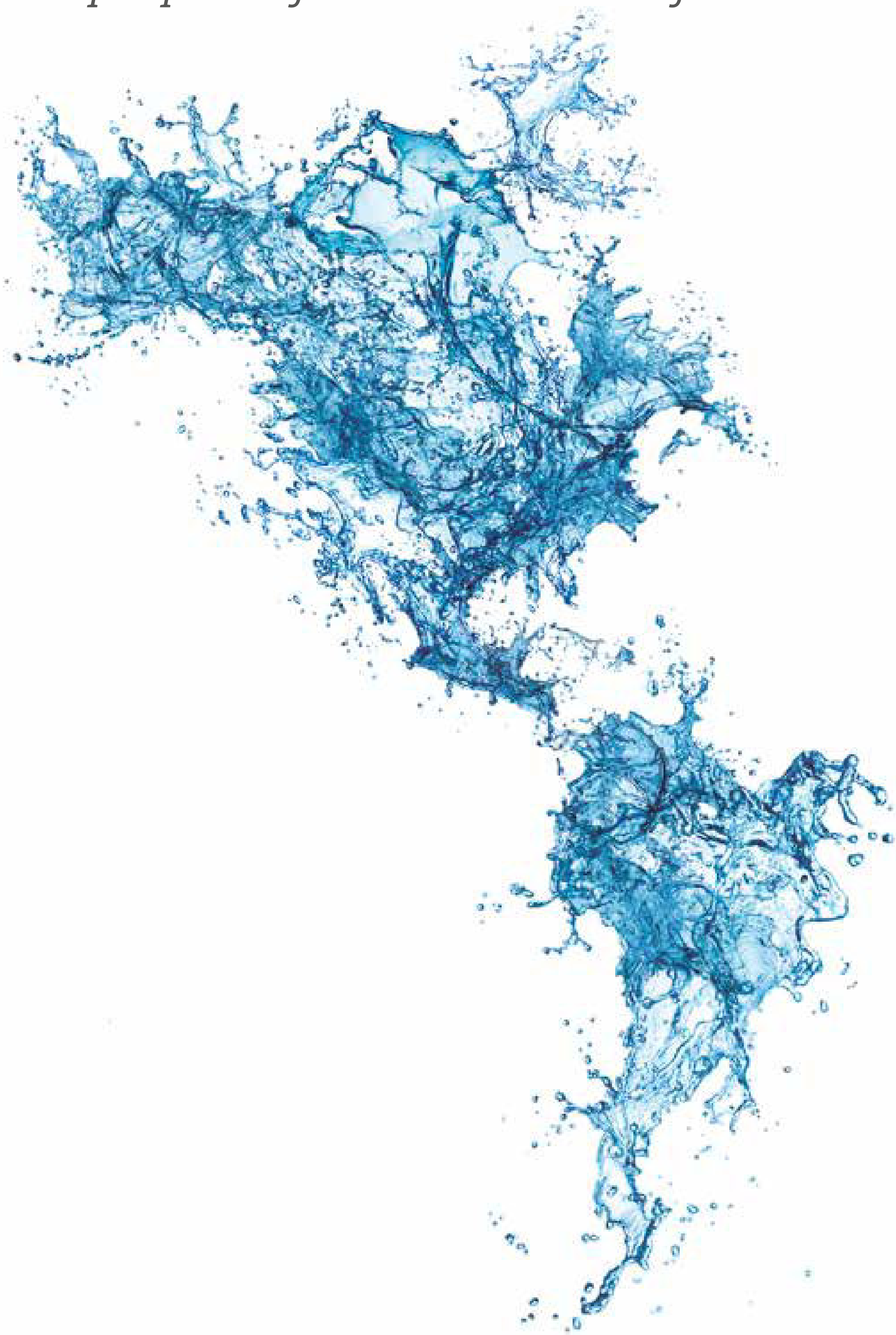
URBAN WATER
CHALLENGES IN THE AMERICAS

A perspective from the Academies of Sciences



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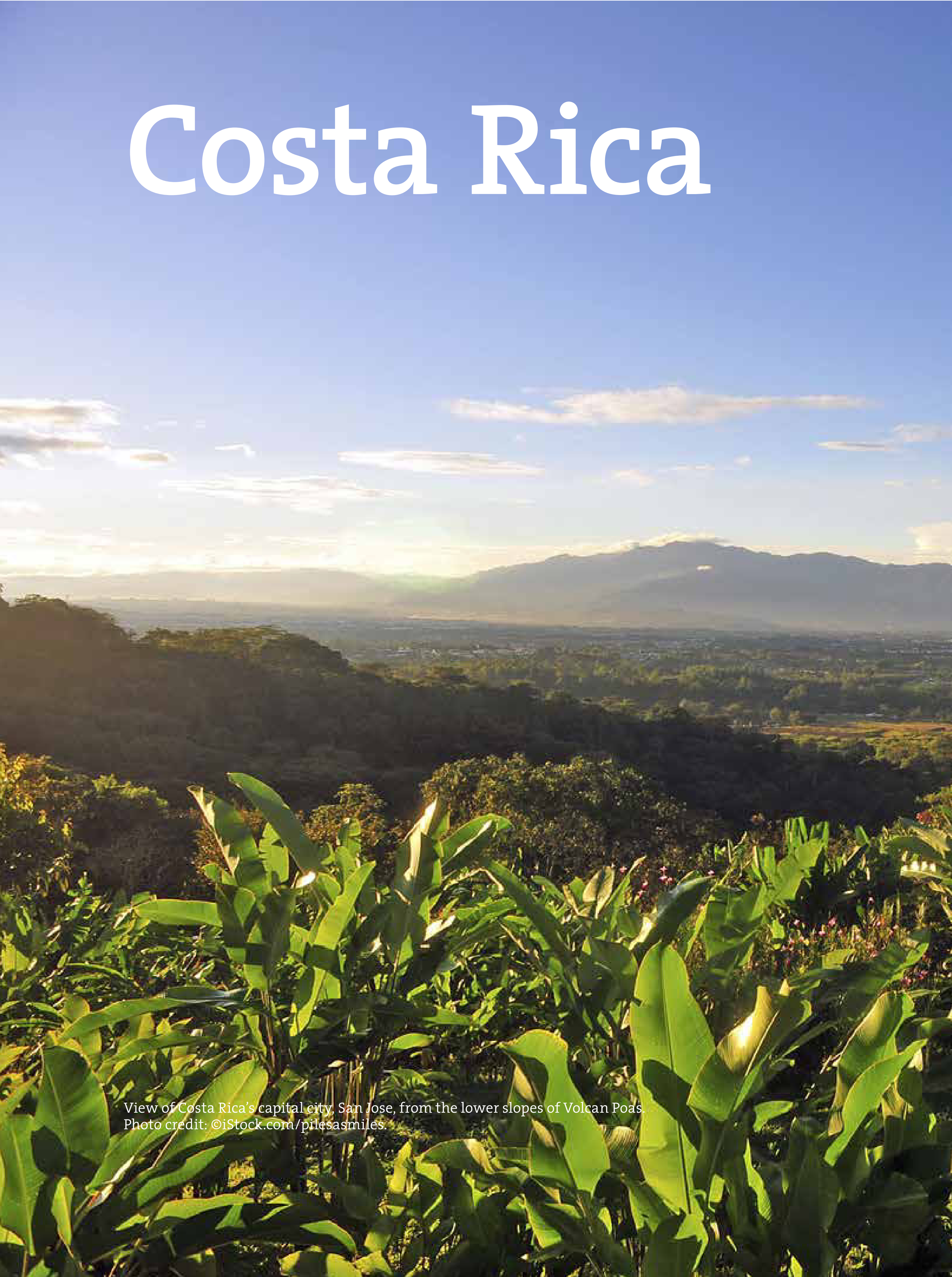


View of Costa Rica's capital city, San Jose, from the lower slopes of Volcan Poas.
Photo credit: ©iStock.com/pilesasmiles.

"Drinking water supply in Costa Rican cities can be considered good. However, sanitation, particularly water treatment, has been one of the most important challenges in urban areas. The upcoming launch of the Los Tajos Treatment Plant in the Greater Metropolitan Area constitutes a significant step towards solving the problem"

Urban Waters in Costa Rica

Hugo G. Hidalgo León, Carolina Herrero Madriz, Eric J. Alfaro Martínez, Ángel G. Muñoz, Natalie P. Mora Sandí, Darner A. Mora Alvarado and Víctor H. Chacón Salazar

Summary

This chapter provides a summary of the main issues related to urban water such as supply, sanitation, health, physical and human dimensions, floods and climate variability and change affecting cities. In general, it was found that except for some cities that have problems, water supply in Costa Rica is fairly good. However, sanitation (especially related to sewage treatment) is an issue that is only just beginning to be addressed. In 2000, sewerage coverage in urban areas was 96%, comprising 34% with sewerage facilities and 62% with septic tank availability. In 2009, the amount of urban water collected and treated remained below 4%. As for health, much of the explanation for the relatively positive indicators in this regard is linked to the integral social health system, although credit must also be given to the effect of the widespread availability of potable water in the majority of urban areas. In Costa Rica, progress has been extremely satisfactory, with 98% coverage of indoor piped water and 99% of improved drinking water sources being achieved in 2012.

