JULY 2019
R: 19-07-A

REPORT

A NEW COURSE:
MANAGING DROUGHT AND DOWNPOURS IN THE SANTIAGO METROPOLITAN REGION

LEAD AUTHOR
ANDREA E. BECERRA

COAUTHORS
JORDAN HARRIS, CAROLINA HERRERA, PÍA HEVIA, AMANDA MAXWELL

ACKNOWLEDGMENTS

The authors would like to acknowledge the valuable contributions of NRDC's staff in the Water program, including Larry Levine, Kate Poole, and Tracy Quinn. This report also benefited greatly from the thorough scrutiny and feedback of Dr. Gonzalo Bacigalupe (CIGIDEN), Sebastián Bonelli (The Nature Conservancy in Chile), Dr. Avery Cohn (The Fletcher School at Tufts University), Daniela Duhart (lawyer, Chile), Dr. John Durant (Tufts University School of Engineering), Dr. Jesse Keenan (Harvard Graduate School of Design), and Bernardo Reyes (Ética en los Bosques in Chile).

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Table of Contents

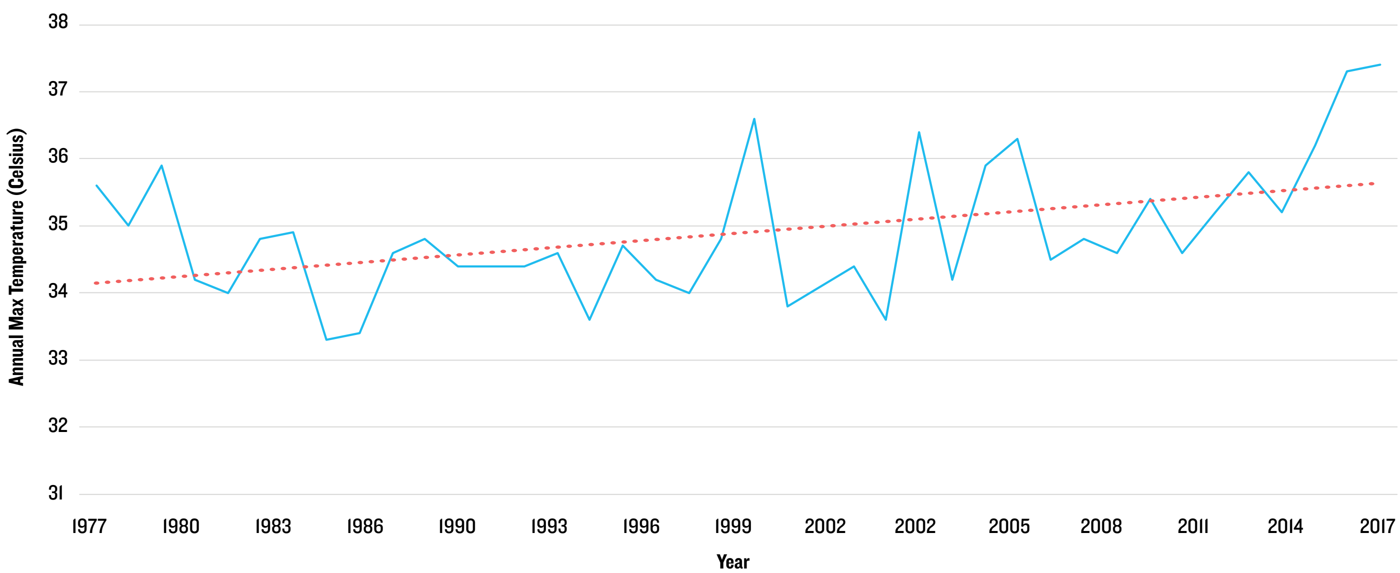
Introduction

In the past decade, climate change has brought record-breaking heat, flooding, drought, and forest fires to central Chile.[1] These events have negatively impacted livelihoods, cut hydroelectric power generation, discouraged tourism, decreased agriculture yields, and limited the availability of potable water in some communities.[2] And the problem is only getting worse. Chile is expected to see an increase in floods and face the greatest water stress—a measure of how much more demand there is for water relative to available supply—in the Western Hemisphere over the next 40 years.[3] In fact, the impacts of climate change, including drought and flooding, are predicted to cost the country's gross domestic product (GDP) 1 percent every year for the next eight decades. To put this in perspective, 1 percent of Chile's GDP in 2018 was equivalent to 1.9 trillion Chilean pesos ($2.8 billion).[*,4]

The Metropolitan Region (MR) is an economic powerhouse and the seat of Chile's capital city, Santiago. It is home to 7.1 million people (40.5 percent of the country's population) and produces 46 percent of the country's GDP.[5] Climate change and the accompanying water stress pose unique challenges for both urban and rural populations in the MR. Extreme heat coupled with precipitation rates that have declined by 20 to 30 percent in the past two decades have resulted in a chronic water deficit.[6] These factors coincide with an existing allocation problem—an estimated 20 aquifers in the MR are over-allocated, meaning the rights to pump groundwater exceed the available water supply.[7] All of this exacerbates the problem of diminishing groundwater supplies, a major source of water for Chile's rural sector. Diminishing water sources are leaving the country's agricultural economy and rural communities increasingly vulnerable to drought.

FIGURE 1: MAXIMUM TEMPERATURE

Maximum temperature recorded annually at the Quinta Normal meteorological station in Santiago, Chile. The red dotted line is a linear trend line indicating an increase in temperatures at a steady rate. In 2016 and again in 2017, the highest temperature in recorded history was measured in the capital.

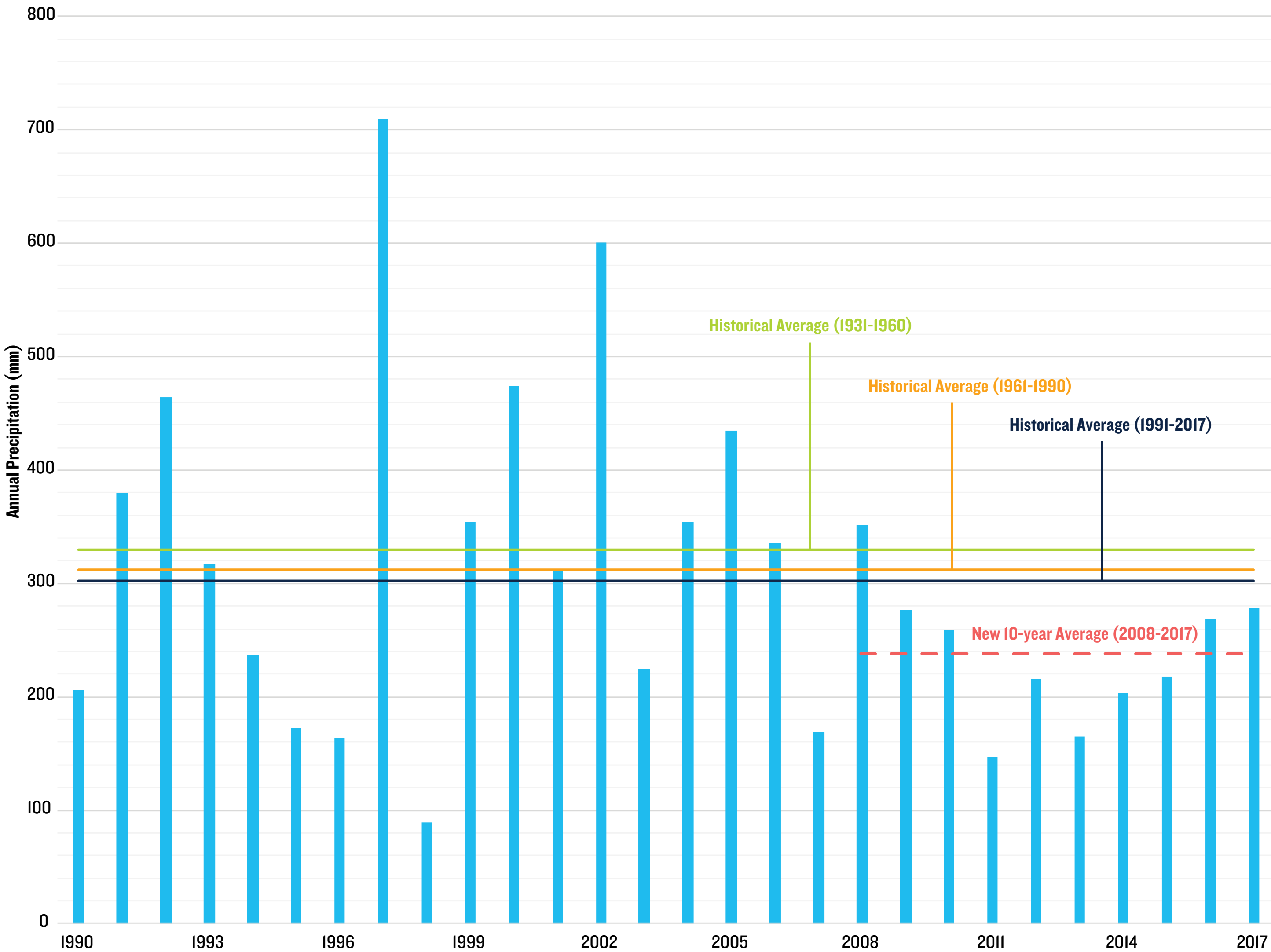


Source: Developed by the authors using data from the Annual Climatology Report by the Meteorological Directorate of Chile (DGAC) for the years 1977–2017.[8]

* All $ in this report are in USD.

FIGURE 2: ANNUAL PRECIPITATION IN SANTIAGO (MM)

While precipitation rates typically vary from year to year, precipitation in the past 10 years, from 2008 to 2017, falls well below Santiago's historical average.



Source: Developed by the authors using data from the Annual Climatology Report by the Meteorological Directorate of Chile (DGAC) for the years 1990–2017.

Even as the region grapples with a water-scarce future, Santiago is expected to see more floods every year, which can compromise water quality and supply, damage infrastructure, and increase health risks.[9] When compared with averages from 1912 to 1999, the MR experienced a 22 percent increase in the number of floods and nearly six times more landslides per year between 2000 and 2017.[10] In less than a decade, the MR has experienced three major flooding events that cut off water supplies to several hundred thousand people.[11] In 2017, for example, a disastrous flood left more than four million Chileans without water.[12] Some communities were affected for several days. As the region braces for a warmer climate, high-elevation regions of the MR that normally receive snowfall are predicted to receive greater rainfall instead, increasing the volume of water and the chances of an extreme flooding event.[13] In addition to disrupting the water supply, floods can cause electricity outages, spread waterborne illnesses, take lives, and cause major damage to infrastructure including roads, bridges, and electricity grids.

Already exacerbated by climate change, these pressing water issues will likely become more complex when paired with population growth and urbanization. Fortunately, there are solutions. And solving these problems also presents real opportunities for Chile to advance toward its Sustainable Development Goals (SDGs) and climate change adaptation targets.

Numerous reports have looked at the water challenges facing central Chile and potential solutions to those challenges. Organizations such as Chile's Water Department (Dirección General de Aguas, DGA), Fundación Chile, the Research Center for Integrated Disaster Risk Management (Centro de Investigación para la Gestión Integrada del Riesgo de Desastres, CIGIDEN), and the Global Change Research Center at the Pontifical Catholic University of Chile (UC Centro Global), have tackled the subject. Several initiatives have emerged in response, including The Nature Conservancy's Water Fund to protect wetlands and native vegetation in the Maipo River watershed in the MR, the 100 Resilient Cities initiative to reduce household water consumption and protect upstream glaciers, and the Maipo Adaptation Plan (Maipo Plan de Adaptación, MAPA), a multi-stakeholder vulnerability assessment of the Maipo River Basin.

