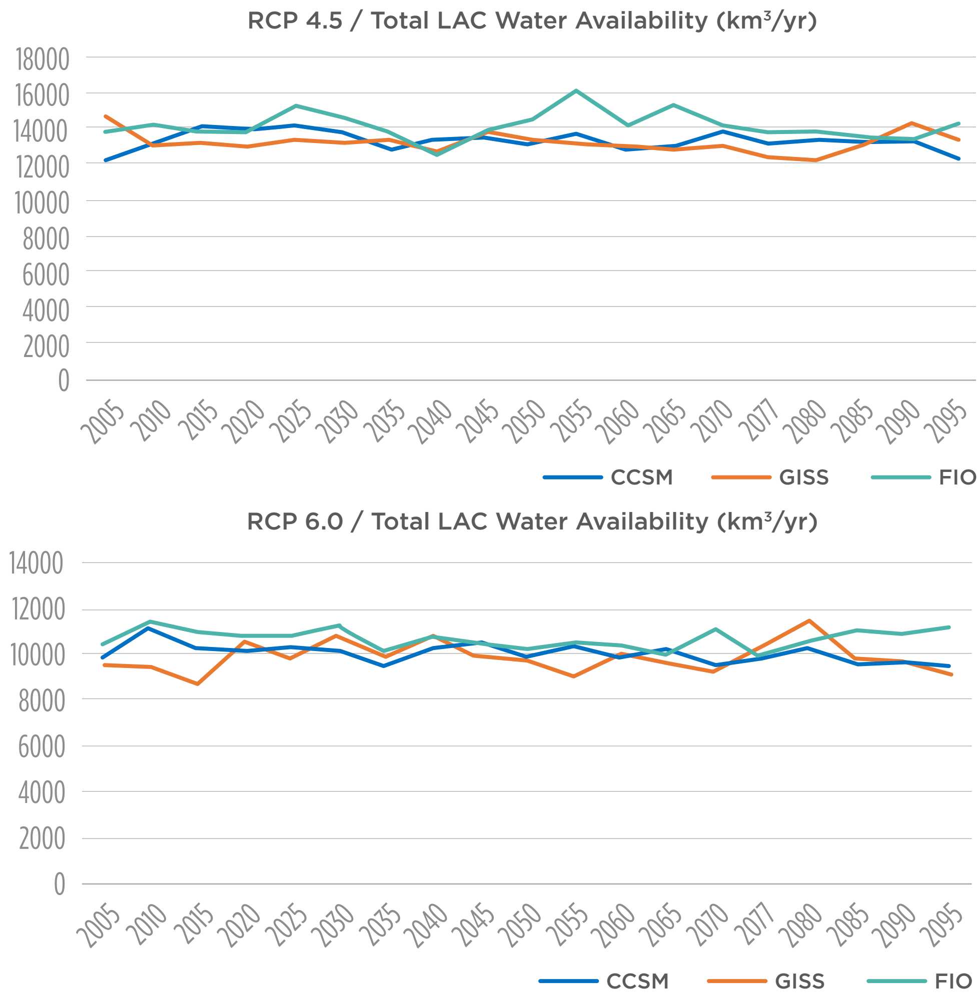
The amount of total water availability in the region for the RCP4.5 (moderate) climate scenario is significantly higher (at 25-30%, overall) than that for the RCP6.0 (severe). **This outcome is consistent with the idea of a decreased mean water availability together with an increased intensity of climate change**, which is thoroughly documented in the literature for the global case and summarized in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Working Group II; Jiménez Cisneros et al., 2014; Magrin et al., 2014 and literature).

The different hydroclimatic models produce similar water availability estimates (same order of magnitude) for each climate scenario, suggesting the **robustness of these estimates at a regional scale in LAC**.

While the total regional water availability volume may not vary significantly in the coming decades, **the spatial distribution surrounding the region shows some meaningful fluctuations** to be highlighted. In this sense, **Figure 2.2** shows the annual water availability volume generated in the whole region, in a RCP4.5 (moderate) climate scenario for the year 2050. Since the availability volume estimated through hydroclimatic models is similar, the outcomes for GISS model are shown as representative for illustrative purposes.

Changes in availability of the region over the period 2015-2050 are shown in **Figure 2.3**. Some localized effects are notable: less water availability in the Amazon basin, north of Mexico, northeast of Brazil, the Caribbean, and Central America. The progressive melting of glaciers in the Andes temporarily keeps water availability relatively stable in the basins downstream of the mountain range until mid-century but, from this point on, it tends to decrease (Miralles-Wilhelm and Muñoz-Castillo, 2018). These trends are to be expected given the combination of changes in precipitation, temperature and dynamics of the different ecosystems in the region (coastal areas, high mountain glaciers, glaciers, dry savannas and others).

Figure 2.1. Regional Water Availability Estimates in LAC (Sum of Surface Runoff and Groundwater for All the Countries) Using Earth System Models CCSM, FIO, and GISS, for Two Climate Change Scenarios: RCP4.5 (Moderate) and RCP6.0 (Severe)



Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

Some of the **trends** shown by these outcomes can be summarized as follows. **The Amazon basin, north of Mexico, northeast of Brazil, and Caribbean and Central America countries dry up** and seem to have a trend towards reduced availability, a trend that is more pronounced towards the second half of the century, particularly in Mexico. During the first half of the century, the Andean countries maintain relatively stable levels of water availability due to progressive glacial melting. As of 2050, it shows a predisposition to dry out. That is apparently the case in the coast of the Peruvian Pacific Coast, which reflects a drying trend that stabilizes towards the end of the century (due to the melting of glaciers draining westward to that basin). Chile shows a steady downward trend in runoff in all simulations. In general, **the trend towards a decreased water availability is projected mainly in the south of Mexico, Haiti, and the Dominican Republic; in some parts of Central America and in large areas of Brazil and Peru**.

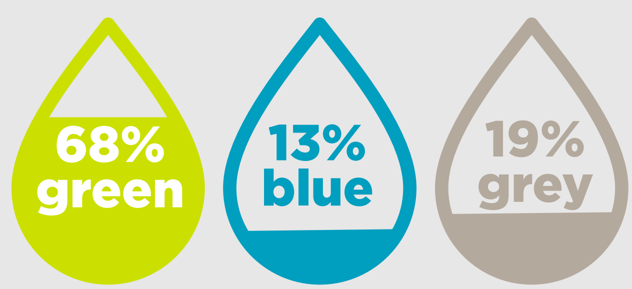
BOX 2.2. WHEN WATER LEAVES A FOOTPRINT

It is important to note that water demand in LAC is not only caused by water uses in the region. **The complexity of water use, due to the commercial trade of products, is a growing concern in the world because of its impact on WS**. In this sense, the concept of "**water footprint"** (Hoekstra and Mekonnen, 2011) has been introduced to quantify the **amounts of water and their different types of use**, providing a clearer picture of water resource consumption and its variation with location and over time. This reference geographically quantifies the water footprint (WF) of humanity, with high spatial resolution, and specifies the **use of storm water (green WF)**, **surface and groundwater (blue WF)** and **polluted water volumes (gray WF)**.

Water footprints have been estimated for each country, both from the perspective of production and use. International virtual water flows are estimated based on agricultural and industrial commodity trade. The global annual average WF over the period 1996-2005 was 9.087 Gm^3/year (74% green, 11% blue, and 15% gray). Agricultural production contributes 92%. **About one-fifth of global WF is related to production for export.** The total volume of international virtual water flows related to the trade of agricultural and industrial products was 2.320 Gm^3/year (68% green, 13% blue, and 19% gray). The WF of the average global consumer was 1.385 m^3/year. The average consumer in the United States has a WF of 2.842 m^3/year, while the per capita average in China and India is 1.071 and 1.089 m^3/year, respectively. The highest contribution to the average consumer's WF is from cereal consumption (27%), followed by meat (22%), and milk products (7%). The volume and pattern of consumption and the WF per ton of product of the products consumed are the main factors determining the WF by consumer. These results illustrate the **global dimension of water consumption**, by showing that several foreign countries are highly dependent on the water resources of others and have significant impacts on water consumption and pollution elsewhere.

2.320
Gm^3/year

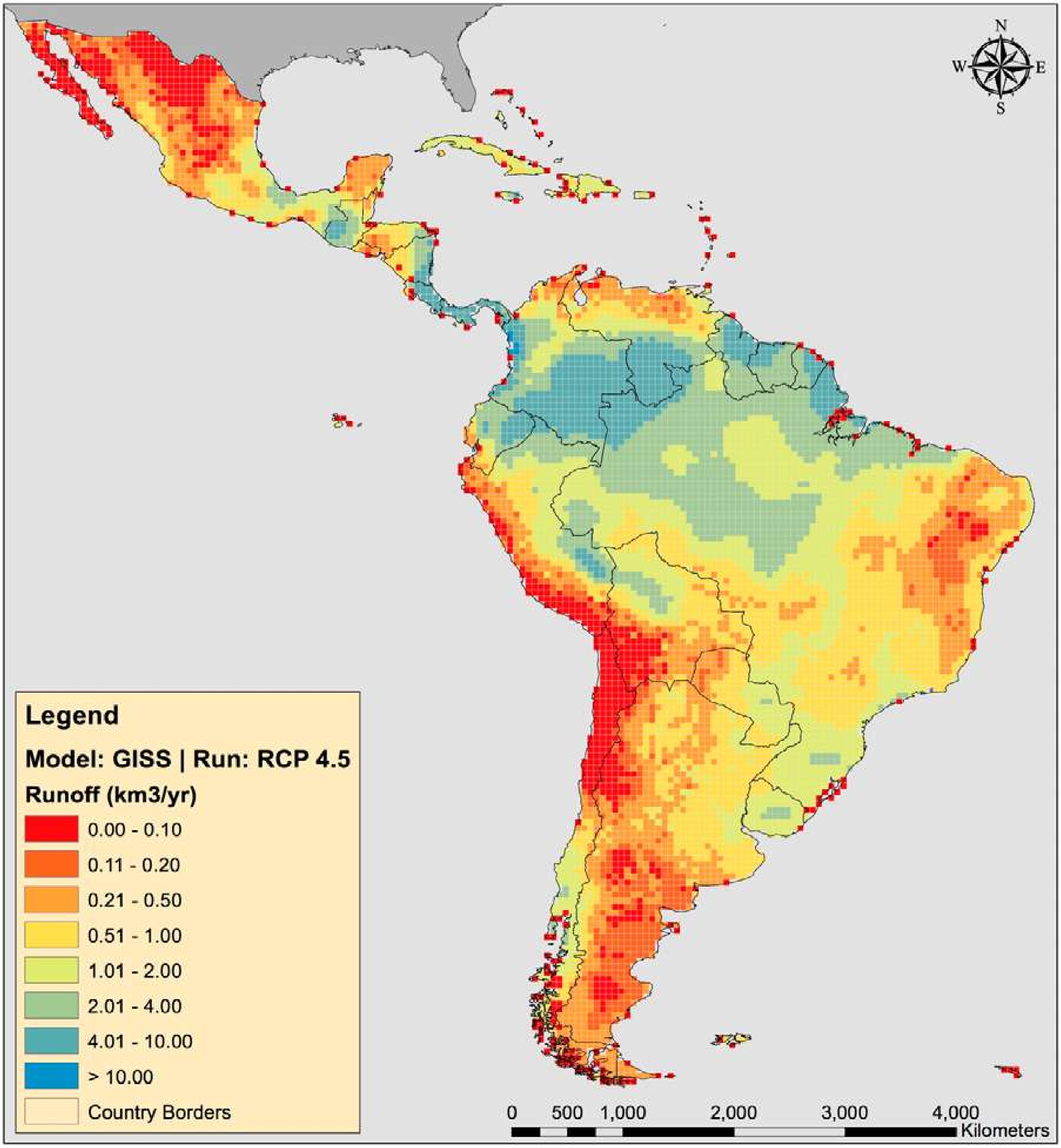
world average related to him agricultural trade and industrial



Although the LAC region is a net exporter of water, the WF varies widely among the countries and there are significant water exchanges within the region. For example, Mexico is one of the world's leading virtual water importers with 91 Mm^3/year (Konar et al., 2011). The water footprint of LAC is 1.136 m^3/person/year (Chapaign and Hoekstra, 2004) and to give an idea of its variability, WF of Argentina, Brazil, Ecuador, Peru, Mexico, Honduras, Chile, Colombia, and Venezuela is 1.404 m^3/person/year, 1.381 m^3/person/year, 1.218 m^3/person/year, 777 m^3/person/year, 1.441 m^3/person/year, 778 m^3/person/year, 803 m^3/person/year, 812 m^3/person/year, and 883 m^3/person/year, respectively.

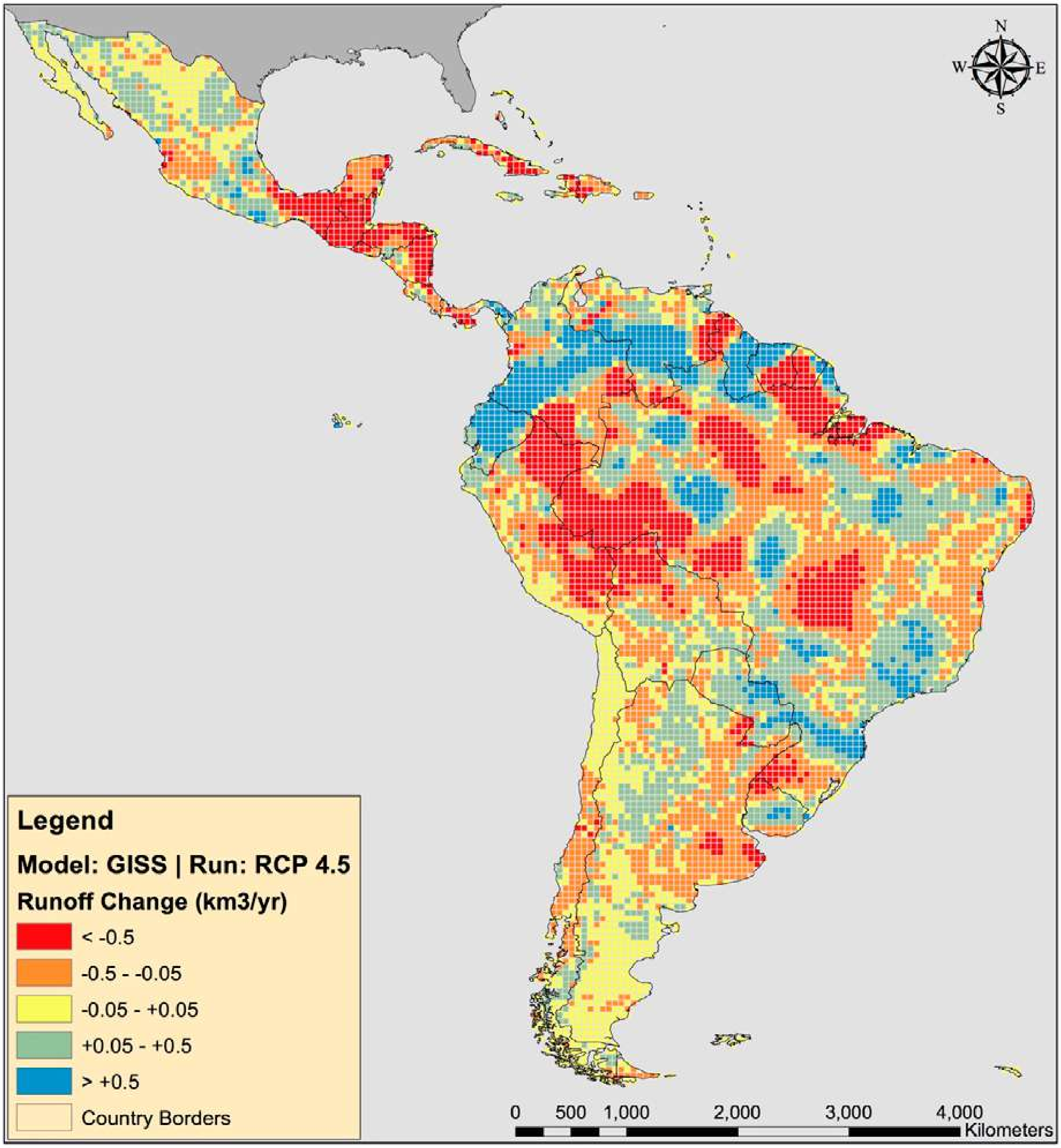
1.136
Mm^3/ person/year
LAC water footprint

Figure 2.2. Water Availability Distribution in the LAC Region in 2050, in a RCP4.5 Climate Change Scenario (Moderate)



Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

Figure 2.3. Projected changes in Water Availability in the LAC region for the Period 2015-2050, projected using the RCP4.5 Climate Scenario (Moderate)



Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

Lesser-known groundwater

In the case of groundwater, there is a lower level of knowledge, compared with surface water resources. In this regard, joint exercises have been carried out by national, regional, and global organizations to characterize the existing aquifers in LAC, their extension, water availability and the quality of their waters. Perhaps, the most complete synthesis of the situation of groundwater resources is found in the series of studies and maps developed by the *Worldwide Hydrogeologic Mapping and Assessment Program* (WHYMAP: http://whymap.org), a global group of organizations co-founded by UN, specifically for its International Hydrological Program (IHP).

The map shown in **Figure 2.4.** presents the geographical distribution of groundwater resources in the region. A wealth of resources (dark colors) can be observed in most of southern and Central America, with exceptions in Chile and northwestern Argentina and Brazil. There is a lower abundance of resources in northern and western Mexico. According to the data presented in this map, there is overexploitation of aquifers in areas of low recharge in central and northern Mexico. This, together with a relative scarcity of surface water in this same area (see map in Figure 3), points to scarce water availability and, therefore, greater risks associated with WS.

In terms of **water quality**, a significant fraction of the aquifers in northern and central Brazil, Chile and northern Argentina, and Mexico are shallow, which makes them more prone to contamination caused by agricultural recharges or exchanges with polluted surface water sources. Additionally, parts of the Guarani Aquifer have salinized, possibly due to the combination of overexploitation and contamination coming from surface water discharges. However, it is important to note that, although maps synthesize existing information, at the same time they suffer from potentially important information gaps: the surface and vertical extension need especially more detailed measurements and the exchange with surface water also requires a higher resolution temporal characterization. This need (which is at the same time an innovation opportunity) is presented in more detail in Chapter IV (Innovation Opportunities in Water Security).

Droughts and Floods: A Present Risk, Although Variable

Another important aspect of WS that should be considered from the physical point of view is the **risks related to extreme weather events, both droughts and floods**. These occur due to a combination of low (drought) or high (floods) water availability (as it occurs in many parts of the region -Figure 3-), and failures or lack of infrastructure to prevent or mitigate their effects. Although the issue of infrastructure is addressed in Section II.4, it is important to analyze here the natural conditions for the occurrence of these events.

Droughts occur when low soil moisture conditions coincide with low precipitation rates for prolonged periods of time. These hydrometeorological conditions (soil moisture and precipitation rate) can result in much lower availability than the historical average usually used in hydrological planning. **Floods**, on the other hand, results from high precipitation rates (higher than the historical average) combined with local topographic conditions: for example, low topographic elevations such as coastal areas whose high tides contribute, along with rainfall, to increased flood risk; or steep slopes that cause flooding in valleys due to runoff dragging. A third example of increased floods risk is the overflow of riverbeds due to higher flows caused by high precipitations. These local conditions vary across the region, which results in different risk levels both for droughts and floods. Figures 2.5 and 2.6 illustrate a synthesis of these risk conditions through a data compilation by the World Resources Institute (WRI).

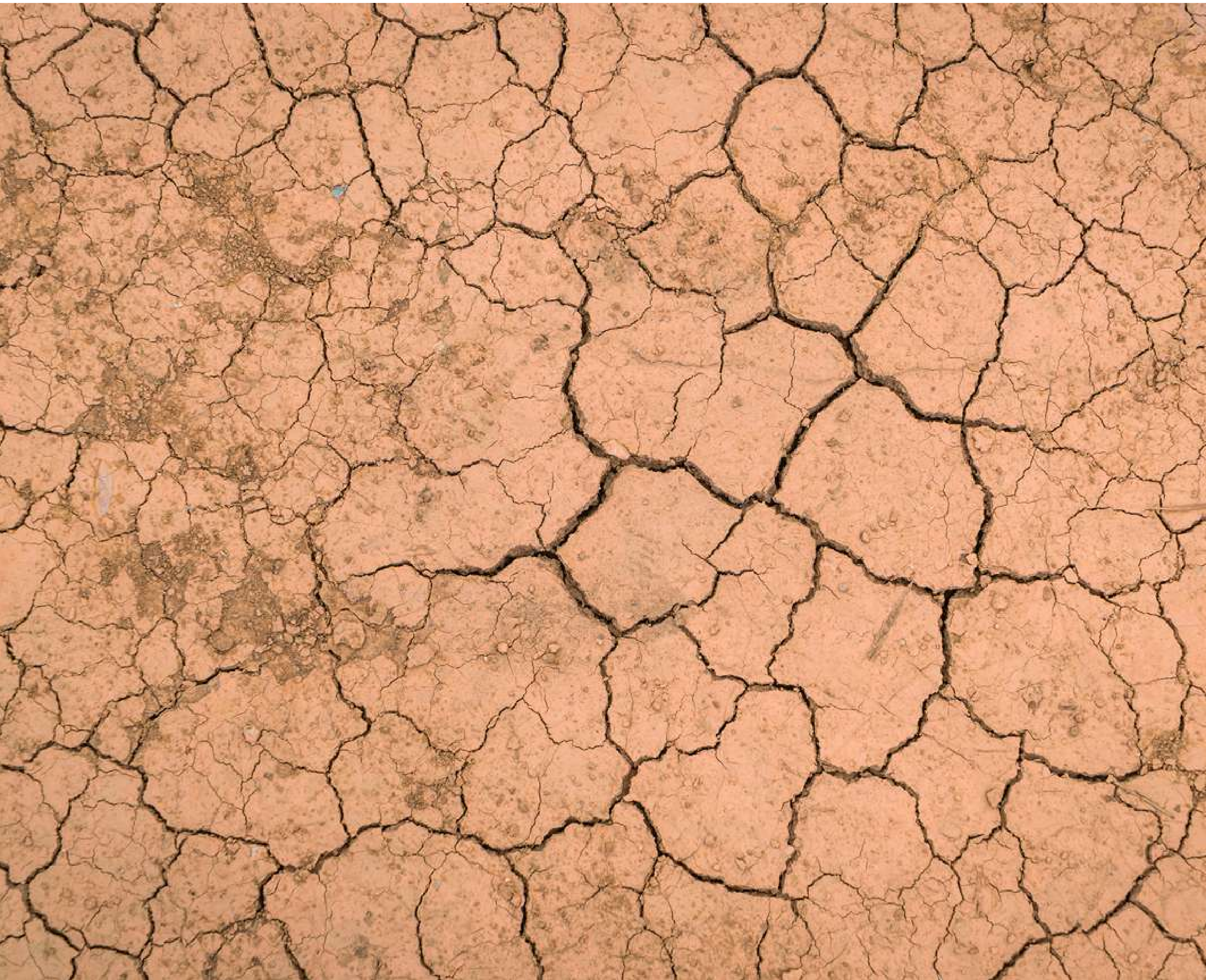
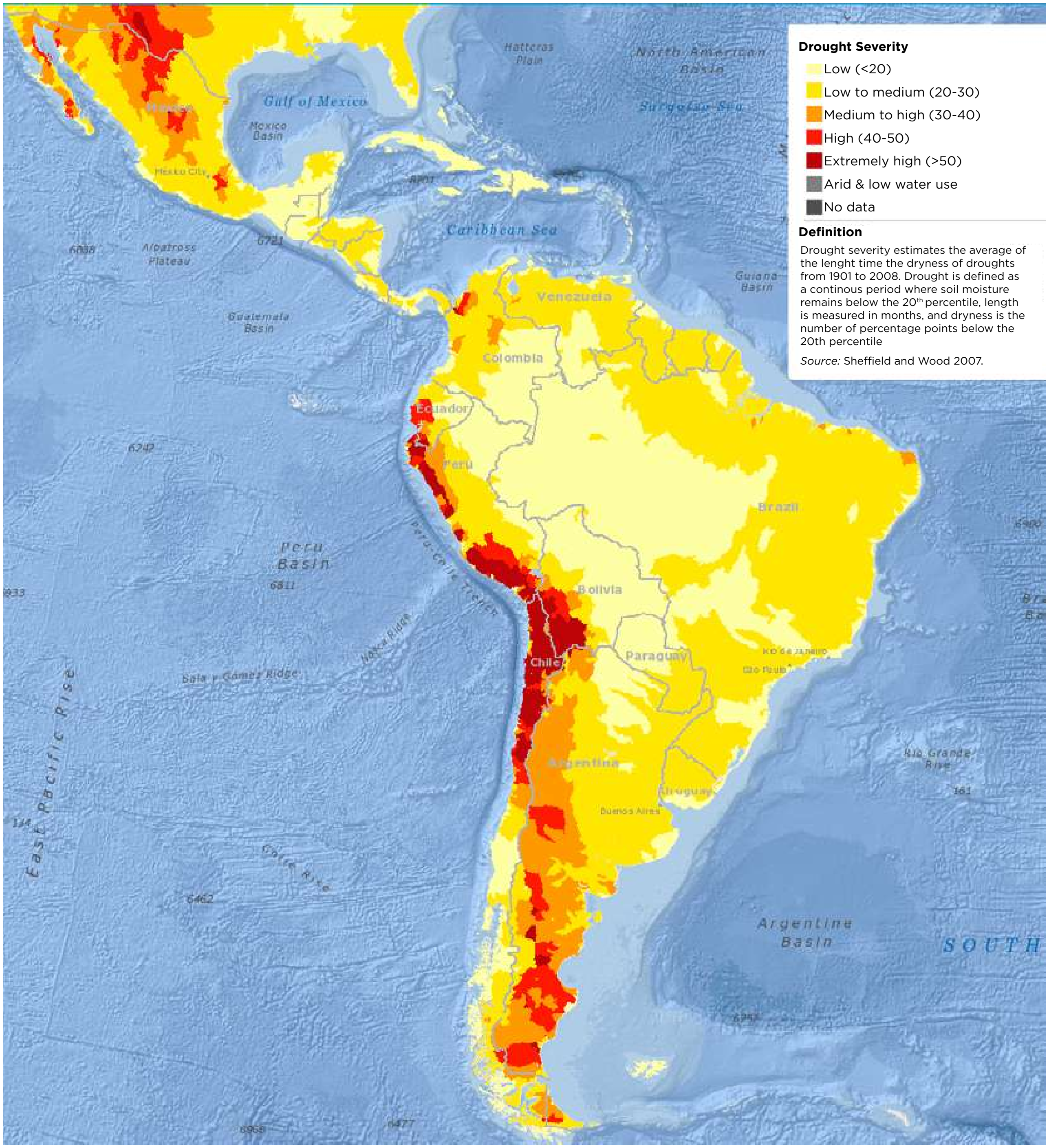


Figure 2.4. Map of Groundwater Resources in LAC.

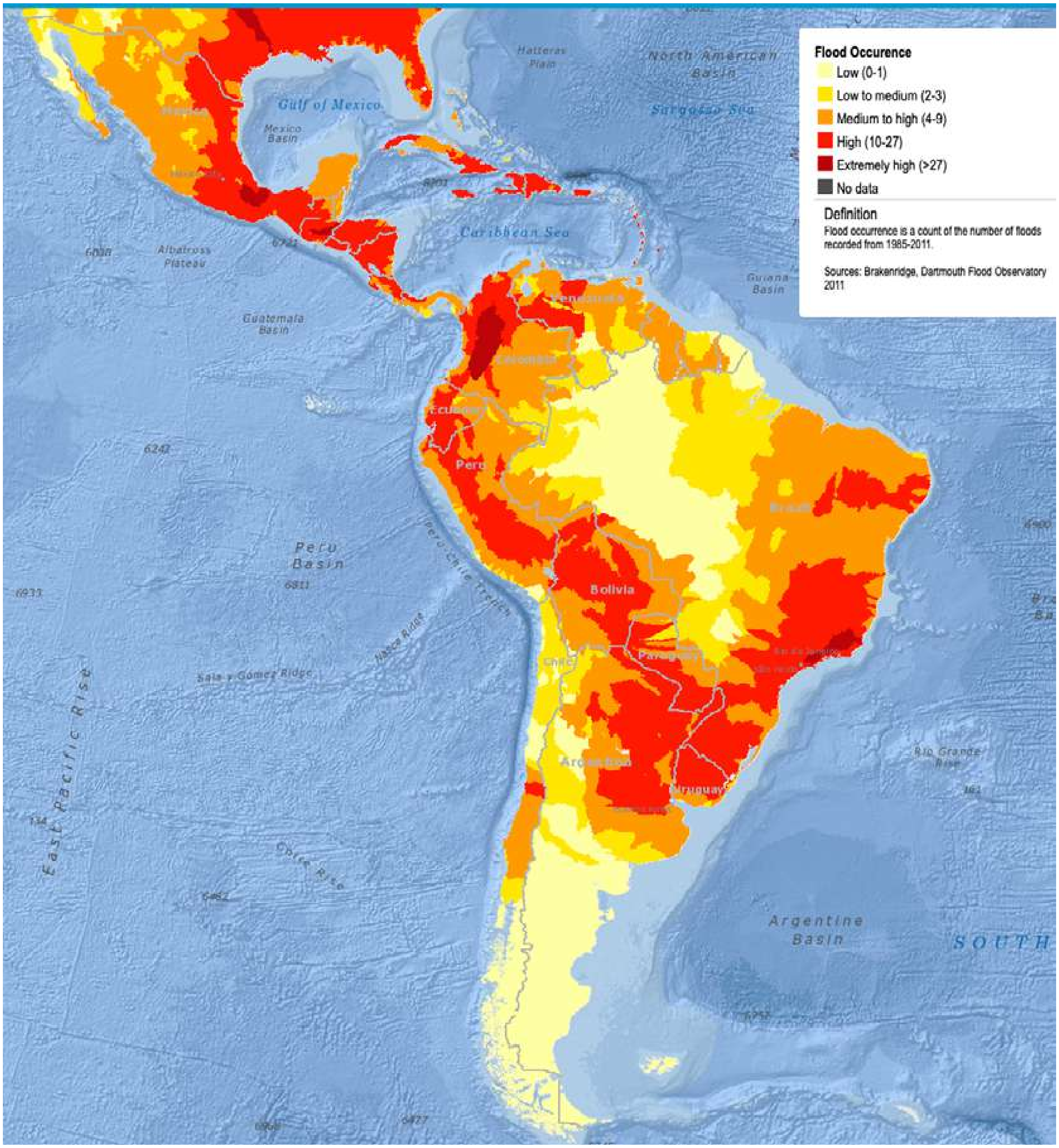
Source: WHYMAP, 2008.

Figure 2.5. Risk Map of Drought Severity in the LAC region



Source: Aqueduct Water Risk Atlas Database of World Resources Institute.

Figure 2.6. Risk Map of Flood Occurrence in the LAC Region



Source: Aqueduct Water Risk Atlas database of World Resources Institute.

II.2 Water Quality, Environment, and Ecosystems

Water quality is a significant additional factor limiting the availability of water resources in the region, especially in arid and semiarid areas. Natural water sources often have a high content of salts and some elements, such as arsenic and boron (associated with volcanic activity), and the presence of evaporites, restricting their availability for certain uses. Arsenic is found in natural sources in the arid areas of Mexico, Central America, Peru, Chile, and Argentina, among other countries (Pérez-Carrera and Fernández, 2010).

In addition to this, **freshwater ecosystems (rivers, lakes, and wetlands) are influenced by the soil area that drains into them, that is, the watershed**. In turn, the basin is the basic unit to determine the estimates (balances) of water (nutrients and sediments that enter each ecosystem and are retained by the ecosystem and carried downstream). The balance among these three compounds determines the environmental impacts and ecosystem responses in both structure and function.

The contamination of water sources derived from human activities is a problem that has been spreading in most of the countries of the region

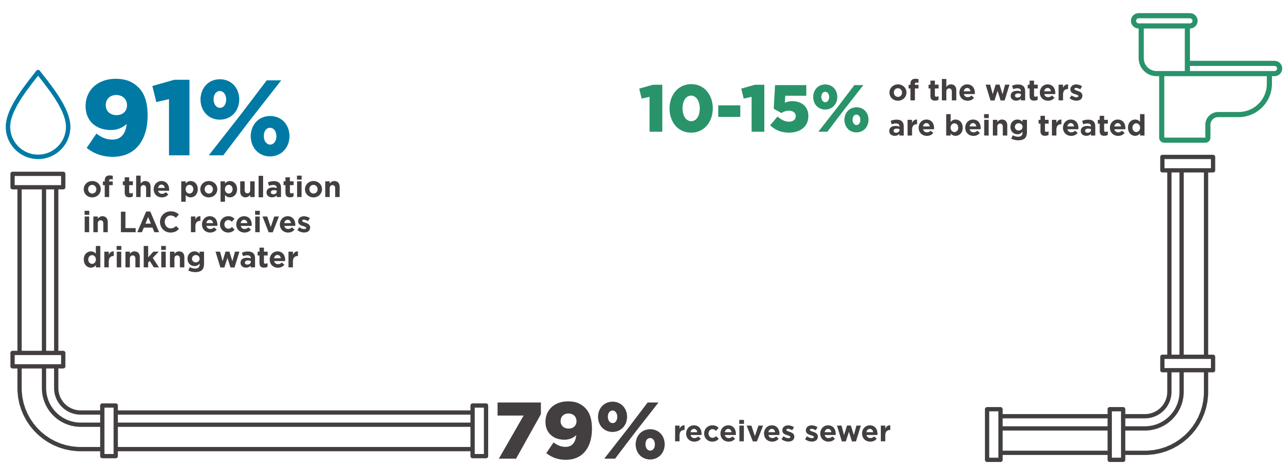
In river basins or watersheds, environmental impacts are additive from the top of the basin to its downstream discharge. Rivers, the dominant freshwater ecosystem in LAC, are originated from the highest points of the basin and contribute to the number (approximately 95%) and length (73%) to the total stream in a basin (Leopold et al., 1994 , Nadeau, and Lluvias, 2007). The structure and function of these water streams are influenced by the entrance of organic matter of plants surrounding the channel and overall concentrations of nutrients and sediments are characteristically low. As the stream flows downstream, the slope widens and becomes richer in nutrients and sediment as the total volume of water entering the channel increases as a result of the progressive increase of the basin area flowing into the stream. The middle and lower reaches of the largest rivers in LAC (e.g. Amazon and Orinoco) have developed important interactions with their floodplains, during periods of seasonal floods, which are critical to the life cycles of commercially important fish species and food web dynamics. **In general, the smaller the basin and the steeper the elevation gradient along the stream, the more sensitive the system is to human disturbance and climate change.** This is particularly true for the watersheds that drain into the small mountains of the Caribbean and those of the coastal forests of Mata Atlântica on the coast of Brazil.

The contamination of water sources derived from human activities (mostly the wastewater disposal – with varying treatment levels -, food production, extractive and industrial activities, and energy generation), **is a problem that has been expanding in most of the countries of the region.** These anthropogenic activities deserve special attention since, historically, they have been increasing as the population grows, thus increasing the urbanization (higher than 75% of LAC's population, since 2010) and, with that, the demand pressure over water resources resulting in accelerated impoverishment of water quality.

Wastewater Discharge

According to the United Nations (ONU, 2018), wastewater from 26% of households in the world do not receive treatment. Latin America and the Caribbean region, with 22%, is only slightly behind the global average. In the last twenty years there has been substantial progress in urban wastewater treatment, doubling treatment coverage. Large municipalities can afford the investment and maintenance costs, but for the process to be sustainable, these costs must be incorporated into the tariffs. Recently, the Atotonilco Wastewater Treatment Project (Mexico), the biggest of the world, started operations, treating more than 30 m^3/s.

While approximately 91% and 79% of LAC's population receives freshwater and sewage system (Noyala et al., 2012), most countries in the region are currently treating 10%-15% of wastewater (Reynolds, 2002; Noyala et al., 2012; Wilk and Altafin, 2018). Treatment percentages vary widely from approximately 5% in Colombia and most of Central America and the Caribbean to 100% in Chile (WSP, 2008; Wilk and Altafin 2018).



Additionally, the gradual increase in average and extreme temperature, as a result of climate change, together with the over-enrichment of nutrients in water, increases the occurrence risk of proliferation of cyanobacteria clusters in water bodies. In this sense, the climate change is a very potent catalytic element for the expansion of these bacteria, and in a warmer future, these organisms will have an advantage over others during eutrophic events. Therefore, it is necessary to monitor and control the amount of surface runoff rich in nitrogen and phosphorus discharged without any treatment into rivers, that end in lagoons and important water reservoirs for the supply of major cities.

BOX 2.3. INVASIVE CYANOBACTERIA

Cyanobacteria, also known as blue-green algae, are eukaryotic organisms with high resistance to high temperatures and especially "lovers" of warm waters. Their outcrop in water bodies threatens the surrounding ecosystems' health and the communities that depend on these sources (Paerl et al., 2008). Global warming seems to be behind the massive increase of this type of organisms in all the water of the planet. Latin America and the Caribbean region is not an exception.

This is the case, for example, of the Guarapiranga lagoon, responsible for supplying water to approximately 3.8 million people, in the metropolitan area of São Paulo, and where several cyanobacteria upwelling events have occurred during the hottest and rainiest time of the summer (Oliver et al., 2016). Given that with climate change a higher number of warm days is expected, as well as an increase on the number of precipitations for this area, it is very feasible that, if investments are not made to remove the excess of nitrogen and phosphorus in water, the frequency of occurrence of cyanobacteria episodes will increase. Argentina has also experienced an increase in the number of cyanobacteria episodes, mainly at the central area of the country (Aguilera et al., 2018). It is to be expected that this situation will worsen with climate change and taking into account the low levels of treatment (in particular nitrogen and phosphorus removal) of the wastewater that goes into the water bodies from which the population is supplied.

BOX 2.4. THE SEWAGE PARADOX

The advances that are taking place in the sewage system, as one of the Sustainable Development Goals is producing a paradoxical phenomenon. If no action is taken in the treatment of wastewater, what is being done is to facilitate the arrival of more urban pollution into rivers, other bodies of water and receiving ecosystems.

On the other hand, rural populations, widely dispersed throughout the LAC region, have long separated wastewater from graywater (from domestic uses such as washing clothes or kitchen utensils). The latter is discharged directly into the environment. With the rapid urbanization of populations, domestic waste is being combined into a single discharge (graywater and wastewater), overwhelming existing treatment plants for even the most basic wastewater treatment.

BOX 2.5. DECONTAMINATION THROUGH THE COURTS

When it comes to the treatment of urban wastewater, two significant and paradoxical cases exist due to their prosecution. The first is that of the Bogotá River, heavily polluted due to the existence of leather tanning industries (tanneries) which discharges metals (chromium and sulfides), as well as blood and other waste from slaughterhouses, especially in the upper part of the basin. In addition, there were untreated discharges from neighboring populations (including the inhabitants of Bogotá) and other industrial discharges, extractive mining and debris. In 2004, a **sentence** was issued by the Administrative Court of Cundimarca (Sentence 479 of 2004) that declared **that public institutions and private individuals were responsible for the state of the river.** This ruling gave rise to decisive action on the basin as a whole to try to address the problem globally.

The second case worth mentioning is that of the **Matanza-Riachuelo river basin in Argentina**, in which the **authorities were convicted to clean up the river,** which led to the design of a comprehensive plan for the environmental recovery of the basin.

Both cases open a window of opportunity to overcome the great difficulties involved in undertaking urban wastewater treatment with the ultimate goal of achieving a healthy state of fluvial ecosystems (rivers, mainly, and, where appropriate, lakes and/humid areas).

The two basins mentioned in **Box 2.5.** (Bogotá and Matanza-Riachuelo) are part of the subset of the four most polluted basins in the region, to which are added those of the Tieté river (which crosses the city of Sao Paulo, Brazil) and that of Lake Ypacarai in Paraguay. In Mexico, the Lerma River, Rio Bravo and Suchiate are identified; in Argentina, the basins of Reconquista, Suquía, Caracaña, River Plate, Curaco, Colorado and Negro; in Chile, those of Maipo River, Biobío, Elqui and Loa; in Colombia, the basins of Cauca and Magdalena; in Brazil, the rivers Doce and Paraiba do Sul; in Paraguay, Paraná and Paraguay rivers; in Venezuela, Guaire and Murillo rivers; in Perú, the Ucayali river and, finally, in Costa Rica, the basins of Tarcoles and Virilla rivers.

Pollution comes, in general, from all conceivable sources: urban supply, trash, industrial and mining discharges, and agricultural discharges. The only way to move towards success is by acting on all fronts simultaneously. Only by tackling the problem in an integrated manner, at the basin level, will we be able to aspire to the improvement of river ecosystems.

Land Use Change for Food Production

The headwaters of the main rivers in LAC, including the Amazon, are dominated by **grasslands** interspersed with high-mountain **wetlands**, **bofedales (which are high altitude wetlands),** or paramos. For centuries, grazing activities have resulted in the construction of channel networks to capture seasonal runoff and direct it to the bofedales that serve as a reliable water supply (Verzijl and Quispe, 2013). These human-modified bofedales have expanded over time and serve a valuable function in storing water in the mountains. **With a stable water supply, alpaca herds have expanded rapidly, and overgrazing is evident in most high elevation areas, leading to severe erosion at 50-60% of the Andes** (Millones, 1982). This situation has been aggravated by the rediscovery of quinoa, which doubled its production in the first decade of XXI century, increasing its prices by 300%. This has compromised the WS of the highlands that has become very unstable as more pastors have increased their alpaca herds with the profits from quinoa sales, thus increasing the pressure over the water stored in bofedales. In addition, climate change has caused a progressive reduction of local glaciers, and in places such as El Alto, in Bolivia, additional multipurpose dams are planned to collect water more effectively and supply La Paz with freshwater.

Alpaca herds have expanded rapidly and overgrazing is causing serious erosion to 50-60% of the Andes

In addition to this example of high mountain grasslands, **the terrestrial ecosystems most threatened by agricultural conversion are the Amazon rainforest, dry forests, and subtropical grasslands** (Grau and Aide, 2008). Currently, only 20% of the Amazon's original biome survives and, with the current deforestation rates, by 2030, 27% of the current forest will be lost, especially in the Andean Amazon of Bolivia and Peru, although their deforestation rates seem insignificant compared to those of Brazil[1]: deforestation of The Cerrado, the savannah lands bordering the eastern and southern Amazon, has experienced a fast decrease, with a projected loss of 30% of its remaining extent by 2050 [2]. While most of the cleared lands in these two biomes were dedicated historically for livestock production, the current trend is towards soybean production. Today, Brazil is the world's leading producer of soybeans, whose crop has quadrupled in the last 20 years to meet, in part, China's growing demands.[3]. This production expansion has been accompanied by massive erosion problems and the delivery of increased sediment loads to the rivers of the Amazon system that flow north, as well as those heading south towards the Pantanal.

The dry forest in the west of Costa Rica (Guanacaste) has traditionally been used for livestock grazing. During the dry season, it relied on wetlands to sustain livestock, especially in the basin of Tempisque River. In 1980 the Arenal Tempisque Irrigation Project (PRAT, for its Spanish acronym) was

1 http://wwf.panda.org/our_work/forests/deforestation_in_the_amazon
2 https://www.worldwildlife.org/stories/saving-the-cerrado-Brasil-s-vital-sabana
3 https://www.producer.com/2018/05/brazil-could-take-soybean-production-crown-de no-sotros/

launched with the objective of providing year-round water and overcoming the constraints imposed by seasonal wet-dry precipitation and periodic droughts (Daniels and Cumming, 2008; De Szoeke et al., 2016). Water was transported from Lake Arenal, in the highlands, through the 7-meter-wide West Channel to encourage the conversion of dry forests to livestock grazing and crop production. The recently irrigated lands quickly contributed 50% of Costa Rica's total rice and sugar production. While the original canal was concrete- lined with underpasses at stream crossings, 20 more kilometers of canals were hastily constructed in the 1990s to account for increased production demand. These new canals were silt-lined and lacked culverts for stream passage under the canal. The result has been a complete alteration of the stream hydrology from intermittent to permanent channel leakage flow.

Infrastructure building needs to be balanced with high-value crop production across the region

These actions clearly show the **fast responses implemented to meet changing trends in the agricultural commodity market without concern for potential impacts on the WS. Wetlands were transformed into rice fields that, while having the functional capacity of native wetlands, lacked the natural structure required by wildlife, especially migratory birds.** This situation is still evolving since many farmers are switching to sugar production to support the biofuels market. Sugar requires land drainage rather than irrigation, thus ignoring the irrigation canal infrastructure, which still flows endlessly and is wasted. **There is a critical need to balance infrastructure construction with high-value crop production throughout the region** (Ringler et al., 2000).

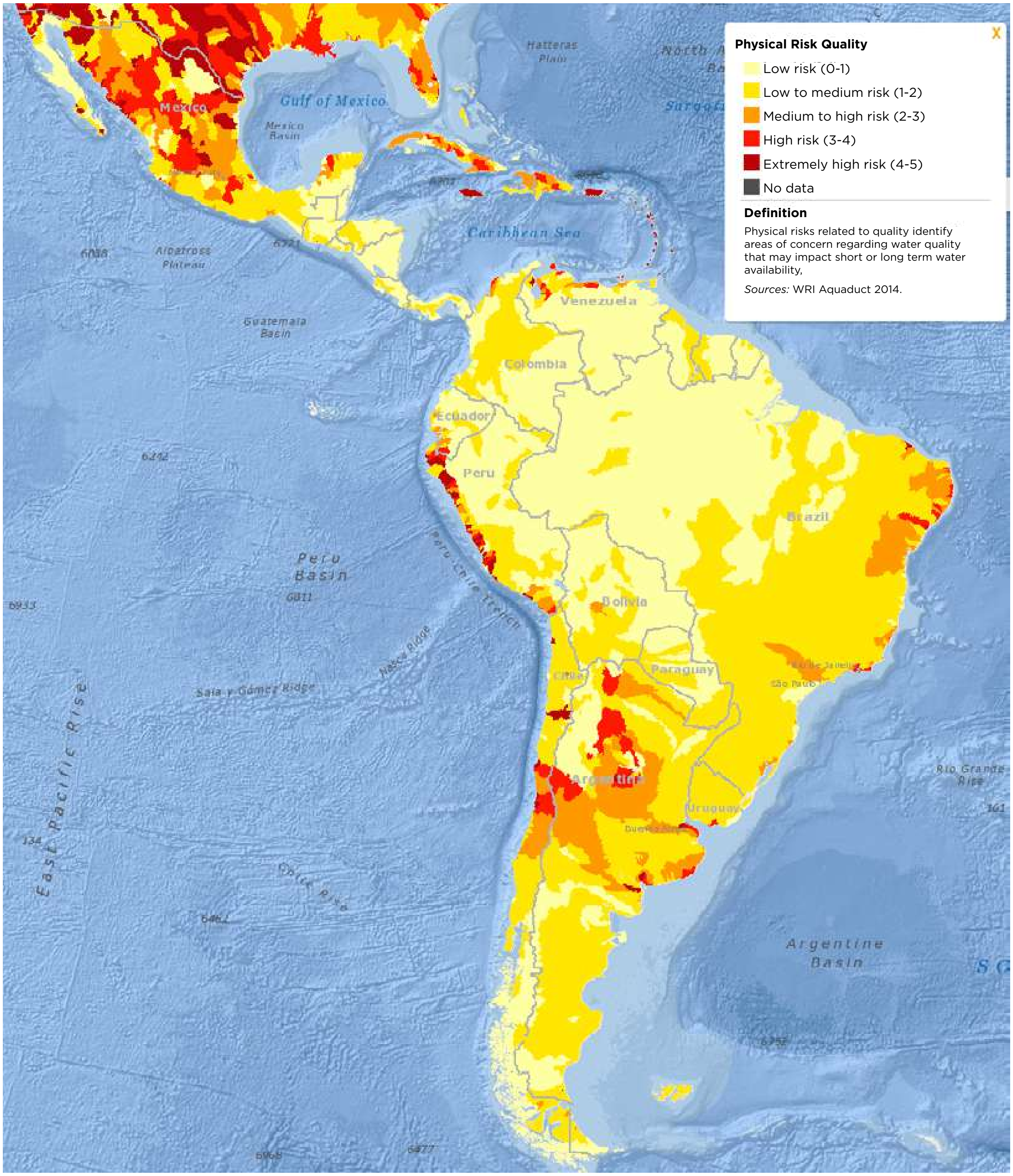
Extractive Activities

Mining in LAC started 500 years ago focusing on precious metals of alluvial deposits in Brazil and in shaft mines in the Andes (Machado and Figueiroa, 2001). **Shaft mining operations have progressively moved to very remote and higher areas in the Andes.** Many of these mines have reached the end of their economic feasibility, leaving **deposits of heavy metal-rich mining wastes leaching to varying degrees into local streams.** Concentrations of many heavy metals (including zinc, copper, and arsenic) exceed safe consumption standards (Oyarzun et al., 2003; and Oyarzun et al., 2006), both in water and sediments. The latter is of particular concern due to long-term downstream leaching and physical movement. It is important to note that many rivers have elevated concentrations of heavy metals naturally, from leaching from bedrock; but the impacts of mining can exceed these values by orders of magnitude. The impact of recharge on groundwater quality is also unknown since it is not monitored in most cases.

Active mining operations in the Andes have a high demand for water that is increasingly met by streams as traditional glacier sources disappear. The result has been water grabbing by mining companies that deprive downstream communities of water to meet their basic freshwater and irrigation needs (Bebbington and Williams, 2008; Sosa and Zwarteveen, 2012). In addition, changes in precipitation patterns and the high variability of the annual hydrological cycle, exacerbated by climate change, make these water use practices for mining production unsustainable and become a risk to the well-being and health of the poorest communities. The reduced discharge also raises fears that remaining stream water will become heavily concentrated in heavy metals leached from mine tailings. Finally, there is an increasing concern that the communities deprived of water on the West Coast of South America are obliged to consider transferring water among the basins to satisfy domestic needs, with the imminent possibility that the polluted streams become part of the water supply, thus exposing populations to health risks.

Alluvial deposit extraction to obtain gold, opals, and uranium is a common practice throughout the nations of the Amazon Basin and eastern Brazil (Minas Gerais). There are three types of ongoing operations: corporate and traditional, centered in terrestrial deposits throughout rivers, and commercial dredging of river channel sediments. Uranium from mining waste deposits is leaching into streams and reservoirs in Minas Gerais (Rodgher et al., 2012), but a certain success has been achieved by decreasing the traditional mining impact for opals through corporate agreements (Milanez et al., 2013).

Figure 2.7. Risk Map of Impact Occurrence to Water Quality in the LAC Region



Source: Aqueduct Water Risk Atlas Database of World Resources Institute.

Impacts of gold mining along and in river currents are of great concern

However, **the impacts of gold extraction throughout the country and in streams and rivers are a great concern**. Both corporate and traditional operations involve deforestation and the use of large volumes of water to remove highly unstable alluvial sediment deposits to settle fine rock material that is then treated with mercury to extract the gold. Sediments are easily eroded in tributaries of the Amazon and have resulted in extremely high mercury concentrations in river sediments, fish, and local human populations (Pfeiffer et al., 1989). Even if terrestrial loading of mercury is reduced or stopped, river sediments still release mercury and promote bioaccumulation in all components of the food web.

Mining within river channels uses boats equipped with small, diver-operated pumps or large mechanical dredges (Malm et al., 1990). But while most are limited to the shallow tributaries of the Amazon, larger dredge boats may operate in parts of the main channel. Environmental concerns with these practices stem from the disturbance of large volumes of bottom sediments, which increases the potential for the release of heavy metals into the water and the release of mercury used in shipboard gold mining in river waters.

Water quality in the region thus results from a combination of the impacts of different activities: agricultural practices, extractive activities, and other discharges such as wastewater, particularly in urban areas. Risk levels of water quality due to these contamination sources have been summarized in risk maps, such as the one shown in **Figure 2.7**. This information, together with the maps and data related to water availability and climate change are summarized in **Box 2.1**.

Box 2.1. Qualitative Characterization of WS Challenges Related with Water Availability (in a Range of Scenarios for Climate Change) and Water Quality. WA=Water availability; GW=Groundwater; WQ=Water Quality; DR=Drought Risk; FL=Flood Risk. **Green** color is for satisfactory conditions (or positive), **yellow** for intermediate conditions, and **red** for unfavorable (or negative) conditions.