Costa Rica is influenced by several large-scale natural climate phenomena such as El Niño-Southern Oscillation, Atlantic climatic variations, the influence of the Intertropical Convergence Zone and the Caribbean Low Level Jet. Likewise, in recent decades, Central America has experienced changes in hydrometeorological variables that suggest anthropogenic origins. Temperature trends towards hotter nights and days are fairly consistent, while precipitation trends (rain) have been less consistent and clear (in some locations there have been positive trends and, in others, negative ones). Moreover, in the capitals of Costa Rica (San José) and Honduras (Tegucigalpa), significant reductions in surface runoff have been found from the 1980s onwards, possibly associated with increased evapotranspiration

losses due to temperature increases. Projections with models point to a drier Central America at the end of the century, especially in the northern part (with runoff reductions of about 30%), and less so in the south (with 10% reductions in runoff). These changes become more significant when examined in light of the socioeconomic differences between northern and southern Central America, and when the vulnerabilities characteristics of countries in the region are considered, such as dependence on subsistence agriculture in some regions or society's vulnerability to extreme hydro-climatic events. Analysis and forecasting systems can help reduce these risks.

1. Introduction

Although Costa Rica has a fairly good potable water supply in general, Costa Rican cities have the problems typical of major Latin American cities, such as: a water supply deficit in specific regions, river pollution and floods. In Costa Rica, water is a relatively abundant resource, since it is a country with generally low water stress. These national figures mask the problem of water availability in some areas, however, especially in the western region of the Greater Metropolitan Area (GMA), which includes San José and the surrounding cities (Hidalgo, 2012). River pollution is a worrying aspect linked to urban sanitation, since rivers in the GMA have concentrations of pollutants several orders of magnitude above recommended levels. Many of these problems have persisted over time, and it has been difficult to make improvements in the system due to lack of funding and the costs that would be involved in its modernization. It is important, however, to highlight positive aspects, such as the low incidence of diseases caused by contaminated water and certain efforts being made, such as the construction of a treatment plant in the GMA.

This study will address some of these issues, as well as evaluating the potential effects of climate change on the future of cities. It also includes a section stating the need to comprehensively assess physical and social aspects in order to determine the vulnerability of populations to climate variability and change.

2. Water Sources in Urban Areas and the Impacts of Urbanization

Drinking Water Service in Urban Zones

The water service provided by the Costa Rican Institute of Aqueducts and Sewers (AyA), the government body responsible for water supply and sanitation, can generally be regarded as good. For example, the specific case of urban coverage, with values of approximately 99%, is an indicator that confirms this condition. Some of the positive health indices, in comparison with other countries in the region, may be partly attributed to the availability of drinking water. Aqueduct infrastructure and technology is generally good, particularly as regards capture and production systems.

Drinking water quality is monitored throughout the process by AyA through the National Water Laboratory (NWL), reaching significant levels of purification (AyA, 2002). Although the percentage of coverage of the water distribution network of drinking water is high, however, there is little confidence in the system in some areas (AyA, 2002). This is paradoxical given that, on average, Costa Rica has low water stress, but these supply problems exist at a local level (Hidalgo, 2012). For example, although in the Metropolitan Area of San José (the capital) water production was slightly lower than demand in 2002, this deficit has grown over time and mainly affects the upper parts of the city (AyA, 2002). These problems are accentuated in certain cities where production capacity is very close to or below demand, as a result of which they already have serious problems during the dry season. As part of the solution, the outlet valves of tanks have been closed overnight and their use rationed (AyA, 2002). This proves that the water supply is insufficient in some sectors, there are significant leaks or that there are insufficient reserve tanks.

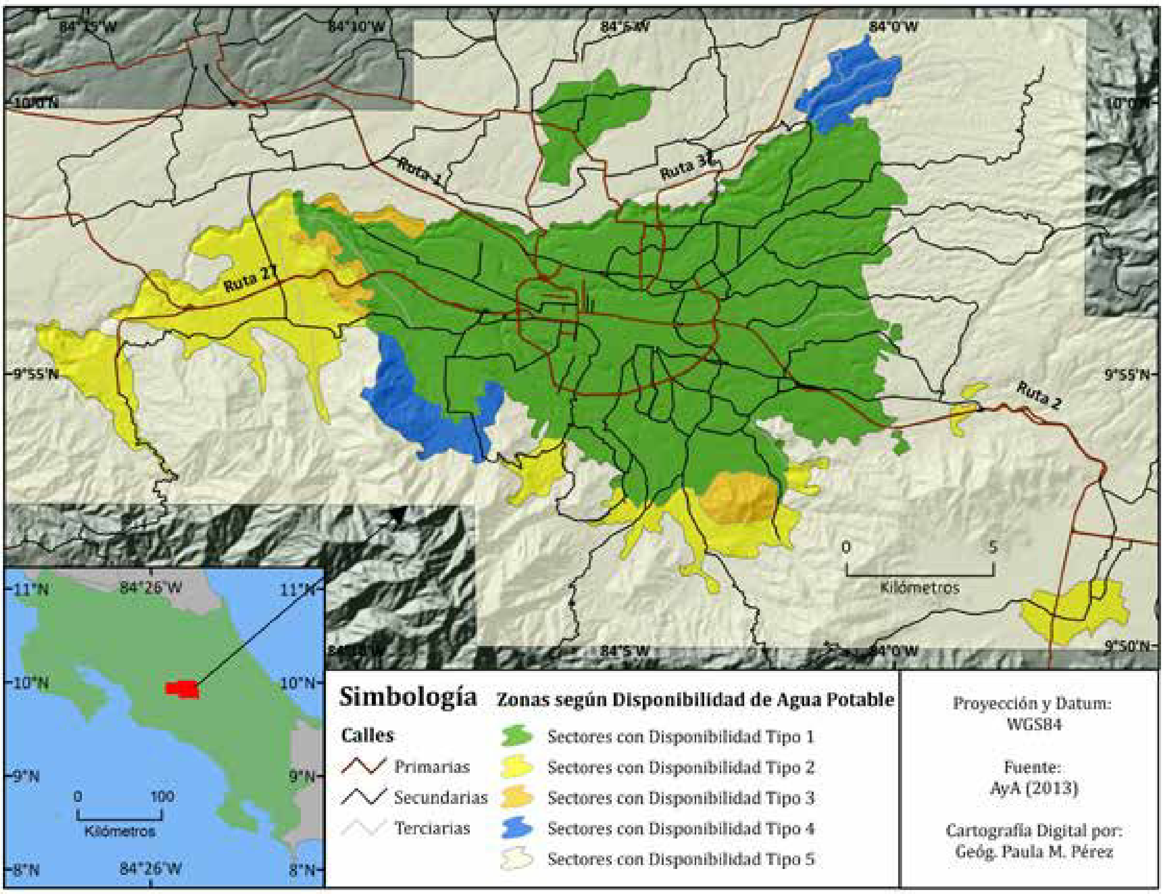
AyA (2002) mentions that one of the main shortcomings of the service is not the water supply per se, but the distribution system, as borne out by the high level of unaccounted for water, estimated at approximately 59% for the San José Metropolitan Aqueduct (and at 50% for the country as whole). Of this 59%, it is estimated that commercial losses are in the order of 29%, divided into cadastral deficiencies (unregistered connections) accounting for about 13%, lack of metering (unmetered connections) in the region of 7% and micrometering deficiencies (unrecorded consumption in meters) totaling approximately 7% (AyA, 2002). In short, the system's shortcomings are caused by several aspects such as deficiencies in the structure of the networks due to their type and age, visible leaks in the networks and connections, invisible leaks, network operation management, reserve tank overflow coupled with the lack of a register of users and networks, micrometering, and pressure control (AyA, 2002). As will be seen later, Costa Rica fares less well as regards sanitation than water supply; public sewerage coverage is relatively low, relying heavily on septic tanks, while wastewater treatment is virtually non-existent.

Table 1. Urban coverage of water and sanitation services, 2013

Area	Services	Population Served (Thousands of inhab.)	Coverage (%)
AyA Urban Area*	Aqueducts	950	99.00%**
	Sewerage	97	6.80%**
Urban Water Municipalities and ESPH	Aqueducts	N.D.	N.D.
	Sewerage	N.D.	N.D.