The goal of this report is to build on the valuable work completed to date and draw on international successes to provide short- to medium-term solutions to the water management problems in Chile's MR. We hope the facts, figures, examples, and ideas in this paper inform conversations and stimulate concrete and forward-looking actions for water management in central Chile.

A THREATENED BASIN

The Maipo River Basin is a critical engine of the MR's regional economy, supplying water for mining, energy generation, irrigation for more than 90 percent of the basin's agriculture, and 80 percent of the region's potable water.[14] Unfortunately, rising temperatures and diminishing precipitation make the waters of the Maipo Basin among the resources most vulnerable to climate change.[15] The basin is fed by approximately 1,000 glaciers that appear to be shrinking.[16] Scientists predict that by 2070, the basin will experience a 40 percent reduction in water flow due to loss of precipitation and glacial retreat.[17]

© Andrea Becerra

The Maipo River flowing through the upstream portion of the basin (the first section)—taken in the summer in January 2018.

© Raphael Nogueira

The Yeso Reservoir in the Cajon del Maipo.

Population growth, a burgeoning economy, and demand for a better quality of life is already stretching available water resources in the MR. The impacts of climate change on the MR's water supply will place new and potentially critical pressure on local communities and economies. To protect these communities in the future, the MR will need to overcome six key water management challenges in the Maipo River Basin, which provides most of the MR's water.

1. RISING FLOOD HAZARDS

Urbanization coupled with increasingly heavy rain events, loss of vegetation, and higher-than-average temperatures due to climate change leaves the MR increasingly exposed to floods. Forty percent of the country's population already lives in the MR.[18] In a business-as-usual scenario, the region's population is expected to increase by around 20 percent by 2050, to 8.5 million.[19] To accommodate this growing population, Santiago's geographical limits have expanded, replacing natural landscapes and agricultural land with paved roads, residential buildings, and commercial centers.[20] There is a direct link between the loss of green spaces and an increase in surface water runoff and flooding events in the MR.[21] Heavy downpours coupled with impermeable city streets mean that water has nowhere to go during storms. If Santiago's current rate of sprawling urbanization continues without any change in the approach to construction, scientists at the Helmholtz Centre for Environmental Research predict that floods will be increasingly severe in both area covered and depth.[22]

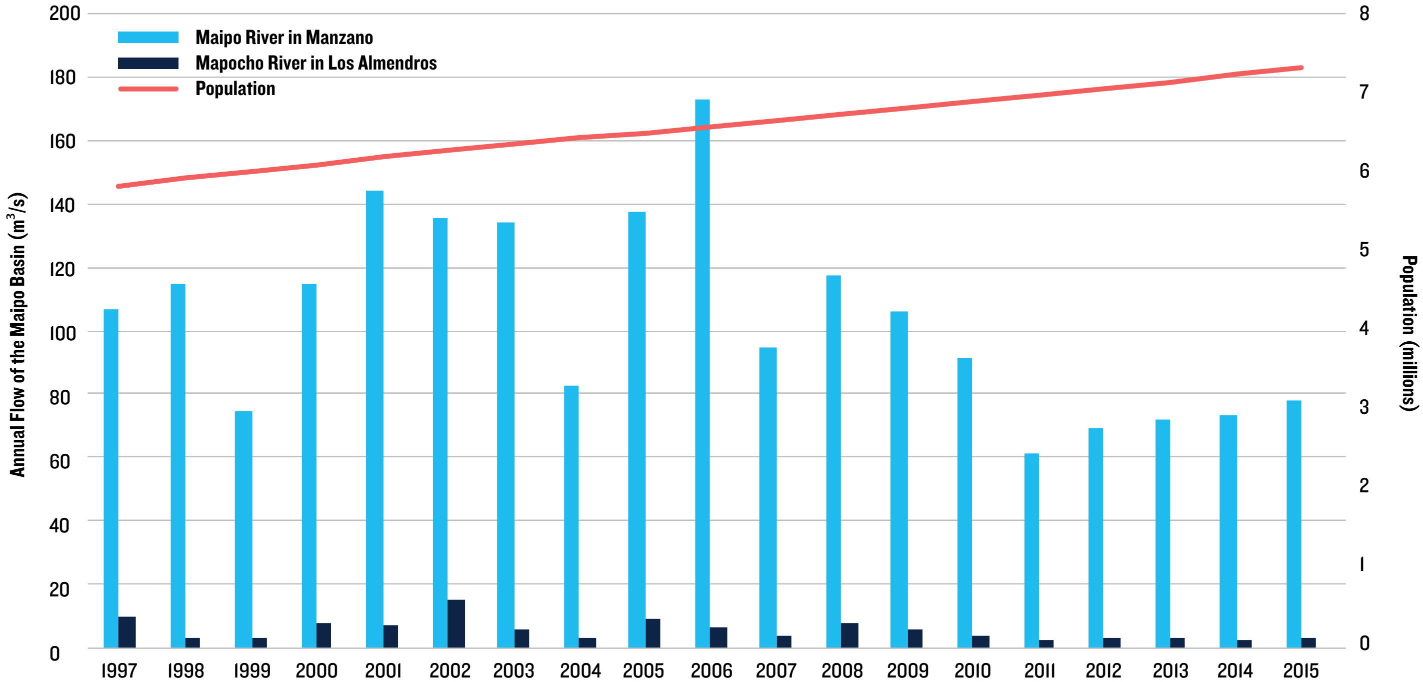
2. INEFFICIENT WATER USE IN URBAN AND RURAL SECTORS

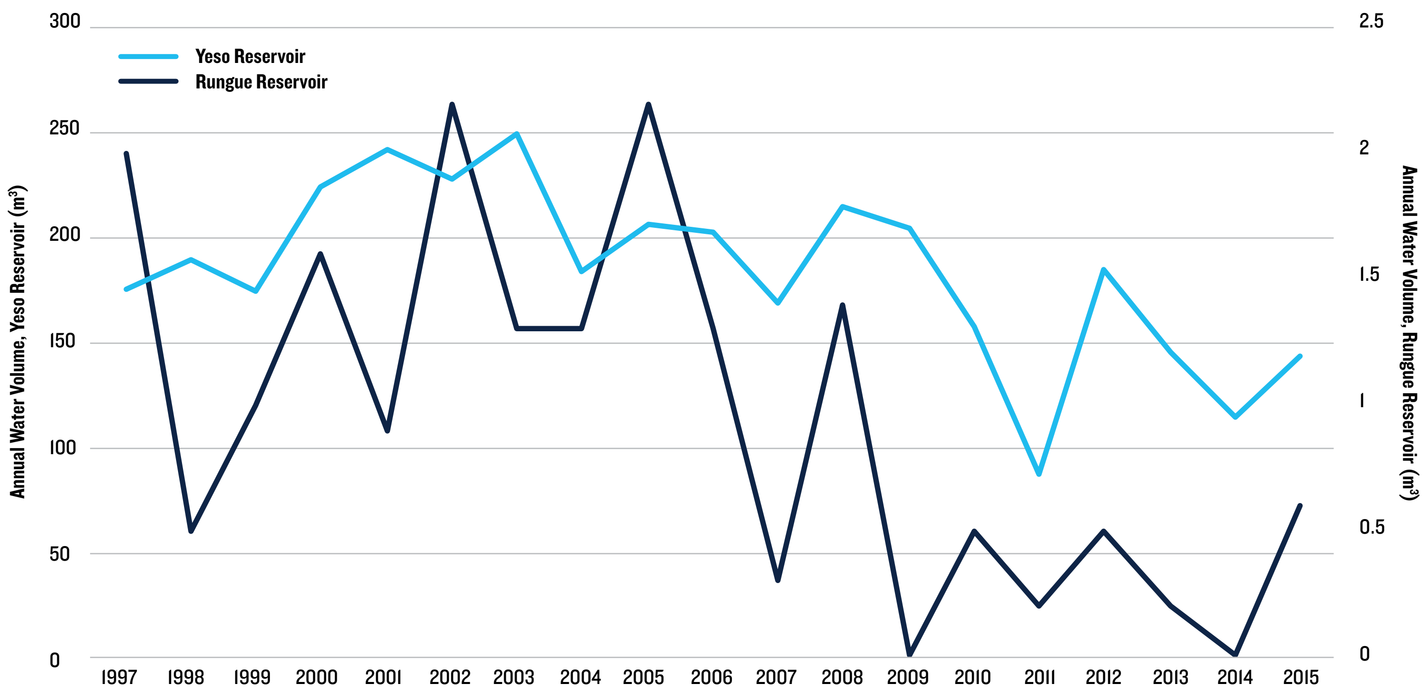
Central Chile has the highest potable water consumption per capita in the country, despite its vulnerability to water scarcity (Figure 4).[23] The Mega Drought of 2010–2015, part of the warmest six-year period on record, was the longest-lasting and farthest-reaching drought recorded in Chile's history. Even then, water habits in Santiago, such as irrigating water-intensive landscapes, filling private pools, washing sidewalks, and taking long showers, remained relatively unchanged, with few incentives to reduce consumption.[24]

Despite advancements in irrigation in the 1990s, water waste in the rural sector still presents opportunities for improved efficiency. The MR contains the fourth-largest agricultural sector in the country with 48,670 hectares (120,266 acres) of farmable land, and nearly 74 percent of fruit production currently uses efficient water irrigation. However, about 21 percent of fruit agriculture continues to employ inefficient furrow irrigation methods.[25] If better technologies and management practices are not implemented in these remaining farms, climate change will result in greater water demand as rising temperatures increase water evaporation from exposed flood irrigation channels.[26]

FIGURE 3: MAIPO BASIN WATER AVAILABILITY & POPULATION GROWTH

As the population in the MR has increased, water resources have decreased. The top graph shows the annual flow of the two main rivers in the Maipo Basin, as well as population growth of the MR. The bottom graph shows the annual volume of the two main reservoirs in the Maipo Basin. It's important to note that from 2010 to 2015 the region experienced record droughts.

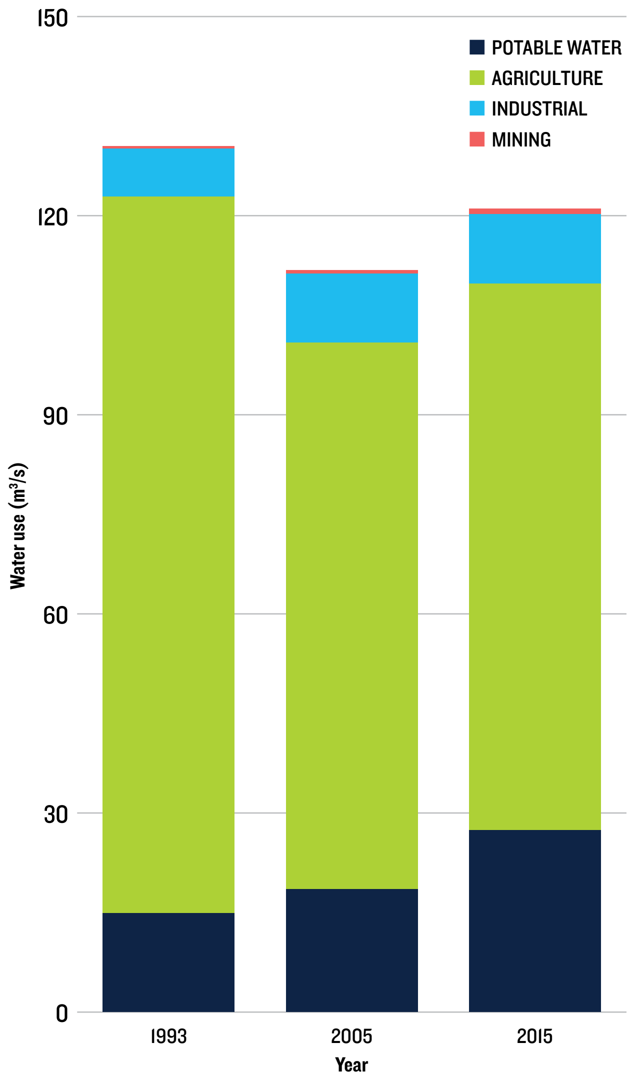




Source: Developed by the authors using data from the Annual Environmental Report by the National Statistics Institute (INE) for the years 1997–2015.[27]

FIGURE 4. WATER USE IN THE MR (1993-2015)

The graph shows water use in the Metropolitan Region in cubic meters per second (m^3/s) during 1993, 2005, and 2015. Even though total potable water consumption nearly doubled from 1993 to 2015, overall water use decreased in that period. This is due to a substantial drop in agricultural water demand between 1993 and 2005 thanks to more efficient agricultural practices, such as drip irrigation, that were implemented in the late 1990s.[28] That said, there is still substantial room for improvement in this sector. Furthermore, growing potable water consumption, likely due to a growing population and economy, is alarming for a country considered the most vulnerable to water stress in the Western Hemisphere.