Country	WA	GW	WQ	DR	FL	Comments
Argentina	Yellow	Yellow	Yellow	Red	Yellow	**WA:** the average WA is reasonable (>20 mil m^3/cap/year), but with marked regional differences. **GW:** Guarani Aquifer (cross-border) serves as water source, but there are numerous groundwater sources needing a more detailed characterization. **WQ:** Both surface and subway water sources throughout the country at risk from agricultural practices, deforestation, use of agrochemicals, and changes of land use, particularly in the River Plate (RLP) Basin. Matanza-Riachuelo, Reconquista, Suquia, Caracaña, RLP, Curaco, Colorado, and Negro basins also stand out for pollution problems due to wastewater disposal. **DR:** 75% of the territory is arid (with an availability <1000 m^3/cap/year) and due to the droughts aggravated by phenomena such as El Niño. **FL:** The highest incidence of flooding is in the northeast of the country around the RLP basin and its tributaries (Bermejo, Paraguay, Uruguay and Paraná).
Bahamas	Red	Yellow	Yellow	Yellow	Yellow	**WA:** The country has a relatively low WA (approx. 3000 m^3/cap/year), which results in a situation of frequent hydric stress. **GW:** There is a delineation of the aquifers at the level of the islands that make up the country, but a good part of them require adequate characterization. **WQ:** There are pronounced problems of contamination due to salinization of aquifers. **DR:** Little information related to drought risks exists, but the country is affected by regional events at the Caribbean basin. **FL:** The country is subject to a moderate flood risk due to extreme events and the proximity of the population to the coasts.
Barbados	Red	Yellow	Red	Yellow	Red	**WA:** The country has the lower WA of the region, approximately 280 m^3/cap/year. **GW:** There is a delineation of aquifers at the national level, but adequate characterization is required. **WQ:** Contamination sources are different (solid wastes, urban discharges, agricultural and industrial activities). **DR:** Little information related to drought risk exists, but the country is affected by regional events in the Caribbean basin. **FL:** Moderate flood risk due to a low precipitation rate.
Belize	Yellow	Yellow	Yellow	Yellow	Red	**WA:** High WA in the country (>60,000 m^3/cap/year), therefore, the hydric stress is negligible. **GW:** There is a delineation of the country's aquifers, but detailed studies are needed to characterize them. **WQ:** Water pollution is due to specific sources (domestic wastewater, industrial, and agro-industrial wastes), and non-specific (soil erosion with agrochemicals). **DR:** Low flood risk mainly due to a high WA. **FL:** An inventory of floods has been conducted identifying the frequency of occurrence.

Country	WA	GW	WQ	DR	FL	Comments
Bolivia						**WA:** The WA is relatively high (approx. 75,000 m^3/cap/year) but unevenly distributed between the Amazon basin, La Plata, and Great Divide Basin (lake or endorheic). **GW:** The aquifers of the Altiplano (La Paz and El Alto) and the Central Valley (Cochabamba) are in exploitation, but without detailed hydrogeological characterization. **WQ:** The Cerrada basin suffers frequent droughts and they have begun to extend into the urban area of La Paz. **FL:** Floods are frequent throughout the country, with heavy human and material losses.
Brazil						**WA:** The WA of the country is high (>48,000 m^3/cap/year) with lower availability for the Northeastern states. **GW:** There is a delineation of aquifers at the national level distributed in hydrogeological regions, but a good part of them requires adequate characterization. **WQ:** Due to high flows, water quality is relatively well maintained in most of the country's basins, with occasional problems due to extractive industries. The Tiete River basin, which runs through the city of Sao Paolo, is of note. The basins of the Negro and San Francisco rivers are of note for problems of contamination through wastewater discharges. **DR:** There are frequent drought conditions in the northeast of the country particularly and in the coastal areas in general. **FL:** Floods have a high frequency in a good part of the territory, particularly in urban areas at the east and southeast of the country.
Chile						**WA:** WA at national level is high (>60,000 m^3/cap/year), but with a significant latitudinal gradient of desert conditions (north) with a higher (south) availability.[13] **GW:** A series of aquifers throughout the country exist but they are mostly used in the northern region for supplying agricultural and extractive activities.[1 2 3] **WQ:** Extensive incidence of contamination for mining effluents and liquid industrial wastes and agricultural and diffuse contamination of groundwater.1 2 The Basins of Maipo, Biobío, Elqui, Loa are important due to contamination problems through wastewater disposal. **DR:** There is a strong incidence of droughts in the central and northern part of the country. **FL:** The extreme precipitation profile towards the south of the country results in floods and extreme debris flow events.
Colombia						**WA:** The WA value of the country is high (>50,000 m^3/cap/year) with a level of access to the resource showing no evidence of hydric scarcity. However, the northern area of Colombia (Guajira department) is an arid and semiarid area which experiences frequent droughts. This is also the department with the highest rates of poverty in the country. **GW:** Due to the abundance of surface resources, aquifers have not been studied or extensively exploited. **WQ:** The pollutant load to water bodies is diverse (domestic and industrial wastewater, extractive and agricultural wastewater, as well as leachate from sanitary landfills). The Cauca and Magdalena river basins are notorious for contamination problems via sewage disposal. **DR:** Droughts in the country represent a relatively lower problem with a moderate incidence in coastal areas. **FL:** Due to a high precipitation, a considerable part of the country is exposed to chronic flooding.
Costa Rica						**WA:** The country has a high WA (>30,000 m^3/cap/year) with an access level to the resource showing no evidence of hydric scarcity. **GW:** An effort has been made to geologically characterize the country's aquifers, with an intermediate level of knowledge of their potential as a water source and their quality. **WQ:** The main source of contamination is the direct discharge of domestic, industrial, and agricultural wastes in water bodies. 1 3 The Tarcoles and Virilla river basins are notorious for contamination problems via wastewater disposal. **DR:** The risk of droughts is relatively minor and increases slightly towards the Atlantic coast. **FL:** The risk of floods is high mainly due to extreme precipitation events.

Country	WA	GW	WQ	DR	FL	Comments
Ecuador						**WA:** The average WA for the country is high (>30000 m3/cap/year), but with greater deficiencies on the country's Pacific coast (almost zero). **GW:** There has been an increased effort to characterize aquifers at the national level, but knowledge is incipient. **WQ:** Water quality is affected by various sources (mining and petroleum, agrochemicals), with a higher incidence of contamination in the coastal zone (Gulf of Guayaquil). **DR:** The aridity of the Pacific Coast results in a higher risk of droughts in the country. **FL:** The country suffers from chronic flood risk conditions.
El Salvador						**WA:** The average WA for the country is moderate (>4000 m^3/cap/year). **GW:** There is information on aquifer delineation, but a more detailed characterization is needed. **WQ:** Quality problems are caused by the disposal of liquid and solid wastes into water bodies without treatment. **DR:** The risk of droughts is quite moderate due to the high precipitation rate. **FL:** High risk of floods due to the high precipitation rate and scarce infrastructure.
Guatemala						**WA:** WA of the country is moderate-high (10,000 m^3/cap/year) and shows a relatively low level of hydric stress. **GW:** Aquifers contribute less to surface water as a source of supply and have been poorly characterized. **WQ:** Water contamination is due to specific sources (domestic wastewater, industrial and agro-industrial), and non-specific (soil erosion with agrochemicals). **DR:** Preliminary drought risk studies and hazard maps have been carried out. **FL:** A flood inventory has been carried out and their frequency of occurrence has been identified.
Guyana						**WA:** The WA is the highest of the region (>300,000 m3/cap/year), with a negligible hydric stress. **GW:** It is used as a freshwater source due to its high purity, and a preliminary characterization of the country's aquifers has been performed. **WQ:** Contamination due to solid and liquid waste and agrochemicals disposal, which affect surface and groundwater sources. **DR:** There is little information related to drought risk, but the country is affected by regional events in the Caribbean Basin. **FL:** Due to the great river flow and lack of infrastructure, the country is vulnerable to floods.
Haiti						**WA:** The country has a low WA (approx. 1000 m^3/cap/year) which results in chronic hydric stress, particularly in the northern part of the country. **GW:** Groundwater is found in exploitation, but with an insufficient characterization of aquifers. **WQ:** Poor water quality due to deforestation and other agricultural practices and diverse sources of contamination (solid wastes, urban disposals). **DR:** The drought risk is relatively low, but subject to regional climate trends at the Caribbean. **FL:** The flood risk is relatively high due to lack of infrastructure.
Honduras						**WA:** WA in the country is high (>15,000 m^3/cap/year) with a low incidence of hydric stress. **GW:** Aquifers are extensively used, and detailed aquifer characterization studies have been carried out. **WQ:** The deterioration of quality is due to the discharge of organic waste from the population centers in the rivers, and by the dragging of agrochemicals from soils and industrial waste. **DR:** The country is subject to a moderate drought risk, with a poor capability of prevention and response. **FL:** The country is subject to considerable flooding due to extreme events and lack of infrastructure.

Country	WA	GW	WQ	DR	FL	Comments
Jamaica						**WA:** The country has a relatively low WA (<3000 m³/cap/year), which results in a situation of chronic hydric stress. **GW:** A preliminary characterization of the country's aquifers has been carried out, but there are no detailed studies of aquifer exploitation. **WQ:** Sources of water contamination are diverse (solid wastes, urban discharges, agricultural activities). **DR:** The drought risk is relatively low, but subject to the regional weather trends at the Caribbean. **FL:** The flood risk is relatively low due to lack of infrastructure.
Mexico						**WA:** WA of the country is relatively low (<5000 m³/cap/year) and unevenly distributed in a northern (lower) to south (higher) gradient. **GW:** Groundwater is extensively overexploited for various uses (satisfying almost 40% of the total demand). **WQ:** Water quality is affected in most of the country's basins by a combination of point (discharges) and diffuse (agricultural) sources. The basins of the Lerma, Suchiate and Bravo rivers are notable for contamination problems through wastewater disposals. **DR:** The high risk of droughts is evident, particularly in the central and northern part of the country. **FL:** A considerable part of the country's territory is subject to severe floods.
Nicaragua						**WA:** WA in the country is relatively high (40,000 m³/cap/year), with almost no evidence of hydric stress. **GW:** The groundwater resource is exploited, but with a scarce characterization of aquifers. **WQ:** Sources of contamination are varied (specific domestic discharges, agricultural and extractive practices). **DR:** Drought susceptible zones have been delineated. **FL:** The country is subject to severe floods due to a combination of extreme events and infrastructure failures.
Panama						**WA:** The country has a high WA (>50,000 m³/cap/year), which results in a negligent hydric stress. **GW:** A hydrogeological map of the country has been prepared, but there is no characterization of aquifers for resource planning and use purposes. **WQ:** Significant contamination sources are solid wastes, pesticides, stone and sand extraction from river channels, and the lack of adequate sanitation systems. **DR:** Due to its high WA, drought risk is relatively low. **FL:** The country has a relatively low flood risk, except for urban areas, where it is moderate to high.
Paraguay						**WA:** The country has a high WA (>60,000 m³/cap/year), which results in a negligent hydric stress. **GW:** The main aquifers have been delineated and characterized and are exploited with sophistication relative to the rest of the region. **WQ:** There is little monitoring and information on water quality, except in some urban basins in Asunción. Basins of the Paraná and Paraguay rivers, and Lake Ypacaraí are of note for contamination problems through wastewater disposal. **DR:** Risk level to droughts is moderate in the north area of the country, which has lower precipitations. **FL:** Flood risk is high in all the country due to a scarce infrastructure.
Peru						**WA:** The country has a very high average WA (>70,000 m³/cap/year), but with a very uneven distribution towards the Pacific Coast. **GW:** Aquifers are exploited particularly in the Pacific coastal zone and are moderately characterized. **WQ:** Agricultural activities, infrastructure construction, industrial uses, mining, municipal, and grazing uses have a significant impact on water quality in a large part of the country's territory. The Ucayali River basin is notorious for contamination problems through wastewater disposal. **DR:** Due to its conditions of arid climate, the Pacific Coast shows high risks of extreme floods. **FL:** At national level, the flood risk is high mainly due to the precipitation gradient between the Amazonia and the Pacific Coast.

Country	WA	GW	WQ	DR	FL	Comments
Dominican Republic						**WA:** The country has a relatively low WA (<3000 m^3/cap/year), which results in a situation of frequent hydric stress. **GW:** There is a national hydrogeological map and several aquifers in the country are characterized. **WQ:** Noticeable problems of contamination due to agricultural activities and salinization of aquifers. **DR:** The drought risk is relatively low, but subject to regional weather trends in the Caribbean. **FL:** The flood risk is relatively high due to lack of infrastructure.
Surinam						**WA:** The country has a very high WA (approx. 200,000 m^3/cap/year), which is reflected in the absence of hydric stress. **GW:** The country's aquifers have been delineated, but detailed studies of their exploitation potential are needed. **WQ:** Contamination sources are diverse (solid wastes, urban discharges, agricultural and extractive activities). **DR:** The drought risk in the country is moderate and caused by hydro-climatological events. **FL:** The flood risk is moderate due to the high precipitation rate and infrastructure needs.
Trinidad and Tobago						**WA:** The WA value in the country is medium-low (approx. 3000 m^3/cap/year), which results in a medium hydric stress level. **GW:** The country's aquifers have been delineated, but detailed studies of their exploitation potential are needed. **WQ:** Contamination sources are diverse (solid wastes, urban discharges, agricultural and extractive activities). **DR:** Vulnerability to drought is relatively low except during extreme events (such as the regional drought of 2009-10). **FL:** Vulnerability to floods is relatively high due to extreme rainfall events and lack of infrastructure.
Uruguay						**WA:** WA in Uruguay is relatively high (>50,000 m^3/cap/year), and this reflects in a low hydric stress. **GW:** The country's main aquifers have been delineated but their characterization needs improvement. **WQ:** There are significant contamination problems in several supplying basins due mainly to agricultural and livestock activities. **DR:** The drought risk in the country is moderate and caused by hydro-climatological events. **FL:** The flood risk is relatively low due to abundant WA and lack of drainage infrastructure.
Venezuela						**WA:** The country has a high WA (>50,000 m^3/cap/year), which translates into a low hydric stress, except in the heavily populated coastal areas. **GW:** Groundwater is in a state of exploitation, but with an insufficient characterization of the aquifers. **WQ:** The contamination sources are diverse (solid wastes, urban discharges, agricultural and mining activities). The Guaire and Murillo river basins are notorious for contamination problems through wastewater disposal. **DR:** The drought risk is moderate due to abundant WA. **FL:** The country is affected by chronic and extensive floods caused by a combination of physical conditions and infrastructure insufficiencies.

Source: Diagnóstico de los Recursos Hídricos en América Latina (2013), Editorial Pearson; Aqueduct Database, World Resources Institute, www.wri.org; Water Resources Assessment of the Bahamas (2004), US Army Corps of Engineers; Groundwater Monitoring in Latin America, (2013), International Groundwater Resources Assessment Centre (IGRAC); Water and Sanitation Belize, (2013), IDB Technical Note IDB-TN-609; Diagnóstico del agua en las Américas, (2012). Red Interamericana de Academias de Ciencias y Foro Consultivo y Tecnológico AC, INbS 978-607-9217-04-4; Adamson, James K. and Jean-Baptiste, Gérald and Miner, W. Javan, (2016). Summary of Groundwater Resources in Haiti, (2016), Geological Society of America; Water Resources Assessment of Jamaica, (2001). US Army Corps of Engineers; Miralles-Wilhelm et al. (2017). Physical Impacts of Climate Change on Water Resources. World Bank; AQUASTAT (FAO) Database.

Environmental Impacts of Dams to Generate Electricity and for Multiple Purposes

Although estimates vary, mountain nations of LAC meet a significant part of their energy requirements through hydropower generation: Costa Rica (about 100%), followed by Ecuador, Peru, and Colombia (more than 70% of the demand). Brazil, at a lower altitude, is currently 80% hydropower (Tundisi et al., 2014). Peru has the greatest number of dams at present and, along with Bolivia, most are small and high in the mountains (Anderson et al., 2018). Brazil's oldest dams were built in the Eastern and southeastern parts of the country, but as all favorable sites for dam construction were occupied, construction began to move towards the Amazon basin (Da Silva Soito et al., 2011 and Tundisi et al 2014).

While there are an increasing number of small dams in the Andes, the current trend to build new hydroelectric reservoirs is concentrated on the lower sites in the Andean Amazon and lowland tributaries of the Amazon River. Small Andean reservoirs have limited potential for hydropower due to their small size and depth, but are critical for irrigation of alpaca grazing areas, quinoa, and as water supply for large cities such as La Paz, Lima, and Quito (Chevallier et al., 2011). Water resources feeding these tributaries are supplied by glacier melting (Guido et al., 2016), and glaciers have been melting progressively over the last 50 years (Rabatel et al., 2013).

300%

Electricity generation in the Amazon will increase with the construction of more than 150 dams

To take advantage of high precipitation and topographic differences, more than 150 large dams are currently planned or under construction on six of the Amazon's eight major tributaries with the goal of increasing electricity generation by 300% over the next 20 years (Finer and Jenkins, 2012; Anderson et al., 2018). Most are located in the high Andes Amazon ecoregion and are larger than any current facility in any of the Andean nations. Peru will site the largest number of planned dams. The Andes contribute 50% of the Amazon River's flow, 93% of its sediment load, and most of the nitrogen and phosphorus to drive river productivity (Anderson et al. 2018). There is a great concern that these new Andean dams will disrupt the connectivity of the Andes with the Amazon lowlands, trap 100% of the sediment needed for the various morphological types of the channel, as well as a significant portion of nitrogen and phosphorus, and isolate higher conservation areas in the lower river mountains (Tundisi et al., 2014; Finer and Jenkins, 2012; Anderson et al. 2018).

As most of the favorable sites for dams have been occupied in eastern and southeastern Brazil, the Amazon basin is seen as the "new hydropower frontier," where 100 dams are already operational and 137 additional dams are planned (Tundisi et al., 2014; Da Silva Soito and Freitas, 2011). Due to the generally low relief, dams in the Amazon basin tend to be wide and not as high, resulting in large areas of forest being flooded as part of hydroelectric reservoirs, which trap large amounts of river-laden sediment critical to the Amazon's lower alluvial plains and channels (Manyari and de Carvalho, 2007;

Finer and Jenkins, 2014). Such large surface impoundments tend to become anoxic (without dissolved oxygen) over large areas (due to decomposition of rainforest vegetation leaving there during construction); pose water quality problems due to excess nutrients, which promote algal blooms; and are important contributors to atmospheric sulfur during low water phases (Tundisi et al. 1998, Rosa et al. 2003).

In addition to trapping sediment and nutrients, dams can have a major impact on SH through their blue water footprint

In addition to trapping sediment and nutrients, dams can have a large impact on WS through their blue water footprint, by transforming river runoff into evaporative water losses from their surface. The larger the reservoir area and the higher the temperature, the greater the vapor release to the atmosphere (Hogeboom et al., 2018). Due to topography that necessitates the need for large reservoir areas, Brazil has the largest blue water footprint of any nation in the world, calling into question the positive benefits of hydropower.

Dams can also have significant ecological and social impacts (Finer and Jenkins, 2012). Rivers evolve in structure and function from headwaters to discharge in a predicted manner (Stream Continuum) that, if interrupted by a dam (serial discontinuity), can have serious impacts on the upstream movements of commercially important and endangered fish species (Ward and Stanford, 1983). Tundisi et al. (2014) recommended spacing dam positions along the length of the river to allow sufficient distance for the river to recover before encountering another reservoir. In addition to this, **dams commonly generate social conflicts due to the resettlement needs of populations and their productive activities, among other factors.**

Perhaps the most significant impact of dams refers to the reduction of ecological connectivity and the interruption of environmental flows. The former refers to the ability to connect similar ecosystems. Environmental flow is "the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems"[4]. To mitigate these impacts, in addition to maintaining a minimum flow in river channels, specifications must be developed for monthly mean flows and for the frequency of high flow pulses and flooding of river floodplains (Richter et al., 2006). Annual flooding of river floodplains is especially critical for forest productivity and the breeding of commercially important fish species in the Amazon basin (Tundisi et al., 2014).

To have greater relevance to sustainable freshwater management, **environmental flows must shift their focus from restoration to adaptation to climate change and land use change; expand from single sites to entire watersheds; and include social-ecological sustainability in all water management scenarios** (Poff and Matthews, 2013). It is very important that environmental flows recognize the differences in river structure and function dictated by the fundamental processes operating in ecosystems and incorporate adaptive

4 Declaración de Brisbane (2007): http: / /www.watercentre.org/news/declaration)

management that considers short- and long-term changes in the extent of individual biomes across the region.

Regarding flooding, the current trend is to use green infrastructure solutions alone or in combination with traditional gray infrastructure solutions. All these measures should be reflected in Flood Risk Management Plans (FRMP).

BOX 2.6. GREEN INFRASTRUCTURE FOR HOPE

At present, both in LAC and in the world in general, **green infrastructure solutions or Nature-based Solutions (NbS)** are preferred over, or in combination with, traditional infrastructure solutions (dams, ditches, etc.). NbS use natural ecosystems and the services they provide to respond to challenges such as climate change, food security or natural disasters. For example, reforestation to stabilize a riverbed and prevent flooding or the creation of wetlands to improve and purify water quality.

The challenge for the NbS lies in demonstrating their efficiency and viability before undertaking larger-scale investment programs. For example, in Colombia (through the Bogota Water Fund -Agua Somos-), land is being purchased to implement green infrastructure, which can range from reforestation of extensive territories (in this case, paramo) to more specific actions in the course of rivers to restore their naturalness and the recovery of their natural flooding areas.

As in the case of the climate change strategy, it would be desirable to have funds to undertake pilot experiments on the efficiency and cost-effectiveness of green infrastructure in the fight against extreme weather events such as floods and droughts.

II.3 Regulatory and Governance Aspects

Scarce or irrelevant regulations

The origin of water regulations in LAC is very old. Apart from regulatory precedents not based on the existence of law but on other types of instruments, including those of the original indigenous populations, it is based on reproductions, more or less literal, of the Spanish Water Law of 1879, of great prestige at the time due to its normative quality.

During the last decade, great interest has been observed in creating new water regulations in different countries, which has clearly improved their formal aspects, regardless of their degree of actual implementation (Embid et al., 2017). This phenomenon has also been captured by other authors (Peña,

2016) who highlight the advances that have been experienced in recent years in the area of water and environment of the region, although they point out that there is still a long way to go.

During the last decade, great interest has been observed in creating new regulations on water in different countries

This appeal to the road ahead, together with certain criticisms of the existing situation, is also a concern of some studies that point out the **inadequacy of regulatory frameworks, the lack of capacity to implement them, the weakness of national water authorities, the weakness of basin committees, the fragmentation of decision-making power and the limited participation of the communities involved** (Altomonte and Sanchez, 2016). As evidence of the deficiencies detected, the absence of capacity to resolve conflicts is mentioned, specifically in the area of conflicts between different water uses.

It is clear that **it is necessary to overcome the gap of informality and the lack of effectiveness of water regulations, even to remedy the still varied cases of countries that do not have water laws** (e.g., Colombia, El Salvador, Guatemala) or those whose norms are so old that their prescriptions are completely disconnected from the fundamental concerns of 21st century society (Panama, with a decree dating from 1966). There are also cases of countries that, although they have recent laws, lack the appropriate regulatory development without which the normative novelty is not implementable in practice (Paraguay).

It is necessary to overcome the gap of informality and the lack of effectiveness of regulations on water

There are some examples of progress in this area, such as, the incorporation of the human right to water into various constitutions in LAC, in accordance with a 2002 Observation of the United Nations Committee on Economic, Social and Cultural Rights and its subsequent proclamation in 2010 by the UN General Assembly. However, many of these efforts suffer from a lack of concrete content and neglect the obvious need for ordinary regulations to make it possible to implement these laws in practice.

But, in addition, there have been a number of laws in recent years, probably connected to the UN Agenda (Millennium Goals 2005-2015) that are discussed in detail in Embid et al. (2017). There are also other regulatory reform projects that have not yet been finalized into an approved and effective law (e.g., Costa Rica, Guatemala, El Salvador, Mexico or Dominican Republic). These laws are summarized in **Table 2.2.**

Table 2.2. Water Acts (reformed or in the process of being reformed) by country (in bold font, acts sanctioned in this century).

This table considers only water laws and not complementary legislation (civil, environmental, water utility, land-use planning, etc.), although these are a substantial part of the water legal regime and some countries, which do not have water laws, are even governed exclusively by them.

Country	Act / Nº	Year	Status
Argentina	**Water Law of Santa Fe Nº 13740** **Autonomous City of Buenos Aires N° 3265** **La Pampa N° 2581** Buenos Aires Province N°12257 Chubut N° 4148 Córdoba N° 5589 (reformed in 2006) Mendoza (with complementary legislation)	**2018** **2010** **2010** 1999 1996 1974 1884	Reform attempt in several of the 24 Argentine provinces
Bolivia	The *Ley de Dominio y Aprovechamiento de Aguas* [law on ownership and utilization of water] has been repealed in several parts and there are a variety of regulations that sometimes overlap and regulate specific sectors.	1906	Several projects and reformation attempts
Brazil	Water Law Nº 9433/97 Since its sanction, each of Brazil's 27 states has enacted its own water law.	1997	In force
Chile	Water Code. Partial reform 2005.	1981	Partial reform attempt 2014/2015. Possibly a partial reformation in 2018 or 2019
Colombia	National Code of Renewable Natural Resources and Protection of Environment	1974	Attempt for issuing a water law
Costa Rica	Water Law Nº 276	1942	
Cuba	**Terrestrial Water Law No. 124 and 2017 Regulation Decree No. 337**	2017	
Dominican Republic	Water Law Nº 5852	1962	Continuous reform attempts
Ecuador	**Organic Law of Hydric Resources and Water Uses**	2014	**2015 Regulations partially amended in 2017.**
El Salvador	Law on Integrated management of hydric resources	1981	General Water Law is on debate

Country	Act / Nº	Year	Status
Guatemala	There is no specific water law or water authority. The legal water regime is dispersed in different regulations of different rank.		Reiterated attempts for issuing a law on water.
Haiti	The country has no specific water law.		
Honduras	**General Water Law**	**2009**	
Mexico	National Water Law of 1992 (partially reformed in 2004/2008/2013)	1992	Reform attempt 2014/2015
Nicaragua	**National Water General Law Nº 620**	**2007**	**Regulations of 2010**
Panama	Water Law Decree Law 35 of September 22 on the use of water with some amendments and complementary laws	1966	No reform attempts Law Project 573 of 2013 for creating a national water authority
Paraguay	Law 3239/07 on Water resources	2007	In the process of regulation
Peru	**Law on Water Resources-Law Nº 29338**	2009	**Amended in 2017. Regulations of 2010 amended in 2014.**
Puerto Rico	Water Law Nº 136	1976	Reform attempt
Uruguay	Water Code, Decree Nº 14859. Constitution Reform in 2004 (art. 47). Law 18.610 of 2009 on principles of a National Water Policy.	1978	
Venezuela	**Water Law**	**2007**	

What about water regulations and governance in LAC?
Once the most recent water regulations in LAC have been listed, a characterization and diagnosis can be made from the perspective of WS.

Water regulations exist in most cases, but they do not always include the issues or principles required by the current WS situation. In this case, it is not only crucial to have "modern" water regulations that are adequate to the problems of current times (Embid et al., 2018b); also, depending on the case, other areas of regulations, such as those related to land use and territorial, urban or environmental planning, or waste policy, may be equally important. However, there are great difficulties in ensuring their effectiveness and compliance. It should be reiterated that informality is the general characteristic in most cases. Some of these difficulties are summarized below.

- **Lack of information. In many cases, basic issues are unknown or there are no instruments to know them which hinders an efficient water**

management. The example of the absence of registers or cadasters, or their updating, is evident. Without reliable knowledge of water uses, volumes used, their origin, destination, owner or quality, among other factors, it is impossible to generate use and discharge permits, effective water management and the degree of existing WS.

- **Deficient resources for water management. Water administration has several deficiencies: (i) it is not always based on the river basin; (ii) it has scarce human and economic resources; (iii) the level of training of personnel is usually not sufficient; (iv) it is sometimes highly politicized (forms of access to the civil service); and (v) it is fragmented.** Except for the first characteristic, the rest are also applicable to administrative entities related to land use or urban planning, which are of great importance for proper water management, as already mentioned. The above is applicable to states, but in the case of federal states, it also applies to federated states (this is the case of the Argentine provinces, for example). In relation to this last circumstance,[5] there are multiple administrative bodies with competencies in matters strongly related to water, such as agriculture, energy, industry, territory or environment. Fragmentation and lack of policy coordination are also noticeable there (Embid et al. 2018b).

- **Hydrological planning is underdeveloped. In most cases, hydrological planning is still incipient.** Although many documents are called "Plans", there are few with a focus on WS (this is the case of the 2016 Panama Plan that uses that denomination). The same is true in the case of land use planning. There are no land use plans that respond to the concept of a plan. Nor are there any special drought or flood risk management plans; nor are there any determination of the riverbank line (Argentine concept that serves to delimit the riverbed -public domain- from the surrounding lands) or delimitation of evacuation routes. If they exist, the level of coordination between sectoral planning involved in WS (energy, agriculture or hydrological planning) is usually very low or even null (Embid et al., 2018b).

- **The balanced interrelationship between uses is not always well conceived or defined**. In particular, it should be noted the **conflictive relationship between mining and water** (a problem that intensifies when it comes to illegal mining -Benavides Vanegas and Ruiz López, 2016-), with water for cities and water for agriculture (Bustos Niño et al., 2016) and also between energy and water (Embid et al., 2017). A clear example of this area of conflicting uses is the application of the fracking technique (hydraulic fracturing) for the search for unconventional energy resources of oil and natural gas (Embid and Embid,

5 In the report CEPAL 2018 b, pp. 99 and ss. a lot of space is devoted to the progress on the topic of coordination mechanisms for institutionalization with the implementation of the Agenda 2030 for the sustainable development. Examples of many countries on the creation of new bodies in some cases or, in others, in charge of roles already existing for the implementation of the Agenda 2030.

2017; Arroyo and Perdiel, 2015). When there is regulation on the matter (e.g., the Argentine province of Mendoza, with regulations that appeared in the first half of 2018), environmental impact assessment is usually provided for projects that intend to use this technique, but it would be necessary to go a step further and provide for a complete risk assessment, including those related to climate change on water availability.

- **The economic-financial regime for water is often deficient for various reasons.** **The self-financing of water policies is not ensured by the amounts paid by users** (when they are established and actually paid), which means that the always recommended principle of cost recovery of the services provided with water is not followed (or is followed in a deficient way). All this is understandable in a general framework in which we have noted the absence of reliable or updated registers or cadasters because in such cases: who to charge and in what amount? On the other hand, in the current context, relying on budgetary funding does not seem advisable or possible as it is often less than necessary.

- **Conflict resolution mechanisms are slow and inefficient.** So is the practice of judges and courts, where **the lack of specialization of its components** is also often denoted (Martín and Justo, 2015). Sometimes, moreover, the independence of the organs of the judiciary is not guaranteed. This generates a **lack of trust** that, among other reasons, has led to the regulation of arbitration mechanisms in the so-called Investment Protection Treaties. In turn, these arbitration mechanisms tend to prioritize the rights of investors in the face of attempts by local authorities to implement policies that defend the general interest. This leads to the so-called "**regulatory chill**" (Bohoslavsky, 2010; Solanes, 2015).

- **Weak and inappropriate assessment and diagnostic tools.** Where they exist, assessment and diagnostic tools prior to decision making are often very weak, inappropriate or poorly applied. Most countries have mandatory environmental impact assessment procedures (and sometimes even strategic environmental impact assessment) with different levels of performance; but they do not have risk assessments, which are essential from the WS approach (as noted above with the specific example of the *fracking* technique). Nor are rigorous economic and social evaluations of the real benefits of projects, budgets, users' ability to pay, etc., often overestimated for their justification, commonplace.

- **Greater emphasis needs to be placed on the "water cycle"**, on both large and small systems for drinking water supply and treatment (and, if possible, reuse) of urban wastewater. Major investments should focus on both areas (facilitating private investment as a first step, as public investment under current conditions will not be sufficient) and organizational and institutional efforts (proceeding with the necessary reforms of the current administrative structure). This must be accompanied by the achievement of economies of scale in supply and sanitation. This is closely related to the insufficiency or incapacity, many times, of the municipal territorial level for the provision of these services, so it would be convenient to seek broader management units, promoting associations of municipalities (associations of municipalities, consortiums) or other similar formulas.

The self-financing of water policies is not guaranteed with the amounts paid by users

On the other hand, in the case where there is a water market (Chile) it is very clear that it is produced without real knowledge of the existing waters, their quality status or the use-rights holders. Nor are the transactions sufficiently publicized and, of course, environmental concerns in the functioning of the market are practically nil in their approach and, consequently, in their practical results. Furthermore, such a market does not guarantee the supply of water to rural areas, an area in which major deficiencies can currently be observed (more than one million Chileans living in rural areas are currently supplied by trucks and not by water supply infrastructure). There is no doubt that the powers and means (personal and economic) of the General Directorate of Water should be reinforced, since the market assumptions (publicity and transparency) are not fulfilled and the existence of a regulator with effective powers is an essential condition of the market.

Special attention should be paid to policies related to extreme climate events such as droughts and floods. The characteristics of a large part of the region (especially Central America) and the advances in the knowledge of the impacts of climate change show that these extreme climate events are likely to increase. It is therefore very necessary to implement drought and flood risk prevention policies, with the examples already known in the European Union of Drought Risk Management and Flood Risk Management Plans. This should lead, in a second phase, to the introduction into existing sectoral regulations (e.g., water, energy, agriculture) of considerations related to the impacts of climate change.

II.4 Status of Water Infrastructure

The human supply situation is highly variable, depending on the country and subregion

Regional and national efforts to improve water infrastructure conditions have focused on different uses and purposes that can be classified as follows: (i) domestic water supply; (ii) water for irrigation and food production; (iii) water for energy production; and (iv) infrastructure to combat extreme climate events (droughts and floods).

Water Supply Infrastructure

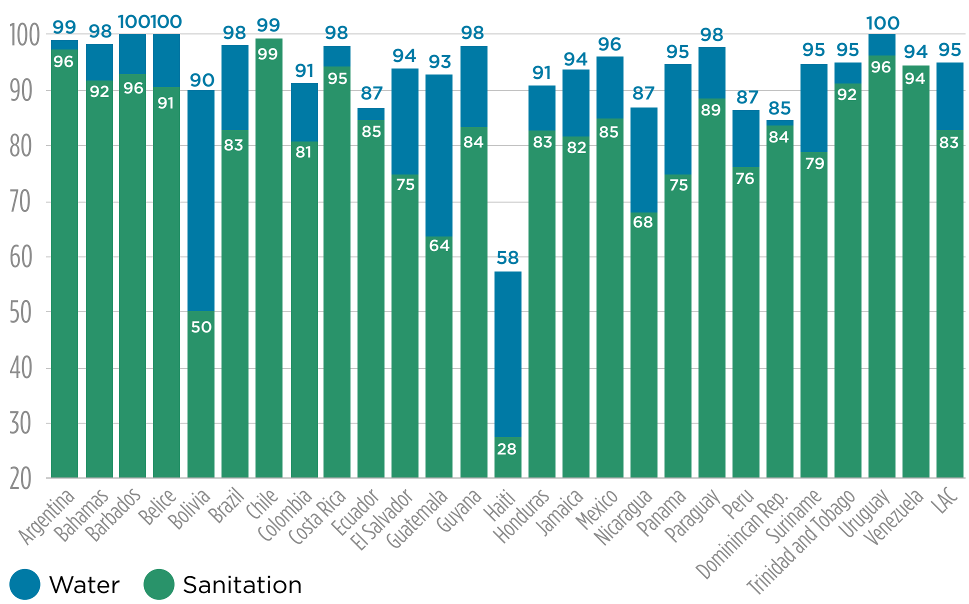
In particular, investments in water infrastructure in LAC have been emphasized due to the role they play, within a WS framework, in **ensuring the water supply for human consumption with acceptable quality for health**. Associated with this supply is the collection of used domestic water through a sanitation network, which improves the hygiene of families and, consequently, their sanitary level. As can be expected, **the situation varies greatly, depending on the country and the subregion.**

95%
of LAC have access to drinking water

83%
to improved sanitation

The most complete and updated information on levels of access to these services corresponds to that reported by WHO and UNICEF in 2015, presented in **Figure 2.8.** It can be deduced from this information that the LAC countries have a level of access to drinking water of 95% and to improved sanitation of 83%, with great variability between countries. The country with the greatest deficiencies is Haiti, where safe water coverage is only 58%, while sanitation coverage is only 28%. The countries with the highest levels of safe water coverage are Barbados, Belize, and Uruguay, with 100%. And above 95% are Argentina, Bahamas, Brazil, Chile, Costa Rica, Guyana, Mexico, Panama, Paraguay and Trinidad and Tobago. In sanitation, Argentina, Barbados, Chile, Costa Rica, and Uruguay are first, with percentages above 95%. The same imbalances that occur between countries occur within the countries as well. For example, in Mexico, the states of Chiapas, Guerrero and Oaxaca have coverage close to 74%, while at the national level the percentages are 96% and 85% in sanitation.

Figure 2.8. Percentages of Water and Sanitation Coverage – Overall for the LAC Region and by Country.



Source: Sector Framework for Water and Sanitation. IDB, December 2017.

In addition, the quality of service is not fully satisfactory, even in areas with reasonable network coverage. The main problems detected, which are widespread in the region, are: (i) lack of potability, due to the presence of fecal matter and chemical contaminants; (ii) lack of sufficient pressure to ensure the water supply to upper floors; (iii) intermittent water supply and related services with extended periods of water cuts. There are reports of 60% of water systems that do not ensure 24-hour service seven days a week, with the risk of breakage when restoring service due to water hammer caused by air that has entered the pipes; (iv) deficiencies in intra-domiciliary connections.

Groundwater supply is also unsafe due to the presence of nitrates, arsenic, boron and other contaminants. In coastal areas, especially in the Caribbean islands, overexploitation of aquifers favors saline intrusion, making the water unsuitable for urban supply by turning it into brackish water with a high saline content. The effects of climate change will make these problems even more acute, so that either sources of potable resources are identified within the islands or desalination technology will have to be considered. On the other side, the loss of these groundwater reservoirs, as well as strategic reservoirs, add difficulty in dealing with drought episodes.

With the reservations inherent to the analyses carried out for this study, the conclusions reached are the following at the regional level:

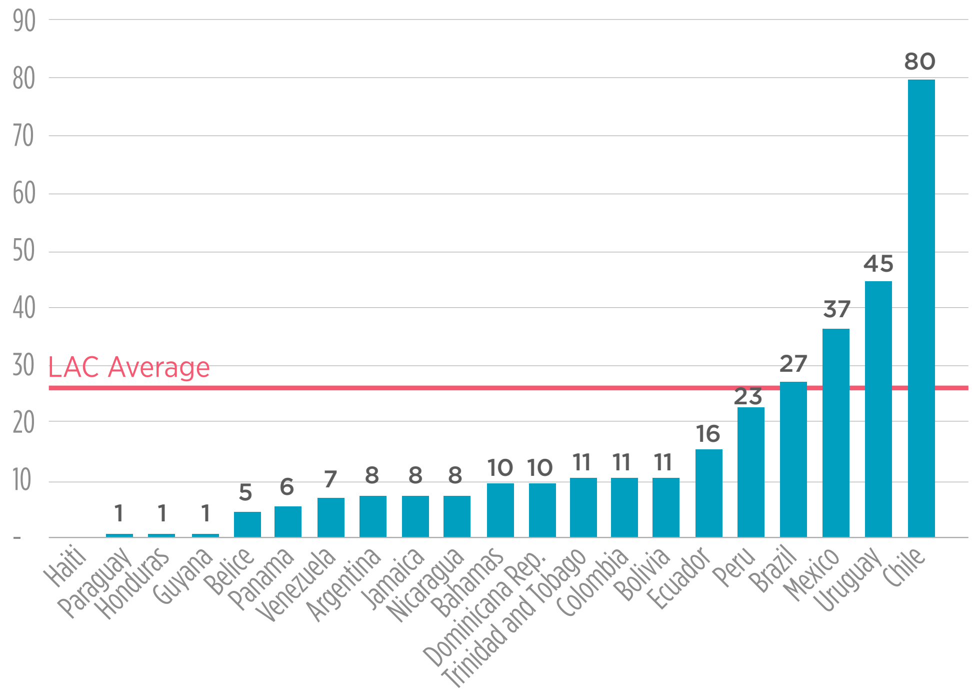
- **Water coverage** (average): **95 %**
- **Safe water coverage** (average): **68 %**
- **Goal Agenda 2030**: **100 %**

- **Average sanitation coverage: 68 %**
- **Actual sanitation coverage: 22 %**
- **Goal Agenda 2030: 100 %**

- **Population without safe water coverage: 198 million**
- **Population without actual sanitation coverage: 457 million**

The *Joint Monitoring Program* (a joint monitoring program by WHO and UNICEF), mentioning the WSA Sector Framework, estimates that, **at a regional level, household coverage with treated wastewater will be approximately 22% in average, with a very high variation between countries** (in Chile it exceeds 80%, followed by Uruguay, with 45%; Mexico, with 37%; Brazil, with 27%; Perú, with 23%; in countries such as Ecuador, Bolivia, Colombia and Trinidad and Tobago, these values range between 10% and 20%). **Figure 2.9**. show the data. The red line marks the average level for LAC, which, as indicated, is 22%.

Figure 2.9. Percentages of Households Coverage Whose Water Is Treated.



Source: Water and Sanitation Sector Framework Document. IDB. December 2017.

Infrastructure for Irrigation and Food Production

Regarding **water for irrigation**, according to FAO (2016), in 2010, in the region as a whole, consumption reached 236 km3, of which about 50 km3 is obtained from groundwater. The largest consumers of the resource are Mexico, the Andean region and Brazil, followed by other countries in South America. The Central American region, the Caribbean and Guyana, as well as the Caribbean and Guyana are far behind.

It is interesting to have an approximation of the average gross endowment per hectare. For this purpose, the consumption in 2010 has been used with the irrigated area in 2013. The resulting figure is only an estimate, but sufficient to make a reasonable approximation: (i) in the LAC region as a whole, the average gross endowment is **9.477 m^3/ha**; a moderately high value within the range in other regions of the world, which indicates that its reduction could be aspired to through modernization projects, (ii) within the regions with maximum irrigation expansion, the Andean region is the one with the lowest water consumption per hectare, with 6. 954 m3/ha/year, which reveals that, overall, it is the region with the most modernized facilities; iii) Brazil is below the average for the region, with 8. 315 m3/ha/year, but almost 20% higher than the Andean region; iv) other South American countries stand out for their strong endowments, with 16,421 m3/ha/year, a figure that is relevant from the point of view of pressure on resources, since in 2013 they had an irrigated area of 3.8 million hectares; and v) the large consumption in the Greater Antilles Caribbean, 12. 000 m3/ha/year, also important from the point of view of the pressure it exerts on the region's resources, since it has an irrigated area of one million hectares.

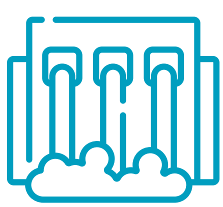
In LAC, the percentage of irrigated area over the total cultivated area (which includes rainfed and irrigated) has increased from 9.7%, in 1973, to 12.7% in 2013 (FAO, 2016). According to the same source, in the world, the average percentage of irrigated area versus total cultivated area is 20.6%. Asia has the highest percentages (40.9%). In Europe, the average percentage is moderate (7.3%), but Mediterranean Europe stands out with a percentage of 31.4%. The framework described about different regions of the world allows us to state that **LAC has achieved a very modest development in irrigation systems as a whole, which gives it comparative advantages in terms of its possibilities of expansion for economic reasons, but with negative consequences for WS.**

LAC has achieved a very modest development in irrigation systems as a whole

Due to its nature as a major consumer of the resource, irrigation has a clear role in pollution. Irrigation waters generally contain nutrients, sediments and other substances from agrochemicals that pollute their discharge into lakes, reservoirs, coastal areas or aquifers. In this sense, the most viable solution is to provide the necessary technical, legal, financial and other support to establish measures to mitigate the negative impacts: irrigation technology, advice and training for farmers and the application of what could be called a "code of good agricultural practices".

Water Infrastructure for Energy Generation

In terms of water infrastructure for energy access, according to the IDB [6], **the LAC population preferentially accesses energy consumption through electricity generation.** In this sense, between 2000 and 2016, the percentage of coverage has increased from 87 to 97 percent, approaching the universal service goal foreseen for 2030. Competition is especially established between hydroelectric energy and energy from coal and oil derivatives. In South America, hydroelectric energy is in the majority, with a share of 71.6 percent, while thermal energy accounts for 10.3 percent. Nuclear energy occupies a secondary position, with 2.2%.



71.6%

of South America's energy is generated from hydroelectric

Due to their importance in the generation of electricity in the region, it is necessary to mention the large hydropower plants. Brazil has 26 large power plants which, including the Itaupú plant, shared with Paraguay, represent a total installed capacity of 62,234 Mw, and an estimated production of 337 Gwh. Argentina, in turn, has nine large power plants which, including Yacyretá, shared with Paraguay, represent another 15,235 Mw and a production of 41 Gwh. Venezuela has four large power plants with a total capacity of 23,664 Mw; Colombia has another four, with a total capacity of 5,829 Mw. Peru and Mexico have only one large plant, Mantaro and Malpaso, respectively, with

6 Energy Sector Framework Document. IDB June 2018.

693.505 Mw
is the hydroelectirc potential in LAC, only 22.6% is used

respective capacities of 1,156 Mw and 1,080 Mw. Considered as a whole, the installed capacity of large plants amounts to 109,198 Mw, which represents almost 70% of the 156,850 MW of hydropower installed in the region.

The growth possibilities of hydropower in LAC are feasible due to the opportunity offered by climate change mitigation through activities that allow the reduction of greenhouse gas emissions, prioritizing renewable energies, both conventional (hydropower) and non-conventional (wind and solar). In these terms, **the hydroelectric potential of LAC has been estimated at 693,505 Mw (Olano, 2011), which means that only 22.6% of this potential is currently being used.** This value should also take into account the impact of climate change on hydrological cycles, which would result in a reduction of turbineable flows in some areas of the region. The final installable potential will depend on economic, environmental, climatic and electricity demand considerations. Chapter IV presents results of future projections of the LAC energy matrix and its impact on WS.

A recent IDB research study (2017) analyzed water demand projections under different socioeconomic and climate change scenarios in the region. The results of projected water demand to 2025 and 2050 were compared with the currently existing water storage capacity in each country of the region to determine water infrastructure storage deficits (dam capacity). The results of this analysis are shown in Table 2.1. In these results, it can be seen that already during 2015 (actual data, not projections), there were water storage infrastructure deficits in a good part of the countries in the region, including countries with large deficits such as Chile, Ecuador and Peru.

Resilient Infrastructure against Extreme Hydro-climatic Events Management
In the last 20 years the LAC region has endured several drought episodes (such as those in the Caribbean in 2009- 2010, Argentina in 2012 or Mexico in 2011-2012) and, more recently, in Chile, São Paulo (Brazil) or Bolivia in 2016-2017. The economic impact of these extreme events can be significant: figures of 2.5% of GDP have been cited, in the case of Argentina and more than 3 billion dollars in the case of the drought in Mexico. Some of these events are associated with the El Niño phenomenon, which links them to climate variability and change. These episodes have raised the need to promote a rational and efficient use of the resource, a circumstance enhanced by the effects of climate change. **However, drought plans that contribute to increasing the resilience of systems in the face of this adverse phenomenon have not yet been sufficiently promoted.**

Table 2.1. Comparison between the storage capacity of existing infrastructure (dams) and water demand in the countries of the LAC region.

Country	Capacity of Reservoirs (R; km3)	D (km3) 2015	(R-D) km3 2015	D (km3) 2025	(R-D) km3 2025	D (km3) 2050	(R-D) km3 2050
Argentina	131.60	48.27	83.33	57.59	74.01	73.87	57.73
Belice	0.12	0.23	-0.110,25	-0.13	0.36	-0.24	
Bolivia	0.60	3.63	-3.03	4.88	-4.28	7.27	-6.67
Brazil	700.40	103.14	597.26	119.51	580.89	152.60	547.80
Chile	14.44	65.06	-50.62	78.47	-64.03	108.12	-93.68
Colombia	11.28	13.68	-2.40	17.71	-6.43	25.60	-14.32
Costa Rica	2.00	2.73	-0.73	2.91	-0.91	4.02	-2.02
Dom. Rep.	2.30	6.72	-4.42	7.13	-4.83	9.83	-7.53
Ecuador	7.70	18.59	-10.89	22.74	-15.04	32.86	-25.16
Guatemala	0.46	5.04	-4.58	5.42	-4.96	7.65	-7.19
Guyana	0.81	2.94	-2.133,58	-2.77	4.78	-3.97	
Honduras	5.80	2.34	3.462,51	3.29	3.55	2.25	
Haiti	0.30	2.04	-1.742,19	-1.89	3.08	-2.78	
Jamaica	0.01	1.70	-1.69	1.84	-1.84	2.65	-2.65
Mexico	150.00	107.35	42.65	122.68	27.32	168.56	-18.56
Nicaragua	32.00	2.22	29.78	2.38	29.62	3.34	28.66
Panama	9.14	0.71	8.430,77	8.37	1.08	8.06	
Peru	5.77	21.39	-15.62	27.51	-21.74	39.17	-33.40
Paraguay	33.53	2.73	30.80	3.50	30.03	5.15	28.38
El Salvador	3.88	3.25	0.633,49	0.39	4.91	-1.03	
Surinam	20.00	1.17	18.83	1.41	18.59	1.89	18.11
Uruguay	17.20	7.29	9.919,19	8.01	13.90	3.30	
Venezuela	157.60	38.02	119.58	43.53	114.07	58.37	99.23
Total	**1306.94**	**460.26**	**846.67**	**541.19**	**765.74**	**732.62**	**574.32**

Source: IDB (2017)

BOX 2.7. DROUGHT IN BOLIVIA

As an example of the recent creation of infrastructure for tackling extreme weather events, the Bolivia's drought of 2016-2017, with impact on the capital cities of La Paz, El Alto, Sucre, Oruro, and Potosí can be highlighted. A report written by the Bolivian Ministry of Environment and Water describes all the facts related to this:

i) Problem origin: A significant decrease of precipitations and its immediate consequence of a decreased supply to rivers.

ii) Produced effects: with reduction in supply in important cities of the country, resulting in restrictions in La Paz, Sucre, Cochabamba, Potosí and Oruro. In December 2016, 51% of the country's municipalities were affected by drought and seven of the ten main cities suffered from water deficit.

As a result, the Bolivian Government adopted **two types of measures: infrastructural measures**, such as the creation of the *Programa Nacional de Perforación de Pozos de Agua Subterráneas "Nuestro Pozo"* [National Program for Drilling Groundwater Wells "Nuestro Pozo"], aimed to ensure water availability for food security; and **governance measures**, such as the **enactment of 13 supreme decrees aimed to improve agricultural production and tackling droughts**.

LAC also suffers chronically from floods, which generate substantial economic losses. The amounts estimated on losses vary, depending on the areas affected by floods. In July 2018, UNICEF informed about the severe floods caused by the tropical storm Noel through Mexico, Dominican Republic, Haiti, Honduras, and Nicaragua: thousands of people lost their homes and needed basic emergency supplies, shelters, and sanitary assistance. The storm generated economic losses estimated in billions of dollars. This is a particularly intense type of disaster that usually affects large areas of territory and different river basins.

To work on its **prevention, a specific response is needed from the hydrological-hydraulic systems (basin systems) that could be materialized in Flood Risk Management Plans (FRMP)**, such as those being implemented in Europe derived from the Directive 2007/60/EC and which were approved in Spain in 2016 (see the details of these FRMP in **Annex A**). In LAC no plans of this nature have been implemented, although there is a potential demand for it.

III Water Security and IDB's Experience

HIGHLIGHTS:

- This analysis aims to identify positive transformational experiences financed by the IDB and to know what **has been the best scale and form of action** in order to propose strategies that will support the achievement of WS in the region over the next decade.

- From the analysis of the Sectoral Framework (SFs) documents and projects included in the Bank's portfolio reveals **extensive action on water resources, climate change, the environment, and natural resources.** It can also be perceived that the IDB has played an important role in the **implementation of a new perception of the importance of water resources.**

- To draw lessons learned that can be applied to a general framework for WS action, it is necessary to understand what worked and what can be harvested as replicable, at what scale and with what methodology. In this regard, some of the most successful experiences during the first decade of the 2000s were in Ecuador, Brazil and Peru.

- From this Bank's portfolio analysis two fundamental and basic future actions for WS stand out: Continue with the **preparation of national plans** within the expanded context of WS and **expand the scope of NbS** with the objective of selecting and establishing conservation governance of strategic water reserves in all countries.

- **From the analysis of the widest actions of IDB in the region, it can be concluded that the Bank has the experience and resources to support the countries in favor of WS.** Most of the actions leading to this goal have already been taken or are in process.