*AyA: Costa Rican Institute of Aqueducts and Sewers. Only the population with available water service is considered through a connection to public supply systems or aqueducts. Source: Jorge Aguilar Barboza, AyA (personal communication, 2014). ** Data from Peripheral Systems

Figure 1. Drinking water availability zoning in various sub regions



In Costa Rica, by 2000, water coverage at the urban level (an area served by the AyA and Heredia Public Service Company (ESPH) was approximately 98.5% (AyA, 2004), reaching 99.5% in 2009 (Arias, 2010). In 2000, sanitation coverage in urban areas was 96%, comprising 34% with sewerage facilities and 62% with septic tanks (AyA, 2004). The treatment rate for urban waters of under 4% (Arias, 2010) remained constant in 2009. In terms of the total population (urban plus rural), in Costa Rica, only 25% have sewerage, with 80% using septic tanks or latrines (Arias, 2010). Table 1 shows aqueduct and sewerage coverage for urban regions in 2013. As one can see, in Costa Rica, water supply coverage in urban areas is high, while sewerage coverage is low. Moreover, the problem of using septic tanks is more serious than one would think, since there are operating problems linked to soil type (such as low permeability), climate, the characteristics of the water to be treated and water volume (Arias, 2010).

The production system barely covers demand in some seasons and in some cases, fails to do so. However, attempts to secure major investments in infrastructure to increase the production capacity of aqueducts could be challenged by international lending agencies, unless losses are reduced to acceptable levels (AyA, 2002).

In order to plan the development of new buildings, the AyA has proposed zoning based on the availability of drinking water in several GMA subregions (Figure 1) (AyA, 2013). The various areas in Figure 1 are listed below (see also AyA, 2013):

- Availability Type 1: Supply Sectors of the Metropolitan Aqueduct without restrictions for new services, housing developments, residential condominiums, commercial condominiums, apartment buildings, shopping malls, schools, hotels and housing developments. Infrastructure installation or additional improvements by developers or stakeholders may be required.
- Availability Type 2: Supply Sectors for the Metropolitan Aqueduct, which, due to their location and topographic elevation, and the lack of sufficient infrastructure for drinking water production, storage and distribution, do not permit the development of housing developments, residential condominiums, commercial condominiums, apartment buildings, shopping centers, schools or hotels. They only permit the vegetative growth of individual new services allowed for single-family residential housing or new subdivisions with six or fewer lots, with public road frontage, and piped drinking water, supplied by AyA. For these cases, infrastructure installation or additional improvements by developers or stakeholders may be necessary.
- Availability Type 3: Sectors currently supplied with drinking water by the Metropolitan Aqueduct, which, due to the lack of sufficient infrastructure for drinking water production, storage and distribution, do not accept individual applications for new services or new housing developments, residential condominiums, commercial condominiums, apartment buildings, shopping centers, schools or hotels.
- Availability Type 4: Areas with water supply restrictions as stated in the AyA Board Agreement from 2005-1012, and subsequent modifications. Drinking water availability will only be provided for residential, single-family housing on existing plots of land or in new housing developments with existing public frontage, which also have piped water. Drinking water will not be supplied to housing developments without public road frontage, or condominiums, urban developments or apartment buildings.
- Availability Type 5: Areas outside the boundaries of the Metropolitan Aqueduct supply, where there are water supply systems administered by the Aqueduct and Sewerage Administrators' Associations (ASADAS), municipal aqueducts, other associations or EPSH. According to the latest data for 2013, there were a total of 163 ASADAS with an average flow rate of 769.6 liters per second

Service delivery in the GMA can be divided into two types of sources: springs and wells (Table 2). There are also 19 water treatment plants. Moreover, the urban area contains three water supply treatment plants in Tarbaca, San Gabriel Aserrí and Higuito de San Miguel de Desamparados, where private wastewater operating regulations have been established.

Table 2. Total annual production for 2013 for various water sources in the Greater Metropolitan Area

Production System	Production Source	Source Type	AyA Classification	Total Production (m³)
Planta Potabilizadora Tres Ríos	Tres Ríos	Surface	Plant	61,660,874
Planta Potabilizadora Tres Ríos	Pozo Mc. Gregor 2 (Registro)	Well	Well	642,159
Planta Potabilizadora Tres Ríos	Pozo Mc. Gregor 1 (Periféricos)	Well	Well	944,269
Planta Potabilizadora Tres Ríos	Pozo Vesco	Well	Well	246,154
Planta Potabilizadora Tres Ríos	Pozo Las Monjas	Well	Well	58,450
Planta Potabilizadora Guadalupe	Guadalupe	Surface	Plant	9,087,921
Planta Potabilizadora Los Sitios	Los Sitios	Surface	Plant	6,809,485
Planta Potabilizadora Los Sitios	Pozo La Florida	Well	Well	1,330,768
Planta Potabilizadora San Juan de Dios	San Juan de Dios Desamparados	Surface	Plant	1,936,634
Planta Potabilizadora San Juan de Dios	Pozo Veracruz	Well	Well	60,267
Planta Potabilizadora San Antonio de Escazú	San Antonio Escazú	Surface	Plant	2,551,857
Planta Potabilizadora Los Cuadros	Los Cuadros	Surface	Plant	2,229,067
Planta Potabilizadora Salitral	Salitral	Surface	Plant	1,829,319
Planta Potabilizadora San Rafael de Coronado	San Rafael Coronado	Surface	Plant	843,644
Planta Potabilizadora San Jerónimo de Moravia	San Jerónimo Moravia	Surface	Plant	652,653
Planta Potabilizadora Quitirrisí	Quitirrisí (1)	Surface	Plant	516,447
Planta Potabilizadora Alajuelita	Alajuelita	Surface	Plant	343,047
Planta Potabilizadora Mata de Plátano	Mata de Plátano	Surface	Plant	313,285
Planta Potabilizadora Guatuso Patarrá	Guatuso Patarrá	Surface	Plant	373,399
Planta Potabilizadora El Llano de Alajuelita	El Llano de Alajuelita	Surface	Plant	180,328
Planta El Tejar del Guarco	Acueducto El Tejar del Guarco			1,342,196
Bombeo Tejar del Guarco	Acueducto El Tejar del Guarco			1,025,620
Sistema de Puente Mulas	Puente Mulas	Well	Well	28,750,137
Sistema de Puente Mulas	Bombeo Intel	Well	Well	518,058
Sistema de Puente Mulas	Pozo La Rivera (Intel)	Well	Well	661,671
Sistema de Pozos La Valencia	La Valencia	Well	Well	27,868,898
Sistema de Pozos San Pablo	Pozo RIncón de Ricardo #1(Pequeño)	Well	Well	N.D.
Sistema de Pozos San Pablo	Pozo RIncón de Ricardo #2 (Grande)	Well	Well	1,749,699
Sistema de Pozos San Pablo	Pozo San Pablo # 1	Well	Well	785,482
Sistema de Pozos San Pablo	Pozo La Meseta	Well	Well	1,627,461
Sistema Potrerillos San Antono	Booster Matra	Well	Well	5,219,019
Sistema Potrerillos San Antono	Pozo Zoológico	Well	Well	178,558
Sistema Potrerillos San Antono	Pozo Brasil de Mora	Well	Well	102,259
Sistema Potrerillos San Antono	Potrerillos-Lindora	Well	Well	1,050,565
Manantiales la Libertad	Bombeo La Libertad	Well	Well	2,754,916
Manantiales de Padre Carazo	Manantiales Padre Carazo	Spring	Spring	2,009,196
Manantiales de Pizote	Manantiales Pizote	Spring	Spring	766,836
Manantiales de Vista de Mar	Manantiales Vista de Mar	Spring	Spring	211,446
Manantiales de Chiverrales	Chiverrales	Spring	Spring	1,321,920
Manantiales de Lajas	Lajas (Fuentes no medidas)	Spring	Spring	N.D.
Planta Barrio España	PP Barrio España	Surface	Surface	183,086
Captaciones Matinilla	Matinilla (Fuentes no medidas)	Surface	Surface	N.D.
Captaciones al Sur de Alajuelita	Sur Alajuelita (Fuentes no medidas)	Spring	Spring	N.D.
Captaciones Sur de Escazú	Pozo Bebedero	Well	Well	34,388
Captaciones Sur de Escazú	Sur de Escazú (Fuentes no medidas)	Various	Surface	0
Captaciones Ticufres	Fuentes Ticufres	Spring	Spring	31,476
Total				170,802,915
Systems whose production is not injected into the Metropolitan Aqueduct:				
Cartago (3)		Plants		10,074,490
Quitirrisí (2)		Plants		1,815,546

ND=Not available. (1) Ciudad Colón, (2) Puriscal-Central West Region, (3) Plant operated by the Metropolitan Region to supply Cartago and Paraíso.
Source: Jorge Aguilar Barboza, AyA (personal communication, 2014)

As can be seen from Table 2, installed capacity in springs is approximately 4.3 million m^3 per year, whereas in wells, it is in the order of 74.5 million m^3 per year, Heredia being one of the provinces with most groundwater contributions (AyA, 2013). In the GMA, groundwater therefore constitutes 68% of drinking water sources, with surface water accounting for 32% (AyA, 2002). The most important aquifers in the country are: Colima Superior, Colima Inferior, Barba, Liberia, Bagaces, Barranca, La Bomba (Limón), Zapandí and the coastal aquifers: Jacó, Playas del Coco, Brasilito and Flamingo. With regard to surface water, Hidalgo (2012) provides a table showing the characteristics of the main rivers.