Source: Developed by the authors using data from three reports by Chile's Water Department (DGA) in 2000, 2015, and 2016.[29]

3. LEAKS AND UNAUTHORIZED CONSUMPTION

More than 30 percent of potable water in Chile is considered non-revenue water (NRW), or water that never makes it to the consumer due to water theft, technical errors, or leaks from broken or corroded pipes.[30] According to one study, Aguas Andinas, the main provider of potable water in the Metropolitan Region, loses about 31 percent of treated water due to issues such as unregulated water use, inaccurate metering, and leaky, aging pipes.[31] This is equivalent to a monthly loss of 700,000 cubic meters (568 acre-feet), worth 468 million pesos (over $685,000).[32] Not only is this a waste of purified water in a drought-prone region, but it is lost revenue that could have been invested in maintenance and modernization.

4. INSUFFICIENT DATA

The DGA lacks the resources to effectively oversee and monitor groundwater rights and uses or to effectively update the National Water Information System (Sistema Nacional de Información del Agua, SNIA).[33] As a consequence, there is insufficient or inaccessible information on how much water is drawn from the MR's aquifers, making it difficult to regulate and sustainably manage this resource. Moreover, Chile's Water Code legally separates groundwater and surface water rights, but in reality the two are hydrologically connected. Alarmingly, the relationship between upstream surface water use and the availability of groundwater downstream is not well studied or documented in the Maipo Basin. Groundwater users in the MR include small farmers, industry, large agriculture companies, and the Rural Potable Water Program (Agua Potable Rural, APR), which supplies water to rural populations. This is particularly concerning because many downstream rural communities in the MR depend on receding groundwater for their drinking supply. While Law 21.064 introduced new amendments in January 2018 that give the DGA more power to monitor water use and sanction illegal activity, there are still numerous challenges with both enforcing water regulation and updating the SNIA.[34]

5. CONFLICTS OVER GROUNDWATER

Article 263 of the Water Code technically includes groundwater users as part of the water users associations (organizaciones de usuarios del agua, OUAs) that manage water distribution, conflict resolution, and construction and maintenance of public works within a basin. However, in reality, groundwater users in the MR are not integrated into any formal management of the basin. This lack of cross-sector collaboration and communication creates challenges in overseeing the water supply and navigating the needs and grievances of groundwater users. During periods of water scarcity in the past decade, conflicts over groundwater have emerged in regions like Chacabuco and Melipilla, typically between local residents, small-scale farmers, and large agricultural industries.[35]

6. ONE BASIN TREATED AS MULTIPLE BASINS

The Maipo Basin is legally divided into three administrative sections, each considered separate in water rights and management. The first section—which includes the source of the river—is made up of multiple water users that have learned to work well together under a formalized structure. Although water use in the first section affects the second and third—given that they are all hydrologically connected as one basin—there is no legal obligation for first section users to collaborate with their counterparts in the second and third sections.[36] As the region experiences demographic and climatic changes that put additional stress on water supplies, it will become increasingly important for users to address conflicting water demands. Basin-wide collaboration can improve activities like information sharing and conflict resolution, becoming an important tool for effective water allocation decisions that maximize the fulfillment of social and economic needs without compromising the environment.

THE LEGAL MANAGEMENT BOUNDARIES ALONG THE BASIN

The Chilean Water Code (1981) establishes the legal rules for the country's privatized water market. Within the framework of the code, the DGA grants water rights to private users who can sell, mortgage, or transfer these water concessions, which are legally separate from land ownership. The Water Code also grants authority to vigilance committees (juntas de vigilancia)—a type of water users association—to oversee the distribution of water, solve conflicts between water users, and manage the construction and maintenance of public works.[37]

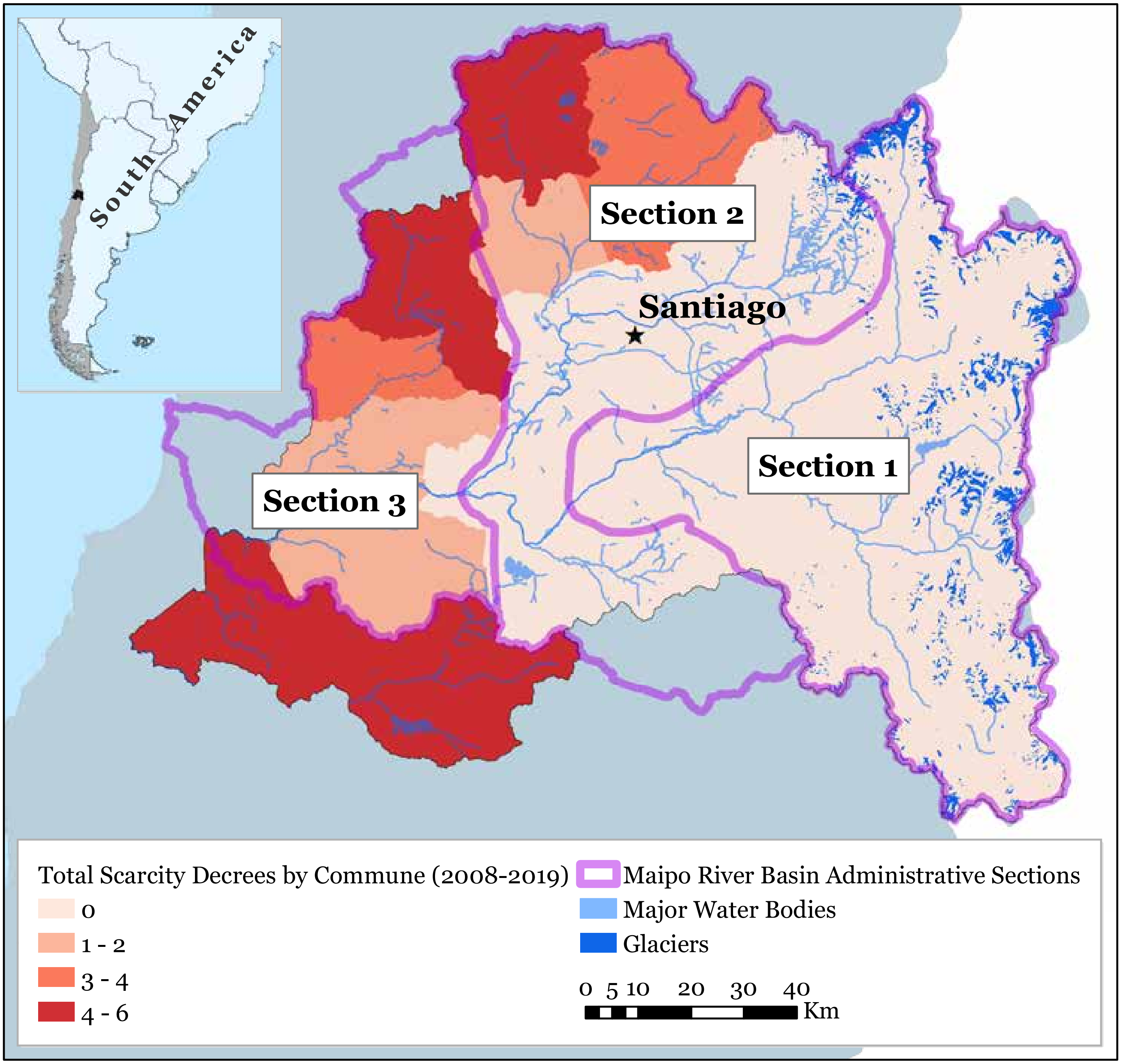
Under the Water Code, river basins in Chile are managed in sections. The Maipo River Basin is divided into three administrative sections (Figure 5). While the basin is acknowledged as "one natural flow," Article 264 of the Water Code allows for separate vigilance committees to distribute and manage water for their sections, each of which is treated independently of "neighboring sections of the same flow." Sectioning is supposed to make it easier for the DGA to organize and manage water rights along the Maipo. However, hydrologically each part of the Maipo depends on the others and no part of the basin functions in isolation. Water rights are over-allocated across the basin, including in the first section. This makes it possible for upstream users to diminish the supply downstream—an issue that will become increasingly problematic as climate change and population growth put more stress on water resources.[38]

Although the Water Code allows for a vigilance committee in each of the Maipo Basin's three sections, in reality only the first one has a fully functioning committee. The second and third sections are at the heart of the region's conflicts over water rights and are the most vulnerable to drought, yet the second has no vigilance committee and the third only a loosely organized one.

Finally, Article 263 of the Water Code calls for groundwater users, such as individual farmers and larger agricultural corporations, to be included as part of a vigilance committee or other water users organization, but in practice they are not integrated into any formal management of the basin.[39] This makes it challenging for users to effectively navigate conflicts around an over-allocated resource, especially in times of drought.

FIGURE 5. WATER SCARCITY BY COMMUNE IN CHILE'S METROPOLITAN REGION

Scarcity decrees issued by the government between 2008-2019 serve as a proxy measure for vulnerability to drought by commune. The purple outline represents the Maipo Basin's three administrative sections. The basin encompasses most of the MR, demonstrating why water management at this regional level requires an in-depth understanding of the Maipo Basin. The first section begins at the headwaters in the Andes, followed by downstream sections two and three where the most vulnerable communes can be found (Til Til, Colina, Curacavi, and part of San Pedro, shaded in the darkest red). Alhue, outside the Maipo Basin but within the MR, also received the most scarcity decrees.[40]



DATUM WGS 1984, Projection UTM, Zone 19S
Data Source: Consbio (2011), General Water Directorate (DGA) (2008-2019),
National Congress Library of Chile (2008-2011), National Statistics Institute of Chile (2017)

Source: Map created by authors on ArcGIS.

With leaky pipes, missing data, and poor collaboration, it is clear that the MR must take immediate steps to reform its water management. Six potential solutions for stakeholders in the MR are outlined below, from green infrastructure to basin-wide cooperation. Other regions throughout the world, facing similar water challenges, have successfully implemented some of these measures. As the MR continues to grapple with water scarcity, those examples serve as useful reference points.