- **Useful lessons can be drawn from the IDB's experience on the following elements:**

    - **Watersheds,** their positive aspects (constituting the most adequate management level) and their limitations (their implementation takes time and requires follow-up).

    - **Water Funds** are an innovative tool for protecting watersheds with enormous potential for WS.

III. Water Security and IDB's Experience

This chapter presents a review of the Bank's action related to WS. Although so far, the Bank has not had a portfolio specifically called Water Security, it does have extensive experiences in issues related to water and sanitation services, water resources management (including IWRM), climate change adaptation, response to extreme climate events and other related issues that are worth highlighting to establish the context of innovative actions in WS for the future.

Focus of the review

To define the period and focus of this review, a critical analysis of the milestones that have marked the Bank's trajectory in the broad field of water resources management is required. Likewise, it is necessary to define which category of projects impact this review. In a region that does not have universal water and sanitation coverage[7], it is important to define what actions are designed to guarantee WS in contexts of scarcity or excess of water resources and the impact of climate change. Achieving universal coverage in water and sanitation is an outstanding debt of LAC countries to their population and, therefore, this is the direction in which sectoral efforts should be directed. **Ensuring universal coverage through the sustainable management of the availability and quality of water resources, in routine or stressful situations, under an increasingly variable climate, are actions aligned with the basic concept of WS.**

In this sense, this review of the IDB's experience focused on the identification of actions financed by the Bank, planned to i) know the availability of water resources; ii) guarantee supply for current and future uses through infrastructure works or recovery and management of environmental services in surface and groundwater recharge areas (green infrastructure); iii) improving the efficiency of water production and use in urban environments; iv) recovering the quality of water from surface sources and strategic aquifers; and v) reuse and support for the creation of specific governance mechanisms for WS.

7 In 2015 water access to secure water reached 94.6% and improved sanitation of 83.1%; other estimates suggest that 70% of sewage waters are not treated whatsoever before being disposed into rivers, lakes, or the sea (Jouravlev, 2014)

HIGHLIGHTS:

- **Water and sanitation utilities,** that should be more proactive in watersheds protection and conservation tasks.
- **Urban recovery and contamination control,** that should be rethought as comprehensive interventions at the urban basin level.
- The **National Water Resources Plan (NWRP),** that should be covered by legislation and have funding resources.
- **Environmental Economic Water Account, which** can become a key tool for hydrological planning.

The IDB should integrate an integrated and comprehensive vision, minimize conflicts over resource use, create demand for projects, play an instrumental and enabling role, and seek investment models and innovative forms of financing.

Temporal and spatial scale of the Bank's operations

In order to develop an effective WS strategy for the Bank and its clients, it is important to analyze the temporal and spatial scale of action. In the public sector, the Bank's divisions have specific counterparts that may be water and sanitation utilities, water or environmental authorities, ministries and national and/or subnational governments, as well as counterparts in other sectors such as agriculture and energy.

BOX 3.1. BRAZIL'S "SMALL" MUNICIPALITIES

Some countries, for example, Brazil, limit the total amount of loans and the action level of the Bank (the country hardly authorizes direct loans to small municipalities). For its part, the Bank is limited in its ability to support a large number of beneficiaries. Brazil has about 5,565 municipalities, 5,153 of which have less than 50,000 inhabitants (32% of the country's population[8]) and are therefore practically out of the Bank's reach. In water and sanitation, the Bank serves some of the large municipalities (São Paulo, Rio de Janeiro, Salvador, Recife, Goiânia, Fortaleza, Porto Alegre, Joinville, Belém and Manaus), but there is a larger demand to be met. The population of Joinville is approximately 500,000; the other cities are metropolitan regions with populations of more than one million.

Some projects and studies may be at the national scale (environmental institutional development, National Water Resources Plan, strategies for mitigation and adaptation to climate change and/or natural disasters, biodiversity and agricultural development strategies); others at the level of urban or rural watersheds and, recently, actions have begun to be defined by ecosystems due to their ecological functions and economic impacts (as in the case of the Pantanal in Brazil and the Puna in the

8 Agência Nacional de Águas-ANA, "Atlas Brasil: Panorama Nacional-Volume 1, Abastecimento Urbano de Água",2010.

Andes). **The procedure followed in this analysis seeks to identify positive transformational experiences, financed by the Bank, and what has been the best scale and form of action to propose strategies that will support the achievement of WS in the region in the following decade.**

A detailed historical account of the evolution of the WS theme in the Bank is presented in **Annex B**.

III.1 IDB Baseline Project Inventory

In 2018, the IDB's Water and Sanitation Division (WSA) prepared an inventory of projects that included its own portfolio as well as that of other divisions with impacts on water resources and WS. To do so, it used a methodology that considered the following criteria:

- **Decision support systems,** which includes **planning tools for water resources management** planning among competing uses, with a cross-sector approach.
- **Environmental**, which includes action **plans against water quality pollution and degradation of basin ecosystems**, increasing the resilience of socioeconomic systems and infrastructure to climate change.
- **Governance for the management of water resources**, with initiatives for the development of public policies, institutional strengthening and governance mechanisms.
- **Drainage and flood control**, for the improvement of storm drainage works and flood control systems.

The inventory results indicate that, between 2010 and 2018, WSA approved 336 projects between loans, technical cooperation and studies with a total cumulative investment of US$9.7 billion, representing 7.5% of the total number of projects approved in the same period by the Bank and reaching 10.5% of the investments made. Applying the aforementioned criteria, 71 projects with relevance to the water resources sector were selected (19 investment loans, 51 technical cooperation projects and 1 study). According to the thematic axis, 17 projects related to decision support systems, 24 to environmental issues, 8 to governance and 22 to drainage and flood control were identified. A similar inventory of projects was made by consulting the portfolios of the divisions: Urban Development and Housing, Climate Change and Sustainability, and Natural Resources and Sustainable Development.

From the analysis of the Sectoral Framework (SF) documents and the projects included in the Bank's portfolio, mainly since 2007, shows extensive action in water resources, climate change, the environment and natural resources. Operationally, the actions proposed in the SFs contribute to and at the same time depend on the WS **(Table 3.1.).**

Within the framework of this review, it is necessary to understand what worked and what can be harvested as replicable, at what scale and with what methodology. To this end, a selection of successful projects and/or programs was made for further analysis as part of this portfolio review. The analysis of projects in the portfolio that include water resources since 1990 shows that the Bank has played an important role in the implementation of a "new" perception of the importance of this renewable natural resource. However, a broader action began in 2006 and intensified in 2010 to meet the mandates of the IDB's Ninth Capital Replenishment.

Box 3.1. Correlation of the sector framework objectives of the Bank with WS

Energy	Environment and Biodiversity
Universal access and high-quality services	Environmental governance systems
Diversified energy portfolios	Mainstreaming the natural capital value
Sufficient infrastructure and network integration	Reducing vulnerability of marginated populations
Institutional strengthening	
Water and Sanitation	**Climate Change**
Universal access and quality of service	Inclusion of CC in sectors
Strengthening of the sector's governance	Strengthening of governance and institutions with CC
Projects incorporating CC, risk management, and WS	Better access to climate financing
Agriculture and Management of Natural Resources	**Urban Development and Housing**
High level of agricultural productivity	Greater capability for institutional management
Sustainable Management	Infrastructure and urban services of good quality and less vulnerable
Risk management of CC and disasters in agriculture	Access to basic social services
Rural family incomes increase	Better use of urban spaces

During the 1990s, the most important objective was to support countries in the process of building and/or strengthening their institutional framework for environmental management, the issue of the moment. The major concern was environmental impact and, although water resources were among the most impacted by untreated domestic, agricultural and industrial wastewater discharges, the concern with the quantity of good quality water to supply an expanding economy was a priority for water and sanitation utilities. On the other hand, with exceptions[9], water companies had not yet internalized that the protection of sources and headwater ecosystems they used was part of their business.

9 The sanitation company of Minas Gerais-COPASA, Brazil, protects several of its springs before 90's.

BOX 3.2. SUCCESSFUL EXPERIENCES OF THE IDB'S PORTFOLIO

Ecuador: Ecuador: A Successful Water Resources Management Plan
Between 2000 and 2006, there were some unsuccessful attempts to include watershed management in IDB-financed water and sanitation projects in the Andean region and the Caribbean. The project to implement a water resources management plan in la Hoya de Quito, directed by FONAG (Fund for Water Protection), is one of the exceptions. This Project was linked to the Environmental Sanitation Program for the Metropolitan District of Quito (1424/OC-EC). It should be noted that FONAG, operational in 2006, had already worked in la Hoya de Quito. The Bank's support was to provide continuity to its actions and the added value was the development of the Water Resources Management Plan of la Hoya de Quito.

Manaus: engaging the population in a project that changed the city
In 2005 the Environmental Sanitation Program for Manaus (PROSAMIM, for its Portuguese acronym) was approved to find solutions to the environmental, urban and social problems affecting the Brazilian city of Manaus and, in particular, the inhabitants of the urban basin known as Educandos-Quarenta in that city. These watercourses were annually dammed by the Río Negro (one of the formers of the Amazon River), flooding an area occupied by precarious dwellings known as palafitas. PROSAMIM not only solved the drainage problem of these watercourses but also transformed the city's landscape and the lives of its inhabitants[10], resettling them in decent housing with all services. PROSAMIM reached its third phase and its implementation completely changed the center of Manaus. **PROSAMIM'S success was due to the innovative process of involving the population in the project from the beginning and the executive arrangement involving a project executing unit with direct access to the state government.**

Peru: Modernizing Water Resources Management
Another successful IDB experience in promoting water resources issues has been the effort to modernize water resources management in Peru, which represents a joint support of IDB-World Bank that started in the decade of 1990. IDB supported the sector in Peru with several technical cooperation projects that promoted specific issues such as support for the management of the Puyanbo-Tumbes binational watershed (border with Ecuador); support to prepare the National Water Resources Plan; support to regularize water access rights for small communities; and support to determine the economic value of water. A three-phase programmatic policy loan was soon approved, which pushed for the modernization of the water resources sector, including the approval in 2009 of the new Water Resources Law, which explicitly contains IWRM. The process culminated with the approval, also in 2009, of the Water Resources Management Modernization Project, which promoted the creation of the National Water Authority, its institutional strengthening, the decentralization of management, and the preparation of management plans for three critical basins in the country.

10 The prior floodable locations were transformed into parks and recreational areas.

What have we learned?

Two fundamental and basic future actions for WS stand out from this analysis of the Bank's portfolio: **To continue preparing national plans within the broad context of WS and expand the scope of NbS** with the objective of selecting and establishing governance of strategic water conservation in all countries.

In relation to **National Water Resources Plans**, it is important to identify a preparation methodology and presentation format to transform it into a living, more objective and user-friendly document. **These national plans and other actions concerning WS**, as highlighted in the Climate Change Sector Framework, **should be included in country programming at the highest level**. The sample of projects presented in **Box 3.2.** is representative of the breadth of actions the Bank has undertaken to support countries in managing their water resources. Some projects, such as environmental accounts, are at an early stage of development within the framework of IDB action but were selected because they represent a good opportunity to insert the WS issue into national planning.

Box 3.2. Some examples of IDB portfolio projects on WS issues.

SCOPE	PROJECTS	IMPLEMENTATION STATUS	ACTIONS	COUNTRY	OBSERVATIONS
BASINS	Ipojuca River Basin Environmental Sanitation Program (2012-Present)	Under implementation	Strengthening of water resources management, sewage network, water supply, sampling for water quality, recovery of riverbanks, payment for environmental services, payment for using water, environmental management system in the company AyS, recovery of the spring quality.	Brazil	The Ipojuca River basin Includes urban and non-urban areas.
	Reconquista River Basin Environmental Sanitation Program (2014-current)	Under implementation	Comprehensive concept of basin management, management plans using a shared vision, sewage networks, drinkable water networks, strategic communication, HR information system, control of industrial contamination, soil residue management, and support to land use planning.	Argentina	The high basin of Reconquista is a rural area.
	Water Resources Modernization Program (2009-2015)	Implemented	Strengthening of the National Water Authority, decentralization of HR management, management plans for three key basins, HR information system, HR monitoring system (quality and quantity).	Peru	Including urban and rural areas.
	Water funds supported by Latin American Water Funds Partnership	Under implementation	Financing mechanism for protecting hydrographic basins and payment provision for long-term environmental services. It eases the management of water resources, promotes conflict resolution, and supports the green infrastructure conservation and/or preservation.	Brazil, Mexico, Colombia, Peru, Ecuador, Dominican Republic, and other countries	Approximately 40 initiatives exist in several states of implementation.
	Multipurpose drinking water and irrigation program for the municipalities of Batallas, Pucarani and El Alto (2015-present)	Under implementation	Construction of new irrigation systems and recovery of existing systems, construction of drinking water supply systems for communities, implementation of basin management plans with a climate change vision, development of community structure for the governance of water resources in the intervened basins.	Bolivia	To be considered an integral management project of basins it would need to include legal and institutional instruments to warrant sustainability of management plans and implemented works.
COMPANY AyS	Environmental Sanitation Program for the Metropolitan District of Quito-Stages I and II (2002-2015)	Implemented	Occupancy control of hillsides for protecting drainage infrastructure, water and sewage networks, control of non-revenue water, management of areas with ecologic protection, works of hydric regulation, stabilization of slopes, repair of collectors, community relocation and development.	Ecuador	The support to the company AyS of Quito is already in its sixth stage.
MUNICIPALITY-STATE	Social and environmental program for Igarapés de Manaus-Stages I-III (2005-present)	Under implementation	Control of flood areas, creation of linear parks, resettlement, sewage and wastewater treatment, drainage master plan, urban planning.	Brazil	Program on its third stage.
	Program of environmental recovery of Belo Horizonte-Drenurbs (2004-2012)	Implemented	Flood control, urban drainage, protection of urban streams, creation of a protection area of urban streams and theme parks.	Brazil	
PLANS	National Water Resources or Water Security Plan	Drafted	Planning and policy tool of water resources, assessment of demand and availability of HR, projections, identification of critical topics, lines for action, monitoring, and assessment of their implementation.	Peru, Brazil, Panamá, Costa Rica, Uruguay, and other countries	Must be attached in the legislation on HR of the country

TOOLS AND STUDIES	System of Environmental-Economic Accounting for Water-SEEA-Water based on the System of environmental-economic accounting[11]	In development	Incorporation of hydrometeorological information in the national economic accounts and use of input- output models (e.g., models de hydric balance) to assess scenarios of HR management and impacts on the economy and vice versa.	Brazil[12], Guatemala[13], Colombia, Costa Rica[14], Mexico	SEEA- Water includes economic and environmental aspects in a single tool for analyzing water resources management, considering both economic and physical dimensions, and considers that water is essentially dynamic in relation to the environment and the economy. It generates information that allows a consistent analysis of the contribution of water to the economic development process and, on the other hand, of the impact of economic activities on water resources.
	HyDROBID	Under implementation	Simulation of water resources availability considering different scenarios, contribution to water resources management and strengthening of responsible institutions. It also includes a module that allows the inclusion of data from climate change models with respect to precipitation.	Brazil, Peru, Chile, Guatemala, Argentina, Haiti.	
	WATER-FOOD-ENERGY NEXUS	In development	Identifies and evaluates mutual impacts and synergies between water resources management, energy generation and food production, when planned in an integrated manner.	Colombia, Argentina, Uruguay, and Brazil	It can be supplementary to SEEA-Water

The analysis of the activities of projects and studies funded with IDB's resources exposes the **abundance and extension of the work performed in the region**. This vision expands even further when the objectives and goals of the sectoral frameworks are incorporated into the context of the Institutional Strategy. However, the dispersion of information due to the Bank's internal compartmentalization makes it difficult to build more thematically focused actions with greater regional or country-level scope and impact.

11 Naciones Unidas. System of Environmental Economic Accounting for Water. New York: ONU, 2012. Available at: https://unstats.un.org/unsd/envaccounting/ seeaw/seeawaterwebversion.pdf.

12 Agência Nacional de Águas (ANA), Contas Econômicas Ambientais Da Água No Brasil, 2018.

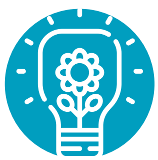
13 Prepared with Deutsch funds.

14 Costa Rica has developed it already.

From this historical range, the efforts related to WS that the Bank has executed so far for different institutions are listed below:

- **Water and sanitation utilities:** governance improvement, adequate pricing, decrease of non-revenue water, improved efficiency and productivity, environmental management system, source protection, basin management, network expansion, water and effluent treatment, reutilization of treated effluents, final waste disposal, community inclusion in the business.

- **Environmental institutions:** institutional strengthening, water, air, and soil contamination; protection of biodiversity and strategic ecosystems, payments for environmental services, adaptation and mitigation of climate change effects, prevention and mitigation of natural disasters, environmental management, environmental information system.

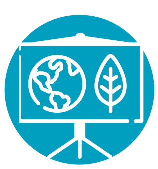


- **Institutions responsible for water resource management:** Integrated Water Resources Management, register of users, hydrometeorological monitoring, hydroclimatological and basin models, basin management, National Water Resources Plan, water resources management model, financing models of water resources management, information systems.

- **Agricultural institutions:** irrigation water guarantee, irrigation system efficiency improvement, decentralization of water management in irrigation districts, strengthening of users' boards, operation and maintenance of irrigation systems, drainage and management of drainage water to groundwater aquifers, irrigation water tariffs, irrigators' cadaster, information system, water use optimization, energy efficiency.

- **Electrical sector institutions:** hydrological studies and dam designs, environmental impact analysis, energy efficiency of water and sanitation utilities.

- **National planning institutions:** national accounts, national development objectives, national environmental accounts, water efficiency by economic activity.



- **Municipal governments:** flood control in urban environments, recovery of riverbanks in urban streams with creation of recreational areas, urban drainage, urban drainage master plans, recovery of quality of streams and urban rivers, adaptation and resilience to climate change and natural disasters.

These actions, already incorporated into Bank projects, are fundamental to building the support that will generate a WS strategy and action plan for its clients. In addition, the literature abounds with even more specific suggestions and examples of solutions to achieve WS in the not-too-distant future. For example, a synthesis of the conclusions of the 2015 World Water Week (Garzón and Sturzenegger, 2016) includes the **region's future challenges to achieve water and sanitation sustainability goals**. These are to:

- Achieve universalization of services.
- Develop innovative mechanisms to attract capital.
- Improve quality of services.
- Improve the efficiency of business management.
- Ensure sustainability of small-scale services.
- Expand wastewater treatment in a sustainable manner.
- Integrally assess water availability.
- Monitor the progress and improve the transparency in the gathered information.
- Improve the institutional organization and governance of the sector.

Many of these challenges are present in the IDB's SF for Water and Sanitation. This document presents the rationale for each challenge and suggests actions to address them. For example, the challenge "Comprehensively assess water availability" links water and sanitation with:

- The need to carry out coordinated and intersectoral work to ensure the availability of water in water supply sources.
- The acknowledgement of natural capital and Nature-based Solutions (NbS) that these provide, especially in the face of climate change impacts. On the other hand, such services will be equally affected by climate change, which is why monitoring systems are important.
- The commitment to reduce or eliminate pollutant loads on water bodies. In this sense, the increase in temperature due to anthropogenic activity becomes a multiplier of the negative effects of environmental pollution.

Additionally, the SF details each challenge. In relation to *Comprehensively assess water availability*, it is recognized that: "In terms of water resources management in Latin America and the Caribbean, successful cases of integrated management are limited. An institutional mapping shows the heterogeneity of ministries, institutions and levels of government in charge of this task, as well as the overlaps and gaps in functions; although, in general, responsibility remains at higher levels of government. There is also a lack of sufficient and stable budgetary resources to develop the activities involved in this work on a permanent basis.

The IDB has the experience and resources to support countries of the WS

If we add the details presented for the other challenges covered in the sector framework, it is possible to corroborate the Bank's extensive action in the region. Therefore, it can be concluded that **the Bank has the experience and resources to support the countries in favor of WS.** Most of the actions leading to this objective have already been taken or are in process. **It remains to be understood how the Bank should organize itself and what type of projects, studies or actions are needed to develop to broaden the scope and impact of future WS actions in the region; also, how it can help countries leverage additional resources to complement investments, through sector loans.**

III.2 Lessons Learned

What are the main lessons that we can draw from the portfolio and the wide experience of the Bank?

Basin Management

The experience with the implementation of basin management projects with IDB financing allowed us to understand the positive points and limitations of this concept. Definitively, **due to its geomorphological characteristics, the territorial unit named watershed is the ideal space to implement water resource management models.** Depending on the size, it can be necessary to divide basins with larger extensions in sub-basins, and to establish institutional structures for a two-level management. For example, although the basin of the Reconquista River, is not too extensive (near 1.670 Km2), due to its characteristics, is divided into upper, middle and lower basins, the upper part being essentially rural and the others urban.

Regardless of its geomorphological characteristics and the occupation of its physical space, the process of implementing basin management takes time.

BOX 3.3. WATER RESOURCES MANAGEMENT: SLOWLY BUT SURELY.

The Water Resources Management Modernization Project (PMGRH, for its Spanish acronym) in Peru is one of the Bank's most successful experiences in designing and implementing water resources management structures. By the end of the project, management plans had been developed for six basins and all of them had basin councils in place and functioning (three basins financed by IDB and three financed by the World Bank). However, Peru began requesting support, mainly through technical cooperation, to manage specific problems or conflicts over water use in one basin since 2000. The first stage of the Water Resources Reform Program

(PE-L1024) was approved in 2007, and the third and last in 2010. The PMGRH was approved in 2009, and the last disbursement was given in 2015. Despite the positive outcomes of the project, there is a long way to go if the implementation of IWRM is sought for the 159 basins of the country[15]. In addition, the Bank financed with non-reimbursable resources (PE-T1168) from the SECCI Fund (IDB's Sustainable Energy and Climate Change Fund) adaptation measures in the Santa and Mayo River basins (Quillcay sub-basin, San Martin and Ancash regions). The specific objectives of the Technical Cooperation (TC) were: (i) prioritize climate change adaptation measures identified in the Local Integrated Assessment (LIA) studies conducted by the Program for Strengthening National Capacities to Manage the Impact of Climate Change and Air Contamination (PROCLIM) and the Second National Communication on Climate Change Project, in the selected basins; (ii) strengthen capacities to implement climate change adaptation measures in the selected basins; (iii) promote the inclusion of climate change variables in policies, plans, and strategies for the development of the regions; (iv) generate new capacities in the formulation, management and implementation of regional development projects with a climate change adaptation approach under the modality of the national public investment system.

In the Reconquista project in Argentina, the first operation was approved in 1993 and was completed in 2006. With funding from the first operation, the Reconquista River Basin Committee (COMIREC for its Spanish acronym) was created through a law that is still unregulated. The second operation was approved in 2014 and is in the execution phase, which is quite delayed compared to the initial schedule. The IWRM plan, which should be the first contract of the project, was put out to bid, but has not yet been contracted.

The Peruvian example described in **Box 3.3.** proves that the time it takes to implement changes in the way countries manage water resources is significant and requires continuous follow-up. This has been the case in Peru and this has also been the experience in the process of implementing water resources management, either by basins or the creation of protection and/or conservation areas (water funds), areas, water reservoirs (México), [16] or water producers (Brazil)[17].

Why is it so expensive in terms of time and efforts to implement changes in water resources management?

- The IWRM concept, conceived since the decade of 1980, **requires institutional coordination at various levels (national, state, and local),**

15 National Water Authority, "National Policy and Strategy of Water Resources",2012

16 National Water Commission-Conagua (for its Spanish acronym) 2011

17 Programa da Agência Nacional de Águas (ANA) implemented in 2001.

and the participation of users in decision making. Until the 1980s, water management systems were sectoral with vertical decisions, without consulting users or peers (many still continue to do so today). Each institution had its own agenda and those who managed it, because of their traditions, did not understand this new concept. These difficulties still persist in many of our countries.

- **Lack of trained human resources in water resources management institutions** due to lack of supply in universities or unattractive working conditions.

- **Lack of reliable information for decision making**. This topic is still pending according to the most recent assessments (Garzón López, 2017). It is necessary to develop information systems on water resources (some countries such as Brazil, Peru, and Colombia already have these systems), and to implement and operate hydrometeorological and water quality monitoring stations. Interestingly, it is not difficult to obtain the resources to implement such stations, but the resources for their operation and maintenance are scarce and almost always provided by governments, so they lack consistency. Normally, there is no registry of the main users. For example, it is not known with certainty how many industries are located in the Reconquista river basin and Peru needed loans from the IDB and the World Bank to carry out a cadaster of users of the country's irrigation systems.

- **Lack of financial resources to finance water resources management**. In Peru, the basins included in the PMGRH currently have water resources management plans, but do not have the financial resources for their implementation. In some cases, the issue of climate change had not been considered in the design of these plans. The problem of lack of resources was corrected in the Reconquista project, in which the budgeted resources include the actions that make up the basin management plan; but this has not yet been developed and the financial resources are being consumed in works defined with institutional objectives and not based on strategic technical definitions and consensus between representatives of the users and the government. The Environmental Sanitation Program of the Ipojuca River Basin (Brazil) finances the implementation of part of a water resources management plan, prepared with government resources. This is one of the fundamental problems for the sustainability of water resources management. The lack of financial resources to finance these plans creates frustration among users, which in turn discredits the proposed management system, generating a vicious circle.

- **The charge for water use has not been adopted, and when adopted does not reflect water productivity by economic sector**. At the end of the PMGRH in Peru, the value collected per cubic meter reached only S/.0.13, a very low value but much higher than the initial goal of the program[18]. In Brazil, it has been implemented in 45 basins, including those in the states of Ceará, Rio de Janeiro, and Paraíba, and some of São Paulo, Minas Gerais, and Paraná[19]. The country is divided into 12 hydrographic regions with multiple basins[20]. The development of environmental- economic accounts of water in Brazil, for the period 2013-2015, evidences the great dispersion of efficiency in the use of water resources among economic activities. For example, the average rates for the extractive industries (603,74R$/m^3) are higher than those of the transformation industries (R$246,62), and the agricultural sector (R$10,81)[21]. These differences reflect the high gross value added and low water consumption of the extractive industries compared to the other sectors. In times of scarcity, the most efficient sectors are disadvantaged if the same criteria for restricting use are adopted. In times of scarcity, the most efficient sectors are affected if the same restriction criteria are adopted for the use. For example, the Brazil's *Confederação Nacional das Industrias*, in its work prepared for the 2018 elections, claims that, by adopting water conservation measures, for the industrial sector, the marginal cost of reducing one m^3 of water withdrawal is much higher than the marginal cost of a user with 30% to 35% losses.

Water Funds

The initiative to create strategic water reserves in each country as preventive measures or to adapt to scenarios of water scarcity is fundamental

The initiative to create water conservation strategies in each country as preventive or adaptive measures to water scarcity scenarios is also fundamental to tackle larger problems, such as climate change. The sustainable use of green infrastructure not only preserves the potential of the sources, but also guarantees its quality with repercussions on water treatment costs. Recognizing the potential of this initiative, the IDB, the Fundación Fomento Económico Mexicano S.A.B de C.V. (FEMSA), The Nature Conservancy (TNC), and the Global Environmental Facility (GEF) launched the **Latin American Water Funds (LAWF)**. The objective of this alliance is to provide technical and financial assistance aimed at creating and strengthening Water Funds as an innovative watershed protection tool. In 2017, an evaluation of five funds financed by LAWF was carried out at the end of five years of implementation. These funds were Espirito Santo, Palmas, and Camboriu (Brazil); Bogotá, Medellín, and Santa Marta (Colombia); Santo Domingo and Yaque del Norte (Dominican Republic); Monterrey (Mexico) and Lima (Peru). The assessment concluded that the process was satisfactory and identified several aspects that can be improved (Garzón-López, 2017). In this document we gather those related to design and monitoring. Regarding the fund design, it

18 Informe de Terminación de Programa (PCR), Programa de Modernización de la Gestión de los Recursos Hídricos, 2016.

19 Confederação Nacional das Indústrias-CNI, "Segurança Hídrica: Novo Risco Para a Competitividade", Para as eleições de 2018.

20 Agência Nacional de Águas-ANA, "Atlas Brasil: Panorama Nacional-Volume 1, Abastecimento Urbano de Agua",2010.

21 Agência Nacional de Águas (ANA), Contas Econômicas Ambientais Da Água No Brasil, 2018

is recommended to perform a **thorough assessment of the watershed**; recognize the limitations of the models used (including financial ones) and work on the recommendations generated by the process so that they are practical and easy to implement. In terms of **monitoring**, it is recommended to **include robust indicators that reflect improvements in water quality and quantity** due to conservation and restoration efforts. The review also recognizes that the establishment of water funds is a long-term process and has positive impacts on the WS.

Projects with Water and Sanitation Utilities (WSU)

The Bank has a wide working experience with Water and Sanitation Utilities. Some outstanding examples are: Empresa Pública Metropolitana de Agua Potable y Saneamiento-Quito-Ecuador, SABESP-Brazil, Empresas Públicas de Medellín-EPM, CAESB-Brasilia-Brazil, and AySA-Argentina. Many of the projects with these companies have already accumulated several phases and years of work. WSA has a range of products for these utilities that include: strengthening utilities, including corporate governance restructuring; tariff studies; non-revenue water reduction; assets assessment; water and sewage network monitoring; water and wastewater treatment; and reuse and disposal of treated effluents, among others. In some projects, the Bank has provided assistance in the development of environmental management systems. **The challenge of climate change and its consequences open up new areas of action for WSU, which will have to develop their adaptation plans and WS strategies.**

The drinking water and sanitation sector must assume a more proactive role in the tasks of protection and conservation of hydrographic basins

Among the conclusions of the 2015 World Water Week, areas were identified in which the water and sanitation sector needs to be more proactive to guarantee the sustainability of the availability of its main input. In this regard, it was stated: "**The water and sanitation sector must take a more proactive role in watersheds protection and conservation tasks,** based on the recognition of the potential economic benefits resulting from better control over land uses and the preservation or restoration of natural ecosystems. The following possibilities should be considered: i) acquiring land strategically located in basins to prevent their degradation and undertake their restoration and/or preservation; ii) promoting land use regulation measures; iii) proposing payment mechanisms for environmental services to basin inhabitants adopting environmental sustainable productive practices, such as agroforestry productive mosaics, and iv) including in tariffs the environmental rates assigned for the protection of the basins of interest"[22].

These innovations will require the IDB to start analyzing and proposing water and sanitation projects following methodologies from the field of Industrial Ecology, monitoring the life cycle of industrial pollution control

22 Garzón, C. y Sturzenegger, G. (2015). "Los desafíos de la Agenda De Desarrollo post-2015 para el Sector de Agua Y Saneamiento en América Latina y el Caribe: conclusiones de la Semana Mundial del Agua 2015"

projects, including all steps of production, distribution, sale to the consumer, treatment and final disposal of the waste generated. **WSU should be perceived as a water industry obtaining its input from a basin that needs conservation and/or restoration, management and, in some cases, preservation with long-term perspectives**. Once the water input is processed, waste must be minimized for the business to be profitable. The effluents generated must be duly treated and reused in a new production process or in processes of recovery and/or return to the environment so that it fulfills its functions. In some cases, the regulations that govern the WSU limit their effectiveness and operation. For example, the Lima water supply and sewage service (Servicio de Alcantarillado y Agua Potable de Lima, SEDAPAL) can only treat domestic effluents, by law. Therefore, when a wastewater treatment plant is designed, it can only consider these effluents to dimension the treatment of the new facility and the corresponding investment. However, the actual effluent carries uncontrolled industrial and agricultural discharges upstream, so the new plant will not be effective in terms of its decontamination objective.

Urban recovery and contamination control

In this regard, the experience with the **PROSAMIM, DRENURBES, Matanza-Riachuelo, Reconquista and Tiete** projects offers multiple positive aspects and lessons to be learned. As already seen, PROSAMIM changed the landscape of Manaus and positively impacted the affected population through urban interventions, drainage, water and sanitation projects, resettlement and contact with the population[23]. One of the requests performed during the design of the project was that, in the following operations, the preservation of the urban stream springs was included. The projects of DRENURBES, Reconquista, and Tiete include this action. Therefore, **it is necessary to rethink these projects as comprehensive interventions at the urban basin level**.

National Water Resources Plan (NWRP)

The PNRH need to be widely protected by the legislation of hydric resources

Despite being a country's policy instruments for water resources, the **NWRP needs to be comprehensively covered by water resource legislation**. For example, in Brazil, although there is a well-defined legal framework, Article 7 (paragraph VII of Law 9.984 of 2000) which establishes the competence of water resources plans, is not yet regulated to define a general rule on priorities for the granting of water resources permits. It is also necessary the existence of a **close coordination between the national plan and the basin plans** and, most importantly, there must be a guarantee of resources to finance the actions proposed in the NWRP. In this case, Peru's plan presents an optimistic picture of financing the actions programmed for the period 2021- 2035, which has as its starting point the costs of water resources management in 2011, which represented only 4.9% of total state investments. International technical cooperation was designated as responsible for financing part of the identified actions. **The analysis of several plans demonstrates the need for standardization, mainly in relation to the minimum content, the legal**

23 Project Completion Report-PCR, 2013.

mechanisms for their due implementation and the way to present the need for a financial commitment linked to the responsibilities for their implementation. This can be covered through an expanded focus on the water security national plans.

Environmental-Economic Accounts for Water (EEA-Water)
This recently created tool promises to be very useful for WS because, through the concepts of "virtual water" and "water footprint", it makes it possible to establish quantitative and comparative evidence of the least efficient economic sectors in water use, thus facilitating the definition of policies for water resource management in both routine and scarcity situations. **The use of EEA-Water is an important entry point for including the WS issue in national economic development decisions through national accounts.**

What factors and criteria should guide IDB action on WS?
Summarizing some key messages about the IDB's experience in WS, the following can be said[24].

The Water Accounts allow establishing quantitative and comparative evidence of the economic sectors that are less efficient in the use of water

- **Integral vision: The lack of synergy between the different actions of the Bank may be one of the obstacles to achieve more significant impacts towards the achievement of WS in the region.** In this sense, it is necessary to coordinate the actions and projects of the divisions involved from the preparation of the Country Strategy to the conception of the operation. Operations become multisectoral and multipurpose. **The Bank needs to incorporate the integral vision into the support it provides to countries.**

- Although the Bank has financed wastewater treatment projects in several cities, **a broader and more coordinated effort is needed to recover water quality in the region's strategic watersheds to make up the range of actions leading to WS.** In this respect, decontamination projects by watershed can be more efficient than working at the city or urban basin levels and allow for a **global vision of the cause-impact-solution relationship.**

- **Minimize potential conflicts:** It is estimated that by 2050, 68% of the world's population will be living in urban areas. These areas will most likely depend on water resources from nearby micro-basins in rural areas to supply water to a growing urban population. Normally, these rural micro-basins already have well-defined uses and users of the resource, which could lead to conflicts over additional urban water demands. In this sense, it is absolutely relevant **to build a governance structure to minimize possible social conflicts over water use, particularly in arid areas where availability will be significantly affected by climate change.**

24 Experiences are not necessarily based on in-depth national diagnoses but are based on limited information and result in interventions that can be diffuse and uncoordinated.

- **IDB as implementer and provider of capacity building: The development of management tools such as HydroBID and the Water-Energy-Food Nexus has been well received in the region**[25], which is indicative of the important role of the IDB as implementer and enabler of key stakeholders to implement actions to achieve the WS.

- **Creating demand:** To drive the movement towards WS in the region, in a context where economic and social objectives are seen as a priority, it is important to create demand in the countries for related projects and actions. **One way to boost demand is through demonstrations of the economic value of WS and the link between WS and economic and social objectives.** This is an open field to the Bank's contribution, either through the development of environmental water accounts or the development of economic models that link national accounts with strategic inputs such as water, under different feasible climate change scenarios.

- **Capacity building for strategic stakeholders:** Even in relation to the creation of demand for projects and actions linked to the WS, **the Bank must develop communication programs aimed at strategic stakeholders both within the Bank (middle to senior management levels) and in client countries.** Such programs could be complemented by courses and seminars that offer training and information on how to insert the WS theme more effectively in each country.

- **Seek investment models: It is essential to understand the importance of investing in water resources management in the region.** The lack of funding for WS-related issues (e.g., IWRM and similar issues) impacts various sectors such as water and sanitation, agriculture, industry, energy, mining and tourism. The Water Funds represent an initiative that should be improved and expanded; but there is still a need to channel more resources from the private sector and to identify willingness to pay for cleaner and better managed basins. For example, in Brazil, fees linked to electricity consumption have been adopted (Water Resources Fund). In the United States, there are fees, such as the Chesapeake Bay protection fee in the state of Maryland, which is included in the water rate. **This is an area where the Bank could contribute extensively through research, the development of specific models for specific basins or support to universities to create forums and exchange experiences at the global level.**

25 The Community of HydroBID users already reaches more than 15 countries and tends to grow.

BOX 3.4. HYDROBID: WHEN THIRST IS CALMED WITH TECHNOLOGY

We have already seen how the LAC region is characterized by an abundance of water resources which, nevertheless, must be properly managed in order to achieve WS and, with it, the sustainable development of the region. We have also seen how the proper management of water resources requires, among others, information on their dynamics, the quantity and quality of the resource and the relationships between water supply and demand.

To address these challenges, the IDB's Water and Sanitation Division has created HydroBID, a simulation tool for water resources management and planning in Latin America and the Caribbean (LAC). The system makes it possible to work under scenarios of change (climate, land use and population), which make it possible to evaluate water quantity and quality, infrastructure needs and the design of adaptation strategies and projects in response to these changes.

It is a simple tool composed of a database, a simple, flexible and accessible platform for all (it has no cost), which allows the efficient management of water basins in Latin America and the Caribbean through the use of information technologies, facilitates decision making and planning in the short, medium and long term, and promotes regional dialogue and the integration of the different stakeholders involved in water resources management in the region (decision makers, technical staff and the scientific community).

Since its launch, HydroBID has been operational in more than a dozen countries, including Argentina, Peru, Ecuador, Guatemala, Bolivia, Brazil and Haiti. It has also incorporated HydroBID Flood, a new tool to assist in flood mitigation and urban drainage improvement projects.

BOX 3.5. WATER FUNDS: THE INVESTMENT YOU DRINK

For a long time, we have underestimated nature's capacity to help us face the challenges imposed on us by the WS. Today we know that this can generate solutions that promote water infiltration, help us to filter it, improving its quality, or prevent flooding.

Water Funds were born to vindicate the role of nature as a key component of the WS. They are financial, governance and management mechanisms that integrate the relevant stakeholders of a basin (users, water management companies, corporations, authorities and civil society) to promote the WS of a metropolitan area through nature-based solutions. They channel long-term investments and leverage public and private resources by allocating their returns to conservation projects such as reforestation, creation of protected areas in areas of high ecosystem value, management of payments for environmental services or improvement of agricultural-livestock practices.

With the aim of promoting the creation and strengthening of water funds in LAC, The Nature Conservancy (TNC), FEMSA Foundation, the IDB and the Global Environment Facility (GEF) formed, in 2011, the Latin American Water Funds Alliance. In its eight years of operation, the Alliance has created 24 Water Funds and has 15 more in the process of being created; it has positively impacted 1.6 million hectares of ecosystems; it has benefited more than 70 million people and has leveraged more than US$120 million for investments in green infrastructure.

IV Opportunities for Innovation in Water Security

HIGHLIGHTS:

- The main deficiencies of WS in the Latin America and the Caribbean region can be summarized in one word: fragmentation. Fragmentation in the conception of the problem; fragmentation in the consideration of solutions, and fragmentation in the institutional and regulatory framework.

- The innovative approach proposed here to solve WS problems is based precisely on integrality. More specifically on the integral management of water cycle. This approach involves four essential areas of innovation: **climate change and multisector planning (Nexus approach), water infrastructure, and NbS, institutional framework for WS**, and **progress in science and technology**.

- Regarding **multisectoral planning**, some possible innovations derive from the water-energy-food nexus, such as the consideration of water supply costs in energy infrastructure planning or multisectoral investments (such as multi-purpose reservoirs), incorporating elements of natural infrastructure (NbS), and climate change projections.

- In turn, **Nature-based solutions** offer multiple opportunities for innovation in various fields such as water source management (e.g., water reservoir programs or river and floodplain bonding), **water and sanitation services** (artificial wetlands, water reuse or rooftop gardens), **irrigation systems and food production** (wetlands to mitigate the negative consequences of traditional irrigation systems and urban agriculture), **power generation** (alternative energies such as tidal current generation, tidal energy, or blue energy), and **drought or flood prevention** (flood plains).

- The water **regulatory and institutional framework** in LAC is characterized by the heterogeneity of scenarios and, therefore, the great challenge lies in coordinating and integrating the actions of the different administrative bodies responsible for water issues with the other authorities involved in achieving WS objectives.

IV. Opportunities for Innovation in Water Security

To move forward in making significant improvements to WS in the LAC region, the countries of the region should explore different options to address the shortcomings identified in Chapter II and take advantage of the experience and lessons learned by the IDB, presented in Chapter III. **In a prospective manner, this report synthesizes a series of innovation opportunities based on improving the identified deficiencies by utilizing the knowledge acquired by the IDB in its work of more than 50 years in the region.**

The main shortcomings exposed in the region in terms of WS described in Chapter II can be summarized as follows:

- An oversimplification of the water availability problem, which is reflected in fragmented water resources planning and management processes that do not consider phenomena affecting water supply and demand or take climate change into account.

- Excessive use of investments in gray infrastructure to try to solve problems related to access to water resources, water quality and risk reduction in the face of extreme hydroclimatical events, addressing these problems individually (e.g., dams, reservoirs, treatment plants, pumping systems and others) and giving little relevance to the use of natural capital and adaptive management mechanisms.

- The formulation of fragmented institutional and regulatory frameworks, with little consideration of the interrelationship between water use sectors is in need of further hydrological planning and relatively weak in terms of implementation capacity.

The innovative approach proposed to solve WS problems in LAC is based on the central concept of water cycle management, rather than management based on the allocation of available water resources among various sectors. The scheme of interactions constituting water cycle is illustrated in **Figure 4.1**.

HIGHLIGHTS:

- The WS approach as such must take the form of a public policy or public policy cycle, which must set out its objectives, translate them into planning, promote the necessary regulatory changes and implement the necessary institutional arrangements. This should be done through **water planning** (transparent, informed, and binding), and **regulations** (including water law, land use planning and risk management).

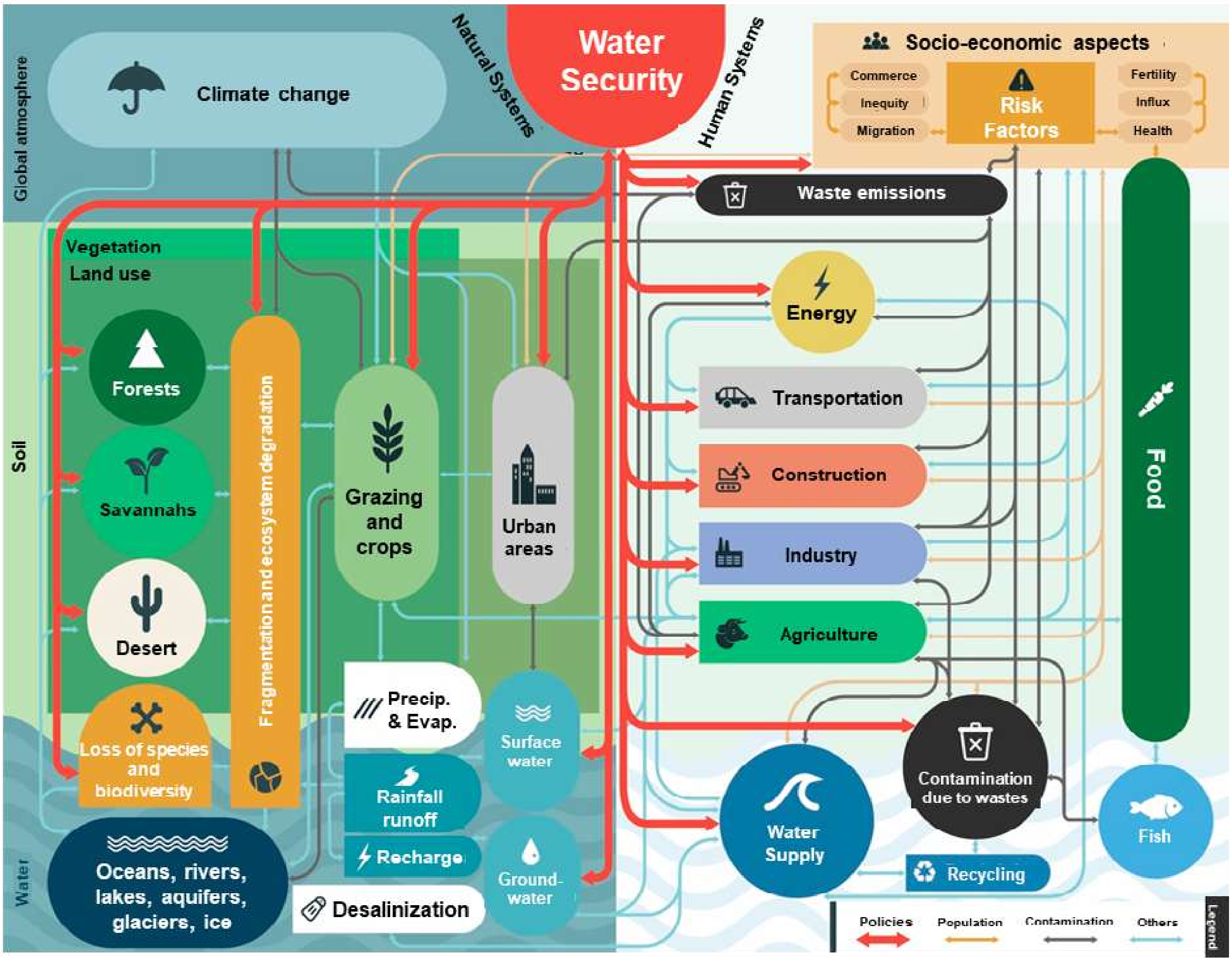
- Advances in **science and technology can play a major role in the service of WS in LAC,** especially in terms of the **availability of data on water quantity and quality** and, more broadly, the monitoring of the water cycle and the **development of tools that transform this data into reliable, publicly accessible information to support decision making and planning.**

- Remote perception or **remote sensing**, which is already used in the measurement of multiple hydrometeorological and environmental variables, offers a significant opportunity for innovation in WS, although policy makers need to be trained in the operationalization of these advances.

This expanded approach involves several areas of innovation that are discussed in this chapter: (i) integrated supply and demand management, which includes environmental and climate change considerations (and how climate change affects water supply and demand), and recognizes multiple interactions in water demand across sectors (referred to as the "nexus"); (ii) the use of NbS to complement and strengthen traditional gray infrastructure approaches, while increasing the natural resilience of water sources; and (iii) an institutional and regulatory framework that links these components and facilitates their implementation in practice by decision-makers in the countries of the region. To these areas of innovation must be added (iv) the advances that have been made in science and technology, applicable to the different components of the water cycle, to accelerate and facilitate significant improvements in WS for the region.

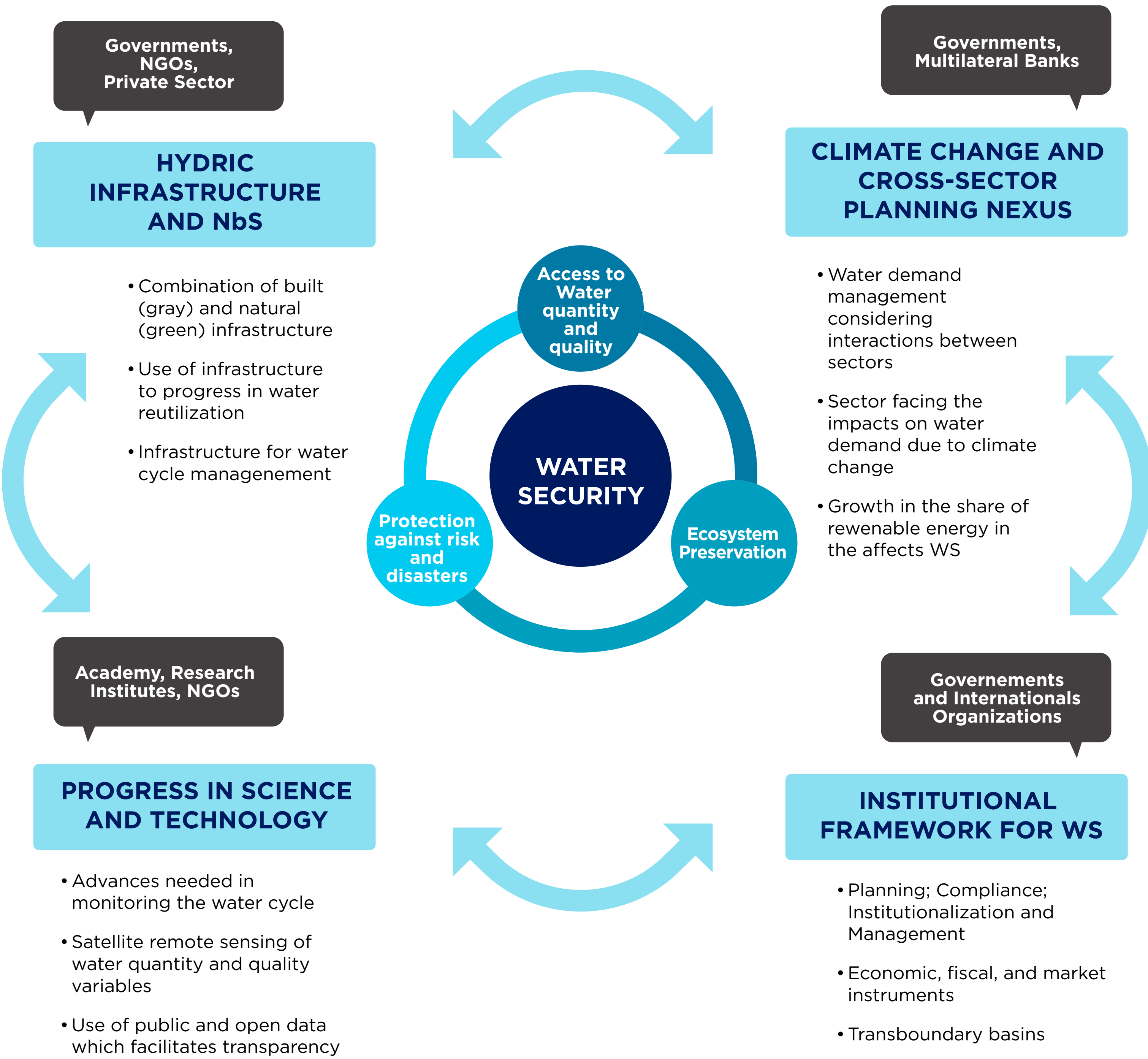
Figure 4.2. outlines a number of specific opportunities in the different areas of innovation proposed. These opportunities can take advantage of the experience and knowledge attained by IDB and the lessons learned through more than five decades of work in the region shown in Chapter III. The ability to facilitate the transition from innovations in different areas to field work in the countries of the region requires knowledge and capacity to implement it. **This combination of recognizing prospective areas for innovation and the ability to bring them to the field is a competitive advantage of the IDB in the process of advancing WS with its clients in the region.**

Figure 4.1. Conceptual Outline of the Water Cycle and the Integrated Aspects Involved in Its Management to Improve WS.



Source: IDB.

Figure 4.2. Innovation Opportunities in WS for the LAC Region. Four Inter-dependent Opportunities Categories which Involve Several Stakeholders Participation.



Source: IDB.

The proposed innovation areas are the following:

- **Climate change and cross-sector planning (Nexus)**, specifically incorporating integrated water demand for various uses in effective WS management.
- **Water infrastructure and NbS,** to make more room for combinations of gray and green infrastructure that provide greater efficiency, reliability and cost-effectiveness in the provision of WS services.
- **Institutional framework for WS**, to adapt policy and decision-making spaces to WS principles, and integrate them with the management of other natural resources (e.g., nexus with energy, agriculture, biodiversity and climate change, among others).
- **Advances in science and technology**, to deliberately make investments in knowledge and implementation of new concepts and advances in WS.

Specific innovation opportunities in each of these areas are described below.