Water Treatment in Cities

The cities with sewerage networks are San José, Liberia, Nicoya, Santa Cruz, Cañas, San Isidro de El General, Puntarenas, Limón, Heredia, Cartago and Alajuela, which together account for 33.8% coverage in the urban area. The only ones providing treatment through stabilization are the cities of Liberia, Nicoya, Santa Cruz, Cañas and San Isidro de El General, while a portion of the water collected in Puntarenas is treated at an activated sludge plant. It is estimated that only 4% of the wastewater generated by the urban population with sewerage (AyA, 2002; Arias, 2010) is treated.

If the country wishes to redress the imbalance in water and sewerage coverage, it must be prepared to make major investments in the urban area (AyA, 2002). It was estimated that the amount of investment required in 2002 to build a treatment plant for the GMA was approximately $289 million USD and at some point it was thought that the project could be implemented through a concession (AyA, 2002). In 2014, costs were revised and is now estimated that the final figure would be $344 million USD (*La Nación*, 2014). On September 12, 2012, a contract was signed with the Spanish company Acciona Agua, responsible for developing the Los Tajos treatment plant in La Uruca, which will receive wastewater from 11 cantons in the GMA, serving 1,070,000 inhabitants. The contract with the Spanish company stipulates that a master plan will be designed for the first, intermediate and second stages of the plant but only the first one will be built. AyA is seeking funding sources for secondary treatment. The plant is currently under construction (in February 2014, the plant was 10.65% complete) and is scheduled to begin operating in May 2015 (*La Nación*, 2014). Half of the cost will be covered by the Japan International Cooperation Agency (JICA). The Los Tajos Wastewater Treatment Plant is a component of the Project for the Environmental Improvement of the Metropolitan Area of San José, which incorporated the construction of a sewerage facility that will collect the water to be treated (EF, 2012). Over the next 14 years, other plants are to be built in the provinces of Heredia and Cartago (*La Nación*, 2014).

At present, 96% of urban wastewater collected by sewerage facilities is discharged untreated into rivers. Two of the country's major basins, those of the Grande de Tárcoles and Reventazón rivers, inhabited by approximately 70% of the population, receive raw sewage from the cities of San José, Heredia, Alajuela and Cartago (AyA, 2002). Hidalgo (2012) shows some of the average concentrations of certain water quality indicators in two of the most polluted rivers in the Greater Metropolitan Area (GMA) (San José and the surrounding cities) such as the Tárcoles River and Virilla River (a tributary of the Río Grande de Tarcoles). This situation shows how concentrations of pollutants far exceed recommended concentrations.

The degradation of the country's environment and water bodies, particularly in the GMA, over the past three decades, has become increasingly costly in human and economic terms. In fact, it has been estimated that the annual cost of pollution in terms of lost productivity and the treatment of associated diseases totals approximately $325 million USD, divided into $122 million USD in the areas of cities connected to the sewerage system and $203 million USD in areas with septic tanks (Moreno Díaz, 2009). Table 3 shows the characteristics of the AyA and ESPH (the company responsible for the water supply and sewerage in the province of Heredia) sewerage systems.

3. Water and Health in Cities

Overall health rates for the country reflect good progress in the global context. Life expectancy at birth rose from 76.7 in 1990 to 80.0 in 2012 (World Bank, 2014). During the same period, the infant mortality rate (death in the first year of life) fell from 15.3 to 8.5 (INEC, 2013). These rates were achieved through the country's effective health policies, where the integral social security health system has played a major role, while drinking water (or in many cases clean water) coverage has undeniably had a major impact. The 2012 infant mortality rate of 8.5 per thousand live births is low in comparison with other countries in the region, since the percentage of infant deaths from infectious diseases, particularly intestinal and acute respiratory infections, is relatively low (INEC, 2013). For example, the percentage of causes of death in infants due to infectious and parasitic diseases is 1.6% and to respiratory infections is 4.3% (INEC, 2013). In contrast, most infants' deaths occur in the perinatal period (48.4%) and as a result of congenital malformations (37.2%) (INEC, 2013). The situation is different with regard to diarrhea, since rates have steadily increased from 1996 to 2000, meaning that there may well be a direct link with the problem of the lack of wastewater collection systems in urban areas and environmental sanitation in general, which jeopardizes the quality of water for human consumption (AyA, 2002). Health indicators are presumably influenced by the scant attention paid to the problem of wastewater in urban areas, where ditches, streams and rivers are used to discharge pollutants (AyA, 2002). However, digestive system diseases are rarely fatal in childhood. For example, in 2011, the percentage of deaths of children under five years due to these causes was 0.01 per thousand, compared with the mortality rate of 2.21 per thousand obtained by adding all kinds of causes of death for that age range (Ministry of Health, 2011).

Drinking water is public service par excellence in which preservation of the population's health is based on providing hygiene and adequate means of disposing of excreta and other solid waste (AyA,

Table 3. Sewerage infrastructure characteristics of AyA and Heredia Public Service Company

Region / System	Rates	No. of Services	Type of Treatment	Disposal Final
AyA Metropolitan Region				
San José	U	0	N	R
AyA Huetar Atlantic Region				
Limón	U	7811	EPA+Em	M
Brunca Region				
San Isidro de Pérez Zeledón	U	3153	LE	R
Boruca, Buenos Aires	U	112	PT	Q
Lomas, Buenos Aires	U	86	LE	Q
AyA Chorotega Region				
Liberia	U	3435	LE	R
Cañas	U	1691	LE	R
Santa Cruz	U	1367	LE	R
Nicoya	U	1461	LE	R
AyA Central Pacific Region				
Puntarenas	U	8127	PT	M
West Central Region				
Ciudad Hacienda los Reyes	U	184	PT	Q
Villa Verano	U	125	PT	R
Santa Cecilia de Puriscal	U	40	PT	Q
ESPH				
Heredia	U	0	N	R

Notes: Type of treatment: PT-Treatment Plant, LE-Stabilization Pond, N-None, Disposal point: S-Stream, R-River, M-Sea. The service number is up to 30/6/2001, except for Puntarenas, which is up to 31/8/2001; In Heredia, ESPH has two small extended aereation and activated sludge plants operating and which treat a small portion of the sewerage effluents with a regular yield.
Source: Internal Commercial System, Datmart Comercial, 2014

Table 4. Cases and rates of incidence (in parentheses) of diseases related to water and sewerage

Disease	1996	1997	1998	1999	2000
Cholera	36 (1.05)	1 (0.003)	0 (0.00)	0 (0.00)	0 (0.00)
Dengue	2294 (66.62)	14279 (406.74)	2628 (69.73)	2628 (68.15)	4908 (124.47)
Diarrhea	99967 (2903.22)	113772 (3240.78)	132995 (3528.75)	140092 (3632.91)	164629 (4175.01)
Streptococcal Disease	62463 (1814.03)	58292 (1660.44)	75124 (1993.26)	91099 (2362.91)	No hay dato
Viral encephalitis	14 (0.41)	22 (0.63)	37 (0.98)	28 (0.73)	17 (0.43)
Typhoid Fever	19 (0.55)	16 (0.46)	10 (0.27)	8 (0.21)	8 (0.20)
All forms of hepatitis	868 (25.21)	1191 (33.93)	1483 (39.35)	2132 (55.29)	1739 (44.10)
Meningococcal Infection	34 (0.99)	23 (0.66)	24 (0.64)	16 (0.41)	19 (0.48)
Leptospirosis	29 (0.84)	27 (0.77)	26 (0.69)	312 (8.10)	156 (3.96)
All forms of meningitis	470 (13.65)	446 (12.70)	458 (12.15)	615 (15.95)	514 (13.04)
Salmonellosis	28 (0.81)	37 (1.05)	15 (0.40)	34 (0.88)	89 (2.26)
Shigellosis	73 (2.12)	40 (1.14)	45 (1.19)	38 (0.99)	89 (2.26)

Source: AyA (2002) using data from the Statistical Unit of the Ministry of Health. Rates per 100,000 inhabitants

2002). The link between drinking-water and health has been proven, since without this service, society cannot develop healthily. Since colonial times, Costa Rica has been concerned with providing this service to all areas. This element is also essential to development, since there can be no development without drinking water (AyA, 2002).

Lack of potable water and sewerage infrastructure or the deterioration thereof, has undoubtedly led to the presence of communicable diseases in certain parts of the country, such as cholera, typhoid fever, salmonellosis, shighelosis, amebiasis, giardisis, other intestinal infections and viral hepatitis (AyA, 2002). Diseases related to water that have been detected in the country include the following: amoebic dysentery, bacillary dysentery, diarrhea (including the previous two), cholera, hepatitis A, typhoid and paratyphoid fever, polio, schistosomiasis, dengue and malaria. Table 4 shows the incidence rates of diseases related to water and sanitation (AyA, 2002).

In practice, monitoring is used to control supply systems, as intensive health surveillance programs are no longer implemented, even though the authorities are aware of the high vulnerability of sources, particularly surface ones. Nor are there any programs to ensure the sustainability of the quality of water used for human consumption, incorporating reforestation, land use, etc. (AyA, 2002). In fact, the lack of a land use plan has been mentioned as one of the most pressing problems in Costa Rica, especially for urban areas (Hidalgo, 2012).