I. GREENING THE CITY

GRAY VERSUS GREEN INFRASTRUCTURE

Wetlands, trees, and grass don't usually come to mind when city planners use the word infrastructure—especially not when the discussion centers on water management. In Chile, as in most of the world, water management infrastructure often equates to human-engineered projects made of concrete and steel in the form of pipelines, culverts, wastewater treatment facilities, and other structures that might help solve one problem in the water cycle while ignoring others. This type of development is called gray infrastructure.[41] On the other hand, "green infrastructure" solutions that capitalize on nature's ability to manage water and other resources can often serve the same function as gray infrastructure, while also providing a host of ecosystem services. Examples of green infrastructure include green roofs, rain gardens, and restored natural areas that can help urban centers participate in the water cycle and improve a city's capacity to redirect, absorb, and reuse rainwater. In fact, there is a widely recognized connection between replacing natural green spaces with pavement and increasing flood hazards.[42] By contrast, studies have shown that increasing the density of forests along the urban edge of Santiago would help prevent river runoff into the city.[43] In the long run, green infrastructure can also be a more cost-effective way to reduce stormwater pollution and sewage overflows.[44]

Currently, however, less than 1 percent of the MR's natural green habitat is protected and conserved by the National Forest Corporation (Corporación Nacional Forestal, CONAF), compared with 19.2 percent for the rest of the country as a whole. In fact, the MR's 3.4 square meters (36.6 square feet) of green space per capita falls well below the 9 square meters (96.9 square feet) recommended by international organizations.[45] The distribution of this limited green space is also unequal. Some neighborhoods have 0.4 to 2.9 square meters (4.3 to 31.2 square feet) of green space per capita, while other—usually wealthier—neighborhoods have 6.7 to 18.2 square meters (72.1 to 196 square feet) of green space per capita.[46] Protecting and creating more green space in the MR and ensuring an equitable distribution would improve resilience across the region.

Green roofs like the one pictured here in Sydney, Australia, can improve air quality, reduce the volume of stormwater runoff, and help bring down energy costs (and greenhouse gas emissions) associated with building cooling. While success varies, some studies have calculated that green roofs can reduce energy use by upwards of 50 percent.[47]

GREEN INFRASTRUCTURE'S BENEFITS TO PEOPLE

Compared with gray infrastructure, well-planned green infrastructure has multiple societal benefits, including improved public health.[48] For example, a recent study documented an improvement in mental health when vacant urban lots in Philadelphia were converted to green space.[49] Green infrastructure also purifies air and filters water. Air purification is particularly important in central Chile, where particulate matter pollution has created some of the most toxic air in the Americas.[50]

Meanwhile, natural water filtration can reduce the need to mechanically pump and treat wastewater, thereby lowering energy use and greenhouse gas emissions. Green infrastructure has resulted in wastewater treatment savings throughout the world, including an annual savings of $600,000 in Lancaster, Pennsylvania, and $1.3 million in Milwaukee, Wisconsin.[51] In addition, green infrastructure is a cost-effective way to capture runoff pollution such as oil, grease, metals, bacteria, and other toxins found on city streets before it is flushed into sewer systems and nearby surface waters.[52] Finally, green infrastructure can increase the overall water supply, mainly by enabling more water to enter the soil through improved soil infiltration. This helps replenish groundwater supplies, a critical pillar in stabilizing water availability in the MR. Rain garden tools like rain barrels can also help collect water for residential and commercial use.

© Ian Lee/Flickr

The U.S. Army Corps of Engineers uses wetlands along the Charles River in Massachusetts to prevent flood damage. The wetlands in the watershed prevent an estimated $17 million in flood damage every year.[53]

USING NATURAL SOLUTIONS TO FLOODING

SPONGE CITIES IN CHINA

In 2015 the Chinese government implemented the Sponge City Initiative, which kick-started green infrastructure projects in 30 cities across the country. More than $12 billion (15 to 20 percent of it from the central government, the rest from the private sector and local governments) has been invested for "sponge projects," including permeable roads, wetlands restoration, bioswales (vegetated alternatives to sewers to treat and infiltrate stormwater), and rainwater collection. The overarching goal is for 80 percent of urban areas to absorb and reuse 70 percent of rainfall by 2020.[54] The Sponge City Initiative focuses on: 1) storing and recycling stormwater, 2) retrofitting existing drainage systems to capture water in storage tanks, and 3) capitalizing on the multiple benefits from green infrastructure, such as green roofs, which help absorb precipitation and insulate buildings.[55] The hope is that the initiative will increase the country's water supply, restore depleted aquifers, and reduce incidents of flooding, which have more than doubled since 2008.[56] The initiative is still in its infancy but has great potential.

STATEN ISLAND'S BLUEBELT IN NEW YORK CITY

The Bluebelt stormwater management system on Staten Island, New York, is a textbook case of effective green infrastructure development. The system directs up to 1.3 million liters (350,000 gallons) of stormwater at a time through wetlands, where layers of soil, vegetation, and rock help redirect and filter the dirty water. This reduces strain on the sewage system and protects downstream communities from flood damage. To date, the award-winning Bluebelt system has saved an estimated $80 million in typical sewer costs.[57] The system performed especially well during several large storms, including Tropical Storm Tammy in 2005, which brought a downpour of 16 centimeters (6.3 inches) in 24 hours. Parts of Staten Island that previously flooded even in minor storms had no issues during these major rain events.

2. INCREASING EFFICIENCY

RESIDENTIAL CONSUMPTION

In the context of Chile's growing economy and population, decreasing per capita consumption and increasing water-use efficiency are just as important as increasing water supply. According to the Superintendent of Sanitary Services (Superintendencia de Servicios Sanitarios, SISS), a citizen can responsibly consume up to 100 liters (26.4 gallons) of potable water per day. More than 200 liters (52.8 gallons) of water per person is considered inefficient and demands a change in habits.[58] While average daily per capita potable water consumption in Chile is about 170 liters (44.9 gallons), parts of Santiago consume a whopping 600 liters (158.5 gallons) per capita per day.[59] That gross disparity has been attributed to large homes in Santiago with water-inefficient landscapes, sometimes equipped with private pools and water-intensive appliances like washing machines.[60] This extremely high level of water consumption puts increasing pressure on an already-stressed resource, especially as the population grows. The MR must take real steps to reduce consumption, through a combination of the approaches listed below.

Incentives—monetary rewards for voluntary reductions:

- Rebate system to encourage the purchase of water-efficient appliances or the replacement of water-guzzling landscapes with climate-appropriate ones that don't require irrigation
- Public education campaigns to raise awareness about water use and encourage voluntary reductions

Penalties—sometimes politically unpopular, but often highly effective[61]:

- Restrictions on nonessential household water consumption (like watering a lawn or filling a pool)
- Tiered water tariff system that penalizes individuals who use water excessively

Standards and codes:

- Updating building codes so that new buildings and appliances are more water efficient (e.g., requiring the installation of efficient toilets, faucets, and showerheads)
- Changing product standards so that manufacturers can sell only water-efficient plumbing fixtures
- Setting ordinances for how landscapes are designed (similar to the Model Water Efficient Landscape Ordinance in California, which promotes efficient water use and retrofitted landscapes)[62]
- Ensuring that the process for implementing an on-site water reuse system (for nonessential purposes like outdoor irrigation) through the recently passed Law 21.075 is clear, efficient, and hazard-free in order to broaden its application across the region[63]

Public education campaigns and financial incentives have succeeded in places like Melbourne, Australia. Other cities, like Santa Fe, New Mexico, have successfully reduced water demand by implementing conservation-oriented rate structures, such as an inclined block tariff that sets tiered rates for users based on consumption.[64] In such an arrangement, the lowest rate tier allows essential uses for water, including drinking and bathing. Each subsequent tier includes an increasing amount of nonessential consumption, like watering a lawn and washing a car. Properly designed tiered water rates can be an equitable way to ensure basic access to water while also charging households a premium for excessive water use. This in turn can incentivize household purchases of low-flow technology, such as water-efficient showerheads, faucets, and low-flush toilets. It can also motivate households to introduce water-smart landscaping, avoid running taps, and fix leaks. These successful initiatives provide a template for policymakers, private actors, and stakeholders in Chile, where the MR faces water challenges similar to those in Melbourne, Santa Fe, and elsewhere.

"In Chile there is no value for the resource, and it's very common to see gardens with high water consumption in arid and semiarid zones, like Santiago, 30-minute showers, and even people sweeping leaves off the street with a hose. In other words, even though we are running out of water, we continue to act as if this resource is unlimited."

–Dr. Pablo García-Chevesich, School of Forestry and Sciences, University of Chile[65]

SCALING DOWN DEMAND

MELBOURNE, AUSTRALIA

From 1997 to 2009, southeastern Australia experienced its worst drought on record. At the peak of the Millennium Drought, water storage volumes fell to 25.6 percent of capacity, an historic low. The reservoirs that serve Melbourne, Australia's second-largest city, were on track to be completely drained by 2009.[66] Luckily, a combination of green infrastructure and policy innovation enabled the region to reduce per capita water consumption by 50 percent.[67] These mechanisms included:

- **WATER USE RESTRICTIONS.** These ranged from Stage 1, minor restrictions on outdoor use, to Stage 4, a complete ban on outdoor use. During the peak of the Millennium Drought, restrictions increased to Stage 3, which allowed minimal outdoor use. Stage 3 combined with a voluntary conservation targets to reduce consumption to 155 liters (40.9 gallons) per person per day prevented restrictions from reaching Stage 4.
- **TELEVISION, RADIO, BILLBOARDS, AND PRINT MEDIA CAMPAIGNS TO PROMOTE WATER CONSERVATION.** An organized campaign called T155 encouraged the population to reduce per capita water consumption to 155 liters per day. This campaign saved an estimated 53 million cubic meters (43,000 acre-feet) of water between December 2008 and August 2010.
- **REBATES AND EXCHANGE PROGRAMS FOR WATER-EFFICIENT APPLIANCES.** Appliance retailers replaced toilets, showerheads, and washing machines with more efficient models. The initiative, funded by the government of the state of Victoria, saved 14.6 million cubic meters (11,800 acre-feet) of water from 2008 to 2010. In addition, the government funded 19,008 rebates to consumers in 2010 and 2011 for water-efficient technology like dual-flush toilets, water-efficient showerheads, permanent graywater systems (which reuse household water for non-potable purposes), and hot water recirculators. This rebate program saved an estimated 350,000 cubic meters (284 acre-feet) of potable water per year.