IV.1 Climate Change and Cross-Sector Planning (Nexus)

Components of the climate-land-energy-water nexus affect each other in several ways

The **water, energy, and land resources nexus**, known also as **water-energy-food nexus**, summarizes the growing concern about the availability of these vital resources and the interrelated systems used to manage them, particularly in response to the challenges posed by human demands and climate change. In a broader sense, the components of the climate-land-energy-water nexus (Muñoz-Castillo and Miralles-Wilhelm, 2018) affect each other in several ways. Water is frequently under stress from the agricultural sector, which is responsible for approximately 70% of total global freshwater withdrawals (FAO 2011a). In particular, food production accounts for approximately 30% of the world's total energy consumption (FAO 2011b). On the other hand, **climate variability and change** are reflected in spatial and temporal variations in water availability, with intensified fluctuations in the hydrological cycle leading to increased flooding and drought events. This is likely to impact **WS in all sectors: agriculture (the world's largest water consumer), but also power generation, drinking water supply and pressures on ecosystems.**

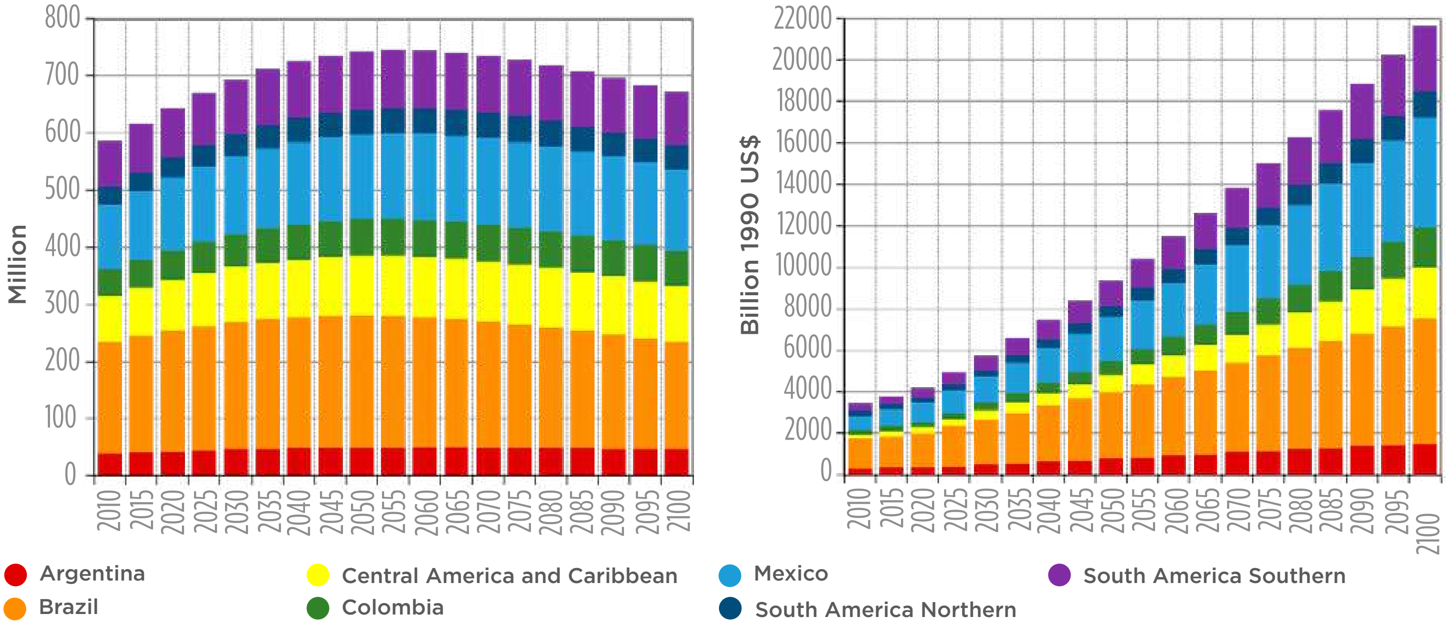
In the LAC region, population and per capita income continue to grow **(Figure 4.3),** which in turn increases the demand for water, energy and food, especially in fast-growing countries. In LAC, the nexus is characterized by an abundance of water, but with large spatial and temporal heterogeneities, a critical dependence on agriculture in economic production, and a diverse and growing energy sector with a broader generation matrix. All this increases the pressure on WS. According to estimates from FAO's AquaStat database (which incorporates average annual river flow and aquifer recharge generated by endogenous precipitation), about 32% of the world's renewable water resources can be found in LAC.

In this context, not only WS, but also food security and energy security, have been recognized as critical considerations for sustainable growth and social stability. Given the complex interactions between these sectors, **it is imperative to move beyond traditional approaches, in which decision making occurs as if these are independent of each other, towards a development of integrated planning (nexus).** In addition to promote the economic and resource efficiency, this integrated planning framework is important to prevent unexpected consequences and potential conflicts related to the use of EWL (*Energy, Water, Land*) resources in the coming decades (Da Silva et al., 2018; Miralles-Wilhelm and Muñoz- Castillo, 2018).

A recent IDB study analyzed future projections of water, energy, and food demand in the region (Miralles-Wilhem and Muñoz Castillo, 2018). **Figure 4.4** shows the regional picture of water demand. The highest water demand in the region is caused by food production (about 65% in average during the period 2010-2100). This includes agricultural crops, livestock, and livestock feeding. This is followed by water demand for energy (about 20%), which includes electricity generation and extractive activities (industry). Domestic water use (municipal and rural) accounts for the remaining 15%. The upper part of the figure shows water demand under a reference scenario that extends the current trend (business as usual); the lower part shows the same projection under a scenario in which NDC (nationally determined contributions) climate policies are implemented for each country in the region. **When comparing these figures, the NDC scenario, which makes efforts to mitigate and adapt to climate change, results in an increase in water demand of more than 35 percent.** This significant increase in regional water demand, although it may seem counterintuitive, is explained precisely for reasons derived from the existing nexus, which is not captured in traditional sectoral analyses.

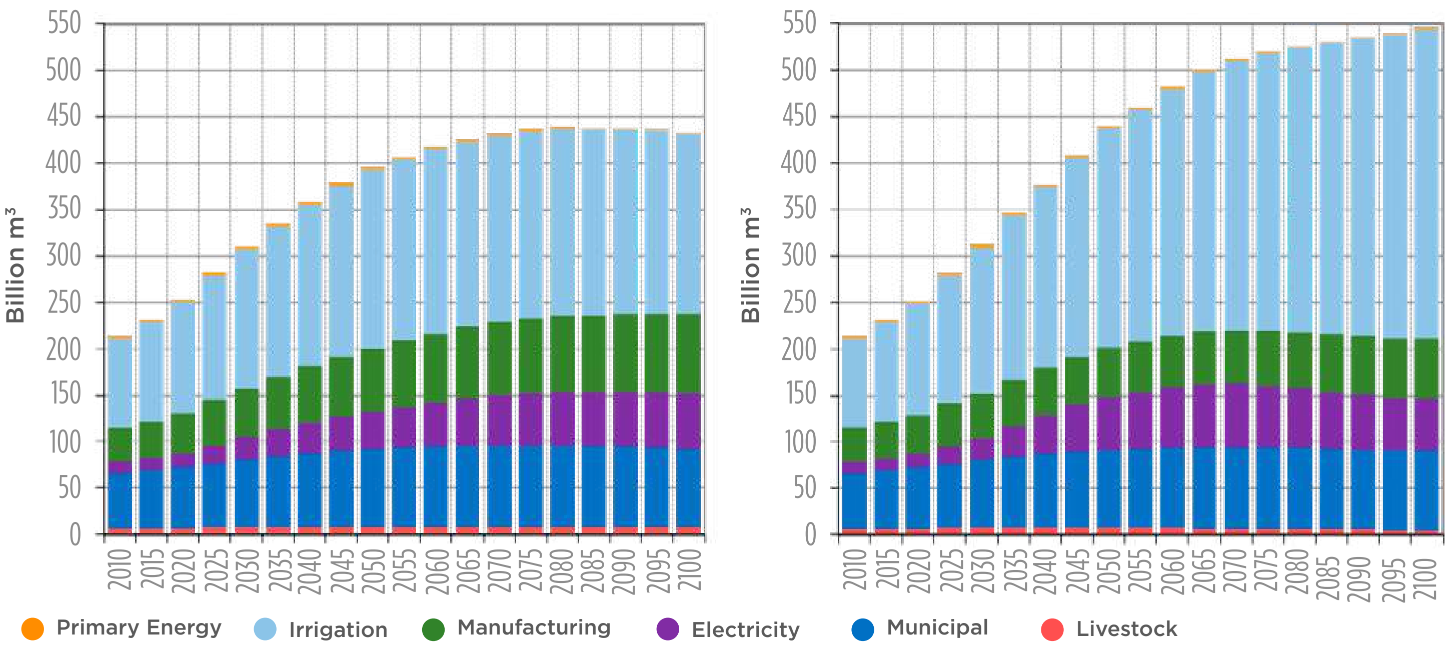
Simultaneously, the primary energy produced in LAC is illustrated in **Figure 4.5**. These figures include energy demand not only within the region, but also energy imported and/or exported to/from other regions of the world. These results for primary energy reflect the growth in energy demand due to population growth, as well as the increase in per capita energy demand as the economy grows. Growth occurs in all over the world. These results suggest that the LAC region will continue to rely on extractive industries (e.g., oil, natural gas, and coal), although over time, there will be rapid growth in **various renewable energy options (wind, solar, or biomass), which have relatively small footprints.** This growth in renewables will contribute to growth in total primary energy produced, particularly in countries with scarce extractive resources (e.g., Central America and the Caribbean). A greater focus on climate change, particularly on mitigation, emphasizes an overall reduction in energy demands from fossil sources and a **"decarbonization" of the economy.** This moves energy sources from traditional primary energy (see top of **Figure 4.5**) to an energy matrix consisting of a broader mix of less carbon-intensive technologies (see bottom of **Figure 4.5**), particularly biomass and CCS (carbon capture and sequestration). These technologies, while carbon efficient, also require larger amounts of water. This general trend of reduced energy demand and decreased demand for traditional primary energy sources, accompanied by increased water demand is another result of the integrated analysis (nexus).

Figure 4.3. Population and Gross Domestic Product (GDP) Projected for the LAC Region



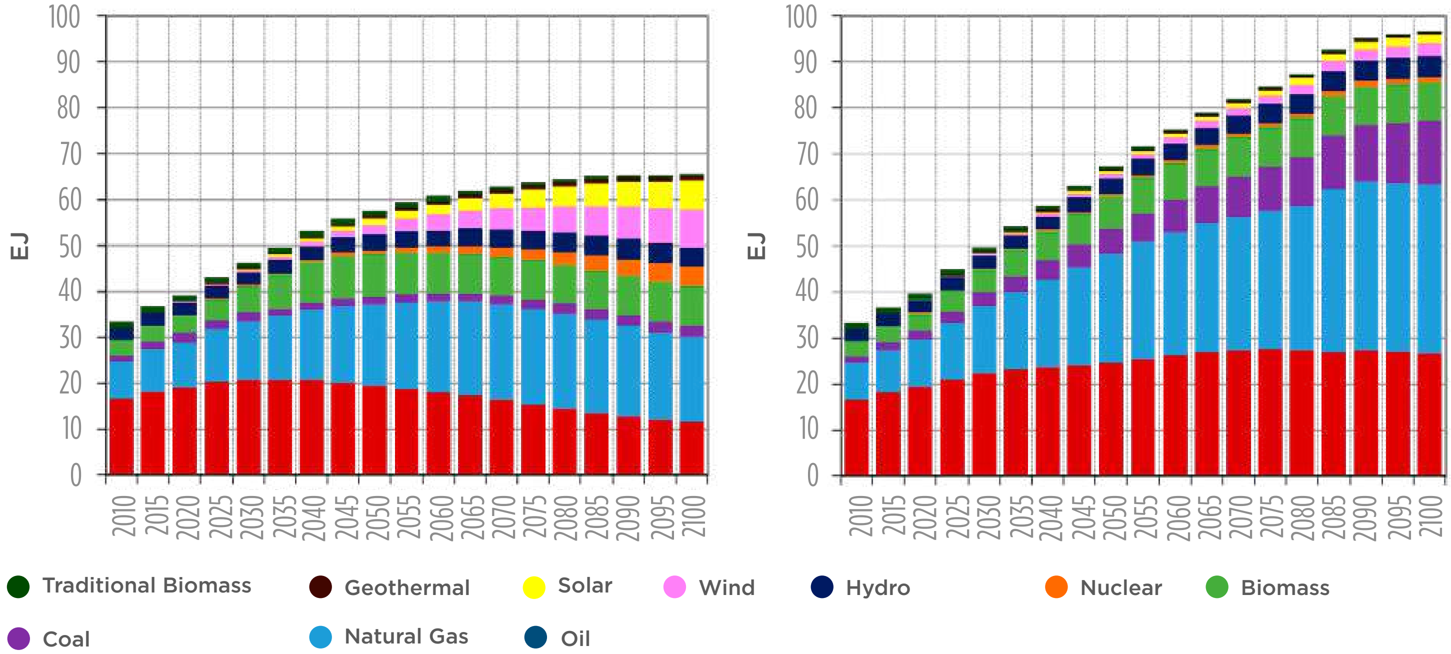
Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

Figure 4.4. Water Demand (km3) Projections in the LAC Region (2010-2100). Left: Reference Scenario. Right: NDC Scenario



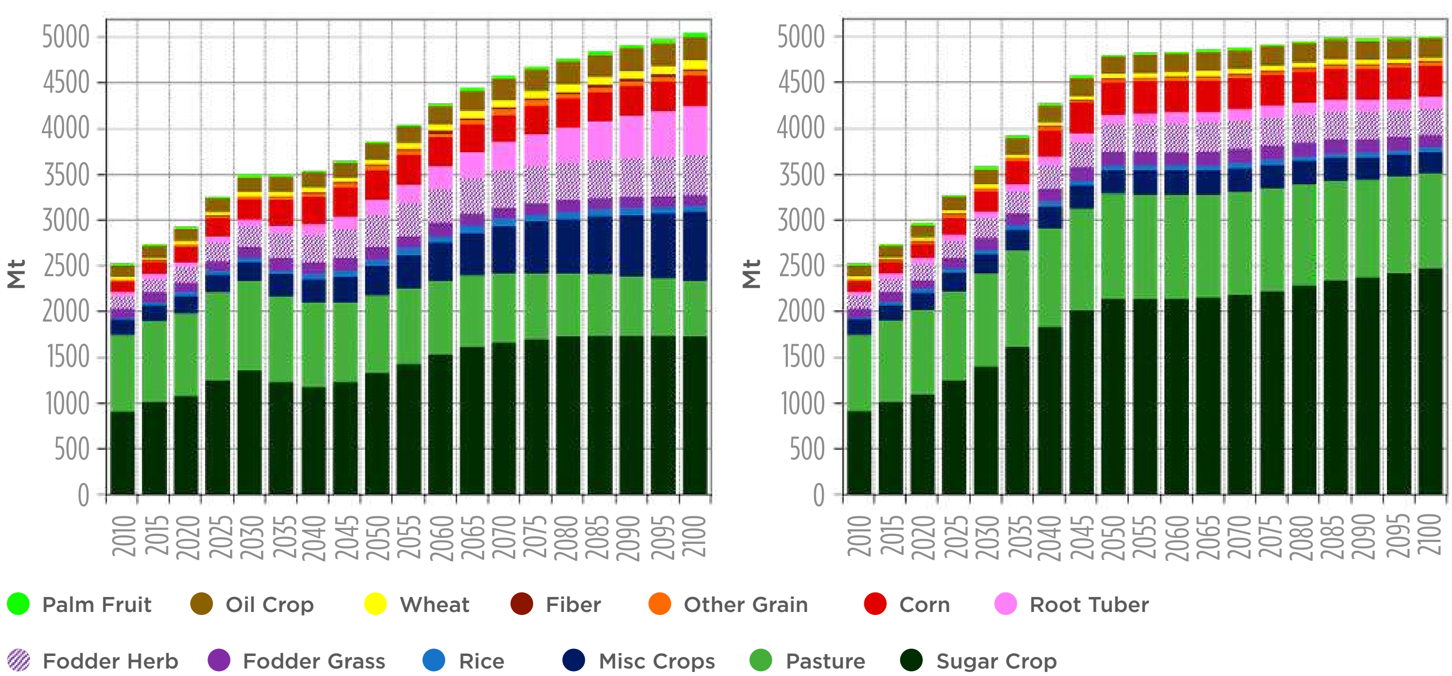
Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

Figure 4.5. Primary Energy Demand (EJ) Projections in the LAC Region (2010-2100).
Left: Reference Scenario. Right: NDC Scenario



Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

Figure 4.6. Agricultural Production (MT) Projections in the LAC Region (2010-2100).
Left: Reference Scenario. Right: NDC Scenario.



Source: Miralles-Wilhelm and Muñoz-Castillo, 2018.

The outcomes for the agricultural production projections in the region are shown in **Figure 4.6**. The overall picture is a progressive growth through 2050; thereafter there is stabilization and, towards the end of the century, moderate growth. This is in line with population growth trends, both globally and in the region, with agricultural production closely linked to per capita crop consumption. The results also suggest that these temporal cadences will occur across all crops, with sugar and corn experiencing a higher growth rate than other crops. **The growth of sugar and corn is partially driven by their use in the production of biofuels to mitigate climate change.** Also, aligned with this, **demand scenarios that focus on increasing resilience and sustainability (such as the NDC) result in increased land use for forest conservation activities for climate mitigation.** This results in an overall increase in land used for forest cultivation rather than agricultural production, which is slightly reduced as shown in the lower part of **Figure 4.6.**

The overall increase in water demand in scenarios that focus on climate change mitigation and decarbonization is a clear trade-off that emerges as a result of the nexus analysis of the water, energy, and food sectors. This result has also been documented in other recent research focused on climate change mitigation and increased water consumption in the United States (Hejazi et al., 2014). Since water is a relatively inexpensive resource for users in these sectors (its supply is relatively abundant but also heavily subsidized in the region) this trade-off has important implications for water-scarce areas of the region. In these regions, a more realistic consideration of water supply costs in such an analysis may provide very different results in the allocation of investment resources in water, energy, and food infrastructure. Recent studies in South Africa (Rodríguez et al., 2017) and China (Rodríguez et al., 2018), countries with chronic water scarcity, show how considering water supply costs in energy infrastructure planning can dramatically change the resulting demands for energy (primary energy matrix) and water (total demand and allocation) over time. This is an important area for future nexus work in the LAC region.

The consideration of the nexus in multi-sector planning offers opportunities for innovation that can be translated into multi-sector investments such as multipurpose reservoirs

Consideration of the cross-sector planning nexus offers opportunities for innovation in linking WS with energy security and food security, two areas of intense activity by the IDB and countries in the region. In practice, **this can be translated, for example, into multisector investments (such as multipurpose reservoirs), including elements of natural infrastructure (NbS) and climate change projections** to reinforce the designed systems and facilitate their resilience and sustainability. Under the technical cooperation project RG-T2660, **IDB** has begun to conduct **pilot studies** derived from the implementation of this multisector nexus planning in **Colombia** (impact analysis of NDC policies on water, energy, and agricultural sectors), **Argentina** (WS at the level of two pilot basins), and **Uruguay** (impact analysis of multisector policies). These efforts should continue and have the opportunity to capitalize on infrastructure and policy investment programs such as those outlined in the Work Plan in Chapter VI.

IV.2 Water Infrastructure and Nature-based Solutions (NbS)

The definition of WS proposed by UN-Water (Chapter I) clearly implies that ecosystems are impacted by human actions and are a key component in achieving WS. Therefore, an **innovative WS approach** requires **solutions combining built (gray) and natural (green) infrastructure** that can reduce vulnerability and increase resilience and reliability of water supply systems for various uses. In these solutions, the issue of infrastructure cannot be dissociated from the issue of environment when managing water cycle in a more efficient and sustainable manner. Given the great "natural capital" that exists throughout LAC, this **combination of built and green infrastructure is a major axis of innovation in WS for the region**. **Box 4.1** summarizes some of these opportunities using NbS to tackle WS problems, individually or combined with gray infrastructure.

Box 4.1. NbS Implementation Potential to Solve WS Problems

Water Security (WS) Problems	Water Availability and Water Sources		Floods and Droughts		Quality of Surface Water				Quality of Ground ater	Wastewater Treatment
Nature-based Solutions (NbS)	River Flow	Recharge of Aquifers	Floods	Droughts	N, P	Sedi-ments	Pesti-cides	Micropol-lutants	N, P	
Land protection										
Reforestation and replanting										
Restoration of buffer areas in riverbanks										
Removal of invasive species										
Recharge of Aquifers										
Reconnection of rivers and flood plains										
Preservation and restoration of wetlands										
Construction of artificial wetlands										
Green areas (bioretention and infiltration)										
Permeable paving										
Establishing flood bypasses										
Better agricultural practices										
Coverage by crops										
Change and/or crop rotation										
Reduction of agrochemicals use										
Changes in the use of pesticides										
Better forestry practices										
Better livestock practices										

Source: adapted from material included in *Green Infrastructure, Guide for Water Management* (UNEP/DHI, IUCN and TNC)[26] and *Beyond the Source* (TNC)[27]

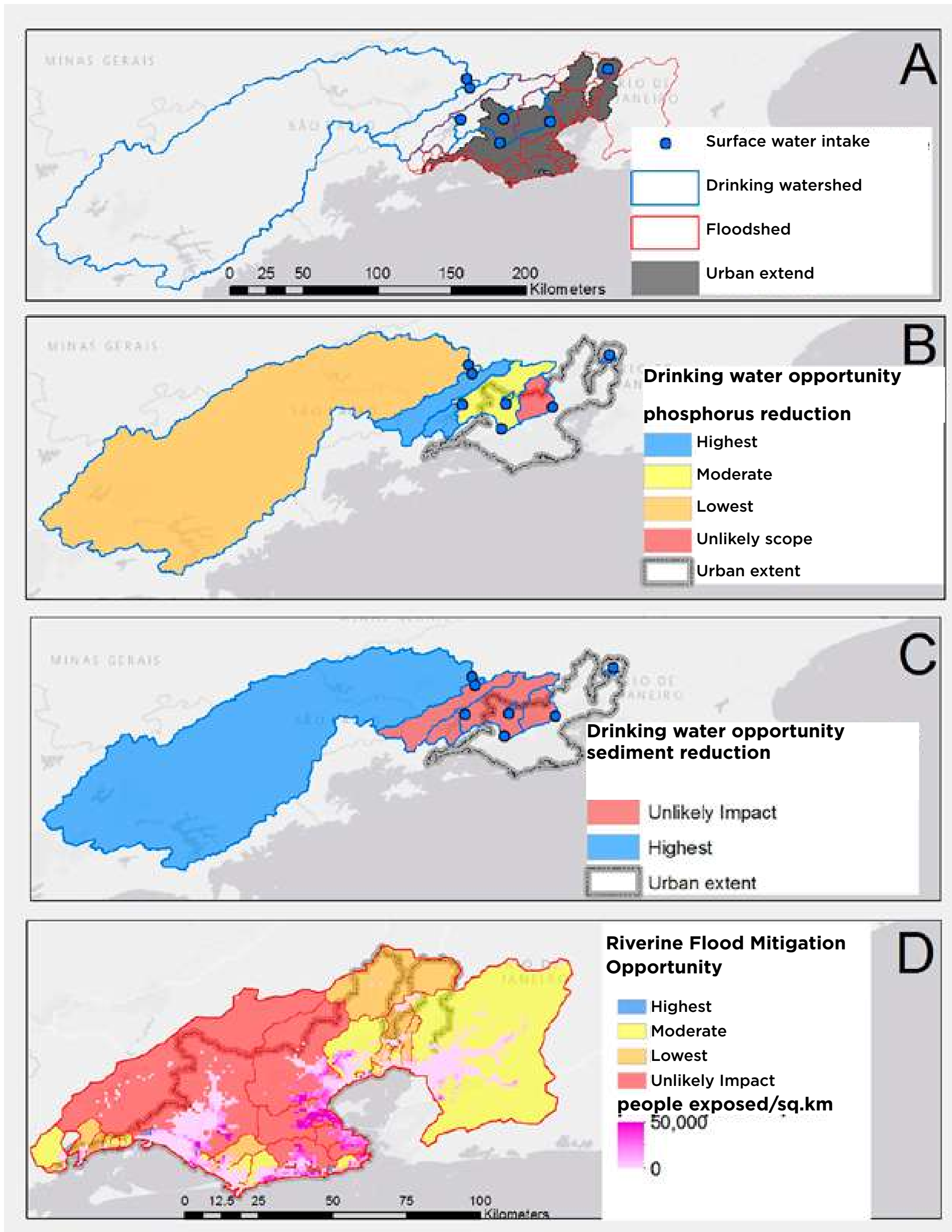
26 http://wedocs.unep.org/handle/20.500.11822/9291

27 https://global.nature.org/content/beyond-the-source-report

Although it is generally accepted that river basins are the basic unit for managing water resources, it is important to recognize that there can be substantial differences (even between adjacent basins) in size, geology, and land use (Crisman, 2014). For example, major river basins starting in the High Andes evolve along their entire length, reflecting different climates, geology, and ecosystems from their origin to their discharge into the Amazon. **Therefore, an approach to manage the water cycle combining traditional water infrastructure with NbS is proposed**. Several preservation organizations such as the World Wildlife Fund and The Nature Conservancy, consider NbS as key water conservation and management strategies. This is observed, particularly, within the LAC region, through initiatives such as *Water Funds*, where IDB is actively engaged. For example, in a recent study (Tellman et al., 2018) analyzed the opportunities of using NbS to solve, in Rio de Janeiro, WS-related issues such as water quality, due to sediments and nutrients, and flood prevention (**Figure 4.7**). The outcomes of this research suggest the potential of NbS to address several WS problems (water quality and flood risks, in this case).

It is also important to recognize that, as a consequence of climate change, the geographic extent of ecosystem services provided by NbS is changing. For example, the high Andes mountain range currently accounts for 9.5% of the world's freshwater resources; but it is experiencing rapid warming manifested in a rapid retreat of tropical glaciers (Bradley et al., 2006), especially in Central Andes. This poses a threat to WS in cities such as La Paz (Russell et al., 2017). Similar changes are predicted in the extent of savanna and rainforest ecosystems (Salazar et al., 2007).

Figure 4.7. Map showing the feasibility of using NbS for drinking water source protection and flood risk reduction in Rio de Janeiro.



Source: Tellman et al., 2018.

Likewise, major metropolitan areas in LAC could be considered anthropogenic ecosystems, which affect the water cycle particularly in terms of water demand. Along with natural ecosystems, there is a critical need to develop and implement adaptive management strategies to account for changes in the water cycle associated with changes in ecosystem functional parameters due to climate change.

Water infrastructure issues related to the different aspects of the water cycle include: (i) water source management; (ii) water and sanitation services; (iii) irrigation systems for food production; (iv) hydroelectricity generation; and (v) protection and prevention of water-related disaster risks. **Annex C** presents a more detailed review of these aspects.

Innovation opportunities in water source management

In general terms, regarding the supply of the resource, it is necessary to have a **combination of supply alternatives, preferably of surface water and groundwater protecting water sources and reuse among different areas with complementary microclimates**. In Quito, for example, the city's water supply system receives water from surface sources found both in the mountainous zone and on the eastern slope, which has a different type of climate and alternates with the western (mountainous) climate.

With respect to surface water, it is advisable to combine traditional infrastructure schemes of storage by means of reservoirs with NbS, in order to provide additional climatic robustness to the supply, essential in periods of droughts. Groundwater offers the advantage of already having its own regulation insofar as the aquifers, if they are not contaminated, constitute subway reservoirs that provide a great robustness to the availability of the resource. In both cases, source protection solutions such as the Water Funds, implemented by the IDB in the region, and whose effective functioning has been proven in other parts of the world, should be considered (TNC, 2018).

As for water demands, they must be managed in an integrated manner, accounting for them simultaneously and in tune with the water balance. To this end, detailed data systems and predictive models can be developed that consider the type of population (urban, rural or peri-urban) and their different activities. At the same time, the basin perspective and the quality of the ecosystem that feeds and maintains it should not be lost. In this sense, many regulations already establish quality objectives that must be met. In the case of the European Union, the Framework Directive is even more ambitious and proposes the concept of "status" of water bodies, which considers not only physical-chemical quality aspects, but also hydromorphological (banks, gallery forest, bedforms, etc.) and biological aspects.

Some innovation opportunities related to an improved water sources management in LAC are listed below:

- **Water Reserves Programs:** Mexico's National Water Reserves Program (http://awsassets.panda.org/downloads/wwf_mex_water_reserves_program.pdf) with the cooperation of the IDB, WWF, CONAGUA, and the Fundación Gonzalo Río Arronte, has implemented an ambitious program to develop maps and characterize watersheds intended to the integrated planning and management of groundwater and surface water. The ultimate goal is to achieve WS through long-term planning and monitoring of water quantity and quality, with emphasis on maintaining ecological flows and biological diversity while meeting supply needs. Initial results of environmental flows and water allocation to ecosystems and human sectors are positive (Ordoñez et al., 2015). These types of initiatives can be expanded to other parts of the region, improving the methodology through advances in science and technology such as those discussed in Section IV.4.

- **Watershed headwaters management:** in Latin America and the Caribbean, most rivers originate in high mountains (montane biome). The Andes contribute 50% of the Amazon River flow, 93% of its sediment load, and most of the river productivity controlling nitrogen and phosphorus (Anderson et al., 2018 The dominant water sources for Andean rivers, glaciers, have been progressively melting over the last 50 years, especially in reaction to climate change phenomena (Rabatel et al., 2013), and mountain wetlands (bofedales and paramos), which store glacial water and emergent food production throughout the year, are affected by overgrazing, conversion to quinoa production, and mining.

  In face of the rapidly descending glaciers and the increased projected number of planned dams, IDB has recognized the importance of these high water sources areas and their importance for drinking water supply in large cities such as La Paz, Lima, and Quito (Chevallier et al., 2011); grazing of livestock; and irrigation and mining. Thus, a comprehensive project was carried out to supply irrigation water to local communities and drinking water to the Bolivian city of El Alto (BO-G1004). This project focused on the regulation, storage and short-term supply of water in the bofedales that feed the small reservoirs that meet the demands of the rural and urban water sectors. It also addressed in detail the issue of environmental flows, providing plans for the management of bofedales, which maximize their value for biodiversity and indigenous communities in the area.

- **Rivers and flood plains**: While it has long been recognized that the structure and function of large rivers such as the Amazon are uniquely controlled by seasonal linkages with their floodplains (Junk et al., 1989), and that these floodplains can provide valuable ecosystem services including flood control, sediment capture, and fish habitat, their use as NbS to enhance WS has been largely unexplored. Flood plains have untapped potential, especially in the upper and middle sections of rivers in LAC. In this regard, some authors have suggested that upstream flood plains could significantly reduce sediment and nutrient loading in the lower Mississippi River and Gulf of Mexico if they were periodically reconnected to the main river channel (Mitsch and Day, 2006). Thus, as they state, flood plains, in headwater bofedales, can store significant quantities of water while the flood conditions are produced and are slowly released downstream, thus reducing its risk. This opportunity of innovation on matters of WS incorporates flood plains as part of the WS planning in LAC. The Bank can explore the performance of pilot projects of basins upstream of urban areas with the purpose of determining the effectiveness and factors of feasibility of this NbS in flood prevention and co-benefits with other ecosystem services.

- **Aquifer recharges**: aquifer recharge (*aquifer storage and recovery*) allows aquifers to be used as natural reservoirs (subway reservoirs). This allows water to be stored underground to mitigate flooding during precipitation events and to have the possibility of using it during periods of scarcity, helping to mitigate the impact of droughts. Aquifer recharge requires detailed knowledge of the local hydrogeology in order to locate, within the aquifers, the areas best able to store and extract water. Aquifer recharge is being explored in many cities that rely solely and exclusively on groundwater (such as Oruro in Bolivia and some areas of northern Chile).

Innovation opportunities in water and sanitation services

In relation to water and sanitation systems, wastewater treatment technologies are well developed and in constant innovation. Additionally, a series of **improvements to the systems have been incorporated into practice through NbS, particularly the use of wetlands to treat water**. Noyola et al. (2012) evaluated 2,734 municipal wastewater treatment plants in six countries representing the various subregions of LAC (Brazil, Chile, Colombia, Dominican Republic, Guatemala, and Mexico). Approximately 67% of the plants were small (with an inflow of less than 25 liters per second) and very small (less than 5 L/s), especially in Mexico and Brazil. However, most of the infrastructure in these plants (80%) consists of traditional equipment: stabilization tanks, activated sludge and anaerobic reactors.

Constructed wetlands have been used for more than a century for municipal wastewater treatment in Great Britain and the United States

Artificial wetlands have been used for more than a century for the treatment of municipal wastewater in Great Britain and the United States (Vymazal, 2011). The system used is based on waste capture by plants and final storage in sediments. Since the 1990s of the last century, artificial wetlands have been increasingly used as stand-alone units or to supplement the outdated and overburdened gray infrastructure to meet the treatment needs of rapidly expanding urban centers. Unlike conventional wastewater treatment plants, which have a life expectancy of 60-70 years for concrete structures and

15-25 years for mechanical and electrical components (USEPA, 2002), artificial wetlands do not have a limited life span; but with proper monitoring and adaptive management to maintain maximum operational efficiency, they can provide long-term services. Arias and Brown (2009) estimated that **the annual cost to operate an artificial wetland near Bogotá, Colombia, is comparable to 20% of the cost to operate a conventional reactor.**

The first documented artificial wetland in the LAC region was in Brazil in the 1980s (Salati and Rodrigues, 1982), but its use has expanded rapidly since the beginning of the century, especially in Brazil and Mexico (Zhi and Ji, 2012). Most systems are small **but there is an opportunity to build larger hybrid (gray and green infrastructure) systems to meet the needs of urban centers.** There is still no comprehensive compilation of data on artificial wetlands in the region; literature is scarce and most projects do not have adequate monitoring protocols or, simply, do not report results. With a **comprehensive and easily accessible data repository, principles for design and operation of these systems** can be developed including when and how to apply an adaptive management to keep the wetland in operations with a maximum efficiency. Key issues include options for linking design components, developing hybrid technologies, and combining green and gray infrastructure to improve treatment efficiency. More empirical evidence is still needed on when constructed wetlands can serve as the sole treatment system, especially in rural communities.

The use of artificial wetlands for wastewater treatment constitutes an opportunity for innovation to significantly improve sanitation coverage targets in the region. Regarding the potential for application to dispersed rural populations throughout LAC countries, there have been a growing number of studies focused on the design of treatment systems incorporating various types of artificial wetlands, linked to gray or stand-alone infrastructure projects (WSP, 2008): pilot projects in small rural villages (Whitney et al., 2003; Dallas et al., 2004; Ríos et al., 2009; Kaplan et al., 2011 and Zurita et al., 2012). These studies have been expanding across universities (Mitsch et al., 2008) and industries, improving the design and species composition of vegetation in wetlands to address specialized wastes from farms and dairy plants, paper plants, solid waste landfills (Nahlik and Mitsch, 2006), pig farms (González et al., 2009) and slaughterhouses (Rivera et al., 1997). Recently, there have been advances in the removal of synthetic compounds (Belmont et al., 2006 and Toro-Velez et al., 2016) that are partially treated in conventional wastewater plants.

Although Zhang et al. (2014) suggest that small, decentralized wastewater treatment systems are ideal for urban settings, others consider multifunctional landscapes that incorporate urban ecosystem services to be more resilient to cope with changing urban conditions and climate change (Anderson et al., 2014; Lovell and Taylor, 2013 and Gomez-Baggethun and Barton, 2013). The

Although they show great potential, urban ecosystem services are, in general, non-existent in the region

development of urban systems that maximize both adaptive management potential and local stakeholder involvement is key to achieving WS in urban areas (Luederitz et al., 2015; Haase et al., 2014; McPhearson et al., 2015). **Although urban ecosystem services demonstrate great potential, they are generally non-existent in the region (with the exception of northern temperate systems) and knowledge about them remains inadequate** (Dobbs et al., 2018 and McPhearson et al., 2015). In general, the data have generally not been transferred to local stakeholders and their potential has not been adequately incorporated into urban planning (Luederitz et al., 2015; McPhearson et al., 2015 and Haase et al., 2014).

Water reuse or reutilization is still a pending challenge in the region, even in arid areas with natural scarcity. For example, discharge from artificial wetlands used to treat wastewater in central Mexico is currently being reused by local communities to alleviate irrigation stresses imposed by drought conditions (Belmont et al., 2004). In the United States, a similar project is being used to pretreat water from coal mines before becoming part of the drinking water supply for a small city. Although the use of NbS, such as wetlands, for the pre-treatment of drinking water has been observed in some places in the region, data on its operation is practically non-existent. A detailed assessment of water reuse and pretreatment in the region is needed. Its application potential for irrigation and drinking water supply is great, but its wide application requires the development of demonstration pilot projects that also include detailed analyses with quantification of economic and social benefits.

Rooftop gardens (green roofs), vertical gardens, and living walls are the recent approaches that show a great potential for water treatment and reuse in Latin American and Caribbean cities. Green roofs have proven to be effective, both in reducing stormwater runoff (from 30% to over 40%) through plant and soil absorption and evapotranspiration, and in improving water quality (Stovin, 2010; Hashemi and Mahmud, 2015 and Feng and Pomeroy, 2016). Mexico City has implemented highly innovative projects using rooftop gardens and living walls to capture stormwater runoff and reduce air pollution (Qiu et al., 2013 and Dieleman, 2017). Data on the application potential for LAC is still scarce, but these are promising technologies to reduce runoff and promote water reuse.

Innovation opportunities in irrigation and food production systems

Traditional irrigation systems, with tens of thousands of hectares in operation, usually consist of a large conductive channel of several dozens of kilometers of length, which carries the water from its intake point, mainly a river, with or without a reservoir, to the irrigation area, from where it is channeled through the distribution network that with a whole system of irrigation ditches carries the water to the irrigated plot. In these systems the channels have traditionally been designed by gravity and usually lack regulation.

To improve the water efficiency of irrigation systems, innovations have begun to be implemented, such as the creation of small reservoirs along the canal that facilitate hydraulic regulation

The negative consequences that this has in the framework of SDG and the fight against climate change can be summarized in two aspects. First, the **lack of flexibility to adapt supply to demand,** which leads to losses of significant volumes of water in the event of sudden interruption of irrigation due to a rainfall event in the irrigable area, in which the water stored in the canal ends up flowing out through the canal's spillway. Second, the **low response to demand**, due to the low velocity with which waves travel through the channel, to the detriment of the farmer.

To **improve water efficiency of irrigation systems**, innovations such as the **creation of small reservoirs throughout the channel easing hydraulic regulation** have started their implementation. In new channels, this is easier; in existing channels, it requires leveling with screeds and the replacement of crossing bridges[28]. These solutions can also be complemented with green infrastructure to provide some storage capacity in the vegetation, thus avoiding water losses during rainfall and accelerating the response to demand. As an example of this, the modernization undertaken in 2013 by the leader company in renewables, EDP, in the Durance-Verdon channel in the French Provence. Begun in 1955, this channel produces 6 billion kWh per year, and is capable of flows of up to 250 m^3/s providing drinking water to the entire basin. In addition to generating electricity, the canal also supplies irrigation water to the whole of Provence, an area that covers approximately one third of all French irrigation.

The natural infrastructure (NbS) has also begun to be adopted in agriculture beyond irrigation systems. For example, in **built wetlands**, **agricultural development** can occur either within or adjacent to wastewater treatment systems; this facilitates the reuse of water and other effluent components (e.g., nutrients). In addition to providing a sustainable source of water for irrigation of crops (Belmont et al., 2004), including rice (Salati et al., 1999) and selected vegetables (Martinez-Cruz et al., 2006), high-value plants, especially flowers, can be planted directly in the constructed system, especially in subsurface horizontal flow wetlands (Belmont et al., 2004; Zurita et al., 2009 and Zurita et al. 2011). Ornamental plants can be very effective in removing nutrients and surfactants from wastewater (Belmont and Metcalfe, 2003). In addition, some specialized waste streams remain so concentrated and toxic after wetland treatment that, while they cannot be used to irrigate crops, they can still provide a water supply for ornamental plants and recreational lands (Rivera et al., 1997).

Perhaps one of the most well-known innovation experiences on matters of WS is the trend towards a greater urban agriculture. At least, 800 million people worldwide participate in urban agriculture which supplies approximately 15% of food supplies (Kisner, 2008). The local production not only reduces food losses after harvesting due to the inadequate preservation

28 A relevant action in this area has been carried out in Spain with the Navarra Channel, with the advantage that it was conceived this way from the beginning, about 10 years ago. It is 177 kilometers long and serves an irrigable area of more than 53,000 hectares.

Mexico City satisfies approximately

20%

of your demand **from food to through roof gardens**

and transportation, but also provides additional benefits which include the reduction of air contamination and temperature (Qiu et al., 2013) and water storage within urban areas to reduce floods and provide supplementary water supply during drought periods (Rowe, 2010).

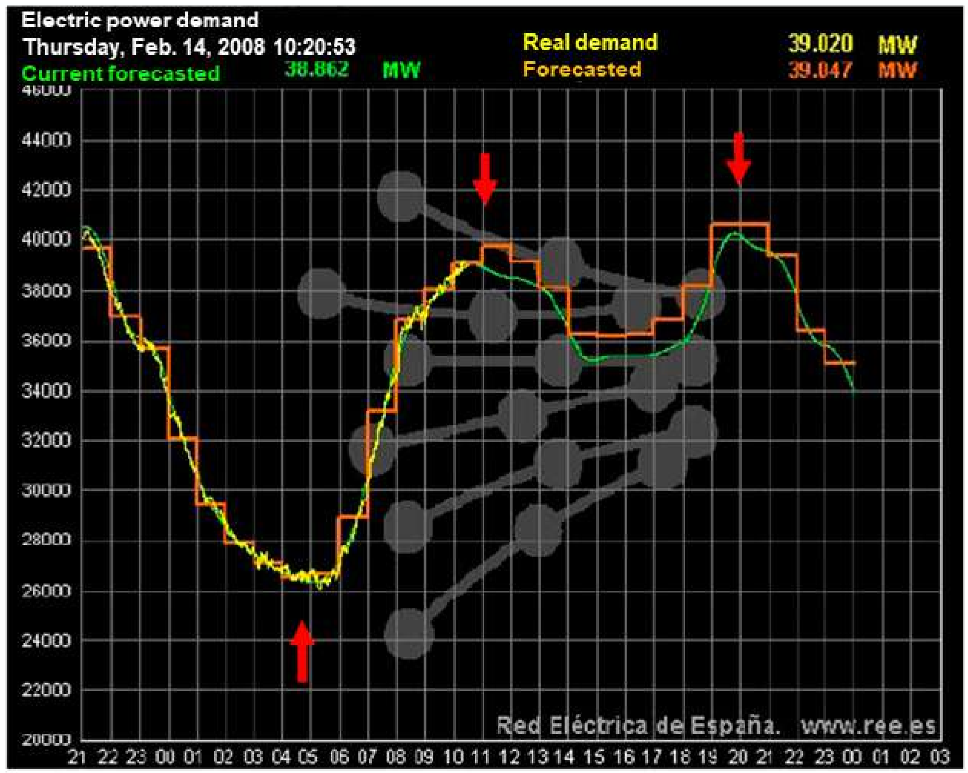
Rooftop gardens are preferred in dense urban centers with limited spaces, while hydroponic gardens (no soil needed) are more commonly used in urban areas with fewer space constraints and available gray water sources. Currently, Mexico City meets approximately 20% of its food demand through rooftop gardens and is working to extend this effort to approximately 22,000 km^2 of the existing rooftops in the city (Dieleman, 2014). Although less developed, hydroponic gardens have produced positive benefits to poor communities in peri-urban areas of Lima, Peru, by decreasing malnutrition and poverty through vegetable production (Orsini et al., 2010). The potential for high-value crop production is excellent as long as markets can be established (Schnitzler, 2012). However, there is a need for studies that evaluate the operational efficiencies of rooftop and hydroponic gardens in LAC. There is no doubt that these operations can enable important components of adaptive management to cope with both floods and droughts in urban areas with significant economic and social performance.

Innovation opportunities in power generation

Although the hydropower infrastructure is highly developed in LAC, there are some aspects where there is innovative potential **to enhance its more efficient use, together with other renewables such as wind and solar, to reduce greenhouse gas emissions that contribute to climate change**. First, to boost its **role as an energy accumulator** thanks to pumped storage plants, especially if wind and solar energy are developed, whose production may not be synchronized with the demand of the electricity market: using surplus energy during off-peak hours, water is pumped to an upper reservoir for later use during peak hours. This alternative has been used in several countries around the world: United States, several European countries, including Spain, Japan, China, and South Africa. However, in LAC it has been used little, except in large centrals. For example, the Rio Grande hydroelectric complex in Argentina, with an installed capacity of 1,000 MW, has been reported. At the current time of development of renewable energies, this can generate important opportunities for innovation.

This results in an increase in reliable energy. It is known that the power demanded daily by the electricity market is highly variable. **Figure 4.8** shows the evolution of the typical power demand in a day: during the night there is a drop in power demand that has its maximum expression between 0.00 and 8.00 hours (off-peak hours). In Spain, and in general in the western world, there are two peaks of demand, the first around 11:00 a.m. and the second around 10:00 p.m. (peak hours); the rest are intermediate power levels (flat and valley). These power variations are difficult to satisfy by the electrical grid when only nuclear, thermal and renewable plants such as wind or solar are available. This **regulatory role of the power offered to the market is usually reserved for hydroelectrical energy,** supported by gas or combined-cycle centrals.

Figure 4.8. Example of daily power demand in Spain



Source: Red Eléctrica Española.

However, **hydropower generation shows evident deficiencies regarding WS.** For example, hydroelectric dams have a **huge impact on watersheds through the storage of water and altered flow downstream.** Its contribution to water loss into the atmosphere through evapotranspiration has been greatly neglected (Hogeboom et al., 2018). In addition to this, although the relationship between water availability and human uses has been characterized in greater detail (water footprint), reservoirs have either been ignored in previous studies (Hoekstra and Mekonnen, 2012; FAO, 2016) or their contribution to water loss through evapotranspiration to the atmosphere has not been considered (EIA, 2016). In this sense, to provide a realistic picture of the influence of reservoirs on watersheds, Hogeboom et al. (2018) proposed the concept of blue water footprint, which calculates the water consumption of blue water resources (surface water and groundwater), including evapotranspiration. Thus, the topographic need to have large surface reservoirs for energy production can have a significant impact on downstream WS. This is the case of Brazil, which

There is an opportunity to carry out a detailed analysis of the impact of existing dams (and those planned) throughout the LAC region

has the largest blue water footprint worldwide, due to its large reservoirs. In contrast, small dams and those located in mountainous areas can be expected to have a much smaller impact on WS. While this is a promising start to addressing the broader impact of dams on WS, there is an **opportunity for a detailed analysis of the impact of existing (and planned) dams across the LAC region.**

Tidal power generation is based on both tidal magnitudes and river discharge currents in ocean turbines. While it is considered an important source of renewable energy, the environmental impacts are still poorly understood (Frid et al., 2012). Another innovation in electricity generation through NbS worth mentioning is the so-called **"osmotic power"** or "blue energy" (blue energy), energy obtained by the difference in salt concentration between seawater and river water, which has shown its feasibility in several research (Jia et al., 2014).

These three power sources (TCG, tidal power generation, and blue energy) have potential applications in LAC that imply the opportunity to conduct **a thorough analysis of the viable locations, the operationalization of these technologies, and their potential environmental impacts**.

BOX 4.1. WHAT ARE VOLUNTARY NATIONAL CONTRIBUTIONS?

The use of NbS also offers innovation opportunities for power generation while contributing to WS in LAC. An example of that is the boost that the use of renewable energy sources is gaining due to climate change and the policies that have begun to be implemented as a result. For example, in United Nations Paris Agreement (2015), countries proposed measures to keep the global temperature increase below 2 °C, and to continue with these efforts to achieve a maximum increase of 1.5 °C. These measures are called NDC ("nationally determined contributions"). In the case of LAC, NDC policies have focused primarily on the use of biofuels and the reduction of atmospheric emissions from land-use changes. Biofuel production, however, requires greater intensification of irrigation, which may increase the WS risks (Silva et al., 2018). Likewise, land use changes offer opportunities to use NbS (e.g., different types of restoration, including reforestation). In this sense, some recent studies (Baruch-Mordo et al., 2019) point towards the **feasibility of increasing electricity supply globally**, through the **better use of already intervened lands**, and propose **a more detailed local studies and pilot projects to define specific opportunities and operational and efficiency aspects.**

Protection and prevention of droughts and floods

A recent trend is **the creation of a Drought Management Plan, of which methodology is already sufficiently developed in other countries to**

be applicable in LAC[29]. For example, with regard to the Basin Drought Management Plan, in the period that has elapsed in Spain since the approval of the first drought management plans in March 2007, there have been important changes in the conceptual consideration of droughts. In the first version of the Drought Management Plans, the interpretation was oriented towards the satisfaction of demands, to establish indicators that would alert of the proximity of a drought and its effect on the different water uses. The European Water Framework Directive is ambiguous in this regard, which is why the Spanish Ministry of the Environment came to the conclusion that it was necessary to clearly diagnose situations of prolonged drought and water scarcity, since the actions and measures to be taken and the management capacity based on this diagnosis could also be different.

Basically, the **Drought Management Plan** in Spain consists of:

- **A system of prolonged drought and scarcity indicators**. The prolonged drought indicator is based on precipitation records and contributions to reservoirs in natural or quasi-natural regime. The conjunctural scarcity indicator is based on volumes stored in reservoirs, contributions to the river network, volumes in aquifers or combinations thereof. They are constructed dimensionless to facilitate their comparison, so that maps such as the one shown in **Figure 4.9** can be presented.

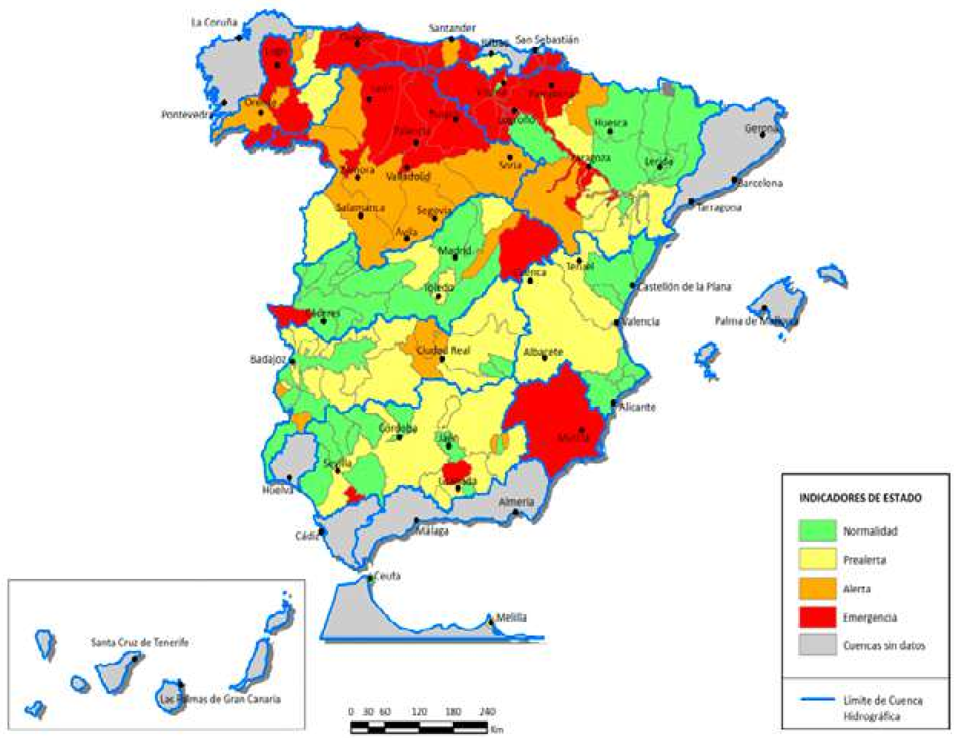
- **Thresholds to define the different drought stages (normal, pre-alert, alert, and emergency)** as the one shown in **Figure 4.10**, based on the volume stored in a reservoir characteristic of the hydrographic sub-basin under analysis. In this case the indicator has not been made dimensionless to better show its physical reality (e.g., volume stored in a reservoir). In the case of prolonged drought, the definition of whether or not this situation exists is simpler. The following criterion has been chosen: if the dimensionless indicator of prolonged drought exceeds or equals the value 0.3, the situation is prolonged drought.

- **A program of measures** to be applied progressively as the drought progresses, so that its effects can be mitigated. In the case of prolonged drought, there are only two types of measures: i) accept the temporal deterioration of the water mass, ii) accept the declination of the ecological flow established for the water mass. In scarcity, the measures cover a wider field: reduction of the nominal provision served for different uses, implementation of new resources, commissioning of system interconnection infrastructures… In the stage of emergency, the basin organism can request the National Government to issue a Decree for the adoption of additional and exceptional measures under Article 58 of the Spanish Water Law.

29 To consolidate the methodology, the Ministry for the Ecological Transition in Spain is in the process of approving the "T*echnical Instruction for the Elaboration of the Special Drought Plans and the definition of the global system of indicators of prolonged drought and scarcity*".