The recent "WHO/UNICEF Report 2014: Progress in Drinking Water and Sanitation" provides data and conclusions on the progress of Goal 10 of the Millennium Development Goals (MDGs) to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015 compared to 1990.

The Joint Monitoring Programme (JMP) established the new concept of "Improved Drinking Water Sources" (IDWS), for the purpose of measuring progress in drinking water by implementing this initiative. An improved drinking water source is one which, due to its type of construction, adequately protects water from outside contamination, particularly fecal matter and includes access to water through piping located indoors or in the patio, a standpipe, borehole or spring 1 km from the house, or even rainwater collection. This concept does not take either water quality or service quality (quantity, continuity, quality, coverage and costs) into account.

Within the framework of this weak concept, "great progress" has been observed worldwide, such as the fact that IDWS coverage rose from 76% in 1990 to 89% in 2012. In this context, it is important to note that this progress has been concentrated in rural communities, with an increase of almost 20% between those years, since it rose from 62% to 82%; However, in urban areas, access to IDWS decreased because the piped water supply fell by 1% in comparison with the 81% reported in 1990 to 80%.

In general, 23 out of the 222 countries evaluated have seen a decline in access to piped water, among which some African and Asian countries. In the Americas, coverage in the United States dropped from 100% to 99% and in Dominican Republic from 95% to 74%. During the 22 years of the study, in most of these countries, the decrease in access to improved drinking water sources is due to economic decline and poverty, migration of the rural population to urban cities and the consumption of packaged water, to the detriment of supply systems. This means that many countries have achieved MDGs within the concept of IDWS, setting standpipes or using water from wells and springs, rather than building aqueducts as has happened in most Central American countries.

Costa Rica has achieved highly satisfactory progress, including 98% water coverage of indoor piping and 99% coverage of IDWS in 2012. However, it is necessary to address water service quality and the universalization of potable water in order for these services to reach the most marginalized villages in the country.

4. Climate Variability

Costa Rica's climate is influenced by natural factors, such as the following: El Niño-Southern Oscillation (ENSO), latitudinal movements of the Intertropical Convergence Zone, the Caribbean Low Level Jet, the Mid-Summer Drought, tropical storms and hurricanes, the influence of the Atlantic and cold fronts. Valle Central de San José, where large urban centers are located, has a climatology typical of the Pacific region, with a dry season from December to April and a rainy season from May to November, with a secondary minimum in July known as Mid-Summer Drought (Figure 2). Average monthly temperature changes very little throughout the year.

High precipitation extremes cause severe flooding and damage to infrastructure in urban areas. The problem is not only caused by possible positive trends in storm intensity (see section on climate change below), but is compounded by constructions near unstable slopes or river beds, lack of maintenance of storm sewers and channels, and rapidly increasing urbanization in some areas. Frequent flooding in much of the country, such as during 2010 (classified as a La Niña year), serve as a reminder that it is essential to make efforts in other areas such as road and sewer maintenance, river care and cleaning, the conservation and strengthening of the network of hydrometeorological observations, the establishment of design standards for slopes incorporating hydrometeorological criteria, the need to update and respect land use planning and investment in education and training at all levels. These actions to ensure the maintenance, planning and development of civil protection systems are less expensive in the long run than the cost of lost infrastructure and human lives after a disaster (Hidalgo, 2010).

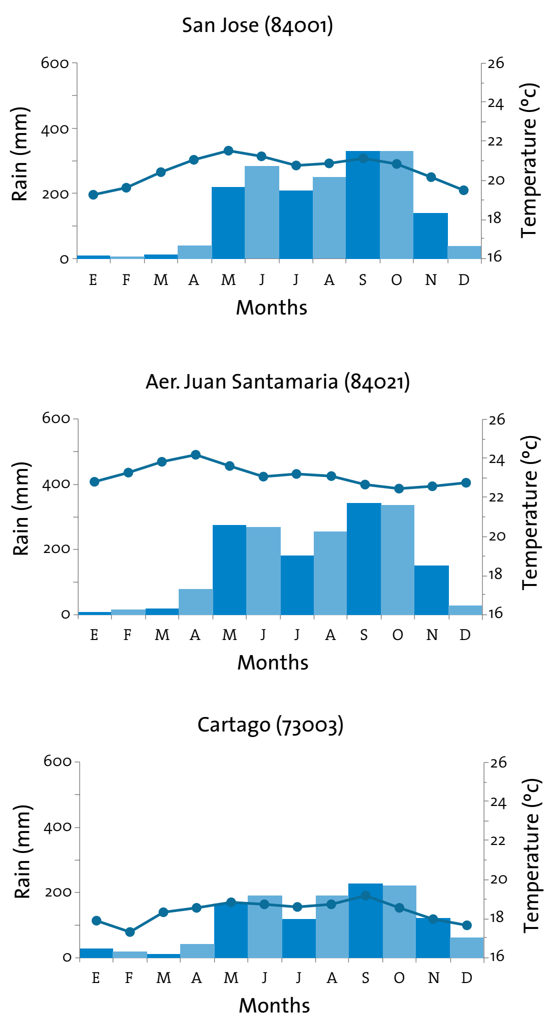
Urban Flooding, Some Case Studies

Urbanization triggered by population growth impacts on watersheds, causing: an increase in water discharge peaks and runoff and its frequency, increased verticality of channel walls, increased sediment in basins and the erosion and degradation of rivers when a basin is already well waterproofed.

This phenomenon has occurred in the basins of the cantons south of Heredia, which have been severely affected over the past 30 years. On 15 April, 2005 the Constitutional Court (the legal body responsible for issuing rulings linked to the interpretation of the Constitution) issued Resolution 2005-04050 in which the following public institutions were convicted of issuing building permits and the mismanagement of municipal water and storm sewers, within the watersheds of Quebrada Seca and the Burío River: the Ministry of Environment and Energy, Costa Rican Institute of Aqueducts and Sewers, Central Region of the Ministry of Health, Heredia Public Services Company, Municipality of San Rafael de Heredia, Municipality of San Antonio de Belen, Municipality of Heredia, Municipality of Barva, and Municipality of Flores.

The report concludes that environmental damage has been caused and obliges these institutions to prepare a joint interim report together with the actions taken to solve the above problems. The situations encountered in these streams include overflowing during intense periods of rain, direct discharge of sewage into these rivers and the disposal of garbage in their waters, resulting in unpleasant odors, a decline in fauna and flora, damage to housing and industries, and frequent evacuation of population centers. Quebrada Seca and the Bermúdez River comprise a major hydrological network in these cantons. They are basins that have historically provided one of the greatest hydrogeological potentials for the GMA and have been heavily exploited for water supply, not only for the region but also for other provinces throughout the country.

Figure 2. Climatology of three seasons in three major cities in Valle Central in Costa Rica



Source: Online atlas of the Instituto Meteorológico Nacional (http:www.imn.ac.car/).

The problems identified have mainly been caused by the exponential, uncontrolled growth of the municipalities in question, without the implementation of any mitigation measures to avoid increasing runoff and its pollution at the time. Intensive urban growth has also increased the aquifer exploitation in the upper part of these basins, with a consequent decrease in the base flow of the channels. This has impacted the environment, since during the dry season, the flow significantly decreases, thereby preventing the wastewater (often without any form of treatment) discharged directly into rivers, from being diluted by the flow of the latter. The situation is not unique to the aforementioned cantons, since it occurs increasingly frequently at the national level. To date, however, no plan or project has been submitted to propose an effective solution to this problem.

Most of the country's municipalities with strong urban development have focused on asking builders to provide rain compensation lagoons for the various housing developments or works with significant areas, without there being any standardized methodology for the design and/or supervision of the construction of these lagoons. The vast majority of these lagoons are designed without considering a full hydrograph of the basin, with different return periods and parameters without any form of calibration.

Preliminary research undertaken on this subject showed that the Municipality of San Antonio de Belén and the National University are virtually the only two entities working on a solution to this problem. Nevertheless, the Municipality of San Antonio de Belén is attempting to solve to its particular problem rather than provide an integral solution.

Urban areas require that drainage systems achieve multiple objectives, such as the following: improved water quality, groundwater recharge, recreational facilities, the creation of a habitat for flora and fauna, and ponds or swamps, landscape protection, erosion control and sediment disposal and the design of open spaces. Therefore, whenever possible, it is always recommended that existing systems be used. Urban development in areas without adequate drainage provision multiplies public spending, since the problems caused must subsequently be solved using taxpayers' money. The southeast of San José also presents problems of urban flooding, particularly in the cantons of Desamparados Aserrí and Curridabat.