AGRICULTURAL CONSUMPTION

In the central region of Chile, climate change is expected to decrease total precipitation while also increasing the number of heatwaves, both of which affect the agriculture industry.[68] Drought conditions are predicted to reduce the amount of water available for recharging aquifers and increase evapotranspiration and the need for irrigation. Crop type, soil, and irrigation processes and technology can be adapted to reduce the amount of freshwater used per meter of soil while increasing farms' resiliency to extreme weather. Given that irrigation makes up the greatest portion of water consumption in the MR (68 percent of total water demand), this arena presents an enormous opportunity for reductions.[69]

Upgrading inefficient irrigation systems to micro-sprinkler systems could increase agricultural water efficiency by 30 percent.[70] Soil moisture sensors, evapotranspiration measurements, and remote sensing would allow farmers to accurately determine their irrigation needs and significantly reduce water consumption. In a recent study of corn and tomatoes, two different soil moisture sensors were successful in reducing water use, to varying degrees: 11 percent savings using TDR soil moisture sensors to trigger subsurface drip irrigation for sweet corn, and 67 percent savings using capacitance soil moisture sensors to trigger drip irrigation for tomatoes.[71]

Focusing on soil conservation or soil stewardship would also help reduce agricultural water consumption. Soil conservation is the name given to several agriculture techniques, such as integrating cover crops or practicing no-till farming, that help build up soil carbon and organic matter to prevent runoff, improve water infiltration, and replenish aquifers.[72] Cover crops are planted in empty fields after the cash crop has been harvested to help keep living roots in the soil. The roots of cover crops like grasses and legumes provide important nutrients for beneficial soil organisms, and they also aerate the soil, which helps rain seep into the ground instead of escaping as runoff.[73] Practicing soil conservation can also improve crop yields. During the 2012 drought in the United States, farms that used cover crops had bigger harvests than those that did not.[74]

Expanding the use of treated wastewater in the agricultural sector is another approach to alleviating the effects of water scarcity in the MR. A wastewater recycling pilot project in Coquimbo, located in Chile's arid north, successfully used treated wastewater for six hectares (nearly 15 acres) of alfalfa. According to the study, the wastewater reuse technology used for alfalfa is also well suited for fruit trees such as lemons, avocados, apples, and peaches because the water doesn't come in contact with the fruit. Additionally, research indicates that if treated wastewater were used to grow avocados, it could save the industry an annual 1.2 billion Chilean pesos ($1.75 million) in water costs.[75] Moreover, using recycled water for agriculture provides "triple dividends" by making more freshwater available for the environment and for human consumption.[76] Wastewater is also rich in nutrients like nitrogen, phosphorus, and potassium, which can lessen the need for expensive fertilizers.[77] In a new study at the University of Illinois, researchers found that if all of the nitrogen present in Cairo's wastewater were used for agriculture, it could cut Egypt's nitrogen fertilizer imports by about 50 percent.[78]

Implementing these solutions may require encouragement through knowledge sharing, awareness campaigns, and financial incentives. Academics, NGOs, policymakers, and farmers alike have important roles to play in identifying and implementing the most effective financial tools and incentives. For instance, NRDC worked with partners in Iowa in 2018 to launch a first-in-the-nation Cover Crop–Crop Insurance Demonstration Pilot Program that gives farmers a discount on normal crop insurance for land that uses cover crops. The program has received strong interest from farmers and will likely exceed the goal of gaining 80.9 hectares (200,000 acres) of new cover crops.[79] It's important to note that improving water efficiency can also create incentives to expand the agriculture industry, given the increase in water supply. Therefore, water-saving initiatives need to be accompanied by mechanisms that encourage the agriculture sector in the MR to use water more efficiently but also prioritizes the role of water in the ecosystem, using water saved to replenish rivers or recharge over-drafted aquifers. Water efficiency programs and solutions like these will be essential in encouraging Chile's agriculture industry to shift toward (or expand) sustainable farming practices that use water more efficiently.

3. REDUCING WATER LOSSES

LEAKS AND OTHER LOSSES

Water lost through leaks, theft, or metering errors is a serious problem. Chile has a 36 percent annual NRW rate, which is certainly lower than Mexico's 51 percent but quite a bit higher than other countries in the Organisation for Economic Co-operation and Development (OECD) such as Spain and Australia, at 26 percent and 10 percent, respectively, or Denmark and the Netherlands, which lead the way at 5 to 6 percent.[80] Aging pipes and infrastructure account for 22 percent of avoidable water losses in Chile; in the United States that figure is 14 to 18 percent.[81] In Chile there are 24 breaks for every 100 kilometers (62 miles) of water pipes, compared with 13 in the United States and 19 in Europe.[82]

Early leak detection can prevent the deterioration of critical infrastructure that leads to massive water losses. Luckily, new technology is emerging to tackle leaks in a more efficient and cost-effective way. For example, a team of MIT researchers recently introduced a system called PipeGuard that uses a small rubber robot to travel through water mains and detect even the smallest leak.[83] The device can be introduced through any fire hydrant—no digging is required, and water service does not need to be disrupted.

GROUNDWATER OVERSIGHT

Unregulated groundwater use in the MR is a significant barrier to reducing the NRW rate. The DGA acknowledges that groundwater management is deficient and that resources are stolen and over-allocated.[84] At the beginning of 2018, a law was approved to give the DGA more power to penalize illegal water use (Law 21.064).[85] However, the new rule didn't increase the DGA's budget to hire the experts or acquire the technology necessary to enforce the law. There are currently only three officials dedicated to fiscalización, supervising infractions of the Water Code, in the MR. As the director of the Water Department of the MR pointed out in a 2018 presentation, this is not enough manpower:

> At the MR DGA, we have three fiscalizadores [on the oversight committee] for the entire MR. So we are either here or we are over there. And when I'm here, talking to you, it also means I'm not seeing to other important issues like responding to transparency queries or issues submitted through the Virtual Citizen Attention Office [Sistema Integral de Información y Atención Ciudadana, SIAC], and this happens to other individuals dedicated to fiscalización. Both in our central office and in the Ministry, efforts are being made so that we can effectively count on more resources, both in my region and in the rest of the country.[86]

More funding for the DGA, better access to monitoring technology (like satellite imagery and drones) or use of a third party to monitor water resources, and greater collaboration among water users could improve transparency in water allocation and reduce the NRW rate.

4. ACQUIRING DATA

In rural parts of the MR, insufficient data is a major barrier to effective groundwater management. This is especially relevant for managing over extraction and aquifer recharge. Given the resource constraints currently facing the DGA, there are other key stakeholders that could help overcome data and analysis limitations. Specialized institutes, universities, and the private sector can play an important third-party role in monitoring groundwater, identifying links between surface water and groundwater use, and studying the implications of river sectioning for downstream users. Moreover, many rural communities in Chile, such as Melipilla, don't trust data collected by the DGA, which has left them open to exploitation in the past. In these instances, creating public–private partnerships or putting a neutral third party in charge of data collection and monitoring could establish fact-based discussions among stakeholders and help mitigate conflict.

HARNESSING DATA FOR CONFLICT MANAGEMENT

Melipilla, a rural province in the western part of the Metropolitan Region, is a good example of how inaccurate data can lead to conflict, particularly in communities dependent on groundwater. Melipilla is in the third section of the Maipo River Basin, where there is a haphazardly organized water users association. In the 1980s, shortly after the enactment of the Water Code, temperature and precipitation data for the Rapel River, nearly 64.4 km (40 miles) away, was used to incorrectly determine that Melipilla had underexploited and abundant water resources. New water rights for the region were put on the market, and these were purchased by agro-industry companies seeking opportunities to expand.[87]

Fast-forward two decades, and water scarcity in the region is a growing threat. It has led to protests, the closure of roads, and complaints from local residents and small-scale farmers to the DGA and agro-industry.[88] Between 2008 and 2019, all of the communes within Melipilla received scarcity decrees, which give the DGA the authority in situations of extreme drought to distribute potable water from any point in the basin to vulnerable populations.[89] The communes San Pedro, Alhué, and Curacaví received more than four scarcity decrees.[90] Several communes in Melipilla depend on water trucks for their basic needs.[91] Industry players blame small-scale farmers for their unregulated use of groundwater and have used studies of the available resource to urge the DGA to set restrictions, "hoping to avoid the granting of further water rights."[92] On the other side, local residents and NGOs have expressed concern over the power of agro-industry actors to enact Articles 63 and 65 of the Water Code to establish "restriction zones" where the DGA can only grant water rights on a provisional basis and blame industries for drilling deeper wells and drying out smaller and shallower ones.[93] One small-scale farmer who used to support his family by growing strawberries said, "I have a small piece of land, one hectare and a half [3.7 acres], but I cannot do anything. I used to live from my garden and now nothing happens; we are surrounded by dirt and without water."[94]

There is a consensus that more communication and collaboration are needed and a desire on both sides to build spaces for dialogue and multi-stakeholder engagement.[95] As water resources become more constrained, it becomes ever more important to effectively inform water management practices with data-gathering that is accurate, transparent, and inclusive.

5. ORGANIZING GROUNDWATER USERS

Sustainable groundwater management in the Maipo Basin requires an end to groundwater over extraction and a balance between water extractions and aquifer recharge. One of the main impediments to sustainable groundwater management is the lack of effective organizations of groundwater users, including stakeholders such as small farmers and APRs.[96] Groundwater user organizations, such as the National Federation of Rural Potable Water (Federación Nacional de Agua Potable Rural de Chile, FENAPRU) and the Groundwater Community (Comunidad de Aguas Subterráneas, CASUB), do exist within Chile. However, the MR is not a member of FENAPRU, and in practice there is only one well organized CASUB, and it operates out of the Copiapó Basin in northern Chile.[97]

Any effective water management in the Maipo Basin must include the voices and experiences of groundwater users, including the APRs, small farmers, industry, and agriculture corporations. As a coalition, they could more effectively raise concerns, lead water management initiatives, and begin to collaborate with one another as well as with surface water users. The DGA, NGOs, and local leaders can help build awareness of the benefits of organizing, and local and national politicians can emphasize the need for urgent action in the face of climate change to build momentum for a groundwater users coalition.

Resources to improve collaboration, trust, and effective decision making should be made available to any groundwater users association. A professional facilitation service, supported by the DGA and managed by a third party, could help foster conversation and establish dialogue between groundwater users when conflicts arise.

A database containing accurate figures should be made accessible to the public, allowing groundwater users to make informed groundwater management decisions and helping to prevent conflict caused by misperceptions, miscommunication, or misleading data.[98] A system of checks and balances could be established to ensure that the data in the system remain accurate. Such a database could be supported and run by the DGA and a combination of neutral and independent third-party organizations.

6. MOVING TOWARD A MORE INTEGRATED BASIN

THE HELPFUL ROLE OF VIGILANCE COMMITTEES

Vigilance committees are an important type of water users association that helps enforce participation and compliance in the water management scheme. Water utilities, irrigators, hydroelectric companies, and the mining industry in the first section of the Maipo have learned to work together under their local vigilance committee to overcome water conflicts and to assist one another in times of scarcity.

However, the vigilance committees for the second and third sections are virtually nonexistent. Without a vigilance committee, the effects of the Mega Drought were exacerbated in provinces like Chacabuco and Melipilla. The vigilance committee in the first section, however, more effectively managed its water and coordinated among diverse stakeholders throughout the drought. Based on the success of this committee, there are two potential road maps for improving multi-stakeholder collaboration across the Maipo Basin. One option is to replicate the existing vigilance committee structure in the second and third sections, incorporating those features that have allowed productive management of the first section. Another option is to create a single vigilance committee for the entire basin, building a more inclusive and comprehensive management structure.

SUCCESS IN INTEGRATED BASIN MANAGEMENT

Integrated Water Resource Management (IWRM) is an approach to water management that emphasizes the role of water as a social, economic, and environmental good. As defined by the Global Water Partnership, IWRM "promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[99] Incorporating IWRM into the Maipo Basin would almost certainly require basin-wide collaboration through more established water user associations or basin-wide agreements.