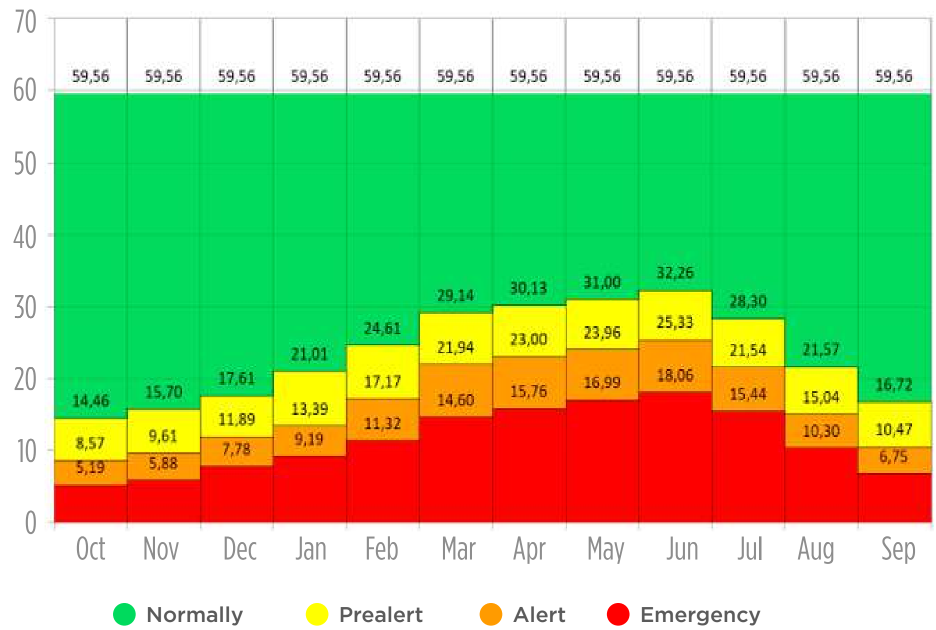
Naturally, measures have always been adopted, even before the drought plans were in place, as occurred during the drought of 1994 and subsequent years in Spain. Given the severity of the drought and the risk to the supply to Madrid, with more than six million users, the Ministry of the Environment promoted a meta-drought program that included a connection from the Alberche river system to transfer resources to the Madrid system.

Figure 4.9. Drought Indicators of Conjunctural Scarcity in Spain



Source: Ministry of Environment. May 2017.

Figure 4.10. Monthly indicator of conjunctural scarcity stage in a Spanish sub-basin. In ordinates, the volume stored in a significant reservoir of the sub-basin, in hm^3



Source: Ministry of Environment. Spain

As is the case with droughts, floods are caused by extreme weather events, whereby rainfall increases far above average values, increasing the flow of water in the channels to such an extent that it causes them to overflow, flooding large areas of the valley, affecting economic assets and putting human lives at risk. As with droughts, climate change tends to increase the extreme degree of flooding.

In this sense, the European Framework Directive refers to floods as natural disasters or disasters of force majeure. The severe floods that occurred in England and central Europe led to Directive 2007/60/EC on the Assessment and Management of Flood Risks. This outlines a number of key observations about floods that are substantially in line with what UNESCO points out in the document of *Flood Risk Management: A Strategic Approach. 2013.* The IDB, through its Water and Sanitation Division also considers the issue of flood prevention and mitigation to be strategic and this is reflected in its Sector Framework Document (IDB, 2017).

These strategical approaches can be summarized as follows: (i) Programming of actions framed in the hydrological planning of watersheds; (ii) efficient risk management, by using a wide range of measures; (iii) consideration of the specificity of each basin and acknowledgement of the impossibility for establishing protection standards of universal implementation for all the basins; (iv) need to incorporate governance actions that prevent urban development plans from aggravating the current situation, already delicate due to the changing nature of the problem caused by natural dynamics and human evolution; (v) establishment of collaboration mechanisms in the area of civil protection (very important for immediate mitigation of the effects of floods) in LAC countries, to increase the efficiency of flood intervention, especially in international basins; (vi) emphasis on the importance of increasingly accurate information and predictive early warning systems, as well as public participation in the acceptance of the program of measures. The response to the flood problem is embodied in Flood Risk Management Plans (FRMP)[30].

Flood prevention is a fertile field for innovation on matters of natural infrastructure and NbS

Flood management is a fertile ground for innovation on matters of natural infrastructure and NbS. In this sense, reforestation is under discussion in Europe as a result of the Biodiversity Strategy that the European Commission established in 2011, with horizons to 2020 and 2050, which already established a clear line of "ecosystem restoration", among other objectives. Some recent studies seem to be demonstrating the important role that forests can play in the fight against climate change, so it seems foreseeable (Rodero, 2018) that the governments of EU countries will soon announce important reforestation projects[31].

From the point of view of flood protection, vegetation in NbS would play a double role: (i) **it reduces the instantaneous runoff coefficient,** thus significantly reducing peak flows in hydrographs; **(ii) it prevents soil erosion caused by water,** also significantly reducing solid drags in the fluvial network. In LAC this second aspect is very important because there are large basins that, either due to natural processes (geology with soft and highly erodible materials) and/or anthropic actions, have large solid drags that cause serious damage to the ecosystem by rapidly altering the hydromorphological conditions of the watercourses and their biological habitat. This is the case, for example, of the Pilcomayo river basin, which with its 270,000 km2 affects Argentina, Bolivia and Paraguay and has given rise to the development of the "Integrated Management Project and Master Plan for the Pilcomayo River Basin", partially financed by IDB, and one of whose specific objectives is, precisely, to reduce erosion and the contribution of sediments into the river basin.

Flood plains can be an effective component in mitigating natural disasters, especially floods, while playing an important role in storing water to counteract droughts. Alluvial plains play an important role both in rural and urban settings, although until recently they were ignored in the latter. Even

30 Flood Risk Management Plan of Ebro Basin. Government of Spain. Ministry of Agriculture, Food and the Environment. Ebro Hydrographic Confederation. September 2015.

31 Afforestation (extension of forestry territory in areas where not necessarily existed a forest) can have an impact regarding water consumption and would also increase the risk of introducing invasive species, such as eucalyptus that is already a problem in many basins in LAC.

if alluvial plains of large rivers such as Amazon and Orinoco provide valuable ecosystem services, including flood control, capture of sediments, and the habitat for fish farming during the seasonal link with the river (Junk et al., 1989), urban streams and rivers are considered channels for wastewater and rainfall water and the flooding plains are classified as waste lands occupied by irregular urban developments.

BOX 4.2. CURITIBA'S FLOOD PLAIN

Based on the proposition that natural floodplains and associated wetlands can be used to reduce river sediment and nutrient concentrations (Mitsch, 1992), the Brazilian city of Curitiba adopted a multifunctional approach to integrate the floodplain of the Iguaçu River into the urban master plan (http://i2ud.org/2013/08/flood-management-in-curitiba-metoropolitan-area-brazil/). Thus, a large part of the floodplain was transformed into a linear park and conservation area capable of reducing flood risk downstream; wetlands were also constructed to treat river water and stormwater from surrounding neighborhoods. Wetlands trap nutrients and sediments and can serve as a pretreatment technology to reduce the cost and increase the quality of domestic water treatment (Varnell et al., 2009). The Curitiba experience is considered a model of environmental management that should be implemented in other parts of LAC. **It is an excellent example of the urban ecosystem services approach in the WS plans with collateral benefits**: water supply, removal of contaminants, food production, microclimate control, carbon sequestration, recreational opportunities, and biodiversity habitat (Lundy et al., 2011; Lovell and Taylor, 2013, and Anderson et al., 2014).

Finally, **innovative approaches in NbS in urban areas**, such as water **reutilization**, **built wetlands**, **rooftop gardens, and vertical gardens** (hydroponic walls), withhold rainfall water that normally would drain and cause floods downstream. Additionally, these practices can have **many complementary benefits** including the **advocacy of food security, water storage for mitigating droughts, and a decreased impact of urban heat islands**.

In this sense, the interested parties and local communities should be encouraged to own the green urban infrastructure in order to improve WS. Although this is still in its early development, **great opportunities exist for communities to become managers of ecologic projects through the performance of productive activities that also contribute to maintain such projects operating with the maximal efficiency**. In addition to providing irrigation water for crops such as rice (Salati et al., 1999) and selected vegetables (Martinez-Cruz et al., 2006), high-value plants can be planted, especially flowers, directly in the built system, especially in subsoil and in horizontal flow wetlands (Belmont et al., 2004; Zurita et al., 2009, and Zurita et al., 2011). Wetlands can significantly support local economies, as seen in Uganda, through the production of fish, vegetables, livestock grazing, and building materials for houses and furniture (Kakuru et al., 2013). **It is necessary to emphasize the cataloging of economic activities of wetlands, flood plains, and urban habitats that can be advocated to support WS programs**.

IV.3 Institutional Frameworks for Water Security

Fragmented policies must be avoided at all costs

Conceptually, the Water Security approach implies the consideration of multiple aspects and objectives that integrate very different competencies that are usually managed separately. Fragmented policies must be avoided at all costs. For this integrated approach to take place, a concrete institutional reflection is necessary.

If we take as a starting point the competent administrative bodies on matters of water in the region, it can be noticed that the situation is characterized by the heterogeneity of scenarios, derived from the multiple geographic, climate, and natural resources conditions of the different countries. This shows the lack of unique or successful recipes or models, regardless of the specific context of performance, but does not prevent us from realizing that, in most cases, **the great challenge lies in coordinating and integrating the actions of these authorities with the other authorities with competencies involved in achieving the objectives of WS.**

Based on the diagnosis made in Chapter II, five dimensions are identified within the framework of which, in terms of best practices, some of the main institutional arrangements for the incorporation of the WS approach are referred to, highlighting some case studies or experiences both in the region and abroad.

The first thing to note in general terms is that WS, as an approach or paradigm within the framework of which these practices are developed, does not depend on the natural availability of water resources but, above all, on their level of demand. Nor is it separated from governance in general and its management in particular; on the contrary, it depends to a large extent on it.

Thus, WS is particularly linked to those paradigms that propose integrated water resources management at the basin level or that emphasize the relationships between different elements (such as the nexus approach). In this context, water resources management appears as the prevalent element, contact point, or central scope of action of all the approaches referred, even from the perspective of climate change, whose main impact is manifested, precisely, through water resources. However, the WS approach makes it necessary to include a series of additional elements to conventional water resources management that are normally considered separately.

The WS approach as such must take the form of a public policy or public policy cycle, a perspective which, in fact, is more appropriate for an approach which, lacking a specific institutional sphere of government action, seeks to progressively influence the various organized sectors involved in their own objectives, regulatory frameworks and plans already in place. **This water security policy must state its objectives, specify them in the different planning involved, promote the necessary regulatory modifications and implement the favorable institutional arrangements to facilitate risk management whose distinctive sign will be the cross-cooperation and coordination of authorities and different sectors.** Thus, the conditions, institutional arrangements, or better practices to be included in a WS public policy can be schematized around five concentrated central topics: planning, regulatory, institutionalism, economy, and instruments and international basins. Beyond the examples exposed in this section, some specific experiences of WS institutionalization are shown in **Annex D**.

Water planning

Planning shows as the prime and key tool for designing any public policy inspired in an approach or paradigm that postulates the way several sectors are managed, such as water, land, or natural resources. Within the framework of the WS approach, hydrological planning appears, naturally, in first place; but aligned with the above mentioned, other sector plans can be even more important. This is the case for land planning, urban planning, or land use, especially in a region with a very disorganized urban expansion pattern. Energy, environmental and climate change planning or those defined by agricultural policy (for example, within a multisectoral nexus approach) are also very relevant, depending on the point of convergence.

The vast majority of the risk dimensions involved in WS rely directly on the coordination of, at least, water and territorial planning: floods, drinking water supply and sanitation, contamination, drought impacts, etc. However, although it is evident that this type of planning is part of broader planning processes, such as economic development, and must be coordinated with other sectoral planning, such as environmental, energy or agricultural planning, etc.

BOX 4.3. SOME REGULATORY EXPERIENCES IN THE REGION

Costa Rica has made significant progress in land use planning since 2010, when it was officially assumed as a central challenge for the country's development, formulating a National Land Use Planning Policy 2012-2040, which incorporates risk management and climate change and the gender and rights approach as crosscutting axes; and, as structural axes, habitat quality, environmental protection and management, and territorial competitiveness, in addition to promoting good territorial practices through fiscal and financial measures (Ferrufino and Grande, 2013).

In some countries of the region, plans have been developed under the specific denomination of water security. This is the case of Panama, where the *National Water Security Plan 2015-2050 Water for All* (PNSH, for its Spanish acronym) is based on a participatory diagnosis of the water resources situation and the short, medium and long term challenges to ensure the provision of water in acceptable quantity and quality for all users[32]. PNHS responds to five achievable goals over a 35-year horizon: 1) universal access to quality water and sanitation services; 2) water for inclusive socioeconomic growth; 3) preventive management of water-related risks; 4) healthy watersheds, and 5) water sustainability.

Although this plan responds to several of the characteristics pointed out as best practice in general (reference to the river basin area, multitemporality, human rights, participation, etc.), it lacks an adequate regulatory basis (Decree Law No. 35 of 1966 regulating the Use of Water), it is not linked to the previous hydrological planning (National Plan for Integrated Water Resources Management of the Republic of Panama 2010-2030), nor is it coordinated with the rest of the sectoral planning. Nor does it have legislative approval or budgetary allocation for its implementation, aspects that are crucial to foresee for its effective implementation and survival over time.

Without outlining a plan as such, there are examples of the implementation of specific policies for drought management in the region, based on preventive approaches with an emphasis on risk management, which seek to overcome the reactive paradigm of the emergency referred to above. Thus, in 2013, **Mexico** implemented the National Drought Against Drought (PRONACOSE, for its Spanish acronym), aimed to address droughts in an integral way by identifying and implementing actions for its prevention and mitigation, agreeing with local authorities on the programs and actions needed to address the particular conditions in each basin and national water user (Arreguín-Cortés et al., 2016).

The same has occurred in **Chile** with the preparation of a series of reports and studies on the 2010-2015 mega-drought (CR2, 2015) and the promotion of the drought risk management approach (FAO, 2010), providing the framework for future institutional and legal reforms. The IDB, for its part, has just synthesized in a document the lessons learned from five drought cases that can be taken into account by countries when addressing the type of risks involved in this dimension of WS (Cathala et al., 2018).

32 The PNSH was prepared with the participation of 19 institutions, representatives of all levels of the central administration and decentralized entities, responsible for the management, administration, protection and regulation of water resources, presented and validated in public forums of open consultation with representatives of all sectors that use water. It was approved by resolution of the Cabinet Council, which established the National Water Council (CONAGUA) as the entity in charge of promoting, guiding, coordinating and guaranteeing its development and implementation, and the Technical Secretariat for Water Security.

What should good water planning look like?
In view of these examples, the opportunities for innovation in water planning in LAC go through the process of being performed in an **indicative** (not imperative) manner, **flexible** (not rigid), and **adaptive** (with periodic mechanisms of review and including the issue of climate change as a relevant point for medium- and long-term planning) and must consider diverse scales (**cross-scale**), sectors (**cross-sectional**), and periods (**pluri-temporal**). Water planning should be acknowledged as a process and be (as a condition for its effectiveness) **transparent, participative, and informed**[33]; hold **regulatory hierarchy** (with effects laid down in the legislation) and be **binding for** both the public sector (current and future) and the private sector. Furthermore, it must be **realistic, feasible,** and have the corresponding **budgetary allocation ensuring its implementation**.

Regulation
So far, **there is no specific regulatory framework for the WS as such; rather,** it is a regime that must be **built and composed from different regulatory frameworks or sectoral legislation that converge in certain aspects** (water, energy, environment, land use planning, civil legislation, drinking water and sanitation, risks, emergency, civil defense, etc.). Normally, these are national legislation, but also provincial or state in the case of federal countries (Mexico, Brazil, and Argentina) and, sometimes, municipal. A body that, in any case, operates within the framework of general international law, such as human rights (water and sanitation, healthy environment, etc.), or particular, such as that formed by international treaties for the use of shared watercourses or basins. Within this general framework, there are at least three areas of regulations that are crucial for defining the WS environment and which are discussed in more detail below: water legislation, land or urban planning and risk management.

A) Water legislation
The diagnosis presented in Chapter II accounts for the advances in water legislation reformed in the last decade incorporating key institutes not only for the WS approach but for water resources management in general. But most of the legislation has not been updated and there is increasing evidence of difficulties in doing so (Embid and Martín, 2015).

A water law suitable to promote or enhance a WS approach should address, in a balanced and simultaneous manner, water as an environmental, economic, and social asset and include a series of institutes and instruments among which are at least: (i) an adequate central institutional structure, with basin authorities or organizations; (ii) a flexible and adaptive hydrological and special (droughts, flood risks) planning system; (iii) an effective cadaster and

33 See, for example, the provisions on information and public consultation contained in the European Union's Water Framework Directive 2000/60/EC of the European Parliament and the Council.

registration system for water uses and rights; (iv) a cadaster and registration system for discharge authorizations and permits; (v) a rational and robust economic and financial regime; (vi) systems and tools for public information, evaluation, participation and consultation (Embid and Martín, 2018).

B) Land use planning legislation

The second relevant approach is the land use planning (and civil legislation in the respective part) that contemplates conditions and enables the use of territory and land, especially taking into account aspects such as water availability, flood risk and the preservation of water resources as one of the backbones of its design. This aspect is extremely important in a region where the prevailing urban expansion patterns are disorder or real estate profitability, regardless of land-use plans (where they exist), increasing the risks for the WS. Hence, **in many countries, the main challenge is not the planning of a territory to be developed but the regularization or urbanization of land already occupied in an irregular manner,** with all that this entails in terms of social issues, pollution, relocation, etc.

A case from which some lessons could be drawn on this matter is the Colombian experience of land use planning, in general, and that of Medellín, in particular, where regulations and plans have gradually begun to incorporate hydrological units and the human rights-based approach. However, it is still a process in transition, where the water resource does not yet account for priority and/or exclusive administrative actions of intervention or management of basins and micro-basins, limiting itself to an auxiliary criterion role that helps to make other rights effective, as in the case of the security criterion for the location of housing and the development of infrastructure for mobility (Vásquez Santamaría, 2014).

C) Risk management

The Colombian example, also considered, makes it possible to connect land-use planning legislation with that of risk management, the third relevant area of normativity that appears as the obverse of the security inherent to the WS approach.

Risk management in relation to WS is perhaps the least developed aspect in regional legislation

In Colombia, the Organic Law governing Territorial Planning (LOOT, for its Spanish acronym) 1454 dated on June 28, 2011, laid the foundations for the formulation of other public policies such as the one contained in this Law 1523 dated on April 24, 2012, where the National Policy of Risk Management is adopted and restructured by establishing the National System of Risk Management (SNGRD, for its Spanish acronym). This system allowed territorial entities to organize themselves in a joint management at the central level, under the principles of decentralization, coordination, complementarity and concurrence, with the objective of promoting coordinated strategic actions towards knowledge, risk reduction and emergency management. This land use planning law allowed improving the competencies of territorial entities for disaster risk management, conferring greater autonomy from the national level towards departments and municipalities, as well as strengthening municipal associations with cases of intermunicipal risk management plans (Calderón Ramírez and Frey, 2017).

Risk management in relation to WS is perhaps the least developed aspect in regional legislation which, in general, continues to consider extreme weather events (droughts and floods) as accidents or unforeseeable natural catastrophes, which are dealt with as crisis situations through emergency declarations and ex post actions. In the face of this reactive paradigm of action**, a good practice suggests the incorporation of a preventive approach that considers that these phenomena are normal and recurring, in the respective legal frameworks, as well as these risks into general planning, arbitrating the mitigation and prevention measures that must be taken beforehand.**

Institutionalization, administration, and management

If the area of regulations is difficult to compose around the WS approach, it is even more so in the area of institutionalization or, more precisely, inter-institutional coordination, where the key to any good practice that may be considered lies. This is so because, essentially, WS problems not only encompass an enormous diversity of territorial scales (continent, region, zone, basin, city, town, village, country, etc.), but also diverse matters (natural factors but also, and above all, cultural or human, social and economic). Hence, the relative inconsistency or usefulness of the WS indexes prepared on the basis of exclusive national jurisdiction and the greater or lesser natural availability of rainfall, water flows or water resources.

The key to any good practice related to SH lies in institutional coordination

The incorporation of the WS approach into the institutional framework presents at least **two challenges**. The first is to **correctly identify the risk in order to address it at the appropriate spatial, territorial and institutional scale** – in other words, the need to make the spatial scope compatible with the national (and/or provincial in the case of federal states) and municipal jurisdictional bases, which most of the policies and legislation involved have. It could also sometimes be international, not only because of the type of basin but also because of the type of exchanges involved, for example. The second challenge is to **articulate the organizational and functional coordination mechanisms, vertical, horizontal and with the private sector, appropriate for the management of these risks.** The characteristic of the institutional framework in the WS area will be the essential horizontal and vertical transversality of its actions.

Of all the available institutional arrangements and coordination mechanisms relevant to the WS approach, the institutionalization of the watershed is essential. The variety of available schemes, according to the particular characteristics of each case, means that these must be taken into account when designing them, since not any arrangement would be effective in any basin (Martín, 2017).

Regional experience shows that the creation and, above all, the consolidation of these organizations is a long and difficult process, the need for which becomes evident as problems worsen. The case of the Matanza-Riachuelo Basin Authority (see details in Annex D) may be a good example of this, which however, is not isolated, and other cases in Argentina, the Bogotá River and the Atrato River in Colombia, or even the Amazon, where new regulatory and institutional mechanisms are adopted (see Annex D), the effectiveness of which, however, has yet to be verified.

In this sense, one of the observable trends in the region, which we have already mentioned, is the **growing judicialization of environmental or water conflicts.** These may have their origin in a simple claim for damage, contamination or violation of human rights to a healthy environment or water[34]. When the limits of the individual solutions are noticed, the courts have begun to transform them into genuine collective environmental processes in the framework of which comprehensive solutions are sought based on dialogue between powers, the implementation of best practices or the adoption of already consolidated principles of water resource management.

This recent phenomenon deserves to be highlighted since **it is within the judiciary framework and this type of process where many of the policies, institutional arrangements and innovative programs that seek to carry out or make effective what the law or the legislative and executive powers, for different reasons, could not do or achieve in advance are being designed or conditioned.** In fact, the role of multilateral bank financing has been key to the execution and development of many of these solutions (as has been the case in the Matanza-Riachuelo basin).

The adoption of adequate economic and financial instruments and mechanisms is vital for the effectiveness of WS policies

Economy: Economic, fiscal, and market instruments

The effectiveness of the above dimensions will depend, however, to a large extent on the general macroeconomic conditions of the country and on the adoption of adequate economic and financial instruments and mechanisms to define policies, implement plans, finance works and determine behaviors aimed at achieving the objectives set by the adopted WS policy.

Economic and financial instruments and mechanisms include tariff and fee systems in at least four traditional areas of water resources management linked to: (i) water uses; (ii) disposals or discharges; (iii) drinking water and sanitation services, and (iv) use of specific infrastructures.

34 Case law produced on the Human Right to Water during the last 15 years in the American region is immense and serves to show to what extent WS is compromised on its more basic feature, which is that of satisfying essential human needs in first place.

The example of the **figure of the discharge or discharge fee** can serve to exemplify how a good practice, consistent with the urgent needs, shortcomings and possibilities of the countries of the region, can be achieved by setting modest objectives in relation to the implementation or improvement of basic economic instruments for water resources management but fundamental for the WS.

In this sense, the figure of the discharge fee should have a legal provision that is far from being a guarantee of effective application. Its effectiveness depends on a series of factors, among which the following may be mentioned: (i) the existence of **control devices**, sufficient technical and police means for its collection and control, which may also be in the hands of an entity other than the water resource administrator with sufficient incentives and authority to favor its independence; (ii) **the amount of the fee** is capital for it to be able to fulfill its task, since many times its irrelevance or merely symbolic character, not only leads to a distorted application of the "polluter pays" principle, but also prevents it from covering the minimum costs involved in pursuing its collection and control; (iii) **the construction of wastewater treatment plants that benefit and at the same time justify their collection** by fulfilling the essential task of preserving water quality; (iv) their collection, which may also have multiple purposes (starting with dissuasion or incentive for treatment prior to discharge) may be used to finance water authorities, river basin authorities or the improvement of sources, among others.

The proper implementation of these figures constitutes an essential requirement for any water resources management model intended to increase WS levels. Not only because they are key to provide **genuine financing** for water management, but also because they have a very difficult potential to replace to **induce behavior** and provide strong signals to the market in line with the postulates of a WS policy.

But this happens only when they are well designed and effectively applied, something that does not usually happen in almost any of the countries of the region, where the null or low prices paid for water services in general (including all uses) operate as an indirect subsidy of the uses or economic activities developed, apart from the lack of control, effective collection and the frequent allocation of public resources to support water authorities or the construction of hydraulic works directly or through indebtedness. Very far, in fact, from achieving any realization of the principle of passing on costs. This brings the issue back to problems linked both to the specific institutional framework of the sector and to the lack of coordination with policies and instruments of other sectors with which water has an obvious nexus: energy, agriculture and food.

Only in the diagnosis framework performed in Chapter II, the implementation of **more sophisticated economic instruments can be seen, such as markets**

for rights or fees, payments for environmental services, green funds (e.g., Water Funds), or hiring schemes such as the partnerships or public-private participation.

The OECD, for example, instead of focusing its WS approach on a development perspective (Hoekstra et al., 2018), has done so on a risk perspective, recommending the implementation of different market-based instruments, including, for water supply and demand: regional and international water markets and incorporation in tariffs of the marginal cost reflecting the value of scarcity; for water quantity and quality: water rights buybacks, emission permits market and discharge charges (OECD, 2013).

However, although these instruments can result from good practices in certain contexts, their proper functioning depends almost entirely on a series of legal and institutional conditions and prerequisites that are not usually met or present in the region. For example, **implementing markets for rights to use water or discharges without an adequate cadaster, information, registry of rights, or institutional control capacity to guarantee a minimum of transparency in transactions, may entail very serious risks for the sustainability of their exploitation, of hoarding or capture, which compromise the guarantee of common or priority uses such as population supply, among others, and consequently affecting the WS**. This vision corresponds to the approach outlined at the beginning, regarding the fact that threats to the WS do not come only from nature but can also come from the inadequate or incorrect implementation of legal instruments or devices. The allocation of water rights in shared sources between the rural and urban population is not a minor issue in countries with areas that have a clear tendency to recurrent drought, a situation that will increase with climate change. For this reason, it is imperative to continue working on community management mechanisms that allow for a rapprochement between the different users to make consensual decisions during times of crisis, thus avoiding conflicts and social tensions.

On the other hand, mechanisms for the repurchase of water rights for environmental purposes, such as those practiced in the United States or Australia, seem to be not only outside from the economic possibilities of most of the countries of the region included in the Bank's portfolio, but even, to a certain extent, unnecessary in systems that are based on the public nature of their waters, and in which the preservation of their sources or ecological flow does not constitute a use as such, but should be considered a precondition for any use (and, therefore, not compensable in principle), as is the case in Spain, whose legislation is in fact the mediated source of most of the water laws in the region (Embid and Martín, 2015).

Transboundary basins

The **growing conflict over water use** in the region escalates the conflict that at first may appear as merely local or regional to the basin level, many of which are international in nature. Experience also shows that, once the conflict has arisen, it is much more difficult to reach agreements to channel them institutionally while preserving peace and the duty of cooperation that presides over relations between states that have shared water streams or basins (Martín and Justo, 2015).

The recognition of the principle of basin unity appears with all the variants of institutional solutions in the American region, although it should be noted that there is no general multilateral convention for transboundary waters in the region. The 1997 New York Convention on the Use Rights of International Watercourses for Other Purposes Apart from Navigation has not been ratified in LAC. Nor has the 1992 UNECE's[35] Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) been the subject of adhesions so far, open to this possibility since 2013 (Martín and Pinto Salinas, 2013).

It is essential to have multilateral or particular treaties and institutions for the international basins and aquifers of the region

In the absence of a general multilateral framework, Latin American international water law is characterized by its particularism, that is, by the execution of specific international treaties between the states involved on certain rivers, watercourses, lakes, basins or for specific uses or infrastructure works. Although no great progress has been made in recent years in the management of international waters in the region (where, on the other hand, there has been an increase in conflicts), there are cases that deserve mention for their sophistication and recent progress in the regulatory field. That is the case of the **River Plate Basin Treaty** or the novel 2010 **Guaraní Aquifer System Agreement**.

While most of the surface watercourses relevant to the region have some kind of treaty or institutional arrangement, this is not the case for transboundary aquifers. Having identified future shared waters as a potential source of conflict and political instability, UNESCO, within the framework of the International Hydrological Program, and together with other organizations, has been the promoter of mutual recognition of the international character of aquifers and of the promotion of legal and institutional agreements for their monitoring, governance and management[36], an example of which the Guaraní Aquifer System Agreement results (see Annex D). The program published an inventory of the aquifer systems identified and recognized by the states of the region that, in 2006 were sixty-eight: seventeen in North America, four in the Caribbean, eighteen in Central America, and twenty nine in South America (UNESCO, 2008).

Given the key nature of the basin level for addressing most of the risks involved in the WS approach, it is essential to have multilateral or specific

35 UN Economic Commission for Europe Information Service.

36 In fact, the 8th Stage 2014-2021 of the UNESCO's International Hydrological Plan (IHP) is devoted to Water Security: responses to local, regional, and global challenges involving eight areas of study (UNESCO, 2013).

treaties and institutions for the region's international basins and aquifers prior to the occurrence or escalation of the conflict. If they exist, it is advisable to support actions to improve, develop or strengthen them through technical, political, economic and diplomatic cooperation.

Basin Committees as an administrative management specific to a WS approach

In the Basin Committees (BC) the possibilities of coordination regarding the fact that institutional and social representatives of the different elements of WS (and others) can be incorporated to them are expressed. This allows the configuration of a **capable organization to discuss and (depending on its specific configuration) to adopt decisions impacting, among others, all the components of WS** (e.g., water availability, water quality, NbS, risks of droughts and floods, etc.). To the date, in LAC, the most usual is the existence of basin committees (with the name applicable for each case), with roles of consultation and coordination, but not managerial.

On the other hand, their territorial field of competence, the watershed[37], is a natural space not linked to a historical or political division, which is a positive element from the technical point or in terms of the effectiveness of their actions, even though this natural fact gives rise to the difficulties inherent in the configuration of bodies that do not strictly consider political divisions (and demands).

Many countries in the region know the existence of Basin organizations; although not all of them have the same composition and functions (at the end of this section, the BC of Matanza Riachuelo in Argentina is offered as an example). Even with all the difficulties that their evolution has had in the region, BC have an essential role for in the water resources management, with special emphasis on the nexus approach (Embid and Martín, 2017).

Due to their scope of action and despite their current weakness, **BC can play a more determinant role in the future by progressively incorporating the WS approach at the basin level**[38]. For all these reasons, **the generalization of Basin Committees is recommended as a public policy** in accordance with a series of guidelines developed below.

37 Definitions of watershed are relatively wide in the existing regulations in the different countries of LAC that, sometimes, fit to the needs of the specific territory where they will be applied. At times, they are called watersheds, but they are rather sub-basins, since the definition technically more accurate of basin should refer to a water course that discharges in the sea (or an inner lake), and collects the deposits of a specific territory that discharges into it. The Andes, a natural entity linked to several countries, determines that only those water courses discharging to the Ocean Pacific can respond accurately to the concept of basin, while the territories from the other side, can create only national sub-basins, integrated at the same time, in international basins, at times of immense size, such as it happens for the case of Amazonas. In practices and due to the large number of existing basins in a country (of regular size), these organizations are constituted for groups of basins (or sub-basins), and/or priority basins (with greater problems and needs for coordination).

38 So far, what is said is only related to the water approach and not the environmental approach in general. The potential of extending its attributions to the environmental approach is controversial, and the level of basin is not always appropriate for such purpose (Dourojeanni et al, 2002).

1) **The potential correspondences between drainage basin and BC:** BC carry out their function within the natural geographical scope of the watershed. This does not mean that each basin must necessarily be the object of the work of a BC, nor that there must always be a relationship of equality or interdependence between the watershed and its corresponding BC. Such a decision may be functionally inefficient and economically very onerous in the case of small watersheds unable to sustain a minimally efficient administrative apparatus (or to justify the economic burdens involved). Therefore, when the size of the basin is sufficient, there is no objection to having a BC for the basin alone, but it may also be advisable for a BC to have a territorial base that extends over several basins, on the basic condition that they are neighbors from the territorial point of view. This presupposes that the legal system applicable in each case must contain a definition of a watershed on the basis of which the competent body will have determined both the existing basins and the BC that should exist.

   This prior determination must be rigorously carried out in order not to foresee the constitution of a BC where there is economic incapacity to support them or where, due to the scarce population or economic importance of water management, their establishment is not a priority. On the other hand, the existence of BC presupposes a prior social conviction of their usefulness, for which actions must be carried out that converge in this result. From the perspective of the WS, the BC can play an important role in the interrelations between their components, so actions for their constitution should be promoted even with all the inconveniences that can be pointed out for the previous steps.

2) **BC as participatory instruments with the possibility of management**: BC should be elements of coordination, participation, and debate, and could also be management instruments. Where BC do not exist, it is necessary to establish them, even when they are only social participation and coordination instruments. The attribution of competences for water resource management can follow the existence of BC with a certain tradition of participation and coordination of criteria regarding water use, the constitution of farmers' groups for the joint use of water resources in their economic activity and the hydropower generation. This is an extremely important issue and one in which gradual, slow but progressive approaches can have a much greater capacity for positive results than hasty or purely formal actions.

   For the compliance of the participative function, it is essential to determine its constitution, which means to establish the distinct bodies that could exist within them. In fully consolidated BC, it is usual to distinguish the existence of general meetings or debate commissions where all the water users or those of a certain productive sector are grouped and, on the other hand, management structures.

In these terms, participation should be broadly defined so that no significant social, political, technical or economic interest can be said to be outside the Basin Organism.

Therefore, representatives of water users should belong to the organization, taking into account the different uses existing in each basin (urban consumption, energy production, agriculture, aquaculture, fishing, recreation...). It is also advisable to include social representations (trade unions, employers, consumers, environmental organizations) and local and regional authorities (municipalities or town councils, regions, provinces and states), which is very important considering that the BC are a natural and not a political-administrative division. In particular, the public companies that provide water services can have their own representation or, also, be incorporated through the political body on which they depend (usually the municipalities).

Of course, the administration, authority or ministry responsible for water should be part of the organization, normally through its peripheral organizations (those which exercise their competences on a territory relatively similar to that of the basin). And if the BC exercises executive functions (granting, modification or review of concessions, police powers including the imposition of sanctions, collection of taxes or fees for the use of water, etc.) the condition of non-duplication of powers will consist in the connection of these ministerial structures in the BC.

This is a higher level of BC higher than those usually existing in LAC, and which corresponds to consolidated European models of water management (hydrographic confederations in Spain, water agencies in France) and to which we should tend, as an ultimate objective, given the effectiveness achieved in the comparative experience. It is precisely around the BC (hydrographic confederations) in Spain where examples of administrative organization in the field of the water-energy-food nexus can be found, since they exercise competences in all these sectors, practically exclusively in the field of water, and important in energy (hydropower, cooling of thermal power plants) and agriculture (granting of concessions in irrigated agriculture).

The percentages of participation of the groups listed above (and of others that may exist depending on the peculiarities of the different basins) is a matter in which political evaluations are mixed with considerations specific to the social and economic characteristics of each basin and with respect to which it is practically impossible to make proposals that are valid and of general application. It can be pointed out that it is desirable that the representatives of irrigation water users should be in the majority among the representative groups because of the much greater volume of water they use. But it is also possible (as in

Europe) to find basins in which the predominant uses are not irrigation but industrial, so that there may be different decisions.

Water, energy, and agriculture in BC: Energy and agriculture sectors must be present in the actions of BC, and they can be through hydropower productors, or if applicable, holders of thermal or nuclear centrals, where water is used as a cooling element (although very few examples of the latter exist in the region). The same would happen for the representation of agricultural producers, through entrepreneurial organizations or agricultural users of water (user communities or associations). Finally, desalinization, still scarce although in development in the region. In this sense, the representation of the owners of the facilities that may exist is, in itself, an element of WS due to the important weight that the use of energy and the subsequent uses of desalinated water have in the production of desalinated water. These elements of the nexus can also be present through the representation of trade unions or business organizations and the political-administrative representations (ministries and their local delegations) responsible for energy and agriculture.

3) **BC and water planning:** The relationship of BC with the preparation of water planning is essential, also, with the preparation of the energy and agricultural planning. This participation will normally operate at a consultative level, with other entities or administrative bodies being responsible for the preparation of the corresponding plans; although in the field of hydrological planning, the actions of consolidated BC, with competent structure and administrative services can achieve a higher level of responsibility. They can even receive the authorship (initial) of the hydrological plans that might be subject to information process, public consultation, and final approval by central administrative bodies (as will be discussed later).

BOX 4.4. UNIQUE BASIN ORGANIZATIONS: THE MATANZA-RIACHUELO BASIN AUTHORITY

The case of the **Matanza-Riachuelo Basin Authority** (ACUMAR: http://www.acumar.gov.ar) can be considered a case of good practices in the region as a recent trial to provide greater intensity to BC characterized by their weakness, centralizing important executive and planning competencies that facilitate the implementation of approaches such as WS. Part of the attractiveness of the case also comes from having been adopted in an adverse context of environmental catastrophe (something increasingly frequent in the region) and judicialization for violation of human rights and conflicts of competences among responsible authorities.

ACUMAR was established by the Mendoza Judgment of 2006 of the Supreme Court of Justice of the Argentine Republic and involves **the collaboration of the Nation, the Province of Buenos Aires, and the City of Buenos Aires**. Several **elements** motivate the decision to create this BC: the **hydrological planning**, the **fight against the contamination**, and the **human-rights based approach**. That is the example of a BC created from a judicial resolution and constitutes an example of judicial activism very present in environmental topics in various countries of LAC.

In fact, it arose from an action for damages brought by several affected neighbors against the State and different companies for the contamination of the Matanza Riachuelo Basin. The Supreme Court of Argentina favored a solution based in the following principles: (i) judicial activism; (ii) enforceability an functionality of the right to a healthy environment as a collective right; (iii) integrity of the solution/interdependence of rights; (iv) design of an environmental collective process; (v) the basin as an indivisible environmental management unit and source of powers; (vi) human rights-based approach, full legitimation, publicity, and participation; (vii) planning at the core of the solution; and (viii) control of the enforcement of the sentence/dialogue with the other branches.

ACUMAR is thus empowered to regulate, control and promote industrial activities, the rendering of public services and any other activity with environmental impact in the basin, and may intervene administratively in matters of prevention, sanitation, restoration and rational use of natural resources. In particular, it is empowered to: a) unify the regime of effluent discharges to receiving bodies of water and gaseous emissions; b) plan the environmental organization of the territory; c) establish and collect fees for services; d) carry out any type of legal act or administrative procedure necessary to execute the Integral Plan for Controlling Contamination and Environmental Reconstitution; and e) manage and administer funds (Art. 5). In order to avoid conflicts between competent authorities, ACUMAR's faculties, powers and competences in environmental matters prevail over any other concurrent in the basin area, and their articulation and harmonization with local competences must be established (Art. 6).

They are powers that together denote an enormous delegation of powers belonging to other administrative jurisdictions that are centralized in the BC, thus easing the coordination for the implementation of policies with a WS approach that require planning and executive competencies in sectors usually organized separately.

Another recent example is the **Resolution of the Supreme Court of Justice of Argentina** in the claim of the Province La Pampa against the Province Mendoza (1/12/2017) **ordering the revitalization of the**

existing, but inactive, interprovincial basin organism, the **Lower Atuel Interprovincial Commission (CIAI, for its Spanish acronym)** for the management of the Atuel River, integrating the human right of access to drinking water, hydrological planning and ordering the agreed establishment of an environmental or ecological (minimum) flow to be transported by the Atuel River. These are important decisions in the field of water management but also in the other components of the nexus, since the relationship of this ruling with the agricultural activity to be developed in the provinces of La Pampa and Mendoza is undeniable and may also affect hydropower production in both provinces.

IV.4 Progress in Science and Technology

In addition to political will, improvements in SH will depend on advances in science and technology that help fill information gaps

In addition to the policy will, improvements in WS both globally and in the LAC region will depend, to a large extent, on **advances in science and technology that help fill information gaps and can support decision-making in the different institutional, technical and political spheres of the water sector and related sectors.** Although an exhaustive review of this topic is beyond the scope of this report, it is worth focusing on one aspect that the IDB and its clients have consistently emphasized: the **availability of data on the water quantity and quality** and, in a broader sense, the monitoring of water cycle and the development of tools transforming these data into reliable information for public access for supporting decision making and planning.

To properly manage water as a vital resource, a good physical understanding of the dynamics of water resources through time and space and a good near real-time monitoring of water balances are necessary. This understanding forms the basis for addressing important WS challenges such as water quantity and quality, ecological-environmental flows, ecosystem services, allocation of water uses for agriculture and energy, and protection against water-related disaster risks, among others.

For example, coping with climate variability and its impacts on the water cycle requires reliable monitoring tools that help users and decision makers and planners to prioritize and manage demand in advance in dry years and consume more rationally during wet years. Better quantification of hydrological flows and storage will help improve WS and thus positively influence the health and well-being of populations by providing more reliable information on water availability and use. In this sense, **remote perception or remote sensing, allows obtaining terrestrial observations of so many hydrometeorological and environmental variables, as well as the identification of so many different types of land use and an increasing number of ecological variables**. Some of the relevant variables are precipitation, soil wetness, change in terrestrial water storage (including vadose zone water and groundwater), evapotranspiration, Normalized

Difference Vegetation Index (NDVI), surface water elevation, and water quality variables. Good monitoring of hydrologic flows and their temporal and spatial distribution will provide quantitative data that will facilitate planning, institutional, economic and other approaches to water management.

How can remote sensing lead to better water resources management?
Remote sensing can provide observations with spatial and temporal distribution that can allow better prognostic capacities and a more efficient use of water in the following ways:

- Operations in areas dominated by **glaciers and/or paramos** can benefit from **ice coverage estimations and water equivalents** corresponding to know **how much water stored exists and in which watersheds it is stored**.

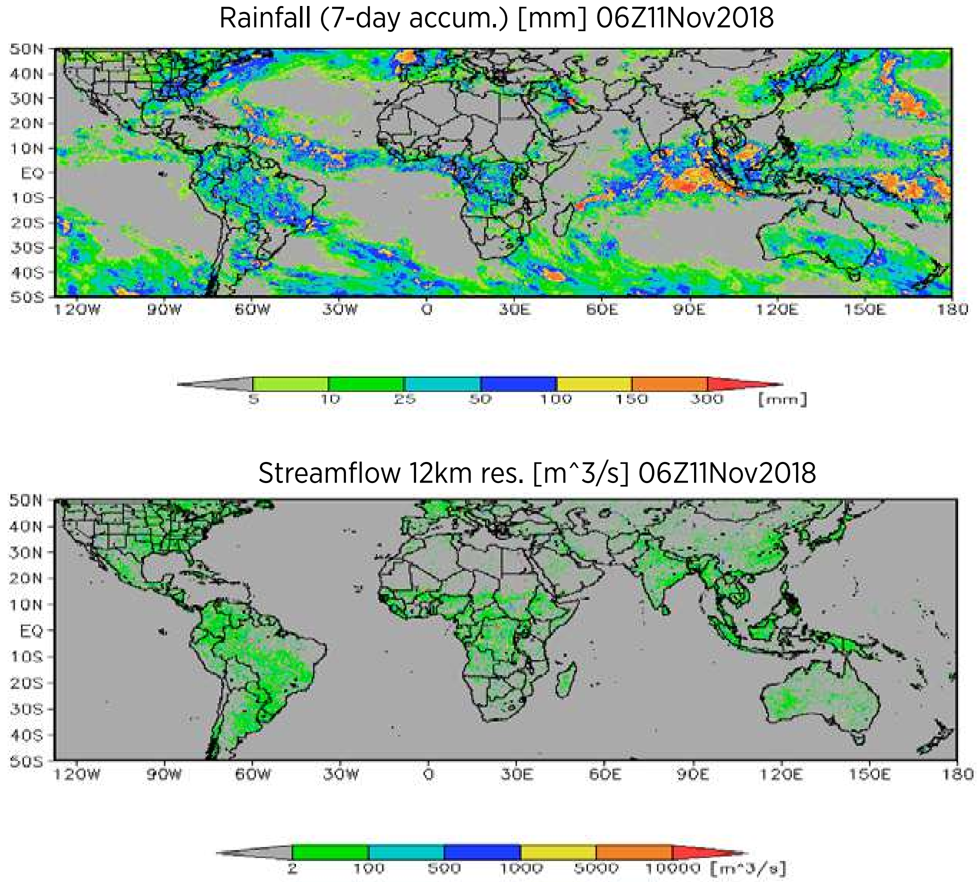
- In **large basins with times of concentration of many days, real-time satellite estimates of precipitation and forecasts of runoff flow** can help operating companies to **distribute water among users and operate reservoirs in a more efficient manner**, taking into account the amount of water expected to be brought by the river in the coming days.

- In **fast-flowing rivers, altimetric data from river surfaces** can be used to **estimate the flow in the upper parts of the basin and elaborate forecasts for downstream flows**, to issue **flood warnings** and for water allocation and operations (Hossain et al., 2014).

- **Satellite measurements of soil wetness** can provide information on the **amount of irrigation needed**, as well as to aid to correct lost vents or false detections of satellite precipitation products and help to assess the flood risk.

- **Evapotranspiration estimations** can help operators of the sector to understand better the dynamics of groundwater pumping in agricultural areas and the impact of water policies implemented and changes in energy subsidies for pumping. More generally, evapotranspiration can be used in combination with field-measured data to understand water use efficiencies, with the goal of decreasing non-beneficial losses and increasing agricultural productivity (Wu et al., 2013).

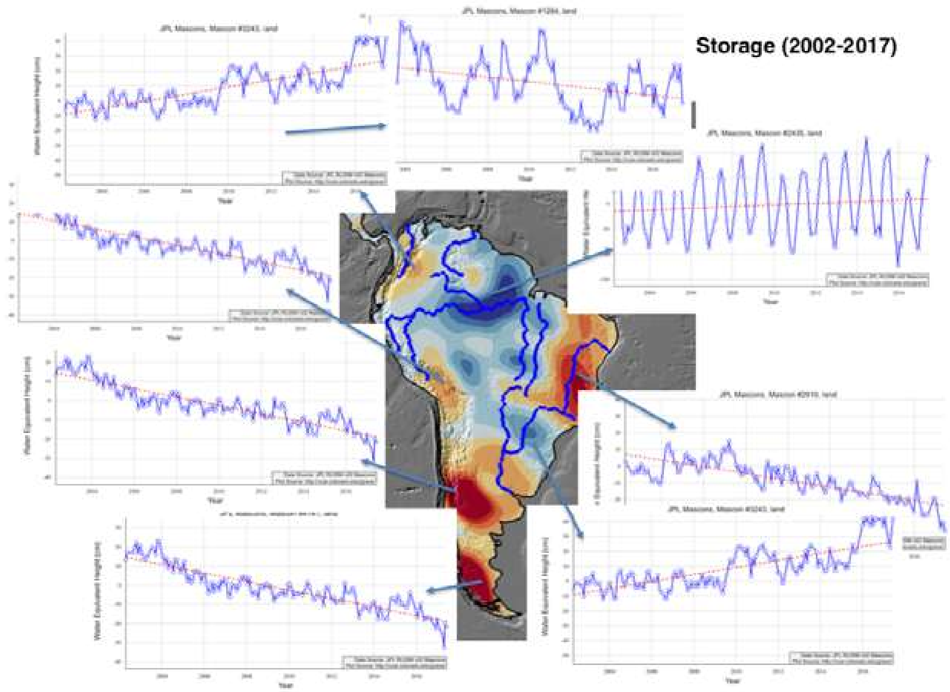
Figure 4.11. Global surface water flow data updated every three hours in real time.



Source: http://flood.umd.edu.

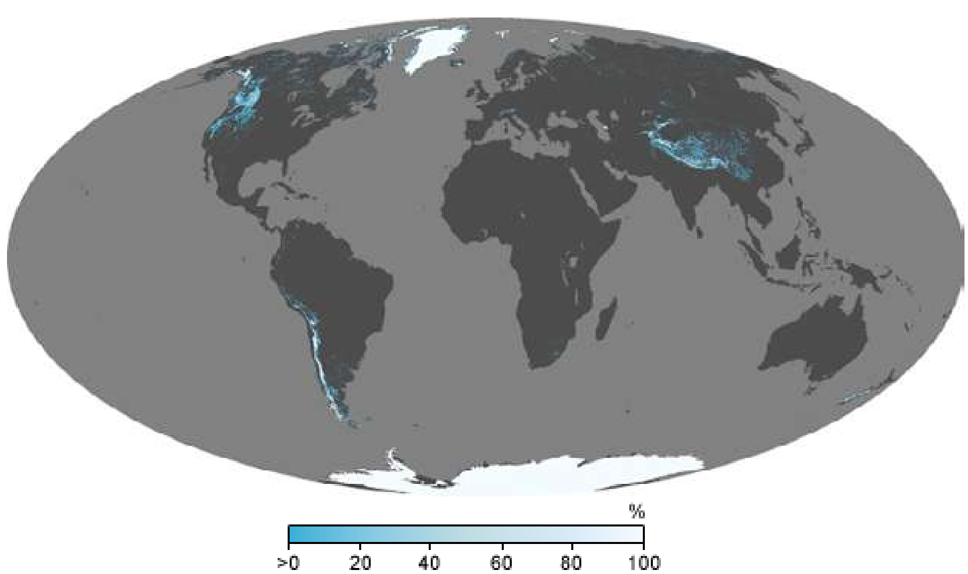
There are several open public sources for remote sensing data for surface water for all the world. For example, the Global Flood Monitoring System (**Figure 4.11**) available at http://flood.umd.edu, using the NASA's precipitation data and hydrological models to create flood detection and severity maps in real time. Or those of Grace Satellite to know the status of groundwater (https://nasagrace.unl.edu) shown in **Figure 4.12**. These data can be used to **assess water balances**, **water storage**, and **hydrological flows** needed for **national, state, or municipal programs,** as well as in **regional initiatives**.

Figure 4.12. Obtaining historical series of groundwater availability from NASA's GRACE mission in the Amazon basin.



Source: https://photojournal.jpl.nasa.gov/archive/PIA13243_gracelenticular_07_web2.gif.

Figure 4.13. Global snow cover (NASA's TERRA-MODIS Satellite)



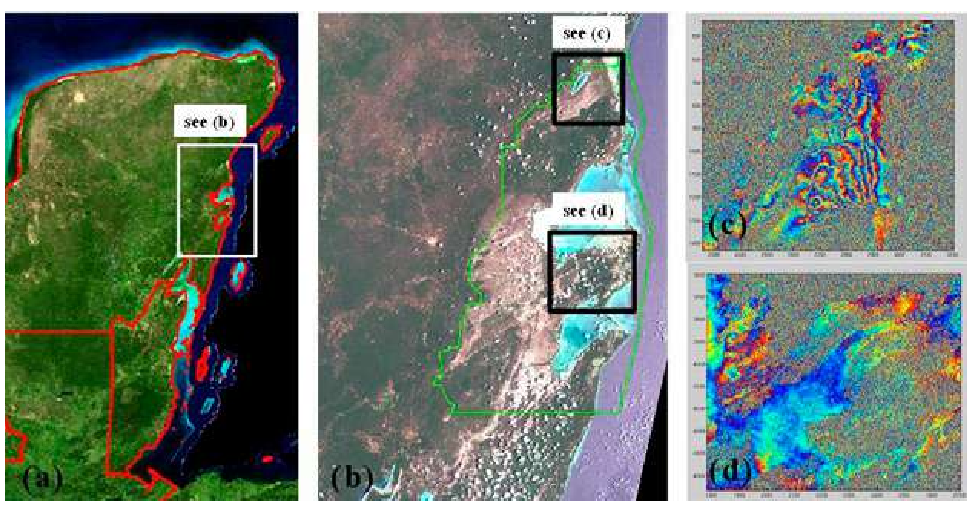
Source: https://earthobservatory.nasa.gov/global-maps/MOD10C1_M_SNOW

For the **monitoring of glaciers and ice and snow cover in general**, there are global public databases obtained from satellite measurements. For example, NASA's TERRA satellite contains the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument that can measure percent snow cover. **Figure 4.13** illustrates a snow cover map with these data, and the website contains the data files with all the measurements.