5. Climate Change

Observations of Climate Change in Records of Recent Decades

In Central America, the average annual temperature increased by approximately 1°C during the period from 1900 to 2010, with the number of hot days and nights growing by 2.5% and 1.7% per decade, while the number of cold nights and days has declined by 2.2% and 2.4% respectively (Corrales, 2010). Temperature extremes show an increase of between 0.2 and 0.3°C per decade (Corrales, 2010). These trends are consistent with the results of the temperature and precipitation extremes encountered by Alexander et al. (2006) in a set of approximately 600 stations across the world. According to this study's maps of Central America, reductions from 1951 to 2003 in the number of cold nights (below the 10th percentile, TN10) total approximately 3-6 days per decade. Hot nights (above the 90th percentile, TN90) have increased from 4 to 8 days per decade, cold days (TX10) have decreased by 0 to 3 days per decade, while hot days (TX90) have increased from 4 to 8 days per decade. Trends in extreme temperature events (TN10, TN90, TX10 and TX90) are consistent with the study by Aguilar et al. (2005) using stations in Central America and the Alianza, Clima y Desarrollo (2012). However, this same report indicates that trends observed in heat waves show a wide spatial variation (with increases in some areas and reductions in others).

Temperature and precipitation analysis reveals a variety of changes over the past 40 years in Central America and northern South America. While this is true for both variables, temperature changes have a greater degree of coherence. This is not surprising, since precipitation in the region varies more than temperature (Aguilar et al., 2005). In the Central American region, there are no significant trends in overall annual precipitation (Figure 9 in Aguilar et al., 2005). In general, trends in average rainfall rates and extremes show no sign coherence in Central America. In other words, some of the precipitation stations show positive trends and others negative ones, most of which are insignificant (Aguilar et al., 2005; Alianza, Clima y Desarrollo, 2012). However, at least one study (Neelin et al., 2006) found negative trends in the northern part of Central America using station (1950-2002) and satellite (1979-2003) data. Corrales (2010) and Aguilar et al. (2005) mention that although there is significant spatial variability, precipitation indices indicate that while there have not been significant increases in the amount of precipitation, there has been an intensification of the latter. This means that rainfall patterns have changed so that now it rains more intensely in a shorter time. Some regions have seen an increased proportion of very severe storms since 1970, which is much higher than that recorded in the simulation using current models for this period. The frequency of occurrence of extreme weather and climate phenomena is likely to increase in the future, together with the frequency and intensity of hurricanes in the Caribbean Basin (Corrales, 2010). This last statement should be viewed with caution, however, since, although some modeling studies have shown there is likely to be an increase in the number of intense hurricanes in the future (Kerr, 2010), there is evidence that historically, there have not been significant increases in the number of tropical cyclones and hurricanes (Alfaro, 2007; Alfaro et al., 2010;. Alfaro and Quesada, 2010).

Hidalgo et al. (2013) changed the scale for the precipitation and temperature data from the NCEP-NCAR Reanalysis (Kalnay et al., 1996), using it as input in a hydrological model for two sites in Central America: Tegucigalpa (Honduras) and San José (Costa Rica), and thereby obtain annual runoff estimates. The results show significant negative trends in annual runoff from 1980 to 2012. These "observed" trends are relatively stronger in the case of San José (south of the isthmus) than in Tegucigalpa (northern part of the isthmus). These trends are consistent with studies in other parts of the world, which have found that in the 1980s, there were particularly significant climate changes in hydrometeorological variables (Barnett et al., 2008 and Meehl et al., 2007). However, other reports on the trends in dryness observed are varied and inconsistent (Alianza, Clima y Desarrollo, 2012).

In the particular case of Costa Rica, the differences between the climate from 1961 to 1990 and from 1991 to 2005 in weather station data show some changes in the North Pacific (with trends towards a drier climate), the Central Pacific (with trends towards more humid climates) and the Southern Caribbean (with trends towards more humid climates) (MINAET, 2009). In particular, the North Pacific area has experienced a significant decrease in rainfall from May to September. Some of these changes may partly be due to natural climate changes, since, for example, phenomena such as the El Niño-Southern Oscillation (ENSO) have changed in recent years toward higher frequencies of warm events and fewer cold events. Although it is difficult to know whether these changes are a response to anthropogenic climate change, there are large-scale, low-frequency natural phenomena, such as the Pacific Decadal Oscillation (PDO; Mantua et al., 1997) that can modulate the frequency of ENSO.

Hydro-Climatic Projections for Central America and Costa Rica

Climate projections are generally based on General Circulation Models (GCMs) or Global Climate Models. These models are mathematical representations of the factors and processes that govern the Earth's climate, considering various forcings such as solar and volcanic influence and greenhouse gases. There are several series of runs of these models, the most recent being the Coupled Model Intercomparison Project 5 (CMIP5). However, because they are relatively new, CMIP5 model runs have yet to be evaluated in great detail as regards their ability to model large-scale climate factors affecting the climate in Central America. Moreover, there are very few published studies with projections of these models. For this reason, the most recent results mentioned here are based on CMIP3 runs. There are limitations in the CMIP3 models, but they usually approximately reproduce some weather patterns associated with the Central American climate (Pierce et al., 2008 and 2009; Delworth et al., 2012; Hirota et al., 2011; Liu et al., 2012; Rauscher et al., 2008; Martin and Schumacher, 2011; Jiang et al., 2012; Hidalgo and Alfaro, 2012).

For annual temperature, the average warming in the Central American region projected for the late 21st century is approximately 2.5 to 3.5°C depending on the location (Hidalgo and Alfaro, 2012), although projections for southern Central America can be as high as 4.5°C in some months. The GCM consensus on the CMIP3 is that Central America will experience a reduction in rainfall in the order of 10-20% and of runoff by 20-40% by the end of the century (see Figures 3.3 and 3.5 respectively from the IPCC report, 2007). End of the century projections in the models, using the A2/A1B emission scenarios, indicate that warmer days are likely to increase, while cold days are likely to decrease. Hot nights are likely to rise and cold nights to fall. There will probably be heat waves and longer, more frequent and/or more intense periods in most of the region. Heavy precipitation trends are inconsistent, and there will be an increase in dryness, with less confidence in the trend in the southern end of the region (Alianza, Clima y Desarrollo, 2012). Using a regional model, Karmalkar et al. (2011) found significant reductions in future rainfall in the dry season in Central America in the A2 emissions scenario. Neelin et al. (2006) found an agreement between the models, showing a dry pattern over the Central American and Caribbean region at the end of the century (2077-2099). Using 17 GCMs, Rausher et al. (2008) cite a decrease in precipitation in summer (JJA), an intensification of "Mid-Summer Drought" or "veranillo" and a shift towards the south of Inter-Tropical Convergence Zone (ITCZ) in the Tropical Eastern Pacific as responses to climate change in the region. Using a vegetation model (rather than a hydrological one), Imbach et al. (2012) studied changes in vegetation and runoff in Central America using 136 GCM runs. These authors concluded that runoff will decrease since higher temperatures encourage evapotranspiration. Hidalgo et al. (2013) confirmed the projections for the northern part of Central America in particular, reductions at the end of the century were found of approximately 30% in some months during the summer. Hidalgo et al. also (2013) confirmed a trend towards a more pronounced Mid-Summer Drought, previously mentioned in Rausher et al. (2008). There is a significant trend (especially in the northern part of Central America) toward greater prevalence of extreme drought (years when runoff is less than the 10th percentile from 1950 to 1999) at the end of the century, and although there is a high degree of variability between the models regarding the magnitude of the predominance of the percentage of dry areas, it is clear that there will be a significant increase in the future (Hidalgo et al., 2013).

MINAET (2012) and Alvarado et al. (2011 and 2012) state that Costa Rica in particular and Central America in general are the most prominent "hot spots" in the Tropics as regards the issue of climate change due to the decrease in rainfall in JJA, consistent with results found in other previously mentioned studies (see, for example, Hidalgo et al., 2013 and Imbach et al., 2012) as well as historical records and the results of 20 global models using different emission scenarios (Neelin et al., 2006; Trenberth et al., 2007).

Although the results of many studies imply a general decrease in precipitation and runoff in Costa Rica, according to MINAET (2012), the climate in Costa Rica is not expected to respond uniformly but rather to be subjected to wet and dry extremes. Thus, projections for a high emissions scenario indicate that for the period from 2011 to 2040 in the Caribbean, increases in precipitation are estimated in the order of 35-75% for the period from May to July due to the reduced activity of cold fronts during winter. On the Pacific slope and the Northern Zone, the model estimates less precipitation than at present, and an intensified Mid-Summer Drought, which is consistent with Hidalgo et al. (2013) and Rauscher et al. (2008).

Table 8.2 of the "Second National Communication to the United Nations Framework Convention on Climate Change" (MINAET, 2009) contains a list of references related to climate change studies in Costa Rica, while Table 1.3 of this document lists recent evidence of climate change in Costa Rica. In this study, expected changes in precipitation at the end of the century (2071-2100) relative to the baseline scenario (1961-1990), obtained through the PRECIS model forced with the HadAM3P model in the A2 low emissions scenario, are negative on the Pacific coast with reductions of up to -56% in the Nicoya Peninsula, and positive on the Caribbean slope, with increases of up to 49% on the north coast of Limón city. The maximum temperature will increase from 2.4 to 7.9°C depending on location, while the minimum temperature will rise by 1.4 to 3.8°C depending on location. Similar conclusions are reached in Alvarado et al. (2012) with respect to precipitation, although the authors show regions of the South Caribbean where temperatures will fall.