While such agreements are notoriously challenging, there have been noted successes throughout the world—including along the Rhine River in Europe. Running from the Alps to the North Sea, the Rhine River crosses nine countries, and its catchment area covers 200,000 square kilometers (77,220 square miles) where 60 million people live.[100] By 1950, the river was experiencing declining salmon populations, and downstream communities were reeling from the effects of chloride pollution in their drinking water supply. That year, the International Commission for the Protection of the Rhine (ICPR) was created, and it gradually transformed the Rhine Basin from the sewer of Europe into one of the cleanest international rivers on the continent. Given the river's turnaround, which included the cleanup of the water supply and the return of the salmon population (though a different species, as the Rhine salmon had gone extinct), the Rhine Basin is considered an IWRM success story.[101] Several factors contributed to the transboundary cooperation witnessed along the Rhine, including high political resolve, strong international and public pressure, and the effective governance of the ICPR.[102]

Similar basin-wide agreements, known as Voluntary Basin Management Accords (Acuerdo Voluntario para la Gestión de Cuencas, AVGC), are emerging throughout Chile. The first AVGC was signed in 2015, and there are now seven active accords for small basins or sub-basins. The AVGC protocol outlines five key components to establishing a successful basin-wide management framework: willingness, responsibility, representation, transparency/access to information, and flexibility.[103] This work is still in its infancy in Chile, and its success is yet to be quantified. However, early results are promising for the AVCG for the Llico, Vichuquén, Torca, Tilicura, and Agua Dulce Basin in the Maule Region, where 23 entities, including indigenous groups and the forestry industry, have signed an AVCG to work together to reduce contamination and forest fire risks that endanger the region's water resources.[104]

A voluntary agreement for the entire Maipo Basin would increase collaboration and improve IWRM efforts. Several experts have noted that a basin-wide Maipo management agreement would be nearly impossible given the level of political support required from the national government and the objections of upstream users. As outlined by the AVGC principles, the right approach and the right environment are needed for the success of this kind of broad initiative. Even so, it's worth noting that the ICPR, which helped restore the Rhine, was an international agreement requiring official support from the EU along with the participation of upstream parties—in this case, countries like Switzerland and Germany—that were initially uninterested in addressing downstream water quality concerns. The structure for such an agreement in the Maipo Basin is already in place, but policymakers, NGOs, and water users from different sectors will need to help persuade users to come together and push for sustainable water management solutions.

Conclusion

Chile faces a growing water deficit. In 2018, four municipalities in the Metropolitan Region received scarcity decrees, including Melipilla.[105] As the Maipo Basin, and Chile in general, brace for a future with more people, less water, and more flooding, it will become increasingly important for water users, policymakers, and regulators to work together to sustainably manage water resources. This report highlights six key challenges and the following six opportunities for improving the MR's water security and resilience to floods and drought.

1. **Incorporate new development models that prioritize green infrastructure.** The Chilean government is beginning to make the connection between green infrastructure solutions and water security in water dialogues and forums.[106] This is promising, but more remains to be seen in the form of concrete plans and actions, such as incentive programs, to encourage green infrastructure on private property or wetland restoration initiatives to manage flooding.
2. **Improve water conservation and efficiency by developing incentives (or penalties), encouraging water-efficient urban development, and capitalizing on new irrigation technology and sustainable agriculture programs.** Water saved should be used to enhance the region's climate resilience, through measures such as replenishing rivers, recharging groundwater supplies, or securing water for populations vulnerable to scarcity.
3. **Strengthen the DGA's capacity to monitor and oversee water management and supply, and tap into new technologies and innovations that can reduce NRW losses.** Chile, dubbed "Chilecon Valley," has already established a robust entrepreneurial community and was rated one of the top five countries for start-ups in a study by Gust and Fundacity.[107] The city has the perfect environment to attract local and global innovation, in terms of both funding and human capital.
4. **Improve data sharing and collection.** If there is one issue experts working in water management in Chile agree on, it is that there are simply not enough data on the use and availability of water. The lack of accurate and transparent surveying of water use is a fundamental barrier to achieving water security.
5. **Provide a formal structure under which groundwater users can organize, collaborate, and manage conflict.** Groundwater users in the MR are the most vulnerable to water scarcity. The over-allocation of groundwater use rights, the lack of accounting around water use and availability, and the existing tension and conflict among users make this a priority issue.
6. **Increase integration within the basin.** Greater collaboration among users, universities, NGOs, and private entities throughout the Maipo Basin can improve our understanding of how upstream use along the basin impacts downstream users to support a more sustainable, holistic, and resilient management of the entire Maipo.

This list reveals just how ambitious and laborious any plan to achieve an effective and sustainable water management plan will have to be, but it also highlights areas of opportunity where civil society, policymakers, and water users can collaborate and advocate for change. While various solutions to the MR's water challenges differ in scope and level of investment, each of them requires a shift in the way we think about water. Instead of considering water a resource to be managed through simple inputs and outputs, we must instead treat it as part of a dynamic system. For example, increasing potable water efficiency and reducing the NRW rate frees up more water for rivers and streams. Similarly, improving water efficiency in the agricultural sector can mean more water for replenishing groundwater supplies and for vulnerable communities that depend on trucked-in water. Green infrastructure can help mitigate floods but can also improve air quality, reduce greenhouse gas emissions, and support mental health. Treating water as a social, economic, and environmental good opens up opportunities to think creatively and discover innovative solutions that can save money and future costs. Finding win-wins in water management is not easy, but channeling resources in the right direction is not only possible but urgent for the MR.

ENDNOTES

1 Ministerio del Medio Ambiente, "Plan de Acción Nacional de Cambio Climático: 2017–2022," 2017, mma.gob.cl/wp-content/uploads/2017/07/plan_nacional_climatico_2017_2.pdf.

2 Diana Berenice Orellana Duarte, "Análisis de los Efectos de una Mega-Sequía Sobre la Generación Hidroeléctrica en Chile," Universidad de Chile, 2017, repositorio.uchile.cl/bitstream/handle/2250/146730/Analisis-de-los-efectos-de-una-mega-sequ%C3%ADa-sobre-la-generacion-hidroelectrica-en-Chile.pdf?sequence=1. Diego Istúriz, "Agricultura, Sacudida por el Cambio Climático," *La Tercera*, April 21, 2019, www.latercera.com/que-pasa/noticia/agricultura-sacudida-cambio-climatico/623063/. Diego Istúriz, "Tres Consecuencias del Cambio Climático que ya se Sienten en Chile," *La Tercera*, October 25, 2018, www.latercera.com/que-pasa/noticia/tres-consecuencias-del-cambio-climatico-ya-se-sienten-chile/375289/. "Drought Wipes Chile's Popular Lake Aculeo from the Map," *Straits Times*, March 20, 2019, www.straitstimes.com/world/americas/drought-wipes-chiles-popular-lake-aculeo-from-the-map.

3 M. P. Salas and C. Pizarro, "Sequía Golpea a Hidroeléctricas: Anotan Menor Aporte de Energía en 12 Años," *La Tercera*, January 4, 2013, www.latercera.com/noticia/sequia-golpea-a-hidroelectricas-anotan-menor-aporte-de-energia-en-12-anos/. Andrew Maddocks, Robert Samuel Young, and Paul Reig, "Ranking the World's Most Water-Stressed Countries in 2040," World Resources Institute, August 26, 2015, www.wri.org/blog/2015/08/ranking-world-s-most-water-stressed-countries-2040.

4 Calculated with 2019 exchange rate. Alicia Bárcena et al., "La Economía del Cambio Climático en Chile," Economic Commission for Latin America and the Caribbean (hereinafter CEPAL), May 2012, repositorio.cepal.org/bitstream/handle/11362/35372/1/S2012058_es.pdf. Base de Datos Estadísticos, "Cuentas Nacionales," si3.bcentral.cl/Siete/secure/cuadros/arboles.aspx (accessed June 30, 2019).

5 Instituto Nacional de Estadísticas, "Primeros Resultados Definitivos del Censo 2017: Un Total de 17.574.003 Personas Fueron Efectivamente Censadas," December 22, 2017, www.ine.cl/prensa/detalle-prensa/2017/12/22/primeros-resultados-definitivos-del-censo-2017-un-total-de-17.574.003-personas-fueron-efectivamente-censadas. Observatorio Logístico, "Estadísticas Socioeconómicas," www.observatoriologistico.cl/perfiles/estadisticas-socioeconomicas/ (accessed January 29, 2019).

6 Ministerio del Interior y Seguridad Pública, *Política Nacional para los Recursos Hídricos 2015*, 51, www.interior.gob.cl/media/2015/04/recursos_hidricos.pdf.

7 Ibid.

8 Figure 1. Maximum temperatures recorded annually at the Quinta Normal meteorological station in Santiago, Chile. The red dotted line is a linear trend line indicating an increase in temperatures at a steady rate. In 2016 and again in 2017, the highest temperature in recorded history was measured in the capital.

9 Kerstin Krellenberg et al., "Flood and Heat Hazards in the Metropolitan Region of Santiago de Chile and the Socio-Economics of Exposure," *Elsevier* 38 (March 2013): 86-95, doi.org/10.1016/j.apgeog.2012.11.017.

10 Héctor Maureira et al., "Resumen Estratégico: Radiografía del Agua," Fundación Chile, March 2018, fch.cl/wp-content/uploads/2018/03/RESUMEN-RADIOGRAFIA-DEL-AGUA.pdf.

11 Gonzalo Bacigalupe, Jorge Gironás, and Jorge Sandoval, "Riesgo de Origen Hidrometeorológico en la Ciudad de Santiago," Santiago Resiliente, May 2017, santiagoresiliente.cl/assets/uploads/2017/05/Informe_Final_CIGIDEN.pdf.

12 Javier Sáez Leal, "Los Aluviones Dejan sin Agua Potable a Seis Millones de Personas en Santiago de Chile," *El País*, February 27, 2017, elpais.com/internacional/2017/02/27/actualidad/1488156815_737807.html.

13 Comisión Nacional del Medio Ambiente, "Estudio de la Variebilidad Climática en Chile para el Siglo XXI," Departamento de Geofisica Facultad de Ciencias, Físicas y Matemáticas Universidad de Chile, December 2016, dgf.uchile.cl/PRECIS/articles-39442_pdf_Estudio_texto.pdf. Gobierno de Chile, "Plan de Adaptación y Mitigación de los Servicios de Infraestructura al Cambio Climático: 2017–2022," 2017, www.dgop.cl/Documents/PlanAccionMop.pdf.

14 Biblioteca del Congreso Nacional de Chile, "Hidrografía Región Metropolitana de Santiago,"www.bcn.cl/siit/nuestropais/region13/hidrografia.htm (accessed July 17, 2019). Consuelo Rehbein, "Cambios Climáticos Ponen en Riesgo a la Cuenca del Maipo," Publimetro, December 9, 2016, www.publimetro.cl/cl/nacional/2016/09/12/cambios-climaticos-ponen-riesgo-cuenca-maipo.html.

15 Ministerio del Interior y Seguridad Pública, *Política Nacional para los Recursos Hídricos 2015*.

16 David Farias et al., "Glacier Elevation and Mass Change over the Upper Maipo Basin, Central Andes, Chile," *Geophysical Research Abstracts*, April 2017, adsabs.harvard.edu/abs/2017EGUGA..1917029F.

17 The Nature Conservancy, "Urban Water Footprint," water.nature.org/waterblueprint/city/santiago/#/c=8:-33.89952:-70.30259 (accessed February 24, 2019).

18 "Según Cifras Preliminaries del Censo 2017, Población Censada en Chile Llega a 17.373.831 Personas," Instituto Nacional de Estadísticas, August 31, 2017, www.censo2017.cl/proceso-censal-resultados-preliminares/.

19 Jürgen Kopfmüller, "Scenarios for Future Development," in *Climate Adaptation Santiago* (Berlin: Springer, 2014), 43-56, www.springerprofessional.de/en/scenarios-for-future-development/4124842.

20 Annemarie Müller and René Höfer, "The Impacts of Climate and Land-Use Change on Flood and Heat Hazards," in *Climate Adaptation Santiago* (Berlin: Springer, 2014), 107-126, www.researchgate.net/publication/263348552_The_Impacts_of_Climate_and_Land-Use_Change_on_Flood_and_Heat_Hazards.

21 Kerstin Krellenberg et al., "Flood and Heat Hazards." Annemarie Müller and René Höfer, "The Impacts of Climate and Land-Use Change."