Water monitoring in wetlands is of great importance in water balance and WS in coastal zones, since these ecosystems play an important role in regulating the connection between freshwater and saltwater. On the other hand, wetlands serve as water storage and regulation systems, helping to mitigate the impacts of droughts and floods in surrounding areas. There are sources of measurements of water volumes contained in wetlands through radar technologies (SAR: *Synthetic Aperture Radar*) that are available. **Figure 4.14** shows the application of this technology in Sian Ka'an wetlands, in the Yucatan Peninsula in Mexico.

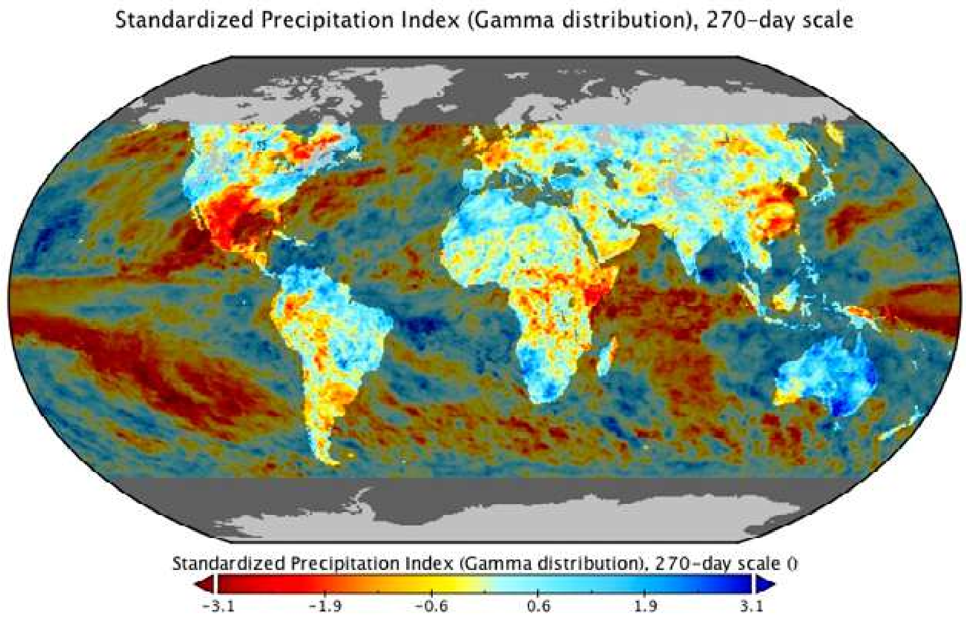
For **monitoring drought and flood patterns**, there are several existing and under constant development databases. Two examples are shown here. The first is a global daily Standard Precipitation Index (SPI) database (**Figure 4.15**), which is used, along with a rainfall database such as the one shown in Figure 17, for early detection of drought and flood conditions. The second example shows the Evaporative Stress Index (ESI), an index that measures drought applicable to agriculture and its impact on agricultural productivity (**Figure 4.16**).

Figure 4.14. Water volume measurements in wetlands of the Sian Ka'an Biosphere Reserve, Mexico. (a) Yucatan Peninsula (b) Sian Ka'an (green area; (c) water volumes between the dates (2006/10/26-2006/11/19; (d) water volumes between the dates (2006/08/15-2006/09/08)



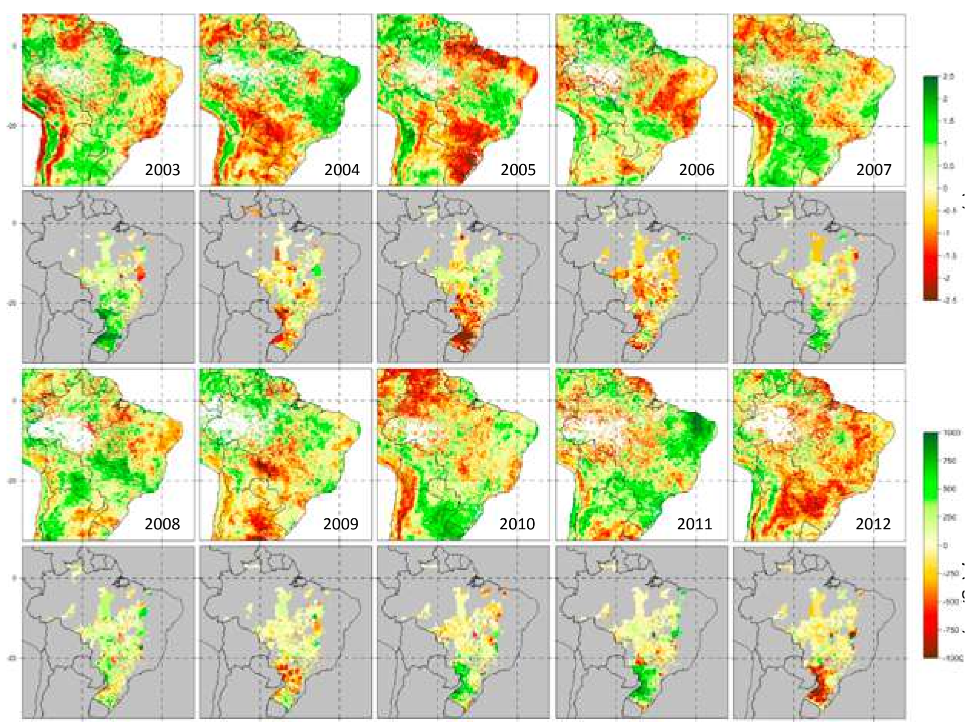
Source: Digital Chart of the World (http://www.maproom.psu.edu/dcw/)

Figure 4.15. Global and daily SPI database



Source: https://www.cpc.ncep.noaa.gov/products/international/dm/daily/index.shtml

Figure 4.16. ESI (Evaporative Stress Index) and its incidence on the annual agricultural productivity in Brazil



Source: http://catalogue.servirglobal.net/Product?product_id=198

In addition to water quantity, **some recent research has made significant progress in monitoring many water quality parameters** (Gholizadeh et al., 2016; Chang et al., 2015). This allows to track the water quality dynamics over time and space through wide regions, significantly complementing costly and limited field sampling point measurements. **Water quality variables that can be assessed with remote sensing** are **temperature**; **chlorophyll** (a phytoplankton biomass, trophic state, and nutrient indicator), and the most widely used index of water quality and nutrient status worldwide; **cyano-phycocyaning and cyano-phycoerythrin** (cyanobacteria biomass indicators, common in the proliferation of harmful and toxic algae); **dissolved organic matter** (an optically measurable compound of organic matter dissolved in the water column which sometimes is used as an organic matter index and aquatic carbon); and **total suspended matter and non-algal particles** (important to assess drinking water quality and control light in aquatic environments).

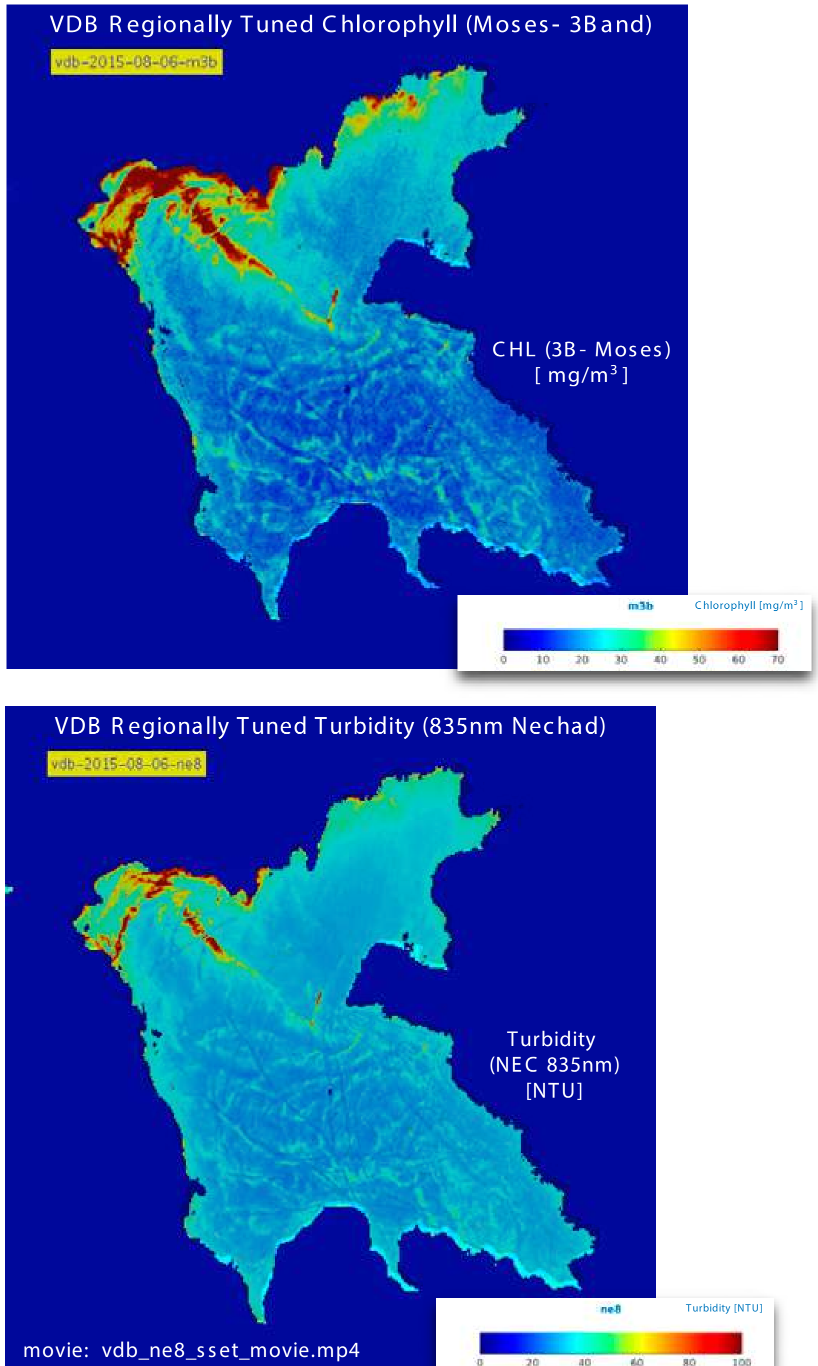
Direct applications for management include:

- Water quality monitoring to assess the impacts of watersheds management policies and land use practices on the environment and surface water. The spatial dimension of this monitoring capability is important for this application.
- Monitoring the probability of algal bloom and other water quality threatens for reservoirs and water supply systems.

Remote sensing techniques allow for a spatial and temporal view of surface water quality parameters and more effective and efficient monitoring of water bodies, quantifying water quality problems. **There are many other important parameters of water quality, such as pH, total nitrogen (TN), ammoniacal nitrogen (NH3-N), nitrate nitrogen (NO3-N), and dissolved phosphorus (DP), on which more knowledge and experience are needed**. The main reason is due to their optical characteristics (to be detected by satellites) which are weak and with a low noise-signal ratio. However, these parameters are an important part of water quality indexes, and their remote sensing is a challenging aspect of research in the field of water quality assessment.

This synthesis of water quality parameters measured through remote sensing summarizes the most commonly employed approaches to estimate the concentration of some key indicators associated with anthropogenic pollution of inland water bodies. **Figure 4.17** shows the image of a recent research (World Bank, 2018) on the use of remote sensors to monitor water quality (rainfall, flows, and groundwater) and water quality (chlorophyll-a and turbidity) for a major water supply reservoir in Mexico (Valle de Bravo, which supplies approximately 20% of Mexico City's water supply). There are also already examples of the development of global water quality databases from remote sensing measurements for indicators such as chlorophyll (**Figure 4.18**) and turbidity (**Figure 4.19**).

Figure 4.17. Water quality map of the Valle de Bravo reservoir (Mexico): chlorophyll-a and turbidity



Source: World Bank, 2018.

Figure 4.18: Regional Chlorophyll-a concentration map for LAC summarized from satellite observations

Source: UNESCO, https://www.eomap.com/world-water-quality/

Figure 4.19. Regional level turbidity map for LAC summarized from satellite observations

Source: UNESCO, https://www.eomap.com/world-water-quality/

In general terms, remote sensing as a measurement tool of the different water cycle compounds, together with GIS (Geographic Information System) techniques, used in combination with traditional field sampling (in situ), simulation models as those shown in Section IV.1, and large databases management techniques offers a significant material innovation opportunity on WS. **Currently, few water management decisions are based on measurements derived from remote sensing**. In most cases, decision makers and policy makers, without technical expertise, often lack the knowledge to understand the technical descriptions, capabilities and limitations of remote sensing techniques. Therefore, **there is a need to build capacity in operationalizing these advances in measurement science and technology in the water cycle. This should be a core activity in the knowledge production activities described in Chapter VI.**

V Water Security Strategy for Latin America and the Caribbean – *Sustainable Watersheds*

HIGHLIGHTS

- The management and improvement of water resources are fundamental for sustainable development and poverty reduction. **Development goals for countries cannot be conceived without sufficient water resources to drive them.**

- The IDB Group will work with national governments, private sector, environmental and civil society NGOs, universities, and other donors and development funders in the region, who will make a concerted effort to advance the strategic objectives that will enable the achievement of WS in the region.

- The **main strategic objective** is **to ensure the availability and sustainable management of water and sanitation for all.** From this main goal, **six specific strategic goals are derived.**

- **Strategic objective 1:** Achieve and sustain **drinking water supply** and the **provision of wastewater collection, treatment, and final disposal services** to 100% of the population.

- **Strategic objective 2:** Encourage the appropriate **development of legal and institutional frameworks** for the effective water resources management having as goal the WS, the management of associated risks, and the sustainable economic development.

- **Strategic objective 3:** Within the framework of the WS, **promote food security and the generation of renewable energy** based on the planning and development of **multi-purpose integral projects** that take into account the development needs, improvements, and security of water infrastructure.

- **Strategic objective 4:** Encourage the **recovery of water quality** and the creation of strategic water conservation for the WS.

- **Strategic objective 5: Modernize the mechanisms and methods for obtaining information** and for supporting decision-making for WS.

- **Strategic objective 6:** Foster the **development of knowledge and innovation** to guarantee the WS.

V. Water Security Strategy for Latin America and the Caribbean – *Sustainable Watersheds*

Water resources are essential for maintaining the planet's life and will also be the main means through which humans, ecosystems, and the countries' economies will experience the effects of climate change (Sadfoff and Muller, 2010). This inter-relationship among water resources, populations, ecosystems, and economy, make the water resources economics extremely complex. **Development objectives for countries cannot be conceived without sufficient water resources to drive them.** Economic growth and water resources availability are related and the impacts of hydroclimatic effects are more pronounced in poor countries with low water availability and/or agriculture-dependent economies. Countries with greater water availability or with a more diversified economy are more resilient (GWP/OECD, 2015). The World Bank's 2004 Water Resources Strategy highlights that **water resources management and development are fundamental to sustainable development and poverty reduction** (World Bank, 2004).

Regarding this, the IDB's Institutional Strategy for 2010-2015 and its subsequent updates[39] includes as strategic goals: (i) manage the needs of small and vulnerable countries, in particular Haiti, and (ii) promote the development through the private sector and the following five priority approaches: (1) social policy in favor of equity and productivity; (2) infrastructure for competitiveness and social welfare; (3) institutions to promote growth and social welfare; (4) international competitive integration at the regional and global levels, and (5) environment protection, response to climate change, promotion of renewable energy and increased food security.

39 The last update of the Institutional Strategy was sent to the Board for its approval in January 2019.

Therefore, we can state that the achievement of such goals is interconnected with the investment needs in efficient water resources management, and, more specifically in WS, as defined in Chapter I: "the capacity of a population to safeguard the sustainable access to adequate quantities of acceptable quality for sustaining livelihoods, human well-being, and socio-economic development for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water, 2013). We also know that investing in water security implies investing in infrastructure and governance and that not always large investments represent the solution. However, investments in efficiency improvement, as they had been performed in Australia and Los Angeles (USA), can represent an effective way to achieve WS. Australia opted to reduce losses in water distribution systems rather than invest in new storage dams by lowering investment expectations from US$1.370/megaliter to US$365/megaliter. Los Angeles saved US$1.216/megaliter in the construction of a desalinizing plant by investing only US$41/megaliter in efficiency improvement and recovery programs (Dickinson, 2018.

This chapter addresses the issue of WS for the LAC region from a strategic perspective. This strategy is called ***Water for the Future***. It presents **a mission, a vision**, and some **strategic goals** aimed to achieve a progress in the WS challenges identified in the diagnosis discussed in Chapter II, capitalize on the IDB's experience in the region (Chapter III), and benefit from the innovation opportunities presented in Chapter IV.

V.1 Mission and Vision

Institutional Mission

Since 2012, **IDB is the main multilateral lender for the public sector of Latin America and the Caribbean**[40]. This **competitive advantage**, together with the greater adoption by borrower countries and their background actions grant the **IDB a great potential to influence the design of policies and programs in the region**.

The IDB's institutional strategy recognizes that, "to respond to an **increasing demand** associated with **slower growth**, a **tighter fiscal stance** in the region and growing challenges to act countercyclically, IDB will need to focus on the **operations that are most effective,** increase emphasis on **resource mobilization** and **design tools that allow the greatest possible leverage of its existing capital**. An annual investment gap is estimated at US$170 billion and the multilateral development bank needs to look beyond traditional activities, especially considering the need to invest in measures to create resilience and a more robust institutional structure for managing disaster risk and climate-related hazards".

40 Annual Reports for World Bank, IDB and CAF.

The Institutional Strategy reinforces the **goal of climate resilience** in the IDB's approach and **provides the conditions for supporting countries in compliance with international climate change agreements (Paris Agreement) and specific and/or general national development plans**. The progress in this area includes: the financing of 30% of the IDB's combined approvals for 2020, the approval of the **Joint Action Plan for Climate Change (ASEAN),** and the creation of the ***NDC Invest***. The ASEAN establishes the connections with the directives of the Institutional Strategy by identifying how to make them more effective, operatively, with the perspective of climate change. In turn, the *NDC Invest* is aimed to support countries of the region to be able to transform their NDC into investment plans.

This broad framework of action by the IDB group creates opportunities, but does not warrant results, because it depends on the countries' demand for the proposed support and the availability of resources. For infrastructure alone, annual financing needs are around US$170 billion, while the total annual amount the IDB lends to countries is US$10 billion. Although the IDB's ability to leverage private resources is on the order of two to five times its contribution, it is not easy to visualize conclusive results of actions to achieve WS. In these circumstances, a new way to target the Bank's actions is necessary in order to be more effective and efficient. As water (either due to excess or defect) reflects the impacts of climate change and considering that the poorest countries are the most affected, **working from the WS perspective, taking into account the water-agriculture-energy-cities nexus, can optimize actions on climate change, sustainable infrastructure, water and sanitation, agriculture and environment, highlighting the role of strategic ecosystems, energy and urban development.** This strategy is aligned with the Institutional Strategy and there is empirical support to justify its implementation[41]. Thus, the Bank should include among its strategic objectives the support to countries to achieve WS, defining actions based on a comprehensive vision and knowledge of the relevant linkages in each case.

For infrastructure only, annual financial needs are estimated in about US$170.000 million

Vision

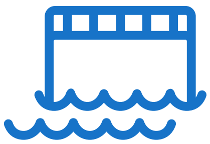
As stated in Chapter II, the LAC region has water sources that, if managed sustainably, would make it possible to achieve the WS (meeting the needs of its population, guaranteeing its sustainable economic development with equity and preserving the functions of basin ecosystems, protected by a legal and institutional framework that makes it possible to manage the risks associated with hydro-climatic extremes of droughts and floods).

In order to materialize this vision, it is necessary to:

- **Invest in drinking water supply and sanitation**, with a view to universal coverage of drinking water and sewage collection, treatment and reuse,

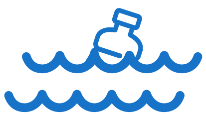
41 GWP/OECD. (2015). *Securing Water Sustaining Growth,* GWP/OECD Task Force on Water Security and Sustainable Growth.

using traditional and innovative solutions and taking into account that investing in improving the efficiency and recovery of existing systems represents a feasible alternative to the construction of new systems.



- **Invest in efficient infrastructure** to guarantee water needs and/or control excessive water. This infrastructure must be designed considering the existing nexus among water-agriculture-energy and its consequences in the national, sub-national, and basin plans for a sustainable economic development prepared taking into account aspects of climate change.

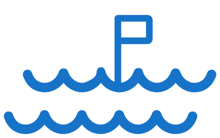
- **Modernization of water resources management** that includes a **legal framework** and the **creation of efficient and relevant institutions** to introduce the topic as a priority in the preparation of sustainable development plans of countries, especially the most vulnerable ones, and to allow the preparation, approval, and implementation of WS strategies at national, subnational, and basin level, including the corresponding drought and flood control plans.



- **Develop a pollution prevention agenda for solid waste disposal in water bodies,** in order to preserve the quality of the resource. This would facilitate the hydraulic management of the resource by minimizing the risk of interruption and interference in channels and drainage. This agenda should focus on three fundamental topics: (a) prevention of waste generation and specific components (for example, microplastics, and macroplastics), (b) adequate management of solid wastes, minimizing the entrance of wastes into watercourses through an adequate management including effective recycling, treatment, and an appropriate final disposal; and (c) capture and interception of solid waste in coastal basin areas, to prevent outflow pollution to basins and oceans.

- **Create the necessary knowledge on the operation of NbS**, including the functions of river flood plains, to increase the range of strategies for water quantity and quality conservation.

- **Develop financing models of water resources management** based on a national agreement that guarantees the sustainability of the institutions and the implemented management systems.



- **Creation of an adequate framework for the pacific discussion and the development of solutions for the shared use of transboundary waters**, thus contributing to WS and the sustainable development of the countries involved.

- **Support the development of knowledge in areas of science and technology** centered on information, data and predictive models of greater accuracy and reliability to support decision making in the socioeconomic sectors involved and affected by WS (water and sanitation, agriculture, energy...).

V.2 Strategic Objectives

To advance with the proposed vision, **the IDB Group will work with national governments, private sector, environmental NGOs and civil society, universities, and other donors and development funders in the region.** This joint effort will drive the implementation of strategic objectives that will form the foundations and supports necessary to achieve the WS at the national, regional and local levels.

The selected strategic objectives are aligned with the SDG 6 (Clean water and sanitation).

Thus, the **main strategic objective** is **to ensure, for 2030, the availability of water and its sustainable management and sanitation for all.** More specific objectives are:

- Attain universal and fair access to drinking water, at an affordable price for everyone.
- Attain equitable access to adequate sanitation and hygiene for everyone and finish with the open defecation, with special attention to the needs of women and girls, as well as those in vulnerable situations.
- Improve water quality by reducing pollution, eliminating dumping and minimizing the discharge of hazardous materials (macro and micro materials) and chemicals. This includes a solid waste strategy that encourages prevention (e.g., eliminating microplastics in everyday consumer products), proper waste management-recycling, treatment and proper disposal, as well as interception (capture of materials in coastal areas to prevent their transfer to larger systems), halving the percentage of untreated wastewater, and substantially increasing recycling and safe reuse globally.
- Significantly increase the efficient use of water resources in all sectors and ensure the sustainability of freshwater abstraction and supply to address scarcity, significantly reducing the number of people suffering from water scarcity.
- Implement the integrated management of water resources at all levels, even by means of transboundary cooperation, as applicable.
- By 2022, protect and restore water-related ecosystems, including forests, mountains, wetlands, rivers, aquifers and lakes.
- Extend the international cooperation and support to developing countries for training in water and sanitation activities and programs, including water harvesting and storage, desalination, water efficiency, wastewater treatment, and recycling and reuse technologies.
- Support and strengthen the participation of local communities in the improvement of water management and sanitation.

A series of more specific strategic objectives can be derived from this main strategic objective, which are described below.

Strategic Objective 1

Achieve and sustain the drinking water supply and the provision of sewage collection, treatment, and final disposal of wastewater in 100% of population.

In Chapter II an extensive discussion on the coverage of water and sanitation services in the Latin American region, which is summarized in **Table 5.1**.

Table 5.1. Coverage levels of water and sanitation services in LAC

Type of coverage[42]	%	Unserved population (in millions)	Agenda Objective 2030 (in %)
Drinking water coverage (average)	95	-	-
Safe water coverage	68	198	100
Sanitary services coverage (average)	68		
Real coverage of sanitary services	22	457	100

The effects and the impact of the lack and/or deficiency of drinking water supply, as well as the lack of adequate sanitary services, on health, productivity, national GDP and education are well documented in the literature. The Water and Sanitation Sector Framework of the Water and Sanitation Division of the IDB provides an extensive review of this topic[43], which has also been the subject of a joint review by the Global Water Partnership (GWP) and the OECD44, presenting results of specific studies for several countries. These documents highlight the positive impact of the provision of adequate water and sanitation services to women and girls, which affirms dignity, improves access to education and the labor market, and contributes to the reduction of gender-based violence.

Performance indicators

Some performance indicators of the proper implementation of this goal could be:

- **124 million people** connected to safe water supply systems and **196 million** people connected to adequate sewage collection and treatment systems.

42The WHO/UNICEF *Joint Monitoring Programme*, which mentions the WS Sector Framework, estimates that, at the regional level, the coverage of households with treated wastewater is around 22% on average, with a very high variation between countries (Chile, where it exceeds 80%; Uruguay, with 45%; Mexico; with 37%; Brazil, with 27%; Peru, with 23%, and countries such as Ecuador, Bolivia, Colombia and Trinidad and Tobago where these values range between 10% and 20%.

43 Inter-American Development Bank (2017). Water and Sanitation Sector Framework Document. Water and Sanitation Division.

44 GWP/OECD (2015). *Securing Water Sustaining Growth.* Report of the GWP/OECD Task Force on Water Security and Sustainable Growth.

- **9.000 tons of BOD5** (Biological Oxygen Demand) are not discharged daily into the region's waterways.
- **50% increase** in the **availability of public and private financial resources** to finance the expansion of water and sanitary services.

What actions should be undertaken to achieve this objective?
Considering the IDB's experience in the water and sanitation sector, the following actions are included:

- In the first instance, prioritize countries with lower coverage with water and sanitation and urban drainage services: Bolivia, El Salvador, Guatemala, Haiti, Nicaragua, Peru and Dominican Republic. In a second stage, work with small cities in countries such as Brazil, through loans to the States. In Brazil, for example, 32% of the population lives in municipalities with less than 50,000 inhabitants45, which are not prioritized by the government to receive IDB loans.
- Work at the priority basin level by incorporating water, sanitation and drainage master plans into integrated basin and/or WS management plans.
- Encourage recovery, reduction of losses, efficiency improvement and reuse as opposed to the construction of new water, sanitation and drainage systems.
- Include in the loans to the Water and Sanitation Utilities (WSU) the preparation of WS and physical security plans for the facilities, a matter of great relevance in the current moment of climate change and growth of exogenous risks to the sector (ASCE/AWWA, 2006). Likewise, it is also urgent to support WSUs to participate in financing the protection of water-producing basins and to incorporate the industrial concept in their water production process, protecting their basic input, optimizing their process, treating their waste and recycling as much as possible, always taking into account the needs of the ecosystems involved and the services they provide.
- Support WSUs to develop effective communication plans to ensure that both the actors involved in the process and the general population assume and internalize that climate change is a reality and that water security is built with the participation and responsibility of all.
- Support countries to create the conditions that encourage the participation of the private sector in the provision of water and sanitary services. This work involves the IDB Group's private sector and should be preceded by an effort of communication and exchange of experiences with other countries, sponsored by several multilateral organizations in addition to the IDB, to disseminate the lessons learned and the importance of private sector involvement, without which it will not be possible to achieve the desired objectives.

45 Agência Nacional de Águas-ANA. (2010). *Atlas Brasil: Panorama Nacional-Volume 1, Abastecimento Urbano de Água.*

- Make alliances with donors (the IDB already works with funds from several countries, but more resources need to be raised) and other multilaterals to focus actions in the critical areas identified in this study and, consequently, maximize positive impacts within the established timeframe.

Strategic Objective 2

Encourage the development of appropriate legal and institutional frameworks for the effective management of water resources with the goal of WS, the management of associated risks and sustainable economic development.

As seen in Chapter II, the region lacks a regulatory framework for WS as such. It is currently a regime that must be built and composed from different regulatory frameworks or sectoral legislations that converge in certain aspects such as water, energy, environment, land use planning, drinking water and sanitation, risks, emergency, defense, etc. We also recognize that WS depends on the water demand and the effectiveness of the governance model, which makes it necessary to include a series of additional elements to the conventional management of water resources that are normally considered separately. The conditions, institutional arrangements or best practices to be incorporated in a WS public policy can be schematized around five axes that are concatenated in the complete design of that public policy (planning, regulations, institutional framework, economics and instruments and international basins) and which have already been discussed in Section 3 of Chapter IV of this report (Opportunities for Innovation within the Institutional Framework in Water Security).

The economic growth of the countries in the region will benefit from a robust water resources management system that guarantees WS. There are World Bank estimates for 2050 that indicate that water pollution, growing demand and scarcity of springs could reduce the expected economic growth of some regions by about 6% of the GDP and that, in some countries, this reduction could be as high as 15%[46].

Performance indicators

Possible performance indicators for the adequate implementation of this objective, until 2030, would be:

- **All countries** in the region have **policies, legislation and institutional structure** at local and national level for integrated management of water resources and promotion of WS.
- **All countries** in the region have developed **national, sub-national and basin-level WS plans** covered by specific legislation and executed with adequately equipped institutions and guaranteed sources of resources.

46 World Bank Group, ¨High and Dry: Climate Change, Water and the Economy, 2016.

- **15 transboundary basins and aquifers** in the region that have **multilateral or specific treaties.**

What actions are recommended to develop legal and institutional frameworks?

From the legal point of view, the guidelines for the implementation of this objective are developed in Chapter II and Chapter IV (Section 3). Taking into account some IDB experiences with institutional modernization in the region, it is recommended:

- Promote the adoption of water legislation in those countries that do not yet have it and in those that, even if they have it, it is old and does not include the elements of planning, social participation, economic-financial regime and other contents recommended in this report.

- Promote a broad discussion with all levels of government to demonstrate the relationship between water resource use and valuation and the outcomes of government economic development plans in a climate change context. This could be done through courses and seminars based on the results of specific studies for the selected country. It is also recommended to use results and conclusions of studies such as water-agriculture-energy nexus and/or environmental accounting systems for water to support the development of appropriate management policies and to demonstrate how hydroclimatic risks can affect economic growth expectations. This debate should start in the countries of areas with the greatest impact predicted by hydroclimatic models (**Figures 2, 3 and 4**): Amazon basin, northern Mexico, northwestern Brazil, the Caribbean and Central America.

- Develop specific communication plans aimed at key stakeholders and the population in general, to achieve their effective participation in plans and programs related to WS. It is important to understand that the pursuit of WS is a new reality that affects everyone and requires everyone's efforts to achieve it. These plans should incorporate a comprehensive view of the situation that includes cultural variables, historical traditions, specific economic and social situations, individual and collective perspectives, and the physical environment.

- Carry out pilot experiences in at least three countries on the list of areas most vulnerable to hydroclimatic phenomena.

- Encourage coordination between countries to jointly plan the use of transboundary waters, strengthening existing institutions, or creating new ones, and the necessary mechanisms for this purpose.

- Use the WS as an instrument for rapprochement and strengthening dialogue between countries.

Strategic Objective 3

Within the WS framework, promoting food security and renewable energy generation through the planning and development of comprehensive multipurpose projects that address water infrastructure development, improvement and security needs.

Sectoral objectives vs. multipurpose perspective

Traditionally, the construction of dams to store water has had sectoral objectives: control seasonal floods, supply irrigation structures for food production, supply water to cities and towns, or generate energy for various uses. Some projects include a multipurpose perspective, storing water for human consumption and irrigation (Multipurpose drinking water and irrigation program for the municipalities of Batallas, Pucarani and El Alto) and others include energy generation and other uses such as population supply, irrigation, recreation and environmental conservation (Hoover Dam in the United States).

Positive vs. negative aspects

The construction of dams has positive impacts for the WS, such as storing water for periods of drought and flood control, producing energy and maintaining minimum flows in watercourses; but they can also displace people from their homes, change the ecology of watercourses from lotic to lentic environments[47],reduce the extension of important flood plains, which in many cases shelter marginal lagoons (which contribute to the repopulation of the fauna existing in the watercourses), and generate evaporation losses from their artificial lakes. However, population growth, both regionally and globally, implies an increase in the demand for food and energy to drive and sustain the economy of the countries. These increases point to the need to increase water sources (in those cases where physical-climatic conditions permit) or to greater water regulation, either through the implementation of new reservoirs, the rehabilitation of those in use or the use of NbS such as those described in Chapter IV.

In 2010, LAC contributed 18% of trade in agricultural raw materials and 12% of food products in the world

Regarding agriculture and food production, some estimates indicate that, in 2010, LAC contributed 18% of the world's trade in agricultural raw materials and 12% of food products. Among the countries to which it exports are China, Israel, Japan, most countries of the European Union and the entire Middle East and North Africa region. FAO estimates indicate that some four million hectares could be incorporated into new irrigation systems in Argentina, Brazil, Chile, Mexico, Peru, Colombia and Bolivia and that, due to their age, between eight and ten million hectares are in need of rehabilitation in Argentina, Brazil, Chile, Mexico and Peru. These trends suggest higher water consumption which, in this sector, already represents more than 70% of total demand.

47 A lotic environment refers to the ecosystem of a river or stream where water flows towards a direction. They contrast with lentic ecosystems in the fact that the water are visibly stagnant, such as lakes or ponds.

The use of hydropower in Latin America is an important component of the energy matrix, accounting for almost 100% in Costa Rica, followed by Brazil (where it accounts for around 80% of demand) and Ecuador, Peru and Colombia (where it accounts for more than 70%) (Tundisi et al. 2014). To meet the growing energy demand, it is estimated that, by 2030, 26 large dams located in Brazil, Argentina, Colombia, Mexico, Peru and Venezuela could be rehabilitated to generate 55,765 MW at a cost of US$70 billion, as well as other smaller dams, raising the rehabilitated potential to 60,684 MW, at a cost of US$130 billion. Additionally, it is estimated that the construction of new dams could add 35,640 MW at a cost of US$198 billion. On the other hand, more ambitiously, more than 150 large dams are planned for the next 20 years on six of the eight major tributaries of the Amazon, which would produce a 300% increase in electricity generation (Finer and Jenkins, 2012 and Anderson et al., 2018). In Brazil, the Amazon basin is seen as the "new hydropower frontier" where 100 dams are operational and 137 additional ones are planned (Tundisi et al., 2014, Da Silva Soito and Freitas, 2011).

Along with the construction and rehabilitation of dams and taking into account the consequences of a possible breakage (especially of structures with years of operation[48]), it is essential to include in this strategic objective the review and analysis of the safety of the dams attached to the hydropower development. It is also necessary to have a legal framework on dam safety and to have operating rules that include i) surveillance and control protocols, ii) conservation and maintenance protocols, and iii) protocols for the operation itself, in normal situations and in floods, with the establishment of seasonal safeguards and warning protocols. In view of the risk of potential rupture, the drafting of an Emergency Plan should be proposed which, activated from the Operating Rules, would establish the indicators, thresholds and states of emergency, with an entire protocol for alerting the populations that could be affected and communication to the regional and civil protection authorities.

Performance indicators

Some possible outcome indicators of the proper implementation of this objective would be:

- Based on hydroclimatological studies that consider the water-agriculture nexus, the search for efficiency and the WS, by 2030, 30% of food production will be incorporated into the harvest of Brazil, Chile, Mexico, Peru, Colombia and Bolivia, through the rehabilitation of ten million hectares of irrigation projects. Four million new irrigation projects will also be incorporated into the productive system of these countries, taking into account the impacts of climate change on local hydrological cycles.

48 For example, the impact of the collapse of two dams in Vale do Rio Doce (Mariana, in 2015 and Brumadinho, in January 2019) caused the death of more than 100 people and millions of dollars in losses. The entire extension of the Doce River and an important area of beaches in the State of Espirito Santo were contaminated in 2015 and about 40 kilometers of the Paraopeba River in 2019.

- By 2030, 154,089 MW of energy will have been added to the potential produced in Latin America, through the rehabilitation of 26 large hydroelectric dams; several smaller ones (with a recoverable potential of 60,684 MW) and the construction of new units (with a potential of 35,640 MW).
- By 2030, all Latin American countries will have specific legislation and protocols for managing their dams.

Strategic Objective 4

Encourage the recovery of water quality and the creation of strategic water conservation for WS.

With few exceptions, most urban rivers in the region are extremely polluted

Extremely polluted urban rivers

The contamination of surface water and aquifers, mainly in urban and peri-urban environments, is part of the reality of the LAC population. With few exceptions, most urban rivers in the region are extremely polluted. Examples are constant and can be found every day in the literature and media: Tiete, in São Paulo; Bogotá, in Bogotá; Matanza-Riachuelo and Reconquista, in Buenos Aires; Guaire, in Caracas; CaGDParibe, in Recife or Rimac, in Lima. In Mexico, according to CONAGUA, six of its ten rivers are polluted[49]. These include: the Balsas, Santiago, Pánuco, Grijalva, Papaloapan, Coatzacoalcos and Tonabá. In Chile, the Maipo, Biobío, Elqui and Loa river basins; in Colombia, the Cauca and Magdalena river basins; in Paraguay, Lake Ypacarai and the Paraná and Paraguay rivers; in Venezuela, the Murillo river; in Peru, the Ucayali river; and in Costa Rica, the Tarcoles and Virilla river basins. Likewise, the Ministry of the Environment and Natural Resources in El Salvador has catalogued 20% of its river basins as being in poor environmental condition, with indicators of contamination by organic discharges and pathogenic organisms[50]. Similar information is available for other countries and/or regions. For example, the Atlas de Esgotos of the Brazilian National Water Agency indicates that 110,000 km of Brazilian rivers are polluted by organic matter coming mainly from by-products of urban activity (www.ana.gov.br).

To pollution of domestic origin must be added: i) industrial discharges which, in addition to organic matter, include toxic substances and heavy metals in their effluents; ii) return flows from irrigation projects, with their high salt loads and pollution from mining activity, which includes mining environmental liabilities[51] and are very common in Peru, Brazil, Chile and Bolivia. For

49 CONAGUA, "Atlas de Agua", 2016.

50 MARN. (2014). *Informe de la calidad de las aguas de los ríos de El Salvador 2012-2013.* Ministerio de Medio Ambiente y Recursos Naturales (MARN), El Salvador.

51 Peruvian legislation defines mining environmental liabilities as those facilities, effluents, emissions, remains or waste deposits produced by mining operations that are currently abandoned or inactive, and which constitute a permanent and potential risk to the health of the population, the surrounding ecosystem and property. http://www.legislacionambientalspda.org.pe/index.php?option=com_content&view=article&id=387&Itemid=3724

example, the aforementioned rupture of the Brazilian dams in Mariana (2015) and Brumadinho (2019) involve old liabilities once the effluents from the mining process are stored in specific dams and often there are no plans for their recovery.

Working with the private sector

The IDB, through its public sector window, has granted loans for the decontamination of water courses, mainly urban, with diverse executors and varying levels of success. Projects have been executed with sanitation utilities (Tiete Project, executed by SABESP in São Paulo, Brazil), provincial agencies (Reconquista in Buenos Aires, Argentina) and central governments (PROSAMIM in Manaus, Brazil). Sanitation works (sewage networks, wastewater treatment plants...), flood control, and institutional strengthening are also implemented. But regarding industrial pollution control, little is implemented. Public enforcement units do not have jurisdiction over private sector industries and national and local systems of enforcement of specific legislation are weak. As a result, the industrial pollution control component remains unimplemented or is implemented only in part (this is the case of the Reconquista River Project in Argentina, which is in its second phase and the total number of polluting industries in the basin is unknown). **The decontamination of urban rivers cannot be achieved without controlling industrial effluents, urban drainage flows and clandestine solid waste dumping. Therefore, to achieve this objective, it is necessary to rethink the design of operations and, perhaps, to work together with the private sector of the IDB group.** In addition, to control industrial pollution, financial resources are needed that are not always available and cannot be allocated from the IDB's public sector. A promising strategy, in this sense, includes working on a basin basis and simultaneous control of all effluent sources related to public administration (sewage, urban drainage and solid waste), as well as coordination with the IDB private sector and government programs to control industrial effluents. The implementation of the public sector components may become a form of "pressure" and/or motivation for industrialists to join the project objectives.

A promising strategy to control industrial effluents is coordination with the IDB's private sector and with government programs

Investing in monitoring and simulation models

Indeed, any water security strategy must start by protecting water-producing basins in good condition and recovering the quality of polluted rivers and/or basins. Ensuring WS is absolutely incompatible with having polluted rivers or basins. They are opposing efforts. **To recover water quality it is necessary to invest in water quality monitoring[52] and simulation models under different scenarios, including the effects of climate change, and in support structures such as laboratories and instruments to process the information generated and disseminate it through a freely accessible information system.** It is especially important to monitor the excess of nutrients in the water, which intensifies eutrophication phenomena and the risk of cyanobacteria

52 This topic will be discussed in a specific strategic objective for the monitoring and the generation of information for decision making.

emergence (even more so in the context of climate change). Given that the costs of extracting these nutrients are higher than those associated with preventing their discharge into water bodies, it is recommended that, together with monitoring, investments be made to improve the technology of phosphorus and nitrogen use in agriculture, minimizing their presence in the surface runoff. An example of this can be direct injection into plant roots (Daverede et al., 2004; Jarvis et al., 1996).

Strategic Water Funds and Conservation

Experiences with the creation of strategic water conservation, either through Water Funds or programs such as the Mexican (Strategic Water Reserves) or Brazilian (Water Producers), are described in chapters II, III and IV. Specifically, chapter III presents an evaluation of the water funds, highlighting their strengths, their importance and some needs for strengthening.

What can be done to recover water quality?

It is concluded that this is a program that should be perfected and expanded complementary to a strategic water reserve program with a clear financial sustainability. In this sense it is proposed to:

- Continue **supporting the creation of Water Funds** and encourage the development of studies and models that demonstrate their effectiveness, with robust indicators that reflect the improvements proposed, as well as the attraction of new resources to consolidate their financial sustainability.
- Encourage countries to **create national strategic water reserve programs** taking into account the achievement of WS and climate change.
- **Facilitate horizontal and north-south dissemination of experiences** with the creation of strategic water reserves with a focus on water security in the context of climate change.
- **Encourage comprehensive programs for decontamination of strategic basins**, including opportunities for private initiative participation (e.g. incentives for industries to treat their effluents with negotiation of realistic goals to implement control actions).
- Support the **inclusion of integrated basin decontamination programs in national, regional and local WS plans.**
- Support the **incorporation of urban basins in territorial planning,** taking into account the functions of ecosystems in flood control and maintenance of water quality.
- Create an award system for the cleanest urban rivers in LAC that includes citizen participation.
- Encourage the development of **communication programs** that link the basins decontamination with the achievement of WS.

- Encourage the **expansion of water quality monitoring networks** including the use of **remote sensing** systems linked to geographic information systems and database management techniques.

- Support the **implementation of trained and certified laboratories** to perform water quality analysis in strategic countries and basins.

- **Develop and disseminate water quality modeling technology,** real-time monitoring, water quality control plans from source to tap, and information management.

Performance indicators
Some possible performance indicators of the proper implementation of this objective would be:

- By 2030, the recovery of water-producing basins has increased in an area of 30,000 hectares through the creation of strategic water reserves in 10 countries within the framework of the national WS plans.
- By 2030, the water quality of 100,000 km of rivers in strategic basins in the countries has been restored to levels compatible with conventional treatment.
- By 2030, 10 cities have been awarded for restoring the quality of their rivers to unpolluted quality levels.

Strategic Objective 5
Access to data, information and decision-support tools for WS.

The effective management of water resources requires reliable information and data, supporting mathematical models and human and financial resources

Need for reliable information
Effective management of water resources requires reliable information and data, supporting mathematical models, and human and financial resources. This demand for reliable information is even more critical under the WS approach and the influence of climate change, when the risks associated with extreme events are greater.

Several countries in the region (Argentina, Brazil, Colombia, Peru and others) have advanced in the expansion and modernization of their data information networks, mainly those related to water quantity. However, in IDB-country dialogues, requests for support to expand the network and operate hydroclimatic stations are common (Peru's water resources modernization program) and requests for support for the implementation of data processing equipment and short, medium and long term forecasts are not uncommon (support to the International Center for Research on El Niño Phenomenon-CIIFEN located in Guayaquil, Ecuador). However, the maintenance of fixed stations is financed by governments, which, depending on their changing priorities, often allow them to deteriorate, compromising the quality of the information generated.

In this context, adding the responsibilities inherent to a commitment to WS, it is necessary **to develop instruments for monitoring, in situ and via remote sensing, the basin, aquifers and aquatic ecosystems.** Although, as mentioned above, progress has been made, especially in rainfall, gauging and piezometry networks[53], the density of the network of water quality measurement stations is below what is desirable. There is also a very important knowledge gap to be filled. It is therefore essential to promote the use of techniques for data analysis and fusion so that, in addition to detecting deficiencies, it will be possible to prioritize projects for the improvement and extension of existing networks, including variables such as their valuation, method of financing, etc. In this way, in the medium term, it will be possible to have reliable stations and data.

All this implies making investments in knowledge, not only in monitoring but also in data analysis, and the support to implement: (i) a network of surface water gauging stations; (ii) a network of piezometry in aquifers; (iii) a network of surface water quality control stations; (iv) a groundwater quality control network,; (v) a climatological network (rainfall, temperature, evaporation and wind); (vi) a discharge control network. All these networks should include databases of in situ measurements and remote sensing measurements. It is also necessary to have a digitized mapping of the river network that allows flood studies and on which the digitized mapping of flood-prone areas can be based. Finally, it is important to have geospatial products of socioeconomic and ecological information to complement the databases for these monitoring networks.

Hydrological, climatological, water quality (self-purification of watercourses, transport of nutrients and pollutants in water and soil), basin management and optimization models are used to support decision making for the selection of suitable alternatives for specific projects. Under the WS approach, the demand for models that simulate extreme weather events and that can be validated or calibrated relatively easily and practically is growing significantly. The need to create interfaces between information gathering systems and the corresponding models is also growing. **The IDB has a great opportunity for innovation in the area of simulation models that support decision-making processes in problems and projects related to WS in the region.**

In fact, the successful experience with the development of HydroBID since 2011 and its application since 2014[54], has motivated the expansion of the experience and HydroBID-Flood has been developed to support urban drainage, flooding and water infrastructure design projects. HydroBID simulates the surface and groundwater water balance and includes a climate *"downscaling"* model,

53 Piezometry is the part of hydrology that studies methods for determining the amount of (ground) water existing at a site above an impermeable layer of a terrain.

54 The HydroBID model is currently applied in more than a dozen countries.

however, it does not yet include other WS components such as water quality, ecosystem services, aquifer hydraulics (under development), droughts, floods (HydroBID Flood), irrigation programs, energy sector demands and other components.

Due to its extensive experience and penetration in LAC, the IDB can support its clients with the development of state-of-the-art tools to support decision making at national, regional, state and municipal/local levels. Furthermore, the different aspects of WS could be covered complementarily by a series of integrated models. In this way, a line of support can be structured in the hydrological part (HydroBID), with nexus cross-sector planning models (GCAM-LAC), ecosystem services models, urban, demographic, socioeconomic models or any other necessary component (using existing models or developing IDB's own tools); all of them developed in an evolutionary manner and with a permanent interaction with the potential users of these models (government agencies, universities, research institutes, NGOs and others).

To promote the movement towards WS in the region, it is important to create a demand for related projects and actions

Catalyze demand through "Economic-Environmental Water Accounts"
To encourage the movement towards WS in the region, in a context where economic and social goals are seen as priority, it is important to create in LAC's countries a demand for projects and related actions. Such demand can be encouraged through demonstrations of the economic value of WS and its link with economic and social goals. This is a field open to the Bank's contribution, either through the development of "Economic-Environmental Water Accounts" or the development of economic models that link the national accounts with strategic supplies such as water, under multiple plausible climate change scenarios.

Performance indicators
Some potential performance indicators of the proper implementation of this goal would be:

- By 2030, **WS-related decisions are made** based on reliable information and on the use of specific models developed with the support of IDB (especially in strategic basins of countries with more vulnerability to climate change).
- By 2030, 20 countries of the region make WS-related decisions using models developed with IDB support.
- By 2030, hydro climatological information created by all LAC countries meets the requirements of the World Meteorological Organization (WMO) and is disseminated for public use.
- By 2030, all the LAC countries have adequate information on water quality (surface and groundwater) and use it on decontamination actions for rivers and the preservation of water sources.

The development of models for making decisions related to WS is due to specific demands from the countries and/or to the perception of their need by IDB teams (HydroBID case) and constant interactions with counterparts. In order to modernize the monitoring and information processing systems, an IDB loan operation is necessary (due to the amount of resources required). These resources are included in loans to the sanitation sector or for basin management. When included in loans to sanitation companies, the implementation of monitoring systems is executed by the corresponding sector and a transfer of resources is necessary, which is not always easy. On the other hand, financing for basin management is low in amount and complex to execute; therefore, it is not very attractive to the IDB. A possible solution would be to develop integrated basin decontamination projects, which could include several cities with several infrastructure works with important synergies that would allow the implementation of monitoring systems and the development of management systems, WS plans, drought plans and flood control plans. The executors could be the states or the governing body of the water resources and/or environment sector.

Strategic Objective 6
Promote the development of knowledge and innovation to enhance WS.

To face the challenge of WS, it is necessary **to be open to new areas of knowledge** and undertake a **constant innovation involving technical, ethical, conceptual, and communicational aspects**. Knowledge needs are manifested throughout the water resources management chain, which includes the protection of strategic reserves, the provision of drinking water, the gathering of information, and the development of instruments for decision-making and action plans to face critical situations of drought and flooding.

The Water and Sanitation Division's Sector Framework includes some innovation topics selected as important for the water and sanitation sector, such as SWIFT (*Sustainable Water Initiative For Tomorrow*) technologies to reduce unaccounted-for water and social and gender issues.

The innovative approach to integrated water cycle management
In this strategy, the innovative approach proposed to solve WS problems in the region is based on the core concept of water cycle management (versus the management based on the allocation of the available water resources among various sectors).

This management concept contributes to i) the incorporation of integrated water demand for various uses explicitly in effective WS management, within the framework of climate change and cross-sector planning (nexus); ii) combinations of gray and green infrastructure that provide greater efficiency, reliability and cost-effectiveness to the provision of water and sanitation services emphasizing NbS; iii) the modernization of the institutional framework to embrace the WS approach by adapting policy and decision-making spaces and their integration with the management of other natural resources (e.g., nexus with energy, agriculture, water and sanitation); iv) the modernization of the institutional framework to accommodate the WS approach by adapting the policy and decision-making spaces and their integration with the management of other natural resources (e.g., nexus with energy, agriculture, water and sanitation); and v) the integration of water and sanitation services with the management of other natural resources. (e.g., linkage with energy, agriculture, biodiversity or climate change, among others); and iv) investing in knowledge and implementation of new concepts and advances in WS.

The use of the nexus concept in multisectoral planning offers innovation opportunities by linking WS with energy security and food security, two target areas of intense activity by the IDB and the countries of the region. In practice, this translates, for example, into multisectoral investments (such as multi-purpose reservoirs, which include elements of natural infrastructure -NbS- and climate change projections for to strengthen the designed systems and facilitate their climate resilience and sustainability). **The experience shows that when considering the water-energy-food nexus in water demand studies, unquantified demands can be detected in sectoral studies; these differences can reach 35% in some cases** (Miralles-Willhem and Muñoz Castillo, 2018). These efforts should be continued and refined due to their potential to optimize programs and projects that include infrastructure and specific policy development.

Combine gray and green infrastructure

An innovative approach on WS needs solutions that combine built (gray) and natural (green) infrastructure that can reduce vulnerability and increase the resilience and reliability of water supply systems for various uses. The issue of infrastructure cannot be dissociated from the environmental issue if the goal is an efficient and sustainable management of water cycle. Due to the great "natural capital" that exists throughout the LAC region, this combination of built and green infrastructure constitutes a major axis of innovation in WS for the region. Therefore, a water cycle management approach that combines traditional water infrastructure with natural capital (NbS) is proposed. To this end, it is necessary to evaluate experiences in the use of NbS in terms of i) management and protection of springs; ii) water provision and sanitation; iii) irrigation systems for food production; iv) hydropower generation; and v) protection and prevention of water-related disaster risks.

The creation of strategic water conservation and Water Funds (www.water-funds.org) are examples of protection of springs and/or water sources that are well accepted in the region. The use of urban river flood plains as linear parks has not only incorporated these rivers into urban planning but has also contributed to flood control (as in the case of the aforementioned PROSAMIM project in Manaus). The range of opportunities offered by working with ecosystems to achieve WS objectives is wide and extends to i) the management of wetlands in the Andean Puna, ii) the use of flood plains for flood control that also contribute to maintaining the productivity of the river ecosystem, iii) the maintenance of ecological flows and the flow of water that contribute to reservoirs, which contribute to the generation of hydroelectricity and/or irrigation. In this sense, it is important to evaluate existing experiences and assess their scalability for replication in other regions. It is also essential to review the lessons learned with the use of NbS in the treatment of water supply and wastewater for pollutant removal and possible reuse.