Seasonal Climate Forecast in Central America for Urban Areas, Including Physical and Human Dimensions

Recent analyses in Central America show that trends associated with the annual number of impacts and disasters related to hydrometeorological events cannot solely be explained by climate trends. This means that other variables, such as those associated with socioeconomic aspects, should be included in this type of analysis to explain these variations and their associated impacts (e.g. Alfaro et al., 2010).

For example, an analysis for Central America of the annual precipitation signal indicates that 84% of the total variability is associated with interannual variations, whereas 14% is related to decadal variations (Figure 3). Assuming that climate change models are correct (which they may not be) and that scenarios with increased susceptibility to drought can therefore be expected, they may also increase or decrease in the region by decadal (10-30 years) or interannual (a few years) episodes, associated with the natural variability of the climate system (Becker et al., 2014 and Greene et al., 2011).

Moreover, Hidalgo and Alfaro (2012) found that the current north-south socioeconomic contrast between countries, in which those in the south -Panama and Costa Rica- have better living conditions than the rest of the region, will not decrease over time and may instead increase, according to some climate and future social scenarios developed by the Economic Commission for Latin America (ECLA). Moreover, Panama and Costa Rica are the only countries with better living conditions at the end of the century to take into account, for example, the positive effect on increasing GDP.

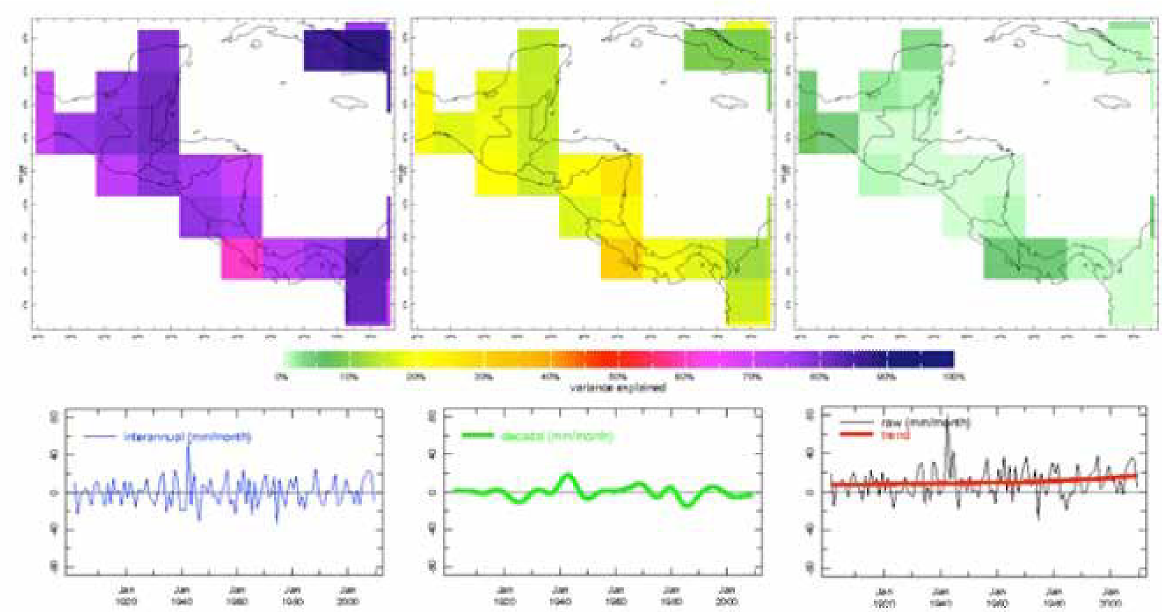
Consequently, north-south differences in living standards will probably increase in the region, meaning that attention should be paid to both the physical and socioeconomic effects which could play an important role in increasing these differences (Hidalgo and Alfaro, 2012).

Given the scenario mentioned above, seasonal climate prediction for urban areas would play a crucial role, especially in the fields of watershed planning and integrated management. These predictions should not only cover matters related to the measures of a central tendency of a particular variable, but also aspects of their variability and extreme events. An important factor to consider when studying extreme events in urban areas is land use (such as territorial planning associated with urbanization), including the maintenance of hydraulic structures in relation to the influence of climatic aspects and their impacts such as flooding and/or landslides. All these aspects should be considered when designing a system of individual forecasting for cities.

Since 1997, various parts of Latin America have organized Regional Climate Outlook Forums (RCOFs), in an effort to produce climate prediction products (IRI, 2001). They have been funded by several international agencies with the assistance of various entities such as the Regional Committee for Water Resources (CRRH) in Central America (Donoso and Ramírez, 2001; García-Solera and Ramírez, 2012) as one of the committees affiliated to the Central American Integration System, SICA, which also participates in other regional initiatives such as the Latin American Observatory of Extraordinary Events, OLE² (Muñoz et al., 2010; Muñoz et al., 2012).

Alfaro et al. (2003) add that these forums usually bring together representatives of meteorological and hydrological services and members of the scientific and academic community, who work with the development of local and regional climate perspectives. The purpose of these forums is to use national climate experience to develop a climate perspective with a regional consensus, usually on precipitation in the coming months, to present it

Figure 3. Total annual precipitation in Central American region



Time breakdown of annual rainfall in inter-annual scales (left), decadal (center) and long-term trend (right). The upper panels show the spatial distribution of the total explained variance by each scale in relation to the total variance, while the lower ones show the time series associated with the corresponding time scale for the entire spatial domain considered. The explained variances for each scale are 84%, 14% and 2% respectively. Spatial resolution is 0.5%, using CRUV 3.21. For details, see Greene et al. (2011).

Figure 4. Spatial distribution for SPI values in different seasons in Costa Rica for time scales of a) 6 b) 12 and c) 36 months.

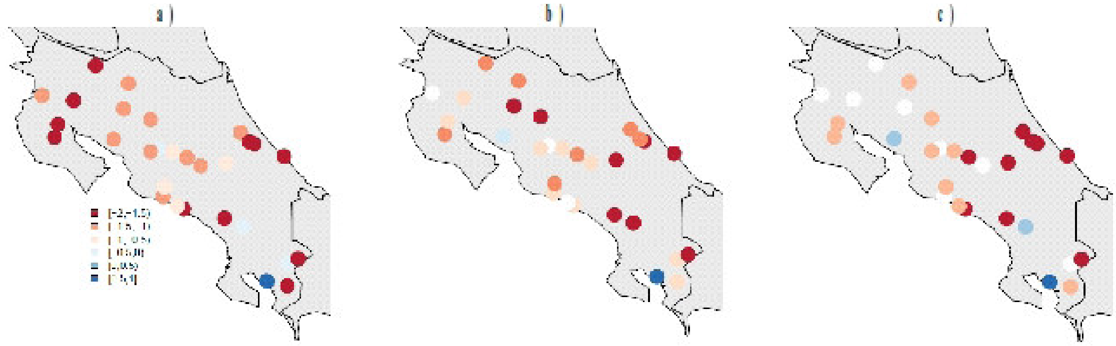
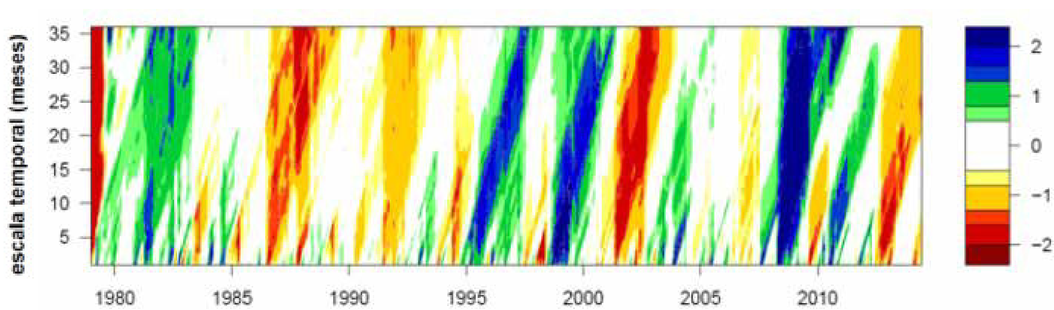


Figure 5. SPI values for the season located in CIGEFI.UCR (9° 56' 10'' N, 84° 2' 42'' W, 1236 masl, San José, Costa Rica)



in a useful way for the various agencies involved. The recommended methodology is simple and this perspective is then integrated regionally to help the various meteorological services with their activities, as well as the decision-makers and stakeholders involved.