22 Annemarie Müller and René Höfer, "The Impacts of Climate and Land-Use Change."

23 Guillermo Donoso and María Molinos-Senate, "Sistema Tarifario de Agua Potable en Chile: Una Propuesta para Mejorar Su Sostenibilidad," Centro UC Políticas Públicas, 2016, politicaspublicas.uc.cl/wp-content/uploads/2017/04/CAP.-5.pdf.

24 Centro de Ciencia del Clima y la Resiliencia (CR)2, "Informe a la Nación: La Megasequía 2010–2015: Una Lección para el Futuro," November 2015, www.forestal.uach.cl/manejador/resources/2015informe-a-la-nacinla-megasequia-2010-2015una-leccion-para-el-futuro-1.pdf. Guillermo Donoso and María Molinos-Senate, "Sistema Tarifario de Agua Potable en Chile."

25 Ministerio de Agricultura, “Región Metropolitana es la Cuarta Región Productora Agrícola del País,” www.indap.gob.cl/noticias/detalle/2014/09/25/regi%C3%B3n-metropolitana-es-la-cuarta-regi%C3%B3n-productora-agr%C3%ADcola-del-pa%C3%ADs- (accessed March 4, 2019).

26 Centro de Innovación UC, “Proyecto de Investigadores UC Estudia Escasez Hídrica en la Horticultura de la Región Metropolitana,” centrodeinnovacion.uc.cl/proyecto-investigadores-uc-estudia-escasez-hidrica-la-horticultura-la-region-metropolitana/ (accessed February 24, 2019).

27 Instituto Nacional de Estadísticas, “Estadísticas Medioambientales: Informes Anuales,” www.ine.cl/estadisticas/medioambiente/informes-anuales (accessed February 28, 2019).

28 Ximing Cai, Claudia Ringler, and Mark W. Rosegrant, “Modeling Water Resources Management at the Basin Level: Methodology and Application to the Maipo River Basin,” International Food Policy Research Institute, 2006, www.ifpri.org/publication/modeling-water-resources-management-basin-level.

29 Dirección General de Aguas (hereinafter DGA), “Gestión del Agua,” Gobierno de Chile, March 17, 2016, www.dga.cl/DGADocumentos/Atlas2016parte4-17marzo2016b.pdf. Ernesto Brown Fernández and Juan Eduardo Saldivia Medina, “Informe Nacional Sobre la Gestión del Agua en Chile,” Gobierno de Chile, January 2000, documentos.dga.cl/REH2731.pdf. Ministerio del Interior y Seguridad Pública, *Política Nacional para los Recursos Hídricos 2015*.

30 Gabriel Caldes, “Las Pérdidas de Agua, un Tema Pendiente: Se Resuelve con Gestión y Uso de Tecnologías,” *Iagua*, February 8, 2017, www.iagua.es/blogs/gabriel-caldes/disminucion-perdidas-agua-no-es-problema-tecnico-es-gestion-y-gobernanza. Superintendencia de Servicios Sanitarios (hereinafter SISS), “Robos y Fallas en Redes Sanitarias Provocan que un Tercio del Agua Potable se Pierda,” June 16, 2014, www.siss.gob.cl/586/w3-article-10547.html.

31 Centro de Investigación Periodista, “Producción y Facturación de Agua Potable,” ciperchile.cl/wp-content/uploads/gestion-siis-2014-pag88.pdf (accessed February 24, 2019).

32 Victoria Patiño Espinoza, “Modelo de Detección de Fraude en Clients Del Servicio de Agua Potable de Una Empresa Sanitaria,” Universidad de Chile, Faculta de Ciencias Físicas y Matemáticas, Departamento de Ingeniería Industrial, 2014, repositorio.uchile.cl/bitstream/handle/2250/117040/cf-patino_ve.pdf?sequence=1.

33 The World Bank, “Chile: Integrated Water Resources Management and Infrastructure Development Project,” October 15, 2015, documents.worldbank.org/curated/en/881091467998209964/pdf/PAD1275-PAD-P152319-R2015-0205-1-Box393228B-OUO-9.pdf.

34 Daniela Duhart, Lawyer, University of Chile, personal communication via email, February 25, 2019. Biblioteca del Congreso Nacional de Chile, “Introduce Modificaciones al Marco Normativo que Rige las Aguas en Materia de Fiscalizaión y Sanciones,” January 27, 2018, www.leychile.cl/Navegar?idNorma=1114175.

35 María Rojas et al., “Agroindustria Agota Derechos de Agua de San Pedro de Melipilla,” Derecho al Agua, www.derechoalagua.cl/mapa-de-conflictos/agroindustria-agota-derechos-de-agua-de-san-pedro-de-melipilla/ (accessed March 3, 2019).

36 Sophia Borgias and Carl J. Bauer, “Trajectory of a Divided River Basin: Law, Conflict, and Cooperation Along Chile’s Maipo River,” *Water Policy* 20 (2018): 127-45, doi.org/10.2166/wp.2017.250.

37 Aurora Puig, “El Fortalecimiento de las Organizaciones de Usuarios para Una Gestión Integrada de los Recursos Hídricos,” DGA, March 1998, documentos.dga.cl/CAN4277.pdf.

38 Sophia Layser Borgias, “Law, Scarcity, and Social Movements: Water Governance in Chile’s Maipo River Basin,” University of Arizona, 2016, www.semanticscholar.org/paper/Law%2C-Scarcity%2C-and-Social-Movements%3A-Water-in-Maipo-Borgias/54f67c9370531c49cae6b1c6ae42f05aa693e484#paper-header.

39 Biblioteca del Congreso Nacional de Chile “Fija Texto Codigo de Aguas,” Ley de Chile, www.leychile.cl/Navegar?idNorma=5605 (accessed March 4, 2009).

40 DGA, “Decretos Declaración Zona de Escasez Vigentes,” Gobierno de Chile, www.dga.cl/administracionrecursoshidricos/decretosZonasEscasez/Paginas/default.aspx (accessed June 14, 2019). Biblioteca del Congreso Nacional de Chile, "Mapas Vectoriales," https://www.bcn.cl/siit/mapas_vectoriales/index_html (accessed June 14, 2019). Instituto Nacional de Estadísticas, "División Política Administrativa para Fines Censales," www.ide.cl/descarga/capas/item/division-politica-administrativa-poligonos.html (accessed June 14, 2019).

41 Gobierno Regional Metropolitano de Santiago, “Plan de Invierno: Visitan a Obras de Colector de Aguas Lluvias en Conchalí,” www.gobiernosantiago.cl/plan-de-invierno-visitan-a-obras-de-colector-de-aguas-lluvias-en-conchali (accessed March 3, 2019).

42 U.S. Geological Survey, “Effects of Urban Development on Floods,” pubs.usgs.gov/fs/fs07603/ (accessed February 24, 2019). S. Suriya and B. V. Mudgal, “Impact of Urbanization on Flooding: The Thirusoolam Sub Watershed: A Case Study,” *Journal of Hydrology* 412 (2012): 210, www.deepdyve.com/lp/elsevier/impact-of-urbanization-on-flooding-the-thirusoolam-sub-watershed-a-w4FePJq0OD.

P. E. Zope, T. I. Eldho, and V. Jothiprakash, “Impacts of Land Use–Land Cover Change and Urbanization on Flooding: A Case Study of Oshiwara River Basin in Mumbai, India,” *Catena* 145 (2016): 142-54, www.researchgate.net/publication/303891393_Impacts_of_land_use-land_cover_change_and_urbanization_on_flooding_A_case_study_of_Oshiwara_River_Basin_in_Mumbai_India.

43 Annemarie Müller and René Höfer, “The Impacts of Climate and Land-Use Change.”

44 Noah Garrison and Karen Hobbs, “Rooftops to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows,” Natural Resources Defense Council (hereinafter NRDC), 2011, www.nrdc.org/sites/default/files/rooftopstoriversII.pdf.

45 Ministerio de Agricultura, “Proteger las Áreas Silvestres Protegidas del Estado Contra el Fuego, Es Una Prioridad para CONAF,” www.conaf.cl/incendios-forestales/prevencion/proteccion-snaspe/ (accessed February 24, 2019). Ministerio del Medio Ambiente, “Estrategia Regional para la Conservación de la Biosidiversidad en la Región Metropolitana de Santiago 2015–2025,” Gobierno Regional Metropolitano de Santiago, 2013, www.gobiernosantiago.cl/wp-content/uploads/2014/doc/estrategia/Estrategia_Regional_para_la_Conservacion_de_la_Biodiversidad_RMS_2015-2024,_2014.pdf. Gabriela Elgueta et al., “Human and Resilient Santiago,” 100 Resilient Cities, March 2017, www.100resilientcities.org/wp-content/uploads/2017/07/Santiago-Resilience-Strategy-English.pdf.

46 Gabriela Elgueta et al., “Human and Resilient Santiago.”

47 Noah Garrison, Cara Horowitz, and Chris Ann Lunghino, “Looking Up: How Green Roofs and Cool Roofs Can Reduce Energy Use, Address Climate Change, and Protect Water Resources in Southern California,” NRDC, June 2012, www.nrdc.org/sites/default/files/GreenRoofsReport.pdf.

48 Eugenia C. South et al., "Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults: A Cluster Randomized Trial," *Jama Network Open* 1, no. 3 (July 2018): 1-14, jamanetwork.com/journals/jamanetworkopen/fullarticle/2688343.

49 Ibid.

50 Nick Van Mead, "Pant by Numbers: the Cities with the Most Dangerous Air—Listed," *The Guardian*, February 13, 2017, www.theguardian.com/cities/datablog/2017/feb/13/most-polluted-cities-world-listed-region.

51 U.S. Environmental Protection Agency, "Spend Less Energy Managing Water," www.epa.gov/green-infrastructure/spend-less-energy-managing-water (accessed February 24, 2019).

52 Noah Garrison and Karen Hobbs, "Rooftops to Rivers II."

53 "Wetlands: Protecting Life and Property from Flooding," Environmental Protection Agency, www.epa.gov/sites/production/files/2016-02/documents/flooding.pdf (accessed March 4, 2019).

54 Faith Ka Shun Chain et al., "'Sponge City' in China—A Breakthrough of Planning and Flood Risk Management in the Urban Context," *Land Use Policy* 76 (2018): 772-78, www.researchgate.net/publication/323738052_Sponge_City_in_China-A_breakthrough_of_planning_and_flood_risk_management_in_the_urban_context.

55 Ibid.

56 Y. O., "Why Are Chinese Cities Flooding?" *The Economist*, August 10, 2015, www.economist.com/the-economist-explains/2015/08/10/why-are-chinese-cities-flooding.

57 Christopher Economides, *Green Infrastructure: Sustainable Solutions in 11 Cities Across the United States,* Columbia University Water Center, Spring 2014, water.columbia.edu/files/2014/04/Green_Infrastructure_FINAL.pdf.

58 SISS, "Manual para el Consumo Responsable De Agua Potable," Gobierno de Chile, www.siss.gob.cl/586/articles-9103_recurso_1.pdf (accessed February 24, 2019).

59 SISS, "Informe de Gestión del Sector Sanitario 2016," Gobierno de Chile, www.siss.gob.cl/586/articles-16848_recurso_1.pdf (accessed June 30, 2019). Instituto Nacional del Torax, "Súmate a Nuestra Campaña de Ahorro de Agua, Cada Gota Cuenta!" February 23, 2017, www.torax.cl/sumate-a-nuestra-campana-de-ahorro-de-agua-cada-gota-cuenta/. Gobierno de Chile, "Cuidemos el Agua: Cifras y Recomendaciones," January 14, 2015, https://www.gob.cl/noticias/cuidemos-el-agua-cifras-y-recomendaciones/. Rocío Rivera Elorza, "Sectores Altos de Santiago Son los que Tienen el Mayor Consume de Agua en Chile," *Emol*, November 27, 2011, www.emol.com/noticias/economia/2011/11/24/514225/np-fds-sobre-los-1000-litros-de-agua-por-persona-son-consumidos-por-habitantes-de-sectores-altos-del-pais.html.