Improve knowledge on NbS

Considering that NbS are specific for each ecosystem, there is a lot of work to identify areas with potential to develop NbS and their correlation with real needs for drought control, flood control and watershed protection in the framework of the WS. In an important effort to provide countries with solutions and tools to address the goals of the Paris Agreement, literature already exists with guidance for initiating the use of NbS[55]. The improvement of these instruments and their use, in the framework of expanding knowledge on the impact of the functioning of specific ecosystems on climate change is part of this WS strategy and of the future actions of the IDB Group.

Encourage an institutional change

In face of this challenge, another greater emerges, represented by the need for an institutional change including policies, laws, and management of water resources. IDB and World Bank analyses recognize that, in the region, policies and an institutional framework characteristic of an era of water surplus are still being used when we are entering an era of scarcity. In this context, actions such as prioritizing engineering solutions, treating water as a no-cost good, and bureaucratic water allocation and management are inconsistent with today's reality. Moreover, because of the important linkages that water has with the rest of the economy, the analysis of water-related problems can no longer be confined to a specific sector (Saleth and Dinar, 2004). As we identified in chapter IV, this change includes crucial institutional issues related to legal, political and administrative aspects of water resources development and management. It is well known in institutional economics that change occurs only when the transactional cost of reform is less than the opportunity cost of doing nothing (Saleth and Dinar, 2004).

In a context where different stakeholders are joining water management (NGOs, civil society, native populations...), it is at the institutional level that

55 World Bank. (2019). *Integrating Green and Gray: Creating Next Generation Infrastructure and World Bank*. (2017). Implementing Nature Based Flood Protection: Principles and Implementation Guidance¨.

greater creativity and innovation are required to achieve WS. In order to make effective and harmonious changes with the new reality in water management, it will be necessary to carry out a "surgical" procedure of situational diagnosis and to convince and involve the stakeholders to become the drivers of the mechanisms that represent this new collective knowledge. And all this through a powerful process of public participation. It is important to understand the institutional links in each country and how they are mobilized in the face of needs for change in water management. This is a challenge that requires a conviction of the need for change at the highest levels of the country's administration, as well as the participation of highly specialized technicians in institutional change.

It is intended to prioritize the countries and basins most vulnerable to climate change (Brazil, Mexico, Peru, Chile, and some areas of Central America and the Caribbean)[56] to develop pilot projects and test innovative solutions using NbS for: i) controlling floods, ii) establishing ecological streams, iii) protecting water sources, and iv) performing an analysis of the institutions responsible for water management to propose strategies for transformation.

Performance indicators

Some possible outcome indicators of proper implementation of this objective would be:

- By 2023, the IDB will have developed specific guidelines for the assessment of ecosystems that could be used as green infrastructure in strategic watersheds, in relation to WS and climate change.

- By 2030, three countries would have implemented NbS in some of the aforementioned areas; these NbS will be based on the guidelines developed by the IDB and their methodology will be widely disseminated in the region.

- By 2023, IDB would have developed **a specific methodology** for institutional change to evaluate the institutions involved in water management. This methodology will generate quantitative information for decision makers and will take into account linkages with other institutions in the country.

- By 2030, the methodology for the promotion of the institutional change will be implemented in three countries and widely spread in the region.

56 See Chapter II-1.

VI Water for the Future - *2020-2030 Work Plan*

HIGHLIGHTS

- To respond to the proposed strategic objectives, a work plan has been designed, **Water for the Future**, which can be initiated and executed by the IDB in the next 10 years.

- This plan has been conceived to operationalize an WS investment program and propose a portfolio of technical cooperation activities for IDB donors. It consists of **a series of multisectoral investment programs** integrating **political activities, infrastructure (gray and green), knowledge and capacity building activities** to "seed" the WS concept in the countries of the region.

- **Integrated investment programs** focus on the development of national WS plans (Program 1), WS urban plan (Program 2), irrigation subsector plan (Program 3), consolidation and improvement of hydropower generation (Program 4), and transboundary basins (Program 5).

- **Knowledge programs** are centered on Nature-based solutions (Program 6), studies on droughts (Program 7) and floods (Program 8), the definition of the regime of ecological streams (Program 9), consolidation and improvement of field monitoring and remote sensing networks (Program 10) and the development of simulation models and support for decision making (Program 11).

- Investment programs proposed in this WS work plan will have measurable positive impacts in the region in terms of sustainable development, with **short-term visible benefits.**

- This plan must consider the **degree of uncertainty surrounding the WS** (due to the hydrological variability, climate change and social and political changes). Therefore, public policy formulation, plans, and investment programs should be **strong and adaptable.**

- **Progress indicators** on matters of WS are not yet sufficiently developed at the global level, which is why it is pending material in the implementation of this work plan. Progress on WS requires the definition of acceptable and achievable service and risk indicators for the region, as well as the establishment of a comparative baseline between countries and with other regions of the world.

VI. Water for the Future - *2020-2030 Work Plan*

This chapter outlines a work plan that can be undertaken and executed in the next 10 years (2020-2030). This plan, which responds to the strategic objectives exposed in the prior chapter, takes into consideration the diagnosis of the current situation presented on Chapter II, the IDB experience summarized on Chapter III, and the innovation opportunities discussed on Chapter IV.

The *Water for the Future* Work Plan consists of a series of multisectoral investment programs that integrate policy, infrastructure (gray and green), knowledge and capacity building activities to "seed" WS concepts on the countries of the region. This plan has been conceived to operationalize a WS investment program and propose a portfolio of technical cooperation activities for IDB donors. The investment programs proposed in this plan also take into account the consultations carried out during the preparation of this document through two successive workshops: one, developed in Washington, with IDB officials (September 24-25, 2018) and another held in Quito, with several Bank clients in the region (October 22-23, 2018). The agenda of these workshops is included in **Annex E.**

Annex F contains a methodology for calculating investments in water infrastructure at large territorial levels, as well as an evaluation of the operation and maintenance costs necessary for the programs proposed in this plan to maintain their functionality and contribute to the improvement of WS and adaptation to climate change. This portfolio of proposed investments has been estimated for the region to achieve the goals of the United Nations 2030 Agenda for Sustainable Development (https://sustainabledevelopment.un.org/post2015/transformingourworld). **Box 6.1** summarizes an estimate of the investment needs for this program. These figures have been compared with figures obtained by entities such as ECLAC in terms of percentage of the region's GDP, noting that they are in the order of magnitude, which gives them some credibility and feasibility.

HIGHLIGHTS

The implementation of this plan will require change management support to IDB countries. The whole world is in a process of learning how to implement, measure and manage WS. This will require a series of support activities, such as the generation of concrete case studies, south-south exchanges to share lessons learned, and mechanisms to encourage the changes in legal and institutional frameworks necessary for the transformation proposed by the WS.

The following interdependent WS priorities emerge from the analysis:

- **Urban supply:** larger investments will be necessary in the **urban supply sector**, especially in sanitation and wastewater treatment. Considering the trend towards an increase in the percentage of urban population in the region and the significant pollution problem to which a large part of its basins are subjected, progress in WS **requires linking the sectoral master plans for urban water and sanitation to basin management plans.** Usually, these plans are not linked.

- **Safe water: It is essential to extend secure water coverage to all the population,** an issue that is still pending, mainly due to the high volume of investment required. This must be addressed by correcting the deficiencies observed in the existing networks and expanding the network so that water can reach 100% of the population. This issue is already being worked on by the IDB, and has begun to be complemented with issues associated with climate change and resilience to strengthen service coverage.

Box 6.1. Summary of Water Security Investment Needs in LAC (on billion US$)

SUBSECTOR	2010-2025	2025-2030	ACCUMULATE 2020-2030
Urban supply	228	163	391
Sanitation	415	297	712
Wastewater treatment	36	26	62
Total urban supply subsector	**679**	**486**	**1,165**
Modernization of existing irrigation systems	38	27	65
New irrigation systems	23	43	66
Total irrigation subsector	**61**	**70**	**131**
Rehabilitation of large centrals	67	4	71
Rehabilitation of the remaining existing centrals	105	25	130
Implementation of new centrals	115	82	197
Total hydroelectric subsector	**287**	**111**	**398**
Knowledge (research, studies, plans...)	50	50	100

- **Irrigation:** given its role as the main user of water resources, a proactive program of Bank action in the irrigation sub-sector is essential. This program should address resource use efficiency while ensuring food security, and should include the modernization of existing irrigation infrastructure and the development of new irrigation systems, with emphasis on actions aimed at reducing the pollution they cause and enhancing farmer assistance and training programs

- **Hydropower:** To warrant the **region's energy production capacity, and its production in a sustainable manner**, through investments in water and energy sector (nexus approach), connected to the goals of mitigation and adaptation to climate change, combining various forms of renewable energy: hydropower, wind, solar, bio-energy and others. Intervention focuses on both the rehabilitation of existing infrastructure and the design of new developments.

- **Risk management: To implement improvements on the prevention, management, and mitigation of extreme weather events, especially of droughts and floods**, through the launch of two subprograms: a) drought management plans at both urban and basin scales, and b) preparation of Flood Risk Management Plans, with attention to Civil Protection programs.

Improvement of knowledge and development of networks for hydro-climate data collection, and processing, its structured storage on databases facilitating access to end users; as well as the development of tools to supporting decision making at the sector, based on what has already been achieved in this field at the IDB and working more closely with other sectors: innovation, agriculture, energy, urban, extractive and others.

Institutional and legal framework: All of this should be accompanied by a package of activities aimed at **establishing an institutional and legal framework to ensure that the actions undertaken to address the above challenges are operational and can be completed.**

The interest that LAC has arisen for **the UN's Agenda 2030, particularly the use of NbS and the adaptation to climate change, constitutes a window for opportunities to encourage the actions proposed in this plan**. The organizational, legal and financial efforts to be undertaken by the countries of the region are of enormous complexity and intensity, so they should not be delayed. The programs proposed in this plan are long term in scope and are intended to formulate a strategy to be implemented beyond their duration. The particularized implementation at various scales of action (basin, city, country) will give rise to specific investment and/or technical cooperation projects on the different topics contained in the proposed work plan.

VI.1 Integrated Investment Programs: Policies and infrastructure

PROGRAM 1: Program of national WS plans at the basin and aquifers level: water availability, water quality, protection of water sources, and ecosystem services.

This first program is focused on strengthening the quantity and quality of water in basins and aquifers, as well as the protection of ecosystems that serve as water sources and provide other ecosystem services. **The scope of this program is to promote the implementation of national WS plans focused on basins and aquifers as management and action units**.

IDB is already intervening in this field, particularly regarding basin management, and has a portfolio of actions on the Titicaca Lake and Reconquista River, among others.

This program is aimed to:

i) Give **importance** to innovation in the **portfolio** related to **basin and aquifer contamination for IDB and its customers**, particularly in terms of linking urban water and sanitation sectoral master plans with management plans in which climate change is systematically taken into account.

ii) **Emphasize the multipurpose approach, by considering the water cycle integrated management and all its uses**, being necessary to include in this program all water uses that could co-exist in the basin or aquifer (water and sanitation services, industrial and extractive uses, and those from the agricultural sector), since only by intervening in all of them will it be possible to achieve the objective[57].

iii) **Move forward in the establishment of monitoring networks (disposal networks, quality station networks, extension of gauging networks)**, in the recording of information in databases, and in the assimilation of these data in predictive models and tools to support decision-making at an operational level, so as to create a structure that supports the follow-up of the program and future interventions.

In those cases where this kind of actions are already implemented[58], the program could be reconverted into an audit of the monitoring of the decontamination plan and its revision, evaluating the efficiency in improving

57 It should not be forgotten that former mining or industrial discharges, with heavy metals and other toxic compounds, have been able to pollute riverbeds and lakes, which would require, although at a later stage, given their complexity and cost, having to treat them to prevent them from continuing to pollute the waters and deteriorate the river habitat.

58 This is the case of the Bogotá River basin, which despite of the sentence of the Cundimarca Court in 2004, still in 2018, the goals pursued are pending.

the quality of the ecosystem and revising the planned measures, in the event that they prove to be insufficient.

Bearing in mind that the states are the first to be interested in the protection of ecosystems, the establishment of funds to help small installations (agricultural, industrial and extractive) to undertake their treatment should not be ruled out.

The criteria to be followed, both in the original version and in the audit alternative, would be as follows:

- **Selection of basins and/or aquifers on which to act.** Chapter II provides a list of possible contaminated basins, which can serve as a guide in the approach to government departments responsible for environmental matters in LAC countries. This program should also include a component for identifying and prioritizing contaminated aquifers for similar actions in groundwater systems.

- **Every national WS plan would complement the components of a traditional hydrological plan** (basin and/or aquifer) with their link to master plans of water and sanitation services for the corresponding population. These plans should also include climate change, ecosystem protection in basins and aquifers, and the inclusion of NbS in the selection of the infrastructure to be used. The technical content of these plans has been detailed in Chapter IV.

- With this **integral vision,** a **multipurpose action** would be carried out for: a) extending the sewage network to 100% of the basin population; b) to treat discharges, regardless of their point sources, not only urban but also industrial and agricultural; c) to reach a state of the ecosystem with acceptable physical and chemical characteristics that would allow its recovery to levels in line with international standards. Measures aimed at protecting these ecosystems should be included, while waiting for future more demanding legislation (for example, along the lines of the European Directive) to address a more integrated approach to the ecosystem, not only physical-chemical, but also hydromorphological and biological.

- It is suggested to **expand the use of water quality data and simulation tools and ecological models in the conception and design of this program,** in the same way that water quantity tools (e.g. HydroBID) are currently used for water resources studies and the establishment of water balances. Chapter IV and the annexes to this document have identified some of the most widely used water quality simulation models in the world.

The expected impacts of climate change on the increase in average temperature, as well as on the frequency and amplitude of extreme weather events and the high variability of hydrological cycles constitute an incentive for countries and regional and local entities to focus on significantly improving climate resilience in basins and aquifers, and to approach a desirable level of WS. In the terminology of the European Framework Directive, the most urgent issue in this regard is "preventing the deterioration of aquatic ecosystems", e.g., that the current quality of their services does not worsen while recovery actions are being implemented. Some Bank clients in the region (e.g., Peru) have already begun to create demand for WS plans with an ecosystem approach as a central element.

PROGRAM 2: Urban Water Security Plans Program

Under this investment program, actions should be targeted to "batches of cities" to increase the efficiency of the program and its speed of implementation. It is important to mention that IDB has already on its portfolio similar activities combined with other activities (e.g. institutional strengthening and legal-regulatory framework, protection against droughts, etc.). This is the case of the *Programa de ampliación y mejora para abastecimiento sostenible y resiliente de agua en ciudades principales de Bolivia* [Expansion and Improvement Program for Sustainable and Resilient Water Supply in Major Cities in Bolivia] and other similar that have been included in the IDB portfolio review.

The priority of this program would be water coverage to 100% of the population, with consideration of the supply of the resource in quality and quantity and with the level of guarantee required for urban supply. This implies explicit consideration of the resilience of services through the protection of sources, the compatibility of master plans with the corresponding basin and aquifer plans and the development of local plans for protection against extreme drought and flood events, with a clear consideration of climate change within the planning exercises.

In order to achieve its **objectives of total coverage and supply**, this program must address the following aspects:

i) Analysis of the network status and the need for repairing specific sections.

ii) Review of the degree of implementation of counters for users (micro-measurement).

iii) Analyses of the non-revenue water percentage with the identification of eventual leakages or water frauds.

iv) Degree of implementation of sectors in the network.

v) Extension of the network in the peripheral settlements.

vi) Review of the network of deposits, their status, and, if applicable, the need for repairs or extension.

vii) Study of tariffs with an analysis of their influence on consumption.

viii) Evaluation of current and future demands.

Regarding the **supply of the resource on matters of quantity and quality,** it is necessary:

i) To develop updated hydrological planning processes and methodologies that undertake the analysis of the sufficiency and sustainability of currently available resources, for which a study of the resources in the current sources of supply (basins and aquifers) must be carried out, with knowledge of flow rates and quality parameters.

ii9 To determine whether the water at the intakes meets pre-pollution characteristics and whether the treatment stations set up before it enters the network are sufficient to produce drinking water, as well as the risks to which it is subjected in the event of toxic discharges from industrial or extractive plants located upstream.

With this preliminary assessment of quality, the quantity will be studied by modeling the hydrological system, taking into account other uses competing with water supply.

As a result of these analyses, it will be possible to assess whether the sources currently available provide resources with adequate guarantees in terms of quantity and quality or whether, on the contrary, it is necessary to look for new sources (in the same basin or in another nearby basin) and whether to access groundwater sources. This must be preceded by an analysis of their availability and quality and of the risks to which these sources may be subject. This should be followed by a hydrological analysis of the multiple basins or aquifers involved in the solution, with simulation via models and complementary tools, resulting in the water balance and the availability of water for transfer from a surrounding basin or aquifer. The study must make it clear that the transferring basin or aquifer has sufficient water resources so that the supply of its own current and future uses is not affected.

The complexity of the multipurpose approach implied by this program is precisely the result of the proposed innovation in hydrological planning, in which the problems of multiple sources, supply to all uses, water quality and the quality of aquatic ecosystems are simultaneously considered.

The approach of this program directly aimed at urban supply is motivated by the shortcomings still present in LAC countries in terms of safe water coverage and the call of the 2030 Agenda to remedy them. **In principle, it could begin to be applied in cities with more than 300,000 inhabitants (which account for more than 50% of the population of LAC)** which, although they have highly developed systems, have significant shortcomings that need to be remedied and which would make it possible to rapidly increase the percentages of safe water coverage in the region.

As a complement and to **increase resilience of urban systems in face of extreme weather events** as part of a long-term adaptation process to climate change, **it is proposed to systematically include the formulation of urban drought and flood plans,** whose technical scope has been described in Chapter IV. For drought plans to be effective with a common language in LAC, it would be necessary to sponsor the prior drafting of a Guide or Technical Instruction defining the content, the definition of indicators, the phases of drought and thresholds, as well as the extension of the program of measures, plus the specific institutional figures for drought and the bodies responsible for their preparation and follow-up. As we can see, the need for a legal and institutional framework to support these plans arises again.

PROGRAM 3: WS Program for Irrigation

As we have seen, irrigation in **LAC contributes to food security not only for the region itself, but for other parts in the world to which it exports significant amounts of food**. In 2010, LAC already constituted an essential piece of the global food system, contributing 18% of trade in agricultural raw materials and 12% of food products in the world (Fundación Botín, 2014)[59]. Therefore, an integrated WS focused on the irrigation sub-sector is necessary.

Irrigation also fulfills a dual function (food security and environmental protection -by reducing consumption and pollution-) that constitutes an incentive to overcome the organizational and economic problems presented by the subsector.

The proposed investment program should be structured along three main lines:

i) **Modernization of irrigation systems:** as we pointed out in Chapter II, according to FAO, between 8 and 10 million hectares are old enough to undergo modernization, technifying both their upstream hydraulic systems and irrigation technology and its effects on the distribution network. The countries most likely to benefit from this modernization program are Argentina, Brazil, Chile, Mexico and Peru.

59 Between the countries and regions for export we can mention China, Israel, Japan, most of the European Union, and all the region of Middle East and North Africa.

ii) **Development of new irrigation systems:** it is predictable that, in the coming decades, some 4 million hectares will have to be put under irrigation. The countries most likely to demand these systems would be those mentioned in the previous paragraph, to which Colombia and Bolivia should be added. These new systems would become part of the IDB portfolio and should be coordinated with the WS programs at basin level (Program 1) and urban plans (Program 2).

iii) **Reinforcement of farmer support programs on WS:** the program should go hand in hand with the reinforcement of the farmer advisory and support network by the institutions of government agriculture departments, with special emphasis on rural organizations which, in the final analysis, are the closest to the farmer. This measure is essential to reduce pollution in the agricultural sector due to the management of agrochemical use, given that it is currently not possible for economic reasons (lack of the sector's ability to pay) to treat agricultural discharges.

Program financing

At this point, it is necessary to make some considerations that influence the financing of this program. **Irrigation systems dedicated to export** are fundamentally of **private initiative** and are the **most profitable**. Those for **domestic consumption** are generally of **public initiative**, although a notorious **trend** exists to **transfer to irrigators the competence and responsibility for their operation and maintenance.** This transfer has been completed in Chile, almost in Mexico, and Peru, and is fully performed in Ecuador, Colombia, and Guatemala. In Brazil, Venezuela, and Panama is ongoing[60]. When this transfer is completed, contacts can be initiated with the relevant authorities to identify and prioritize irrigable areas for intervention.

On the other hand, the **low payment capacity of farmers** complicates the financing of these activities, especially those in public areas (current or already transferred). However, countries are usually the most interested in the environmental benefits of modernizing irrigation systems: hence the practice of establishing subsidies with public funds. This has been the case in Spain, where more than 1.5 million hectares of irrigated land have been modernized in the last 20 years, and where farmers have participated in the financing of projects and works with percentages of around 50% under very good financial conditions. The farmer has understood that, although the saving of the resource and the lower pollutant load were not relevant for him, the improvement of his quality of life was, by freeing him from the slavery of irrigation shifts, night or day, weekends and holidays. This duality has favored a consensus that the State should contribute an important part and the rest should be financed by the farmer himself, with great flexibility on the part

60 FODEPAL Project, FAO.

of the financial entities when it comes to facilitating credits to the irrigation communities.

The sub-program on modernization of irrigation systems together with the local institutional reinforcement of advice and support to the farmer can be combined with Program 1 of the fight against pollution due to its influence on the quality of ecosystems. The subprogram for new irrigation systems could be combined with Program 2 to consider the impact of this competing use with urban supply in a more global vision of basins and aquifers as sources of water. Finally, as in some cases, irrigation systems have regulating dams, reference should also be made to the following program (Program 4) on the safety of dams.

PROGRAM 4: Program to consolidate and improve the role of hydropower generation with emphasis on multipurpose dam safety

Currently, one of the most appreciated roles of hydropower in WS is related to climate change mitigation, by being a renewable energy, allowing to refrain the greenhouse gas emissions.

Dams offer three vectors that link them with WS:

- Its valuable role in flood control, through the storage capacity.
- The possibility of establishing reserves to meet urban supply needs during periods of drought.
- The danger of their potential bursting, generating floods of much higher intensities than the natural ones. For this reason, this program dedicated to multipurpose dams must be complemented by a dam safety subprogram.

Regarding hydropower, this document has established three types of actions: (i) rehabilitation (for age) of existing large plants; (ii) rehabilitation (for age) of the remaining existing plants; and (iii) the implementation of new hydropower potential, considering electricity needs, other generation sources and the social and environmental impacts of new dams.

Rehabilitation of existing large power plants: 26 large power plants have been identified that could be modified by 2030, with a total capacity of 55,765 Mw. The plants are located in Brazil, Argentina, Colombia, Mexico, Peru and Venezuela. For purely indicative purposes, the estimated investment amounts to approximately US$ 70 billion.

Rehabilitation of the remaining existing power plants: the identified potential to be rehabilitated by 2030 amounts to 60,684 Mw. In this case, the dams have not been identified individually (although the potential for rehabilitation has been distributed by subregions), so it is a rehabilitation package pending to be customized with the competent authorities of each country and with the organizations that operate the dams. The necessary investment has been estimated at approximately US$130 billion.

Implantation of a new potential: The estimated potential of a new implantation until 2030 raises to 35,640 Mw, and their locations are not identified, although they are located territorially by country. As in the previous case, this would have to be specified in successive approaches with the authorities of each country and with the organizations of the electricity companies. In this case, site selection studies could be launched on the basis of the work that has been carried out on this subject in the countries on the occasion of certain master plans. The estimated investment amounts to US$ 198 billion.

Chapter IV highlights two additional areas of intervention in the hydropower sector: (i) pumped storage plants as energy accumulators; (ii) increasing the installed capacity of existing plants in order to increase the role of hydroelectricity in regulating demand in the electricity market. The investment for these actions has not been included in this program.

This investment program also includes certain safety-related actions on dams. Thus, **this subprogram should include the review and analysis of the safety of the dams annexed to the hydropower exploitation** (once again, it is necessary to have a legal framework on dam safety, for which we refer to the corresponding section of this document). The following basic components related to dam safety can be included:
To have operating norms that contemplate surveillance and control protocols, conservation and maintenance protocols and protocols for the operation itself, in normal situations and in floods, with the establishment of seasonal safeguards and warning protocols.

In face of the risk of potential rupture, the drafting of an Emergency plan should be proposed which, activated from the operation standards, would establish the indicators, their thresholds, and emergency status, together with a warning protocol for populations that could be affected and communication to the regional and civil protection authorities.

PROGRAM 5: WS program in transboundary basins

WS should also be promoted in international or transboundary basins, an area of particular relevance in Latin America (Orinoco, Amazon, Paraná-La Plata, Guarani Aquifer, among others), although sometimes postponed due to the difficulty of any action at the international level. This, identified as an appropriate area for innovation, will be facilitated by the IDB through several sub-programs.

Sub-program 1. Institutional Frameworks

Through the actions included in this sub-program, **IDB will provide technical and economic assistance to actions prone to sign agreements or international treaties over transboundary waters** (both surface and groundwater) or to modify already existing agreements aligned with the principles of WS, in order to adapt them to the evolution in relations shown by comparative good practices (such as that observed in Europe with the implementation of the Water Framework Directive of 2000).

Likewise, **actions related to institutional improvement** will be included in this sub-program, understood as the **establishment of collaboration bodies or improvement in the operation of existing ones.** Special attention will be paid (consistently with other programs of this Work Plan), to actions aimed at achieving supranational hydrological plans. In particular, these plans will incorporate provisions for joint treatment, from the point of view of drought and flood prevention in a context of climate change, in order to avoid conflicts and cooperate in the joint search for WS.

Sub-program 2. Infrastructures

On many occasions, transboundary water agreements require the **execution of hydraulic works (reservoirs and canals)** that often present specific difficulties related to their international status and to the various problems involved in their design, approval and execution. **This sub-program will pay special attention to actions aimed at improving the processes for carrying out environmental impact assessments of such works.**

This sub-program covers the international dimension of Program 1 on integrated infrastructure investment programs, which includes not only their financing but also the promotion of agreements, treaties or annexes that guarantee, in addition to their operation, the creation of procedures and institutions capable of working in a programmatic manner on joint WS objectives. It also connects with Program 4, which has great potential for development in the region, by promoting binational or joint hydropower developments, with simultaneous objectives of water and energy security, flood control and drought mitigation.

Sub-program 3. Other actions

In transboundary areas, the **effective implementation of the right to water**, both in its supply, purification and basic sanitation aspects, may involve special difficulties. **This sub-program will include actions aimed at the specific implementation of this fundamental and basic right.** It will also include works and actions aimed at compensating transboundary populations, which in many cases is often associated with the management of their water. The "Cultivating Bona Water" program linked to the management of the Iguazú dam (agreement between Brazil and Paraguay) may be an example of good practices to be taken into account.

This type of actions may also include the development of studies (scarce in the area of transboundary aquifers) and systems for joint monitoring and exchange of information and early warning of events that may affect the WS (Programs 7 and 8), but should also go further in the support and financing for the implementation of international protocols for action that promote cooperation in the event of droughts, floods or pollution, with the aim of strengthening the WS in basins of this type.

VI.2 Knowledge Programs

PROGRAM 6: Nature-based Solutions for Water security
One of the core aspects of any innovative WS program is the use of NbS. The applicability and advantages of NbS have been sufficiently addressed in Chapters II and IV. However, **there are still important knowledge gaps that must be addressed before NbS can be effectively applied on a significant scale in the region.**

In the first place, it should be acknowledged that there is no single solution for applying NbS in general and that every project should consider how local conditions (changes in hydro climatological conditions, type of land, population, and land use) will affect the efficiency of NbS, as well as appropriate adaptive management strategies to prolong the effective life of hybrid water infrastructure systems in each proposed scheme program.

The knowledge on NbS for WS must answer questions such as whether they can be implemented independent of gray infrastructure or be part of a hybrid gray-green solution, and currently this knowledge is in a nascent state. Even the most basic data for individual NbS applications is lacking in LAC. Important areas of NbS that need IDB funding to do research, pilot studies and generate knowledge in the short and long term include:

Monitoring requirements should be standardized for individual projects and data compilation of all projects with NbS should be done and placed in a user-friendly database for subsequent planning. Special attention should be given to constructed wetlands and urban applications for water treatment, reuse and agriculture.

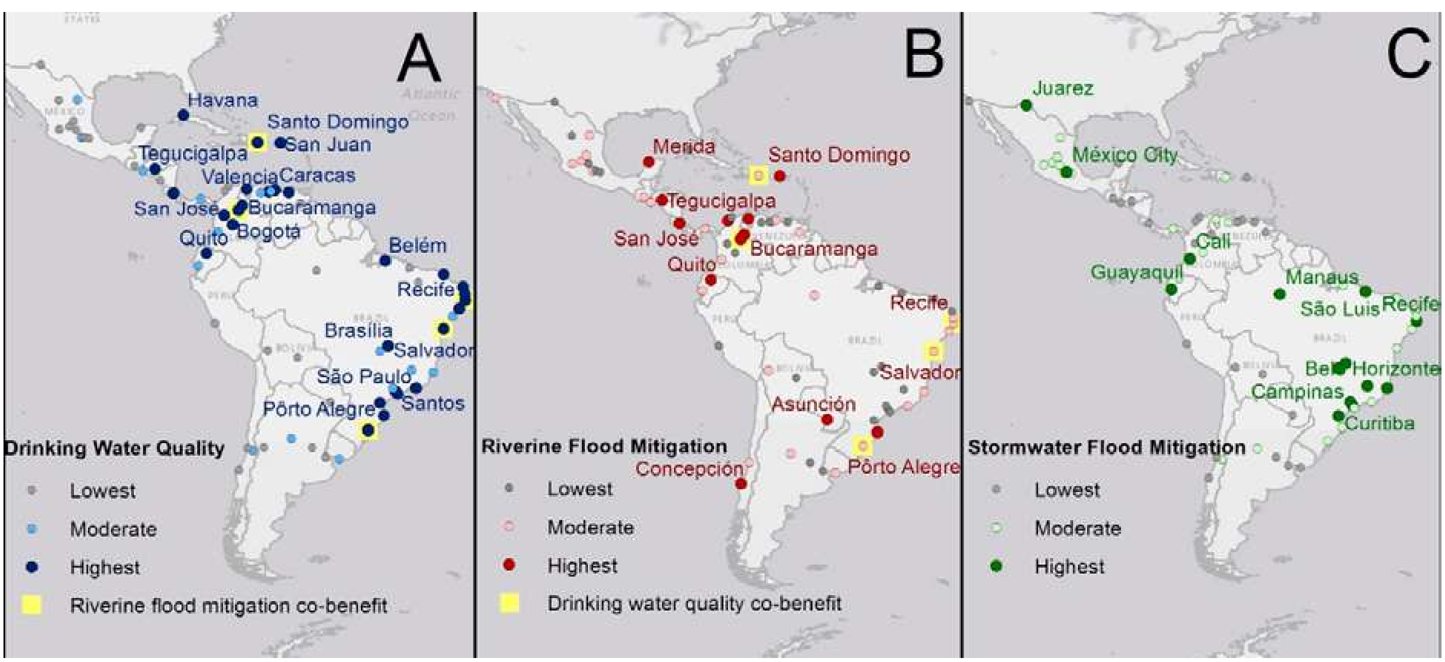
In most of the projects with existing NbS in LAC, **it is necessary to develop pilot demonstration projects to define effective temporal and spatial scales of application and to establish when the NbS can be independent or must be developed in hybrid systems with gray infrastructure**. A study already cited in Chapter IV (Tellman et al., 2018) presents a regional-level assessment of NbS aimed at drinking water source quality improvements and flood mitigation. This assessment picks up some priority cities and watersheds for more detailed pilot studies **(Figure 6.1).** **There are other aspects to be explored** in relation to other WS fields: wastewater treatment, water quality improvement, drought prevention, floodplain water storage and aquifer protection. In addition to this, some NbS **have started to be progressively implemented in other parts of the world, and the IDB should encourage south-south dialogue** to understand lessons learned elsewhere and broaden the portfolio of potential solutions for application in LAC.

Some promising areas for the use of NbS on a larger scale in LAC have already been highlighted in section IV.2 of this report (Box 4.1). A more detailed account of this program and its activities is presented in **Annex G.**

PROGRAM 7: Studies on extreme weather events in LAC: Droughts

This is a knowledge program to be developed as a complement to that set forth in Program 2 (that includes the proposal of drought plans for urban supplies). In this case, the program is addressed to the **study of drought conditions at basin and aquifer level** that should feed urban supply master plans, agricultural development plans (e.g. irrigation plans) and energy sector plans, considering aspects of climate change and ecosystem protection. Therefore, **this program should cover all water uses and the land use in the basin or aquifer, so that it can serve as an input and support for infrastructure and policy investment programs** (Programs 1-4). The scope of the drought plans has already been explained in Chapter IV and in this same chapter the need for a Guide or Technical Instruction that harmonizes the methodology for all LAC countries has been referred to.

Figure 6.1. Prioritization of locations in the LAC region regarding the feasibility of using NbS for WS aspects (A: drinking water quality improvements; B: mitigation of river flooding impacts; C: mitigation of pluvial flooding).



Source: Tellman et al., 2018.

Some examples of types of knowledge products are the development of dynamic maps of meteorological, agricultural, and hydrological drought conditions derived from global information products such as the *Global Drought Information System* (https://www.drought.gov/gdm/current-conditions), the GIDMAPS system (http://drought.eng.uci.edu) and the *Global Forecast Drought Tool* system (https://iridl.ldeo.columbia.edu/maproom/Global/World_Bank/Drought_Monitor/index3.html?gmap=%5B10%2C5%2C2%5D), among others.

PROGRAM 8: Studies on extreme weather events in LAC: Floods

This program consists of **preparing the Flood Risk Management Plans (FRMP)**, whose scope has been described in Chapter IV and that should be undertaken considering the stages described therein. **With the purpose of harmonizing its scope for all the LAC countries, it is valuable to develop and apply analytical products (such as HydroBID Flood) to support the countries in the methodology to be followed.** This program should be promoted independently of all others and eventually be integrated into the basin hydrological plan.

Some examples of knowledge products related to this program include the development of dynamic maps of flood conditions such as the *Global Flood Monitoring System* (http://flood.umd.edu), *Global Flood Monitor* (https://www.globalfloodmonitor.org), the *Global Flood Detection System* (http://www.gdacs.org/flooddetection/), and the GLOFFIS system (https://www.globalfloodforecast.com), among others.

PROGRAM 9: Ecological flow regime definition

An ecological flow regime definition is an important instrument for minimizing the effects of extremely low flows on ecosystems that serve as water sources and supply other ecosystem and environmental services. In the example described in Chapter IV, the idea of ecological flows was introduced by the European Union precisely because of the number of dams needed to achieve a level of regulation that European rivers already had without the need for any infrastructure, due to the relatively regular rainfall regime. In the case of LAC, the situation is similar. **This program focuses on the definition of an ecological flow regime that should consider**:

- **The minimum flow:** Different according to the season of the year to consider the natural cycle of fish life and other species that inhabit the ecosystem. Ecological models must be used, which require considerable field studies and therefore require capacity, time and economic resources.

- **Limitation of the maximum flow**: In reservoirs, for example, if there is no transport channel and the riverbed itself is used to convey the flows to the intakes of irrigable areas (a fairly common situation in LAC), there is a reversal of the hydrological flow: in summer (tropical areas are more unique) a high flow circulates when nature would be in low water and in winter the reservoirs cut the flow when the rains would give a significant flow in the riverbed. To avoid deterioration of the river habitat, it is necessary to limit the maximum flow in the basin.

- **Exchange rate**: This is another important parameter that seeks to prevent strong flow gradients in the river that do not occur naturally (except in the case of floods, usually of lower gradient). This, which is applicable to any reservoir, is especially important in hydropower plants with a peak power vocation. The ideal solution to control the situation and not affect the operation is to have a counter reservoir (or parallel relief reservoir) at the foot of the dam to store the water discharged during peaks and subsequently return it to the river at a rate that respects the established rate of change.

- **Replenishment flow**. This fourth parameter is based on the fact that that a natural annual flood occurs in rivers that reshapes the riverbed. This reshaping, to which aquatic life is accustomed and which it demands for its habitat, poses an additional problem because it requires discharges that have a significant cost due to the use of the resource involved.

Definitely, the ecological flow regime is a **complex process that should be addressed progressively**, starting with the implementation of the minimum flow, desirably obtained by habitat models. It will also be essential to develop analytical products (e.g. technical guides, dynamic maps) establishing a harmonized methodology, as well as pilot case studies for basins and aquifers operating under different conditions (size, biome, level of urbanization, water use). **Due to its specific characteristics, it is a program that can be implemented by sets of basins and/or aquifers, where a higher density of dams of reservoir exists**. To **minimize** the **cost** of the program it is recommended to select **strategic points in each system**, and then proceed with **regionalization techniques** to extend the flow regime to other points where studies have not been carried out.

PROGRAM 10: Consolidation and improvement of field monitoring and remote sensing networks

This program consists of the **development of fundamental instruments for in situ and remote sensing monitoring of the basin, aquifers and aquatic ecosystems.** In the region, progress has been made in field monitoring, especially on rainfall, gauging, and piezometry networks. However, there **is still a very important knowledge gap to be filled in terms of quality measurement stations.** In addition, the use of remote sensing as an operational tool for monitoring the water cycle and WS (described in Chapter IV) is in a practically non-existent state.

Investments in the IDB portfolio often include proposals for monitoring. It is desirable to maintain and leverage this strategy, to be able to identify and correct gaps in existing networks and to complement them with field instrumentation and remote sensing methods as needed. Programs 1 and 2 would provide information in this regard.

This program should be encouraged in order to allow the use of **analytical techniques and data fusion (big data and macro data)** so that it not only detects deficiencies, but also allows prioritization of projects for improvement and expansion of existing networks (including their valuation, form of financing, etc.), so that a major action can be undertaken in the medium term to put the monitoring network in the state it deserves, given its important condition for the monitoring and control of basins, aquifers and their corresponding ecosystems. This would imply investments of knowledge not only in monitoring but also in data analysis.

The data and analysis packages to be included in this program are: (i) network of surface water gauging stations; (ii) network of piezometry in aquifers; (iii) network of surface water quality control stations; (iv) groundwater quality control network; (v) climatological network (rainfall gauges, temperature, evaporation, wind) and (vi) discharge control network. And all of them must include databases measured in situ and measured via remote sensing.

It is also necessary to have a **digitized mapping of the river network,** which will allow studies on floods and on which the digitized mapping of flood-prone areas can be based. Likewise, it is important to have **geospatial products of socioeconomic and ecological information** to complement the databases for these monitoring networks.

> **PROGRAM 11: Simulation and Decision Support Models**

The **Bank's experience with the development of HydroBID** in recent years [61] is **indicative** of the **need for quantitative tools to support decision making processes in the water sector** in the region. HydroBID has had a very positive reception, going from a modest case study in the Bermejo basin in Argentina in 2014, to being used, five years later, in more than a dozen countries in the region, including Peru, where the model is being applied to all basins in the country.

However, to address a more complex problem such as WS, HydroBID is only part of the puzzle, since although it simulates the water balance it does not yet simulate other WS components such as water quality, ecosystem services, aquifer hydraulics (under development), droughts, floods (recently started with the HydroBID Flood application), irrigation programs, energy sector demands and other components detailed in Figure 2.7.

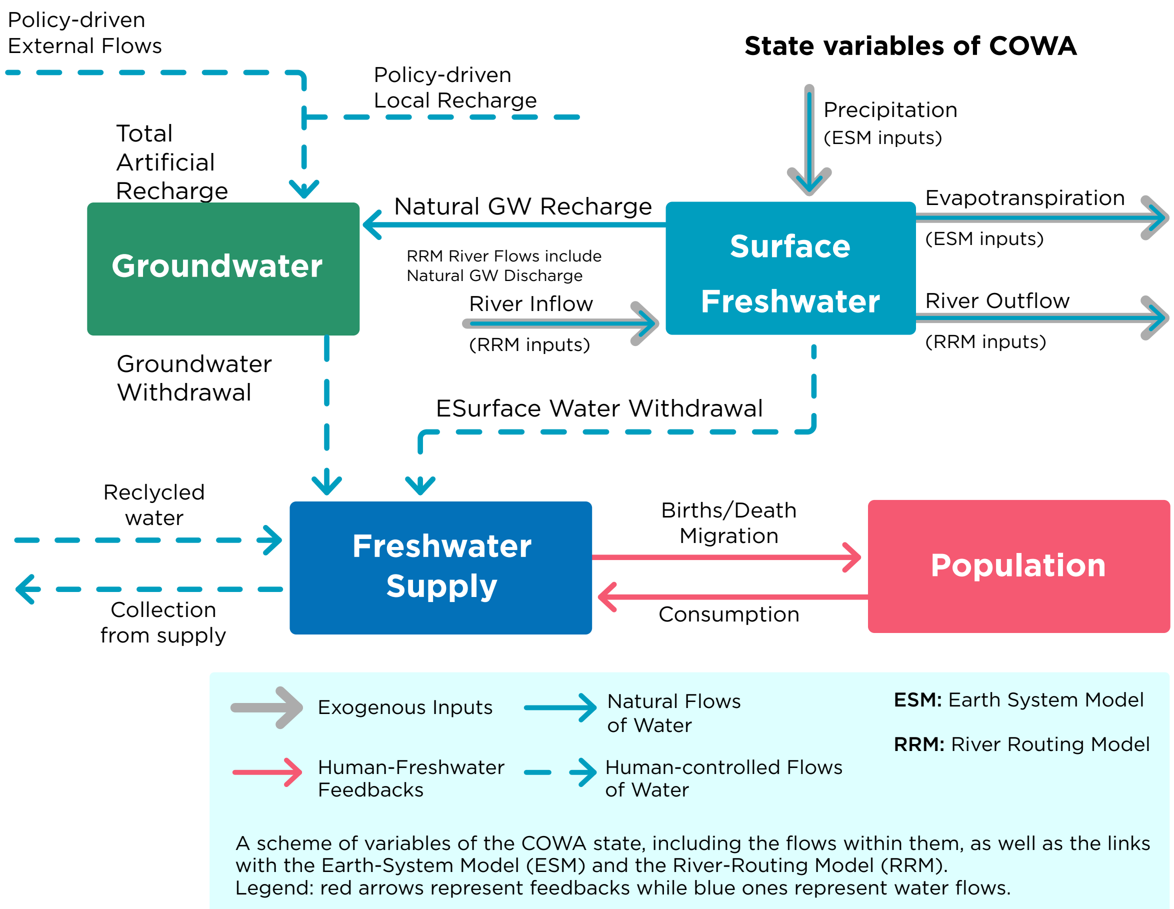
61 The development of the model started in 2011 and its implementation started in 2014.

The IDB has a great opportunity for innovation in the area of simulation models that support decision-making processes in problems and projects related to WS in the region. Its role as a regional financing entity and its knowledge of the reality of the region allows it to address WS problems at various scales (municipal, state, national and regional) and to provide its clients with state-of-the-art and modern tools to support decision making at all these levels. In addition to the HydroBID example, there is the recent example of the GCAM-LAC model to simulate the water-energy-food nexus, which is currently being applied in pilot studies in Colombia, Argentina, Uruguay and Brazil with a good level of reception.

This program can be conceived as a series of integrated simulation models that cover in a complementary manner the different aspects of WS that we have developed in this report. Thus, the program can be structured in the development and application of models that integrate the hydrological part (e.g., HydroBID) with the cross-sector planning nexus (e.g., GCAM-LAC), with ecosystem services models, urban, demographic, socioeconomic and other necessary components (using existing models or developing IDB's own tools) in an evolutionary manner and with a permanent interaction with the potential users of these models (government agencies, universities, research institutes, NGOs and others).

An example of this way of developing integrated models is System Dynamics, which has been used for several decades to develop interdisciplinary and multisectoral simulation models and has been widely applied in the water sector (Saysel et al., 2002; Winz et al., 2009 and Simonovic, 2002). A conceptual illustration of this integrated simulation methodology is shown in **Figure 6.2**. In this figure, each color block can refer to a simulation model for that particular variable (e.g., basins, aquifers, population...).

Figure 6.2. Schematic of a dynamic systems model that includes a coupled socio-economic component



Source: Motesharrei et al., 2016.

Given the increasingly multisectoral nature of the IDB's portfolio and the interest of its clients in the region, this program, a concrete example of innovation in WS for the IDB, can be very fruitful.

VI.3 Some implementation considerations

Box 6.2 summarizes the correspondence of each of the programs proposed in this work plan with the strategic objectives of WS described in Chapter V. In order to facilitate implementation, this table separates investment programs and policy-based lending (PBLs); it also separates knowledge studies into technical cooperation and economic sector studies (ESWs), making specific reference, within each strategic objective, to each program in the work plan. The Plan also involves the development of a prioritization process with the countries to develop budgets and stages or phases (annual or multi-year) for its implementation.

Box 6.2. Water for the Future Work Plan: Strategic Objectives and Proposed Programs

Strategic Priorities for Water Security	Proposed Action for the IDB				Comments
			Studies & Knowledge Development		
	Investment Projects	Policy-Based Lending (PBLs)	Technical Cooperations	ESWs	
Strategic Objective 1: Achieve and sustain potable water supply and the provision of wastewater collection, treatment and disposal services to 100% of the population.	Water and sanitation projects by basin with the incorporation of WS plans harmonized with sectoral master plans, loss reduction, reuse and innovation (Program 1 at the national level and Subprogram 5.2 for transboundary projects). Urban water and sanitation projects incorporating WS plans harmonized with sectoral master plans, loss reduction, reuse and innovation (Program 2).	Support countries to create the conditions to attract private sector participation in WS (Program 1 for national plans and Program 2 for urban plans).	WS plan templates for WSC. Communication Strategy Models for WS. *Note:* these technical cooperations would support the preparation of loan operations within Program 1 (national level) and/or Program 2 (urban level).	Economic models for WS financing. Note: these ESW studies would support the knowledge base for loan preparation within Investment Programs 1-5.	Focus efforts on Bolivia, Dominican Republic, El Salvador, Guatemala, Haiti, Nicaragua, Peru and Peru, as well as cities with less than 50,000 inhabitants in Brazil.

	Proposed Action for the IDB				
			Studies & Knowledge Development		
Strategic Priorities for Water Security	**Investment Projects**	**Policy-Based Lending (PBLs)**	**Technical Cooperations**	**ESWs**	**Comments**
Strategic Objective 2: Encourage the Development of Appropriate Legal Frameworks for the Effective Management of Water resources with a focus on Water Security, the management of associated risks and sustainable economic development._		Modernization of the legal and institutional framework for WS. (Program 1 at the national level and Subprogram 5-1 for transboundary projects).	Promotion of the discussion on the urgency of achieving WS in the region. Terms of Reference to develop legal and institutional framework under the WS approach. Model national WS plans with legal support. Promotion of the need for multilateral treaties in transboundary basins. (5-3). *Note:* these technical cooperations would support the preparation of loan operations under Program 1 (national level), Program 2 (urban level) and Subprogram 5-2 (transboundary level).	Institutional economics study to determine the momentum of each country in relation to the motivation for institutional and legal change for WS. *Note:* these ESW studies would support the knowledge base for loan preparation within Investment Programs 1-5.	All countries are lacking, perhaps to varying degrees, in modernizing their legal, institutional and administrative frameworks for water resources.

Strategic Priorities for Water Security	Proposed Action for the IDB				
	Investment Projects	Policy-Based Lending (PBLs)	Studies & Knowledge Development		Comments
			Technical Cooperations	ESWs	
Strategic Objective 3: Within the framework of water security, promote food security and renewable energy generation based on the planning and development of comprehensive projects that address development needs or improvements in infrastructure and dam security.	Rehabilitation and expansion of irrigation area for ES[62] under the WS approach. (Program 3). Rehabilitation of hydroelectric dams under the WS (multipurpose) and sustainability approach (Program 4). Construction of new multipurpose dams to meet increased consumption under the WS approach and sustainability (Program 4).		Model protocols and legislation for dam safety. Hydrological planning models using the water, energy, food nexus in a WS context. *Note:* these technical cooperations would support the preparation of loan operations under Programs 3 and 4.		Countries with potential to rehabilitate irrigation systems: Brazil, Chile, Mexico, Peru, Colombia and Bolivia.

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Strategic Priorities for Water Security	Proposed Action for the IDB				
			Studies & Knowledge Development		
	Investment Projects	Policy-Based Lending (PBLs)	Technical Cooperations	ESWs	Comments
Strategic Objective 4: Encourage the recovery of water quality and the creation of strategic water reserves.	Basin decontamination with an integrated concept in the context of WS (Program 1). Creation of strategic water reserves under the WS and NbS approach (Program 6).		Forum to exchange experiences with basin decontamination and creation of the LAC Cleaner Watershed City Award. *Note:* these technical cooperations would support the preparation of loan operations within Program 1 (national level) and Program 2 (urban level).		Select priority basins in dialogue with countries. You can start with Brazil, Peru, Mexico, Chile, Colombia and Venezuela

Strategic Priorities for Water Security	Proposed Action for the IDB				
			Studies & Knowledge Development		
	Investment Projects	Policy-Based Lending (PBLs)	Technical Cooperations	ESWs	Comments
Strategic Objective 5: Modernize the mechanisms and methods for obtaining information and supporting decision making.			Regional needs of LAC hydro-climatological monitoring systems (Program 10). Hydro-climatological models in a dynamic platform complementary to HydroBID (Program 11).	Development of dynamic maps of meteorological, agricultural and hydrological drought conditions derived from global information products such as theGlobal Drought Information System (Program 7). Development of dynamic maps of flood conditions such as the Global Flood Monitoring System (http://flood.umd.edu), Global Flood Monitor (https://www.globalfloodmonitor.org), Global Flood Detection System (http://www.gdacs.org/flooddetection/), and the system GLOFFIS (https://www.globalfloodforecast.com) (Program 8)	Implementation of in situ monitoring systems cannot be included as a component of a sector loan.

Strategic Priorities for Water Security	Proposed Action for the IDB				
	Investment Projects	Policy-Based Lending (PBLs)	Studies & Knowledge Development: Technical Cooperations	Studies & Knowledge Development: ESWs	Comments
Strategic Objective 6: Promote the development of knowledge and innovation to ensure the WS			Methodology to identify strategic ecosystems and implement NbS in priority basins in LAC, independently or in combination with gray infrastructure (Program 6). Methodology to develop drought and flood control plans including NbS (Programs 7 and 8). Methodology for the development of ecological flows in the context of WS. Identification and development of models that impact WS e.g. groundwater dynamics and optimal levels of exploitation. (Program 9). Creation of a regional WS forum to follow up on the implementation of agreed actions and exchange of experiences. *Note:* these technical cooperations would support the preparation of loan operations within Program 1 (national level) and Program 2 (urban level).		

This **work plan** moves from the traditional concept of water resources management, based on the availability of natural water resources and the allocation of these resources to various uses, to one focused on WS based on **water cycle management with the integration of climate change aspects, the combination of gray infrastructure and NbS, institutional aspects of regulation and the assimilation of recent findings in the field of science and technology.** It is also **a deliberately cross-sector (nexus) work plan,** focused on access and efficient use of water in adequate quantity and quality and for various sectors (e.g., agricultural production, drinking water supply and power generation). This distinction is particularly important for the LAC region, as the results of the diagnostic conducted in this document (as well as many other studies) show that the region is relatively well endowed with water resources, so **WS will depend on the ability to manage the water cycle in a sustainable manner,** and adaptable to a wide and varied set of physical (e.g., climate change), social (e.g., population and land use change) and economic (e.g., development and public policies) conditions.

As we have seen, WS encapsulates complex and interconnected challenges. This work highlights the importance of water for regional progress in terms of security (water, energy, food), sustainability, development and human well-being. Many factors contribute to WS: from biophysical to infrastructural, institutional, political, social and financial, many of which are outside the water sector space. In this sense, **WS is at the intersection of many other areas of importance for development.** For example, energy, food or environment, each of which is intrinsically linked to water. Management and investment approaches must incorporate related goals and targets to achieve WS, and this will involve multiple priority development areas of urgent concern: conflict and fragility; environmental sustainability; economic growth and employment; health, hunger, food and nutrition; inequities; energy, among others.

The investment programs proposed in this work plan for WS **will have measurable positive impacts in the region in terms of sustainable development, with visible benefits in the short term**. This plan aims to make a contribution to the analytical work behind these investments for the coming years (both for the Bank and for its clients in the LAC region).

Similarly, in order to advance to WS levels consistent with different development goals (e.g. Agenda 2030), it is necessary that this plan considers the degree of uncertainty that exists, derived both from hydrological variability and climate change, as well as from the socioeconomic and political changes that are envisioned in the region. This requires **prioritizing the formulation of robust and adaptable public policies, plans and investment programs,** so that they represent an effective advance in WS considering a wide range of possible future scenarios.

An important aspect that needs to be developed in more detail for the proper implementation of this plan has to do with the indicators of progress

of WS in the region. A review of recent literature on WS indicators shows that it is a field of knowledge that is in its initial stages at the global level, and is not yet established at the regional, country, basin or aquifer level. In recent years there have been some synthesizing efforts in this sense (Garrick and Hall, 2014; GWP, 2014 and, more recently, Hoekstra et al., 2018. In these works, WS indicators are conceived from a risk management perspective, which has facilitated the definition of indicators for monitoring disaster risk, exposure and vulnerability to extreme weather events. In this sense, WS indicators should capture the sequence of investments in institutional aspects and infrastructure to reduce WS-related risks.

The development of WS indicators for IDB activities and its clients must be compatible with other Bank, regional and national initiatives, such as the sustainable infrastructure framework recently published by the IDB (IDB, 2018). Therefore, **making progress on the WS issue requires the definition of acceptable and feasible service and risk indicators for the region, as well as the establishment of a comparative baseline (benchmark) between countries and with other regions of the world,** for each of the geographic areas and sectors of water resource demand, taking into consideration that such levels and risks will vary according to the socioeconomic development of the countries and phenomena such as climate change. It should also be taken into account that WS has benefits and costs associated with these levels and risks and that, among the different requirements of WS in the region, there are various options for investment projects in the development of policies and infrastructure, particularly in a framework of limited resources. **The development of such indicators is a pending issue in the implementation of this work plan.**

The implementation of this plan will require change management support to IDB countries. Given that WS challenges the ways of management practiced in the water sector both in the region and in other parts of the world, it is important to understand that the whole world is in a learning process on how to implement, measure and manage WS. **This will require a series of supporting activities, such as the generation of concrete case studies, south-south cooperation to share lessons learned, and mechanisms to encourage the necessary changes in legal and institutional frameworks.**

This plan and the analysis that justifies it can serve as an input and contribute to the dialogue on WS between the IDB and countries in the LAC region; it can also contribute to other efforts (for example, those related to the NDCs or the SDGs) focused on sustainability among the multiple human activities and their trajectories towards regional and global development pathways. **Through this research and analysis, this work plan provides an integrated set of WS programs that include climate change considerations (mitigation and adaptation), socioeconomic and technological developments and water demand for the main demand sectors at the country level and within a regional and global context.**

References

1. AAVV. (2018). *Proceso regional de las Américas. Foro Mundial del Agua 2018. América Latina y el Caribe. Resumen ejecutivo*, 18 pp.
2. AAVV. (2018). *Proceso regional de las Américas. Foro Mundial del Agua 2018. América del Sur. Resumen ejecutivo,* 19 pp.
3. AAVV. (2018). *Proceso regional de las Américas. Foro Mundial del Agua 2018. Centroamérica. Resumen ejecutivo*, 10 pp.
4. AAVV. (2018). *Proceso regional de las Américas. Foro Mundial del Agua 2018. México. Resumen ejecutivo*, 14 pp.
5. ACUMAR (Autoridad de la Cuenca Matanza Riachuelo). (2018). Buenos Aires, Argentina (http://www.acumar.gob.ar/).
6. Altomonte, H. y Sánchez R. J. (2016). *Hacia una nueva gobernanza de los recursos naturales en América Latina y el Caribe*, CEPAL, Santiago de Chile.
7. Andersson, E.P, S. Barthel, S. Borgstrom, J. Colding, T. Elmqvist, C. Folke y A. Gren. (2014). "Reconnecting Cities to the Biosphere: Stewardship of Green Infrastructure and Urban Ecosystem Services". *Ambio*, 43: 445-453.
8. Andersson, E.P., C.N. Jenkins, S. Heilpern, J.A. Maldonado-Ocampo, F.M. Carvajal-Vallejos, A.C. Encalada, J.F. Rivadeneira, M. Hidalgo, C.M. Canas, H. Ortega, N. Salcedo, M. Maldonado y P.A. Tedesco. (2018). "Fragmentation of Andes-to-Amazon Connectivity by Hydropower Dams". *Science Advances,* 4: eaao1642.
9. Arias, M.E. y M.T. Brown. (2009). "Feasibility of Using Constructed Treatment Wetlands for Municipal Wastewater Treatment in the Bogota Savannah, Columbia". *Ecological Engineering,* 35:1070-1078.
10. Arreguín, F., López M., Ortega-Gaucín D., Ibáñez-Hernández O. (2016), "La política pública contra la sequía en México: avances, necesidades y perspectivas", *Tecnología y Ciencias del Agua,* vol. VII, núm. 5, septiembre-octubre, 2016, pp. 63-76.
11. Arroyo A. y Perdriel A., 2015, *Gobernanza del gas natural no convencional para el desarrollo sostenible de América Latina y el Caribe. Experiencias generales y tendencias en la Argentina, el Brasil, Colombia y México.* CEPAL, Santiago de Chile.
12. ASCE/AWWA. (2006). *Guidelines for the Physical Security of Water Utilities.* American Society of Civil Engineers y American Water Works Association.
13. Banco Mundial. (2016). *Water Security and Infrastructure for Development in Latin American and the Caribbean 2050. White Paper on Research Performed for the World Bank*, 101 pp.
14. Banco Mundial. (1994). *La ordenación de los recursos hídricos. Documento de política del Banco Mundial*, Banco Mundial, Washington, 158 pp.
15. Banco Mundial. (2004). *Water Resources Sector Strategy, Strategic Direc-*

tions For World Bank Engagement.

16. Barberis, J., Armas, F. y Querol, M. (2002). Aplicación de los principios de Derecho Internacional en la administración de los ríos compartidos. Argentina con Paraguay y Uruguay, en A. Embid (ed.), *El derecho de aguas en Iberoamérica y España: cambio y modernización en el inicio del tercer milenio*, Civitas, Madrid.
17. Baruch-Mordo, S., J. Kiesecker, C. Kennedy, J. Oakleaf y J. Opperman, (2019). "From Paris to practice: sustainable implementation of renewable energy goals". *Environmental research Letters*, 14.
18. Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komor, P., Tol, R. S. J. y Yumkella, K. K., (2011). "Considering the Energy, Water and Food Nexus: Towards an Integrated Modelling Approach". *Energy Policy* 39(12): 7896–7906. doi: 10.1016/j.enpol.2011.09.039.
19. Bebbington, A. y M. Williams. (2008). "Water and Mining Conflicts in Peru". *Mountain Research and Development* 28 (3/4):190-195.
20. Bellfield, H. (2015). *Water, Energy and Food Security Nexus in Latin America and the Caribbean. Trade-offs, Strategic Priorities and Entry Points*, Global Canopy Programme.
21. Belmont, M. A., Ikonomou M. y Metcalfe, C. D. (2006). "Presence of Nonylphenol Ethoxylate Surfactants in a Basin in Central Mexico and Removal from Domestic Sewage in a Treatment Plant". *Environmental Toxicology and Chemistry* 25(1):29-35.
22. Belmont, M. A., Cantellano E., Thompson, S., Williamson M., Sanchez A. y Metcalfe C. D. (2004). "Treatment of Domestic Wastewater in a Pilot-Scale Natural Treatment System in Central Mexico". *Ecological Engineering* 23:299-311.
23. Benavides Vanegas, F. S y Ruiz López, C. E. (2016), "La minería ilegal y la reacción jurídica del Estado colombiano para su control", en J. C. Henao y M. P. García Pachón (eds.), *Minería y Desarrollo. Medio ambiente y Desarrollo sostenible en la actividad minera* (pp. 437 y ss). Universidad Externado de Colombia, Bogotá.
24. BID. (2012). *Recursos hídricos y adaptación al cambio climático en América Latina y el Caribe: directrices estratégicas y líneas de acción propuestas*, Nota Técnica Nº 478, Banco Interamericano de Desarrollo.
25. BID. (2018). *What is Sustainable Infrastructure? A Framework to Guide Sustainability Across the Project Cycle*, Nota Técnica Nº. IDB-TN-1388, Banco Interamericano de Desarrollo.
26. Bohoslavsky, J. P. (2010), *Tratados de protección de las inversiones e implicaciones para la formulación de políticas públicas (especial referencia a los servicios de agua potable y saneamiento)*, CEPAL, Santiago de Chile.
27. Bustos Niño, V., García Pachón, M. P., Ortiz Rodríguez, C. (2016). Derecho

de aguas y minería en Colombia, en J. C. Henao y M. P. García Pachón (eds.), *Minería y Desarrollo. Medio ambiente y Desarrollo sostenible en la actividad minera* (pp. 107 y ss.), Universidad Externado de Colombia, Bogotá.

28. Buytaert, W., Celleri R., De Bievre, B., Cisneros, F., Wyseure, G., Deckers J. y Hofstede, R. (2006). "Human Impact on the Hydrology of the Andean Paramos". *Earth-Science Reviews* 79:53-72.

29. CADIS (Centro De Análisis de Ciclo de Vida y Diseño Sustentable). (2016). *Huella de agua (ISO 14046) en América Latina, análisis y recomendaciones para una coherencia regional.* CADIS.

30. Calderón, D. R. y Frey, K. (2017). "El ordenamiento territorial para la gestión del riesgo de desastres en Colombia". *Territorios*, pp. 239-264. Doi: http://dx.doi.org/10.12804/revistas.urosario.edu.co/territorios/a.4795

31. Cathala, C. Núñez A. M. y Ríos A. R. (2018). *El agua en tiempos de sequía. Lecciones de cinco sequías alrededor del mundo*, Resumen de políticas del BID: 295, Banco Interamericano de Desarrollo.

32. Centro de Ciencia del Clima y la Resiliencia (CR)2. (2015). *La megasequía 2010-2015: una lección para el futuro,* Informe a la Nación. Santiago de Chile. Available at http://www.cr2.cl/megasequia/

33. CEPAL. (2017). *Informe anual sobre el progreso y los desafíos regionales de la Agenda 2030 para el desarrollo sostenible en América Latina y el Caribe,* Santiago de Chile.

34. CEPAL. (2018). *Plan de Acción Regional para la implementación de la Nueva Agenda Urbana en América Latina y el Caribe. 2016-2036,* Santiago de Chile.

35. CEPAL. (2018b). *Segundo informe anual sobre el progreso y los desafíos regionales de la Agenda 2030 para el Desarrollo Sostenible en América Latina y el Caribe*, Santiago de Chile.

36. Chapaign A. K. y Hoekstra A. Y. (2004), *Water Footprint and Nations, Value of Water Research Report,* Nº 16, UNESCO-IHE.

37. Charveriat, C. (2000). *Natural Disasters in Latin America and the Caribbean: an Overview of Risk*. Inter-American Development Bank. Washington, D.C.

38. Chevallier, P., Pouyaud, B. Suarez, W. y Condom, T. "Climate Change Threats to Environment in the Tropical Andes: Glaciers and Water Resources". *Regional Environmental Change 11* (Suppl 1): S179-S187.

39. Comisión Europea. (2013), *Infraestructura verde: mejora del capital natural de Europa*, Bruselas 6.5.2013 COM (2013) 249 final.

40. COMIT. (1992). *Aprovechamiento energético del Río Paraná. Documentos y tratados*, Buenos Aires.

41. Crisman, T. L. (2014). Estimating Ecological Flow within the Kara Kho-

ta and Kullu Cachi Basins, La Paz, Bolivia. Inter-American Development Bank, Washington, DC.

42. Daniels, A. E. y G. S. Cumming. (2008). “Conversion or Conservation? Understanding Wetland Change in Northwest Costa Rica”. *Ecological Applications* 18 (1):49-63.
43. Dallas, S. Scheffe B. y Ho G. (2004). “Reedbeds for Greywater Treatment - A Case History in Santa Elena-Montegreen, Costa Rica, Central America”. *Ecological Engineering,* 23:55-61.
44. Da Silva, S., McJeon H., Miralles-Wilhelm F., Muñoz-Castillo, R., Clarke L., Delgado, A., Edmonds, J., Hejazi, M., Horing, J., Horowitz, R., Kyle, P., Link, R., Patel,P., y Turner, S. (2018). *Energy-Water-Land Nexus in Latin America and the Caribbean,* IDB Working Paper Series Nº IDB-WP-901.
45. Da Silva, J. L. y M.A. Vasconcelos, M. A. (2011). “Amazon and the Expansion of Hydropower in Brazil: Vulnerability, Impacts, and Possibilities for Adaptation to Global Climate Change”. *Renewable and Sustainable Energy Reviews* 15:3165-3177.
46. Del Castillo, L. (2005). *El régimen jurídico del Río de la Plata y su frente marítimo*, Consejo Argentino para las Relaciones Internacionales, Buenos Aires.
47. Denny, P. (1997). “Implementation of Constructed Wetlands in Developing Countries”. *Water Science and Technology* 35 (5):27-34.
48. De Szoeke, S. M., Crisman, T. L. y Thurman, P. E. (2016). “Comparison of Macroinvertebrate Communities of Intermittent and Perennial Streams in the Dry Forest of Guanacaste, Costa Rica”. *Ecohydrology,* 9:659-672.
49. Dickinson, M. A. (2018). “Why Efficiency Programmes are the Best Strategy for Water Security”. *International Water Association.* Recuperado de https://www.thesourcemagazine.org/efficiency-programmes-best-strategy-water-security/
50. Dieleman, H. (2014). “Urban Agriculture in Mexico City; Balancing Between Ecological, Economic, Social and Symbolic Value”. J*ournal of Cleaner Production,* 83:1-4.
51. Dinerstein, E., Olson, D. M. Graham, D. J., Webster, A. L., Primm, S. A., Bookbinder, M. P., Ledec G. y World Wildlife Fund. (1995). *A Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean.* World Bank, Washington D.C.
52. Dobbs, C., Escobedo, F. J., Clerici, N., De la Barrera, F., Eleuterio, A. A., MacGregor-Fors, I., Reyes-Paecke, S., Vásquez, A., Camaño J. D. Z. y Hernández H. J. (2018). “Urban Ecosystem Services in Latin AmeriWQ: Mismatch between Global Concepts and Regional Realities?” *Urban Ecosystems.* Available at: https://doi.org/10.1007/s11252-018-0805-3
53. Dourojeanni, A., Jouravlev, A. y Chávez, G. (2002), *Gestión del agua a nivel de cuencGW: teoría y práctica,* Comisión Económica para América

Latina y el Caribe (CEPAL), Santiago de Chile.

54. Ducci J. (2017). Temas críticos de la prestación de servicios de agua y saneamientos urbanos en América Latina: visión del BID", in G. Delacámara, F. Lombardo Y J.C. Diez (coordinadores) *Libro Blanco de la Economía del Agua* (pp. 29 and ss.), McGraw-Hill/Interamericana de España S.L, Madrid.

55. Embid Irujo, A. (1991), *La planificación hidrológica. Régimen Jurídico*, Tecnos, Madrid.

56. Embid Irujo, A. (2013). El acuerdo sobre el sistema del acuífero Guaraní de dos de agosto de 2010 en el marco de la incipiente regulación general de las aguas subterráneas transfronterizas", *RADA* 24, 2013, pp. 31-54 y también en las pp. 179-210, de *Derecho de Aguas V,* Universidad Externado de Colombia, Bogotá, 2013.

57. Embid Irujo, A., 2017, "Aproximación a una teoría general de las sequías e inundaciones como fenómenos hidrológicos extremos", *RADA* 37, 2017, ISSN 1695-2588.

58. Embid Irujo, A. y Embid Tello, A. E. (2017). "Fracturación hidráulica: entre la prohibición y la exigencia de evaluación ambiental. Evaluación de riesgos y moratoria aconsejable", *RADA* 35, 2016.

59. Embid Irujo, A. y Martín L. (2017a). *La experiencia legislativa del decenio 2005-2015 en materia de aguas en América Latina*, CEPAL, Santiago de Chile.

60. Embid Irujo, A. y Martín L. (2017b). *El nexo entre el agua, la energía y la alimentación en América Latina y el Caribe. Planificación, marco normativo e identificación de interconexiones prioritarias*, CEPAL, Santiago de Chile.

61. Embid Irujo, A. y Martín L. (2018), *Lineamientos de políticas públicas. Un mejor manejo de las interrelaciones del Nexo entre el agua, la energía y la alimentación,* CEPAL, Santiago de Chile.

62. FAO. (2010). *Gestión del riesgo de sequía y otros eventos climáticos extremos en Chile,* Santigo de Chile.

63. FAO. (2016). *AQUASTAT Online Database.* Food and Agriculture Organization, Rome.

64. FAO. (2011a). *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW) – ManagingSsystems at Risk.* Food and Agriculture Organization of the United Nations, Rome and Earthscan, London. Available at: http://www.fao.org/docrep/017/i1688e/i1688e.pdf

65. FAO (2011b). *"Energy-Smart" Food for People and Climate – Issue paper.* Food and Agriculture Organization of the United Nations, Rome. Available at: http://www.fao.org/3/a-i2454e.pdf

66. FAO/UNESCO (2005): *Groundwater in International Law. Compilation of Treaties and Other Legal Instruments*, Roma.

67. Feng, Y., Burian S. y Pomeroy C. (2016). “Potential of Green Infrastructure to Restore Predevelopment Water Budget at a Semi-Arid Urban Catchment”. *Journal of Hydrology* 542:744-755.

68. Ferrufino, C. y Grande, C. (2013). *Tendencias del ordenamiento territorial en América Central y República Dominicana (2009-2012).* San Salvador: Cooperación Alemana para el Desarrollo (GIZ).

69. Finer, M. y Jenkins C.N. (2012). “Proliferation of Hydroelectric Dams in the Andean Amazon and Implications for Andes-Amazon Connectivity”, *PloS One* 7 (4): e35126.

70. Frid, C., Andonegi, E., Depestele, J., Judd, A., Rihan, D., Rogers S. I. y Kenchington, E. (2012). “The Environmental Interactions of Tidal and Wave Energy Generation Devices”. *Environmental Impact Assessment Review* 32:133-139.

71. Fundación Botín, (2014). *Seguridad hídrica y alimentaria en América Latina y el Caribe. Implicaciones regionales y globales.*

72. Garrick, D. y Hall, J. (2018). “Water Security and Society: Risks, Metrics and Pathways”. *Annual Review Environmental Resources*, 39:611-639.

73. Garzón, C., Sturzenegger, G. (2015). *Los desafíos de la agenda de desarrollo post-2015 para el sector de agua y saneamiento in Latin America and the Caribbean: conclusiones de la Semana Mundial del Agua 2015.* Banco Interamericano de Desarrollo.

74. Garzón-López, C. (2017). Regional Platform for Water Resource Management-Final Evaluation. Banco Mundial.

75. Gause, M. (2008). *Constructed Wetlands: a Promising Wastewater Treatment System for Small Localities. Experiences from Latin America.* Water and Sanitation Program (WSP-LAC).

76. Génez Báez F. F. (2017). *Sector eléctrico en Paraguay. Régimen jurídico.* Tesis doctoral leída en la Universidad de Zaragoza el 20 de septiembre de 2017.

77. Gholizadeh M., Melesse A. y Reddi, L. (2016). “A comprehensive Review on Water Quality Parameters Estimation Using Remote Sensing Techniques”, *Sensors 16*, 1298; doi:10.3390/s16081298

78. Gobierno de Colombia. (2018). *Plan Director Agua y Saneamiento Básico. Visión Estratégica 2018-2030*, Bogotá D.C.

79. Gómez, C. M. (2017). La seguridad hídrica como envolvente, en G. Delacámara, F. Lombardo Y J.C. Diez (coordinadores) *Libro Blanco de la Economía del Agua* (pp. 5 y ss.), McGraw-Hill/Interamericana de España S.L, Madrid.

80. Gomez-Baggethun, E. y Barton D.N. (2013). “Classifying and Valuing Ecosystem Services for Urban Planning”. *Ecological Economics* 86:235-245.

81. Gonzales, F. T., Vallejos, G. G., Siveira, J. H., Franco, C. Q. Garia J. y Puigagut J. (2009). "Treatment of Swine Wastewater with Subsurface-Flow Constructed Wetlands in Yucatan, Mexico: Influence of Plant Species and Contact Time". *Water SA 35*(3):335-342.

82. Grau, H.R. y Aide M. (2008). "Globalization and Land-Use Transitions in Latin America". *Ecology and Society* 13 (2) 16.

83. Grimm, A. M. y Saboia, J. P. (2015). "Interdecadal Variability of the South American Precipitation in the Monsoon Season". *Journal of Climate* 28: 755–775. doi:10.1175/JCLI-D-14-00046.1

84. Grimm, A. M. y Zilli, M. T. (2009). "Interannual Variability and Seasonal Evolution of Summer Monsoon Rainfall in South America". *Journal of Climate* 22: 2257–2275. doi:10.1175/2008JCLI2345.1

85. Guido, Z., McIntosh, J. C., Papuga S. A. y Meixner T. (2016). "Seasonal Glacial Meltwater Contributions to Surface Water in the Bolivian Andes: a Case Study Using Environmental Tracers". Journal of Hydrology: Regional Studies 8:260-273.

86. GWP. (2014). *Assessing Water Security with Appropriate Indicators*, Global Water Partnership.

87. GWP. (2013). *La estrategia de GWP hacia el 2020: un mundo con seguridad hídrica*, Global Water Partnership.

88. GWP/OECD. (2015). *Securing Water Sustaining Growth*. Informe del Grupo de Trabajo en Seguridad Hídrica y Desarrollo Sostenible. GWP/OECD.

89. Haberl, R. (1999). "Constructed Wetlands: a Chance to Solve Wastewater Problems in Developing Countries". *Water Science and Technology* 40 (3):11-17.

90. Harden, C.P. (2006). "Human Impacts on Headwater Fluvial Systems in The Northern and Central Andes". *Geomorpholog* 79:249-263.

91. Hasse, D., Larondelle, N., Andersson, E., Artmann, M., Borgstrom, S., Breuste, J., Gómez-Baggethun, J., Gren, A., Hamstead, Z., Hansen, R., Kabisch, N., Kremer, P., Langemeyer, J., Rall, E. L., McPhearson, T., Pauleit, S., Qureshi, S., Schwarz, N., Voigt, A., Wurster D. y Elmqvist, T. (2014). "A Quantitative Review of Urban Ecosystem Service Assessments: Concepts, Models and Implementation". *Ambio* 43:413-433.

92. Hashemi, S. S. G., Mahmud, H. B. y Ashraf, M. A. (2015). "Performance of Green Roofs with Respect to Water Quality and Reduction of Energy Consumption in Tropics: a Review". *Renewable and Sustainable Energy Reviews* 52:669-679.

93. Hoekstra, A. y Mekonnen M. (2011), "The Water Footprint of Humanity", *Proc. Nat. Acad. Sci.* 109(9), 3232-3237.

94. Hoekstra, A., Buurman, J. y Van Ginkel, K. (2018), "Urban Water Security:

a Review", *Environ. Res. Lett.* 13 053002.

95. Hogeboom, R.J., Knook L. y Hoekstra A. Y. (2018). "The Blue Water Footprint of the World's Artificial Reservoirs for Hydroelectricity, Irrigation, Residential and Industrial Water Supply, Flood Protection, Fishing and Recreation". *Advances in Water Resources* 113:285-294.

96. Hossain, F., Siddique-E-Akbor A. H., Mazumder, L. C., ShahNewaz S. M., Biancamaria, S., Lee, H. y Shum C. K. (2014). "Proof of Concept of an Altimeter-Based River Forecasting System for Transboundary Flow Inside Bangladesh". *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,* 7, 587–601.

97. IEA. (2016). *World Energy Outlook 2016.* OECD/International Energy Agency, Paris.

98. IPCC (2014): *Cambio Climático 2014. Impactos, adaptación y vulnerabilidad. Resumen para responsables de políticas. Contribución del Grupo de Trabajo II al Quinto Informe de Evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático*, Suiza.

99. IRENA (2015): *Renewable Energy in the Water, Energy & Food Nexus*.

100. Jager, H. I. y Bevelhimer M. S. (2007). "How Run-Of-River Operation Affects Hydropower Generation". *Environmental Management* 40:1004-1015.

101. Jia, Z., Wang, B., Song S. y Fan Y. (2014). "Blue Energy: Current Technologies for Sustainable Power Generation from Water Salinity Gradient", *Renewable and Sustainable Energy Reviews* 31, 91-100.

102. Jiménez-Cisneros B. y Galizia Tundisi J. (coordinadores). (2012). *Diagnóstico del agua en las américas*, Foro Consultivo Científico y Tecnológico, AC, México.

103. Jiménez-Cisneros B. (2015). "Seguridad hídrica. Retos y respuestas, la fase VIII del Programa Hidrológico Internacional de la Unesco (2014-2021)". *Aqua-LAC,* vol 7, nº 1.

104. Jiménez Cisneros, B. E., Oki, T., Arnell, N. W., Benito, G., Cogley, J. G., Döll, P., Jiang, T. y Mwakalila S. S. (2014). Freshwater resources. FL: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 229-269.

105. Junk, W.J. Da Cunha, C. N. (2018). The Pantanal: a Brief Review of its Ecology, Biodiversity and Protection Status. En C.M. Finlayson, G.R. Milton, R.C. Prentice y N.C. Davidson (eds.). *The Wetland Book* (pp 798-811).

Springer, New York.

106. Junk, W. J., Bayley, P. B. y Sparks, R.E. (1989). The Flood Pulse Concept in River-Floodplain Systems. En D.P. Dodge (ed). P*roceedings of the Large River Symposium* (pp 110-127). Canadian Special Publication Fish and Aquatic Sciences 106.

107. Jouravlev, A. (2014). *Los servicios de agua potable y saneamiento en el umbral del siglo XXI.* CEPAL, Chile.

108. Kakuru, W., Turyahabwe, N. y Mugisha, J.. (2013). "Total Economic Value of Wetlands Products and Services in Uganda". *The Scientific World Journal.* Article ID 192656, 13 pages. http://dx.doi.org/10.1155/2013/192656.

109. Kaplan, D., Bachelin, M., Munoz-Carpena, R. y Chacon W. R. (2011). "Hydrological Importance and Water Quality Treatment Potential of a Small Freshwater Wetland in The Humid Tropics of Costa Rica". *Wetlands* 31:1117-1130.

110. Kisner, C. (2008). *Green Roofs for Urban Food Security and Environmental Sustainability.* Climate Institute http://climate.org/topics/international-action/urban-agriculture.htm

111. Kivaisi, A. K. (2001). "The Potential for Constructed Wetlands for Wastewater Treatment and Reuse in Developing Countries: a Review". *Ecological Engineering* 16:545-560.

112. Konar, D., Dalin, C., Suweis, S., Hanasaki, N., Rinaldo A. y Rodriguez-Iturbe, I. (2011). "Water for Food: the Global Virtual Water Trade Network", *Water Resources Research* 47, doi:10.1029/2010WR010307.

113. Leese M. y Meisch S. (2015). "Securitising Sustainability? Questioning the 'Water, Energy and Food-Security nexus'", *Water Alternatives 8 (1), pp. 695-709.*

114. Leopold, L. B., Wolman M. G. y Miller, J. P. (1964). *Fluvial Processes in Geomorphology.* Dover Press. New York

115. Lo, M. H., Famiglietti, J., Reager, J. T., Rodell, M., Swenson, S. y Wu, W. Y. (2016), "GRACE- Based Estimates of Global Groundwater Depletion, in Terrestrial Water Cycle and Climate Change: Natural and Human-Induced Impacts", *Geophysical Monograph* 221, AGU Geophysical Monograph Series, 252 pages.

116. Lovell, S. T. y Taylor, J. R. (2013). "Supplying Urban Ecosystem Services Through Multifunctional Green Infrastructure in the United States". *Landscape Ecology* 28:1447-1463.

117. Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., Panzer, L., Partelow, S., Rau, A. L, Sasaki, R., Abson, D. J., Lang, D. J., Wamsler C. y Von Wherden H. (2015). "A Review of Urban Ecosystem Services: Six Key Challenges for Future Research". *Ecosystem Services*

14:98-112.

118. Lundy, L. y Wade, R. (2011). "Integrating Sciences to Sustain Urban Ecosystem Services". *Progress in Physical Geography* 35 (5):653-669.

119. Machado, I. F. y De M. Figueiroa, S. F. (2001). "500 years of mining in Brazil: a brief review". *Resources Policy* 27:9-24.

120. Magrin, G. O., Marengo, J. A., Boulanger, J. P., Buckeridge, M. S., Castellanos, E., Poveda, G., Scarano F. R. y Vicuña, S. (2014): Central and South America. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V. R., C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea y L. L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom y Nueva York, NY, USA, pp. 1499-1566.

121. Malm, O., Pfeiffer, W. C. Souza C. M. M. y Reuther R. (1990). "Mercury Contamination Due to Gold Mining in the Madeira River Basin, Brazil". *Ambo 19 (1):11-20.*

122. Manyari, W. V. y De Carvalho Jr., O. A. (2007). "Environmental Considerations in Energy Planning for the Amazon Region: Downstream Effects of Dams". *Energy Policy*: 6526-6534.

123. Martin, L. (2017). El futuro de los organismos de cuenca en Latinoamérica", en Antonio Embid (Ed.), *El futuro de los organismos de cuenca*, Cizur Menor.

124. Martin, L. y Justo, J. B. (2015). *Análisis, prevención y resolución de conflictos por el agua en América Latina y el Caribe*, CEPAL, Santiago de Chile.

125. Martínez, R. (2017). "With Melting Glaciers and Mining, Bolivia's Water is Running Dangerously Low". *GlobalPost.* Available at: https://www.pri.org/stories/2017-01-04/la-paz-short-water-bolivia-s-suffers-its-worst-drought-25-years

126. Martinez-Cruz, P., Hernandez-Martinez, A., Soto-Castor, R., Esquivel Herrera A. y Rangel Levario, J. (2006). "Use of Constructed Wetlands for the Treatment of Water From an Experimental Channel at Xochimilco, Mexico". *Hydrobiologica* 16(3):211-219.

127. McPhearson, T., Andersson, E., Elmqvist T. y Frantzeskaki, N. (2015). "Resilience of and Through Urban Ecosystem Services". *Ecosystem Services* 12:152-156.

128. Milanez, B. y Puppim de Oliveira, J. A. (2013). Innovation for Sustainable Development in Artisanal Mining: Advances in a Cluster of Opal Mining in Brazil.

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129. Millones, J. O. (1982). "Patterns of Land Use and Associated Environmental Problems of The Central Andes: An Integrated Summary". *Mountain Research and Development* 2(1):49-61.

130. Ministerio de Agricultura y Riego de Perú. (2015). *Plan Nacional de Recursos Hídricos.*

131. Ministerio de Medio Ambiente y Agua de Bolivia. (2018). *La sequía 2016-2017 en Bolivia y su repercusión en las ciudades capitales de La Paz-El Alto-Sucre-Oruro-Potosí. Evaluación de capacidades de gestión; impacto socioeconómico en las empresas prestadoras de servicio.*

132. Miralles-Wilhelm, F. (2014). "Desarrollo y aplicación de herramientas analíticas a la planificación trinómica agua-alimentos-energía en América Latina y el Caribe", *Water Monographies,* número 2.

133. Miralles-Wilhelm, F., (2016). "Development and Application of Integrative Modeling Tools in Support of Food-Energy-Water Nexus Planning—A Research Agenda". *J. Environ. Stud. Sci.* 6(1): 3-10. doi:10.1007/s13412-016-0361-1

134. Miralles-Wilhelm, F. y Muñoz-Castillo, R. (2018). "An Analysis of the Water-Energy-Food Nexus in Latin America and the Caribbean Region: Identifying Synergies and Tradeoffs Through Integrated Assessment Modeling", *Int. Jour. Eng. Sci.* 7(1), 8–24.

135. Miralles-Wilhelm, F., Clarke L., Hejazi, M., Kim, S., Gustafson, K., Muñoz-Castillo, R. y Graham N. (2017). *Physical Impacts of Climate Change on Water Resources,* Banco Mundial, https://openknowledge.worldbank.org/handle/10986/26028.

136. Mitsch, W. J., Tejada, J., Nahlik, A., Kohlmann, B., Bernal B. y Hernández, C. E. (2008). "Tropical Wetlands for Climate Change Research, Water Quality Management and Conservation Education on a University Campus in Costa Rica". *Ecological Engineering* 34:276-288.

137. Mitsch, W. J. y Day Jr., J. W. (2006). "Restoration of wetlands in the Mississippi-Ohio-Missouri (MOM) River BasFL: Experience and Needed Research". *Ecological Engineering* 26:55-69.

138. Mo, K. C. y Schemm, J. E. (2008). "Droughts and Persistent Wet Spells over the United States and Mexico". *Journal of Climate* 21: 980–994. doi:10.1175/2007JCLI1616.1

139. Motesharrei, S., Rivas, J., Kalnay, E., Asrar, G., Busalacchi, A., Cahalan, R., Cane, M., Colwell, R., Feng, K., Franklin, R., Hubacek, K., Miralles-Wilhelm, F., Miyoshi, T., Ruth, M., Sagdeev, R., Shirmohammadi, A., Shukla, J., Srebric, J., Yakovenko, V. y Zeng, N. (2016). "Modeling Sustainability: Population, Inequality, Consumption, and Bidirectional Coupling of the Earth and Human Systems", *National Science Review*, 3(4), 470-494.

140. Muñoz-Castillo, R. y Miralles-Wilhelm F. (2018). *A CLEWS Nexus Modeling Approach to Assess Water Security Trajectories and Infrastructure Needs in Latin America and the Caribbean***,** Working Paper, BID.

141. Nadeau, T. L. y Rains, M. C. (2007). "Hydrological Connectivity Between Headwater Streams and Downstream Waters: How Science Can Inform Policy". *Journal of the American Water Resources Association* 43(1):118-133.

142. Nahlik, A. M. y Mitsch, W. J. (2006). "Tropical Treatment Wetlands Dominated by Free-Floating Macrophytes for Water Quality Improvements in Costa Rica". *Ecological Engineering* 28:246-257.

143. Noyola, A., Padilla-Rivera, A., Morgan-Sagastume, J. M., Guereca L. P. y Hernandez-Padilla F. (2012). "Typology of Municipal Wastewater Treatment in Latin America". *Clean- Soil, Air, Water* 40 (9):926-932.

144. OECD. (2013). *Water security for better lives: a summary for policy makers.*

145. Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnut, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W, Hedao P. y Kassem K. R. (2001). "Terrestrial Ecoregions of the World: a New Map of Life on Earth". *BioScience* 51(11):933-938.

146. ONU (2017). *Informe Mundial de las Naciones Unidas sobre el Desarrollo de los Water resources, 2017. Wastewater. El Recurso desaprovechado.*

147. ONU-Agua. (2013). *Analytical Brief on Water Security and the Global Water Agenda.*

148. Ordóñez, J. E. B., Rodríguez, S. A. S., Pérez, M. L. Bracamonte, R. A. V., Angeles, F. R., Gilbert, A. G. y R. S. Navarro. (2015). *National Water Reserves Program in Mexico: Experiences with Environmental Flows and the Allocation of Water for the Environment.* Nota Técnica BID-TN-864. Water and Sanitation Division. Inter-American Development Bank.

149. Orsini, F., Morbello, M., Fecondini M. y Gianquinto, G. (2010). Hydroponic Gardens: Undertaking Malnutrition and Poverty Through Vegetable Production in the Suburbs of Lima, Peru. En G. Prosdocimi Gianquinto y F. Orsini (eds.). *Proceedings 2nd International Conference on Landscape and Urban Horticulture* (pp 173-178). Acta Hort 881 IWSS2010.

150. Oyarzun, J., Maturana, H., Paulo A. y Pasieczna, A. (2003). "Heavy Metals in Stream Sediments from the Coquimo Region (Chile): Effects of Sustained Mining and Natural Processes in a Semi-Arid Andean Basin". *Mine Water and Environment* 22 (3):155-161.

151. Oyarzun, R., Guevara, S., Oyarzun, J., Lillo, J., Maturana H. e Higueras P. (2006). "The As-Contaminated Elqui River BasFL: a Long-Lasting Perspective (1975-1995) Covering the Initiation and Development of Au-Cu-As Mining in the High Andes of Northern Chile". *Environmental Geochemistry and Health* 28 (5):431-443.

152. Passos Gomes, V. y Delgado Piqueras, F. (2016), "The role of the Amazon

Cooperation Treaty for Shared Water Management", *Actualidad Jurídica Ambiental*, 53.

153. Pedersen, S. F. (2015). *Introduction to the Quinoa Dilemma*. 8th Nordic Latin American Research Network Conference. Helsinki, Finland.

154. Peña, H. (2016). *Desafíos de la seguridad hídrica in Latin America and the Caribbean*. Serie Recursos Naturales e Infraestructura, CEPAL.

155. Pérez-Carrera, A. y Fernández, A. (2010). Arsenic and Water Quality Challenges in South America, en G. Schneier-Madanes y M.-F. Courel (eds.), *Water and Sustainability in Arid Regions*, DOI 10.1007/978-90-481-2776-4_1, Springer Science+Business Media B.V.

156. Perrone, D. y Hornberger, G. (2014). "Water, Food, And Energy Security: Scrambling for Resources or Solutions?" *WIREs Water*, 1: 49–68. doi:10.1002/wat2.1004.

157. Pfeiffer, W. C., Drude de Lacerda, L., Malm, O., Souza, C. M. M., Gloria da Silveira E. y W. R. Bastos. (1989). "Mercury concentrations in inland waters of gold-mining areas in Rondonia, Brazil". *The Science of the Total Environment* 87/88:233-240.

158. Phillips, O. L. et al. (2009). Drought Sensitivity of the Amazon Rainforest. *Science* 323:1344-1347.

159. Poff, N. L. y Matthews, J. H. (2013). "Environmental Flows in the Anthropocene: Past Progress and Future Prospects". *Current Opinion in Environmental Sustainability* 5:1-9.

160. Poff, N. L., Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B., Sparks R. y Stromberg, J. (1997). "The Natural Flow Regime: A New Paradigm for Riverine Conservation and Restoration". *BioScience* 47:769-784.

161. Qiu, G-Y., Li, H-Y., Zhang, Q-T., Chen, W., Liang, X-J. y Li X-Z. (2013). "Effects of Evapotranspiration on Mitigation of Urban Temperature by Vegetation and Urban Agriculture". *Journal of Integrative Agriculture* 12 (8):1307-1315.

162. Rabatel, A., Francou, B., Soruco, A., Gomez, J., Cáceres, B., Ceballow, J. L., Basantes, R., Vuille, M., Sicart, J. E., Hugel, C., Scheel, M., Lejeune, Y., Arnaud, Y., Collet, M., Condom, T., Consoli, G., Favier, V., Jomelli, V., Galarraga, R., Ginot, P., Maisincho, L., Mendoza, J., Menegoz, M., Ramirez, E., Ribstein, P., Suarez, W., Villacís M. y Wagnon, P. (2013). "Current State of Glaciers in the Tropical Andes: A Multi-Century Perspective on Glacier Evolution and Climate Change". *The Cryosphere* 7:81-102.

163. República Argentina. (2017ª). *Plan Nacional de Agua Potable y Saneamiento. Cobertura Universal y Sostenibilidad de los Servicios. Lineamientos y Principales acciones*.

164. República Argentina. (2017b). *Plan Nacional del Agua*.

165. República de Panamá, Resolución de Gabinete nº 114, de 23 de agosto de 2016 que aprueba el *Plan Nacional de Seguridad Hídrica* y establece el *Consejo Nacional de Agua y la Secretaría Técnica* (y documento técnico como *Plan Nacional de Seguridad Hídrica 2015-2050*. Agua para todos, 2016, Ciudad de Panamá).

166. República Oriental del Uruguay. (2017). Decreto de 31 de julio de 2017 por el que se aprueba el *Plan Nacional de Agua*s.

167. Reynolds, K. (2002). "El tratamiento de las aguas residuales en Latinoamérica. Identificación del problema". *Agua Latinoamericana.* Recuperado de http://www.agualatinoamerica.com/docs/PDF/DeLaLaveSepOct02.pdf.

168. Richter, B. D., Warner, A. T., Meyer J. L. y Lutz., K. (2006). "A Collaborative and Adaptive Process for Developing Environmental Flow Recommendations". *River Research and Applications* 22:297-318.

169. Ringler, C., Rosgrant, M. W. y Paisner, M. S. (2000). "Irrigation and Water Strategies in Latin America and the Caribbean: Challenges and Strategies". *International Food Policy Research Institute*, Washington, DC.

170. Ríos, D. A., Vélez, A .F. T., Pena, M. R. y Parra, C. A. M. (2009). "Changes of Flow Patterns in a Horizontal Subsurface Flow Constructed Wetland Treating Domestic Wastewater in Tropical Regions". *Ecological Engineering* 35:274-280.

171. Rivera, F., Warren, A., Curds, C. R., Robles, E., Gutiérrez, A., Gallegos E. y Calderón, A. (1997). "The Application of the Root Zone Method for the Treatment and Reuse of High-Strength Abattoir Waste in Mexico". *Water Science Technology* 35(5)271-278.

172. Rodell, M., Famiglietti, J. S., Wiese, D. N., Reager, J. T., Beaudoing, H. K., Landerer, F. W., y Lo., M.H. (2018). "Emerging Trends in Global Freshwater Availability". *Nature* https://doi.org/10.1038/d41586-018-0123-1

173. Rodgher, S., De Azevedo, H., Ferrari, C. R., Roque, C. V., Ronqui, L. B., Burato de Campos B. y Nacimento, M. R. L. (2012). "Evaluation of Surface Water Quality in Aquatic Bodies under Influence of Uranium Mining (MG, Brazil)". *Environmental Monitoring and Assessment*. DOI 10.1007/s10661-012-2719-5.

174. Rodríguez, D., Bazilian, M., Delgado, A., Liden, R., Miralles-Wilhelm, F., Toman M. y Sohns, A. (2017). *Modeling the Water-Energy Nexus: How Do Water Constraints Affect Energy Planning in South Africa?* Banco Mundial, https://openknowledge.worldbank.org/handle/10986/26255.

175. Rodríguez, D., Bazilian, M., Delgado, A. y Miralles-Wilhelm, F. (2018). *Thirsty Energy: Modeling the Water-Energy Nexus in China (English).* Washington, D.C. World Bank Group. http://documents.worldbank.org/curated/en/817631521818240201/Thirsty-energy-modeling-the-wa-

ter-energy-nexus-in-China.

176. Rosa, L. P., Dos Santos, M. A., Matvienko, B., Sikar, E., Lourenco, R. S. M. y Menezes, C. F. (2003). "Biogenic Gas Production from Major Amazon Reservoirs, Brazil". *Hydrological Processes* 17:1443-1450.

177. *Rowe, D. B. (2011). "Green Roofs as a Means of Contamination Abatement". Environmental Contamination* 159 (8-9):2100-2110.

178. Russell, A. M., Gnanadesikan A. y Zaitchik, B. (2017). "Are the Central Andes Mountains a Warming Hot Spot?". *Journal of Climate* 30:3589-3608.

179. Sadoff, C. y Muller, M. (2010). *La gestión del agua, la seguridad hídrica y la adaptación al cambio climático: efectos anticipados y respuestas esenciales,* Global Water Partnership.

180. Salati, E. y Rodrigues, N. S. (1982). "De Poluente a Nutriente, a Descoberta do Aguape". *Revista Brasileira da Tecnologia* 13(3):37-42.

181. Salati, E., Salati, E. Jr. y Salati, E. (1999). "Wetland Projects Developed in Brazil". *Water Science Technology 4*0(3):19-25.

182. Salazar, L. F., Nobre, C. A. y Oyama, M. D. (2007). "Climate Change Consequences on the Biome Distribution in Tropical South America". *Geophysical Research Letters* 34: https://doi.org/10.1029/2007GL029695

183. Saleth, R. M.; Dinar, A. (2004). *The Institutional Economics of Water, a Cross Country Analysis of Institutions and Performance,* Banco Mundial.

184. Saysel, A. K., Barlas, Y., Yenign, O. (2002). "Environmental Sustainability in an Agricultural Development Project: A System Dynamics Approach". *Journal of Environmental Management* 64 (2002), Nr. 3, S. 247–260. – URL http://www.sciencedirect.com/science/article/pii/S0301479701904888.

185. Schnitzler, W. H. (2012). "Urban Hydroponics for Green and Clean Cities and for Food Security". *International Symposium on Soilless Cultivation*. IWSAS Acta Horticulturae 1004. 10.17660/ActaHortic.2013.1004.1.

186. Simonovic, S. P. (2002). "World Water Dynamics: Global Modeling of Water Resources". *Journal of Environmental Management* 66 (2002), Nr. 3, S. 249–267.

187. Solanes, M. (2015). *Gobernanza y finanzas para la sostenibilidad del agua en América del Sur.* Corporación Andina de Fomento.

188. Solanes, M. (2017), *Institutional Arrangements, Efficiency, Equity and Sustainable Water Resources Management in Selected Countries of Latin American*. Unpublished, author's personal communication.

189. Sosa, M. y Zwarteveen, M. (2012). "Exploring the Politics of Water Grabbing: the Case of Large Mining Operations in the Peruvian Andes". *Water Alternatives* 5 (2):360-375.

190. Stillwell, H. D. (1992). "Natural Hazards and Disasters in Latin America". *Natural Hazards* 6:131-159.

191. Stovin, V. (2010). "The Potential of Green Roofs to Manage Urban Stormwater". *Water and Environment Journal* 24:192-199.

192. Tellman, B., McDOnald, R., Goldstein, J., Vogl, A., Fiorke, M., Shemie, D., Dudley, R., Dryden, R., Petry, P., Karres, N., Vigerstol, K., Lehner, B. y Veiga, F. (2018). "Opportunities for Natural Infrastructure to Improve Urban Water Security in Latin America", *PLoS ONE*, 13(12): e0209470. https://doi.org/10.1371/journal. pone.0209470.

193. TNC. (2018). Water Funds Field Guide. The Nature Conservancy.

194. Toro-Vélez, A. F., Madera-Parra, C. A., Pena-Varn, M. R., Lee, W. Y., Bezares-Cruz, J. C., Walker, W. S., Cárdenas-Henao, H., Quesada-Calderón, S., García-Hernández H. y Lens, P. N. L. (2016). "BPA and NP Removal from Municipal Wastewater by Tropical Horizontal Subsurface Constructed Wetlands". *Science of the Total Environment* 542:93-101.

195. Tundisi, J. G., Goldemberg, J., Matsumura-Tundisi T. y Saraiva, A. C. F. (2014). "How Many More Dams in The Amazon?" *Energy Policy* 75:703-708.

196. Tundisi, J. G., Rocha, O., Matsumura-Tundisi T. Y Braga, B. (1998). "Reservoir Management in South America". *Water Resources Development* 14 (2):141-155.

197. UNESCO. (2010). Atlas de Zonas Áridas de América Latina y el Caribe, dentro del marco del proyecto "Elaboración del Mapa de Zonas Áridas, Semiáridas y Subhúmedas de América Latina y el Caribe". CAZALAC. Documentos Técnicos del PHI-LAC, N°25.

198. UNESCO. (2008). *Marco legal e institucional en la gestión de los sistemas acuíferos transfronterizos en las Américas*, Serie ISARM Américas No 2.

199. UNESCO. (2012). *Managing Water under Uncertainty and Risk*, Paris.

200. UNESCO. (2013). *International Hydrological Programme (IHP) Eighth PhaDR: Water Security: Responses to Local, Regional and Global Challenges, (2014-2021).*

201. United Nations. (2013). *Water Security and the Global Water Agenda.* United Nations University.

202. Van Beek, E. y Wouter Lincklaen, A. (2014). *Water Security: Putting the Concept into Practice*, Global Water Partnerschip, Elanders.

203. Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R. y Cushing, C. E. (1980). "The River Continuum Concept". *Canadian Journal of Fisheries and Aquatic Sciences* 37(1):130-137.

204. Varnell, C. J., Thawaba, S. y Brahana, J. V. (2009). Constructed Wetlands for Pre-Treatment of Drinking Water from Coal Mines. *The Open Environmental Engineering Journal* 2:1-3.

205. Vasallo Magro, J. M. (2015). *Asociación Público Privada en América Lati-*

na. Aprendiendo de la experiencia. Bogotá: CAF.

206. Vásquez, J. E. (2014). "Transición del ordenamiento territorial y tratamiento del recurso hídrico: algunos determinantes desde el caso de Medellín". *CES Derecho*, 5 (1), pp. 165-180.

207. Verzijl, A. y Quispe, S. G. (2013). "The System Nobody Sees: Irrigated Wetland Management and Alpaca Herding in the Peruvian Andes". *Mountain Research and Development* 33 (3)280-293.

208. Vymazal, J. (2011). "Constructed Wetlands for Wastewater Treatment: Five Decades of Experience". *Environmental Science and Technology* 45:61-69.

209. Ward, J. V. y Stanford, J. A. (1983). The Serial Discontinuity Concept of Lotic Ecosystems. En T.D. Fontaine y S.M. Bartell (eds.). *Dynamics of Lotic Ecosystems* (pp 29-42). Ann Arbor Scientific Publishers, Ann Arbor, MI.

210. Whitney, D., Rossman, A. y Hayden, N. (2003). "Evaluating an Existing Subsurface Flow Constructed Wetland in Akumal, Mexico". *Ecological Engineering* 20:105-111.

211. Wilk, D. y Altafin, I. (2018). *Innovaciones en el desarrollo e implementación de humedales construídos para el tratamiento de aguas residuales. Parte II: análisis de la implantación de humedales construidos para el tratamiento de aguas residuales en Latinoamérica y el Caribe*. Banco Interamericano de Desarrollo.

212. Willaarts, B., Garrido, A. y Llamas, R. (eds). (2014). *Water for Food Security and Well-Being in Latin American and the Caribbean*, Earthscan Studies y Water Resource Management, Routledge.

213. Winz, I., Brierley, G., Trowsdale, S. (2009). "The Use of System Dynamics Simulation in Water Resources Management". *Water Resources Management* 23 (2009), Mai, Nr. 7, S. 1301–1323. – URL https://link.springer.com/article/10.1007/s11269-008-9328-7

214. World Economic Forum. (2011). *Water security. The water-food-energy-climate nexus*, Island Press, Washington.

215. World Economic Forum. (2018). *The Global Risks Report 2018,* 13th edition, Geneva.

216. Wu, H., Adler, R. F., Tian, Y., Huffman, G. J., Li, H y Wang, J. (2014). "Real-Time Global Flood Estimation Using Satellite-Based Precipitation and a Coupled Land Surface and Routing Model", *Water Resources*. Res., 50, 2693.2717, doi:10.1002/2013WR014710.

217. WWAP (Programa Mundial de Evaluación de los Recursos Hídricos de las Naciones Unidas)/ONU-Agua. (2017). *Informe Mundial de las Naciones Unidas sobre el Desarrollo de los Recursos Hídricos 2017. Aguas residuales: el recurso desaprovechado*, Paris, Unesco.

218. WWAP (Programa mundial de evaluación de los recursos hídricos de las Naciones Unidas)/ONU-Agua 2018: *Informe Mundial de las Naciones Unidas sobre el Desarrollo de los Recursos Hídricos 2018: soluciones basadas en la naturaleza para la gestión del agua*, París, Unesco.

219. Yánez, L., Franco, P., Bastidas, W., Córdova, V. (2017). "Resumen del Plan Nacional de Gestión Integrada e integral de los recursos hídricos y de las cuencas y microcuencas hidrográficas de Ecuador", *Aqua-LAC,* vol. 9, nº 2, pp. 124 y ss.

220. Zhang, D. Q., Jinadasa, K. B. S. N., Gersberg, R. M. y Liu, Y. (2014). "Application of Constructed Wetlands for Wastewater Treatment in Developing Countries – A Review of Recent Developments". *Journal of Environmental Management* 141:116-131.

221. Zi, W. y Ji, G. (2012). "Constructed Wetlands, 1991-2011: A Review of Research Development, Current Trends and Future Directions". *Science of the Total Environment* 441:19-27.

222. Zurita, F., DeAnda J. y Belmont, M. A. (2009). "Treatment of Domestic Wastewater and Production of Commercial Flowers in Vertical and Horizontal Subsurface-Flow Constructed Wetlands". *Ecological Engineering* 35. 861-869.

223. Zurita, F., Roy, E. D. y White, J. R. (2012). "Municipal Wastewater Treatment in Mexico: Current Status and Opportunities for Employing Treatment Systems". *Environmental Technology* 33(10):1151-1158.

224. Zurita, F., Belmont, M. A., DeAnda, J. y White, J. R. (2011). "Seeking a Way to Promote the Use of Constructed Wetlands for Domestic Wastewater Treatment in Developing Countries". *Water Science and Technology* 63(4):654-666.

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