60 Rocío Rivera Elorza, "Sectores Altos de Santiago."

61 Guillermo Donoso and María Molinos-Senate, "Sistema Tarifario de Agua Potable en Chile."

62 California Department of Water Resources, "Model Water Efficient Landscape Ordinance," water.ca.gov/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Model-Water-Efficient-Landscape-Ordinance (accessed February 24, 2019).

63 Law 21.075 makes it possible for residents in both urban and rural sectors to apply for permits to implement graywater reuse systems for nonessential uses, such as landscape irrigation and washing cars. Given that the law was enacted less than a year and a half ago, in February 2018, experience with the implementation process has not been documented. Biblioteca del Congreso, "Regula la Recolección, Reutilización y Disposición de Aguas Grises," www.leychile.cl/Navegar?idNorma=1115066 (accessed March 4, 2019).

64 Rita Martins et al., "Assessing Social Concerns in Water Tariff," *Water Policy* 15 (2013): 193–211. Nelson D. Schwartz, "Water Pricing in Two Thirsty Cities: In One, Guzzlers Pay More, and Use Less," *New York Times*, May 6, 2015, www.nytimes.com/2015/05/07/business/energy-environment/water-pricing-in-two-thirsty-cities.html.

65 "La Necesidad de Reducir el Consumo de Agua Ante el Inminente Agotamiento de los Recursos Hídricos," Universidad de Chile, March 22, 2018, www.uchile.cl/noticias/141937/la-necesidad-de-reducir-el-consumo-de-agua-ante-su-agotamiento.

66 Kathleen G. Low et al., "Fighting Drought with Innovation: Melbourne's Response to the Millennium Drought in Southeast Australia," *WIREs Water* (2015), water-pire.uci.edu/wp-content/uploads/2015/05/wat2-1087.pdf.

67 Ibid.

68 Ministerio del Medio Ambiente, "Plan de Acción Nacional."

69 DGA, "Gestión Del Agua."

70 Douglas Aitken et al., "Water Scarcity and the Impact of the Mining and Agricultural Sectors in Chile," *Sustainability* 8, no. 2 (2016): 1-18, www.mdpi.com/2071-1050/8/2/128/htm.

71 Michael D. Cahn and Lee F. Johnson, "New Approaches to Irrigation Scheduling of Vegetables," *Horticulturae* 3, no. 2 (2017): 1-22, www.mdpi.com/2311-7524/3/2/28.

72 Y. Bai et al., "Modeling Soil Conservation, Water Conservation and Their Tradeoffs: A Case Study in Beijing," *Journal of Environmental Sciences (China)* 24, no. 3 (2012): 419-426.

73 "The Secret Weapon to Healthier Soil," NRDC, January 26, 2018, www.nrdc.org/stories/secret-weapon-healthier-soil. "Soil Health and Cover Crop Facts: Ten Ways Cover Crops Enhance Soil Health," Soil Health Institute, December 2017, soilhealthinstitute.org/wp-content/uploads/2017/12/10-ways-cover-crops-enhance-soil-health-FINAL.pdf.

74 Ben Chou, Claire O'Connor, and Lara Bryant, "Climate-Ready Soil: How Cover Crops Can Make Farms More Resilient to Extreme Weather Risks," NRDC, November 2015, www.nrdc.org/sites/default/files/climate-ready-soil-CA-IB.pdf.

75 Calculated with 2018 exchange rate. Agenda País, "Los Beneficios del Reúso de Aguas Residuales Tratadas en Zonas Rurales," *El Mostrador*, May 11, 2018, www.elmostrador.cl/agenda-pais/2018/05/11/los-beneficios-del-reuso-de-aguas-residuales-tratadas-en-zonas-rurales/.

76 James Winpenny et al., "Reutilización del Agua en Agricultura: ¿Beneficios para Todos?" Food and Agriculture Organization, 2013, www.fao.org/docrep/017/i1629s/i1629s.pdf.

77 Jeff Kart, "Largest-Ever USDA Grant To Grow Vegetables With Wastewater," *Forbes*, December 11, 2018, www.forbes.com/sites/jeffkart/2018/12/11/largest-ever-usda-grant-to-grow-vegetables-with-wastewater/#6377f7e62c52.

78 Lois Yoksoulian, "Human Wastewater Valuable to Global Agriculture, Economics, Study Finds," *Phys Org*, August 16, 2018, phys.org/news/2018-08-human-wastewater-valuable-global-agriculture.html.

79 Lara Bryant, "Guest Blog: Iowa's 'Good Farmer Discount' First-Year Success," NRDC, April 30, 2018, www.nrdc.org/experts/lara-bryant/guest-blog-iowas-good-farmer-discount-first-year-success. "Cover Crop–Crop Insurance Demonstration Project," Iowa Department of Agriculture & Land Stewardship," https://www.cleanwateriowa.org/covercropdemo-main (accessed March 4, 2019).

80 Dongwoo Jang and Gyewoon Choi, "Estimation of Non-Revenue Water Ratio for Sustainable Management Using Artificial Neural Network and Z-Score in Incheon, Republic of Korea," *Sustainability* 9, no. 11 (October 2017): 1-15. Gabriel Caldes, "Las Pérdidas de Agua, un Tema Pendiente. GHD, "Non-revenue Water Losses," www.ghd.com/en/about-us/non-revenue-water-losses.aspx (accessed February 24, 2019). El Instituto Nacional de Estadística, "El Coste del Agua en España Sube un 3,2% yAlcanza los 1,95 Euros por Metro Cúbico," *Iagua*, www.iagua.es/noticias/instituto-nacional-estadistica/coste-agua-espana-sube-32-alcanza-195-euros-por-metro-cubico (accessed April 15, 2019).

81 SISS, "Robos y Fallas en Redes Sanitarias." David Schaper, "As Infrastructure Crumbles, Trillions of Gallons of Water Lost," *NPR*, October 29, 2014, www.npr.org/2014/10/29/359875321/as-infrastructure-crumbles-trillions-of-gallons-of-water-lost.

82 SISS, "Robos y Fallas en Redes Sanitarias."

83 David L. Chandler, "Finding Leaks While They're Easy to Fix," *MIT News*, July 17, 2017, news.mit.edu/2017/robot-finds-leaks-water-pipes-0718.

84 Ministerio del Interior y Seguridad Pública, *Política Nacional para los Recursos Hídricos 2015*.

85 Biblioteca del Congreso Nacional de Chile, "Introduce Modificaciones al Marco Normativo que Rige las Aguas."

86 From presentation by DGA in the Paine region, organized by the DGA on June 29, 2018; quote confirmed by presenter via email in May, 2019; quote translated by author.

87 Tomás J. Usón, Cristián Henríquez and Juliane Dame, "Disputed Water: Competing Knowledge and Power Asymmetries in the Yali Alto Basin, Chile," *Geoforum* 85 (October 2017): 247-258.

88 Tomás J. Usón, Cristián Henríquez, and Juliane Dame, "Disputed Water: Knowledge and Power Asymmetries."

89 DGA, "Decretos Declaración Zona de Escasez Vigentes," Gobierno de Chile, www.dga.cl/administracionrecursoshidricos/decretosZonasEscasez/Paginas/default.aspx (accessed March 4, 2019).

90 DGA, "Decretos Declaración Zona de Escasez Vigentes," Gobierno de Chile, www.dga.cl/administracionrecursoshidricos/decretosZonasEscasez/Paginas/default.aspx (accessed March 4, 2019).

91 Solange Sánchez G., "Recursos Hídricos en la Región Metropolitana de Santiago de Chile," CEPAL, June 2015, conferencias.cepal.org/mapa_cepal/Miercoles%203/Pdf/S%20Sanchez.pdf.

92 Tomás J. Usón, Cristián Henríquez and Juliane Dame, "Disputed Water: Knowledge and Power Asymmetries."

93 Solange Sánchez G., "Recursos Hídricos en la Región Metropolitana de Santiago de Chile."

94 María Rojas, et al., "Agroindustria Agota Derechos de Agua de San Pedro de Melipilla," in Sara Larraín and Pamela Poo, eds., *Conflictos por el Agua en Chile: Entre los Derechos Humanos y las Reglas del Mercado*, (Santiago: Chile Sustentable, 2010): 237, www.archivochile.com/Chile_actual/patag_sin_repre/03/chact_hidroay-3%2000026.pdf; quote translated by author.

95 Tomás J. Usón, Cristián Henríquez and Juliane Dame, "Disputed Water: Knowledge and Power Asymmetries."

96 Sophia Layser Borgias, "Law, Scarcity, and Social Movements: Water Governance in Chile's Maipo River Basin."

97 Daniela Duhart, Lawyer, University of Chile, personal communication via email, February 25, 2019. Comunidad de Aguas Subterránes (CASUB), www.casub.cl/conozcanos/ (accessed March 4, 2019).

98 Christopher W. Moore, *The Mediation Process: Practical Strategies for Resolving Conflict*, (San Francisco: Jossey-Bass, 2014): 237.

99 United Nations, "Integrated Water Resources Management (IWRM)," www.un.org/waterforlifedecade/iwrm.shtml (accessed February 24, 2019).

100 Anne Schulte-Wülwer-Leidig et al., "Transboundary Cooperation and Sustainable Development in the Rhine Basin," Intechopen, December 19, 2017, www.intechopen.com/books/achievements-and-challenges-of-integrated-river-basin-management/transboundary-cooperation-and-sustainable-development-in-the-rhine-basin.

101 Koos Wieriks and Anne Schulte-Wülwer-Leidig, "Integrated Water Management for the Rhine River Basin, from Pollution Prevention to Ecosystem Improvement," *Natural Resources Forum*, October 9, 2009, onlinelibrary.wiley.com/doi/abs/10.1111/j.1477-8947.1997.tb00686.x.

102 Anne Schulte-Wülwer-Leidig et al., "Transboundary Cooperation and Sustainable Development in the Rhine Basin."

103 Producción Limpia, *Acuerdo Voluntario para la Gestión de Cuencas*, December 2015, www.agenciadesustentabilidad.cl/resources/uploads/documentos/protocolo_operativo.pdf.

104 Interview with author, Claudio Bustamante Lanctot, Advisor for AVGCs, personal communication in person, March 21, 2018. "Firman Inédito Acuerdo para Protección de la Cuenca del Lago Vichuquén," *El Centro*, October 10, 2017, www.diarioelcentro.cl/noticias/cronica/firman-inedito-acuerdo-para-proteccion-de-la-cuenca-del-lago-vichuquen.

105 Carlos Montes, "Escasez de Agua Afecta a 61 Comunas del País," *La Tercera*, February 2, 2018, www.latercera.com/tendencias/noticia/escasez-agua-afecta-61-comunas-del-pais/54429/. DGA, "Decretos Declaración Zona de Escasez Vigentes."

106 SISS, "Experto Mundial Habla Sobre Infraestructura Verde en el Seminario SISS," March 20, 2019, www.siss.gob.cl/586/w3-article-17412.html.

107 Naomi Larsson, "Welcome to Chilecon Valley: A Startup Hub with Its Own Special Charm," *The Guardian*, December 22, 2016, www.theguardian.com/small-business-network/2016/dec/22/chile-accelerator-startup-grants.

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NATURAL RESOURCES DEFENSE COUNCIL

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