Maldonado et al. (2013) reported that Climate Applications Forums were recently held, after the Central America RCOFs, to translate the potential impacts associated with climate predictions for users and to compensate for the fact that this information is not necessarily used by decision-makers. Feedback from these meetings raised the need for seasonal predictions on aspects related to extreme events and days with precipitation (in other words, how it rains in addition to how much it rains). These issues may be addressed using different variables, tools and scale tuning techniques (Maldonado and Alfaro, 2011; Amador and Alfaro, 2009; Alfaro et al., 1998). However, Alfaro and Pérez-Briceño (2014) and Maldonado et al. (2013) in an analysis of the seasonal geographical distribution of reports of disasters, found that it is not necessarily consistent with the geographical distribution of extreme precipitation events, reinforcing the ideas presented earlier that social variables such as population vulnerability, should be included in the analysis of the impacts of extreme events, highlighting the need to include aspects related to the seasonal prediction of extreme events and their variability in urban areas of Central America.

The use of a standardized precipitation index (SPI) has recently been suggested as a way to address the need for the monitoring or surveillance and forecasting of extreme events (WMO, 2012).

Figure 4 shows the SPI values for various weather stations in Costa Rica, by comparing periods of 6, 12 and 36 months working backwards from June 2014. Several of these weather stations are located in major urban areas such as San José, Alajuela, Cartago, Limón and Liberia. Note that in Figure 4, precipitation deficit conditions have prevailed for over six months and up to three years in some stations, such as the urban area of Limón and the

Box 5

The Environmental Service Payment Program (ESPP) in Costa Rica

by Mary Luz Moreno Díaz*

The ESPP process responded to the problem of deforestation that emerged in the mid-50s in Costa Rica. Deforestation in Costa Rica rose from 46,500 ha/year in 1950 to approximately 16,000 ha/year in 1997 (De Camino, Segura, Arias and Pérez, 2000). It began with a series of forestry incentives and evolved into the ESPP.

Costa Rica established the basis of an ESPP as a policy instrument to “strengthen the development of the natural resources sector” (Art. 46) through the Forestry Act No. 7575 (1996). Environmental services are defined in Article 3, section k of the Forest Act as “those provided by forests and forest plantations, which directly affect the protection and improvement of the environment. The following environmental services are recognized: mitigation of greenhouse gas emissions (fixation, reduction, sequestration, storage and absorption), protection of water for urban, rural or hydroelectric use, protection of biodiversity to conserve it and sustainable, scientific and pharmaceutical use, research and genetic improvement, protection of ecosystems, livelihoods and natural scenic beauty for tourism and scientific purposes (Act No.7575, 1996, Art.3, section k) .

ESP stakeholders can be classified into two categories: public and private. Actors in the public sphere representing various state and non-state organizations that have direct influence on ESP (National System of Conservation Areas-SINAC, National Forestry Financing Fund-FONAFIFO, among others).

Stakeholders in the non-public area include mostly private organizations such as non-governmental organizations (NGOs), County Agricultural Centers (CAC), associations and private companies, which perform activities directed towards the development and benefit of the owners of the forest resource receiving ESP. They also comprise the owners of forest resources, which in turn include private owners and indigenous territories.

The main sources of financing for ESPP have come from the 3.5% tax on fuel, loans from International Bank for Reconstruction and Development (IBRD), financial support from the German KfW Bank, the water use canon and contributions from companies and organizations. In total, the ESPP paid $27.2 million USD in its various modalities during the period from 1997 to 2012.

Since its inception in 1997 and until 2012, the ESPP contracted 934.274.60 hectares nationwide in the categories of: forest protection (89.7%), reforestation (6.1%), forest management (3.1%), natural regeneration (1%) and established plantations (0.1%). The last three modalities have been intermittently used during this period. In 2003, the Agroforestry System was established, whereby owners were compensated according to the number of trees recognized; the total number of trees recognized by 2012 being 4,677.135 (Fonafifo, 2014).

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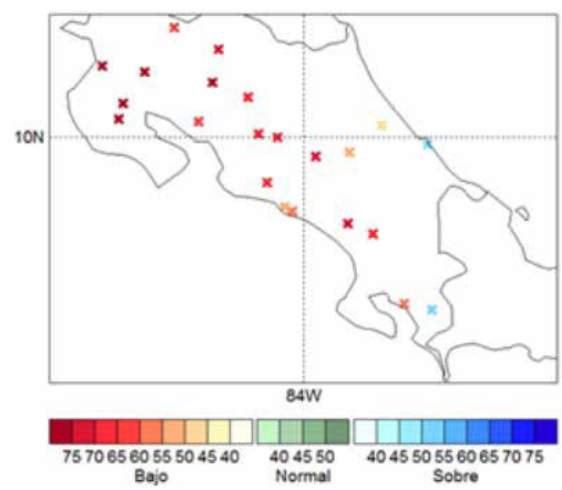
capital, San José. The cumulative effect of droughts, such as the one mentioned here, generally entails significant adverse impacts on decision makers in various sectors. However, the advantage of this type of event is that since they occur more slowly than other climate events, their occurrence, spatial distribution and intensity can often be predicted sufficiently ahead of time.

Figure 5 shows the particular case of the station located at the Center for Geophysical Research of the University of Costa Rica in San José. Note that this index can be used not only for monitoring rainfall deficit conditions (2002-2003, etc.), but also for situations in which periods may be considered humid or very humid. This is the case for the period from 2007 to 2010, for example. This figure can also be used to analyze the cumulative effect of drought on different time scales (vertical axis), giving an idea of their severity and type: prolonged periods in red indicate long durations, while red tones extending over multiple time scales (vertical axis) indicate droughts that have evolved from droughts (lasting a few months), to agricultural or hydrological droughts (several months).

Another advantage of this index is that it can be used in seasonal forecasting. Figure 6 shows the SPI forecast for the quarter from July to October 2014. One can infer from this figure that the most likely scenario is the persistence of precipitation deficit conditions over the next four months, especially on the Pacific Slope of Costa Rica. In conjunction with the fact that the deficit can be traced backwards in some regions, months or years, the above could affect key socioeconomic issues in urban areas, such as drinking water supply or hydroelectric power generation, since this aspect experiences a dry spell during the boreal winter (Alfaro, 2002).

Figure 6. SPI Probabilistic seasonal climate forecast for the July-August-September-October 2014 period



SPI probabilistic seasonal climate forecast for the July-August-September-October 2014 Period. Using a canonical correlation statistical model based on the CPT tool. (see http://iri.columbia.edu/our-expertise/climate/tools/cpt/). As a predictive field, the anomalies of the sea surface temperature for the month of June were used [60°N-10°S; 150°E-30°W] together with the persistence of the seasons in May and June. The period of the calibration was from 1979 to 2013, with a maximum of 15 modes.

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6. Conclusions

Drinking water coverage in Costa Rica's major cities is generally quite high. In certain cities, however, water is rationed in the dry season. Although over-exploitation of water resources in some regions is the main cause of the problem, water availability could be improved if the amount of losses in the supply system were reduced. Water losses are quite significant and limit the amount of credit that can be obtained to improve the system from financial institutions that demand the reduction of these losses as a pre-requisite. It has also been argued that there is a need to create land use plans to protect surface and groundwater sources.

The greatest challenge in terms of water supply and sanitation in the country, however, involves the low sewerage coverage, particularly the low percentage of water treated before being discharged into rivers. The construction of a new treatment plant in the GMA is a step in the right direction towards increasing this percentage. However, much remains to be done. Septic tanks are widely used in the country, albeit less so in urban areas. Their use has been criticized, since in many cases, they are not given proper maintenance, and sometimes these tanks have been constructed with drains into soils with low permeability. There is also a lack of studies measuring the contamination of aquifers used for water supply by this type of tank.

The lack of potable water and sewerage infrastructure or the deterioration thereof, has undoubtedly led to the presence of communicable diseases in certain parts of the country, such as cholera, typhoid fever, salmonellosis, shighelosis, amebiasis, giardisis, other intestinal infections and viral hepatitis (AyA, 2002). Diseases related to water that have been detected in the country include the following: amoebic dysentery, bacillary dysentery, diarrhoeal diseases (including the previous two), cholera, hepatitis A, paratyphoid fever and typhoid, polio, schistosomiasis, dengue and malaria. Variability and climate change as well as land use changes, such as urbanization, have resulted in severe flooding in the country's major cities. In fact, the Constitutional Court has ruled in relation to the need to seek a solution to some of the most serious problems of flooding in certain cities.

Recent studies have indicated that runoff reductions are expected in Costa Rica in the coming decades. It is worth noting, however, that these climatic reductions could paradoxically be accompanied by a trend toward larger, positive extreme events. This is because runoff reductions occur in monthly or annual time scales, whereas weather events are in the order of hours or days.

Urban flooding in Costa Rica is related to three origin factors: 1) inadequate capacity of stormwater works and rivers, 2) changes in land use (e.g. urbanization), and 3) climate change (e.g. increase in extreme events). It is essential to determine the relative contribution of these factors.

7. Recommendations

Greater awareness of the problem of sewage treatment is required and more resources must be invested in treatment plants in urban areas. Urban river pollution is perhaps the most serious problem related to urban water.

As for urban flooding, more studies are required to determine the solution to these problems. Each basin has specific characteristics, making it difficult to find a "one size fits all" solution. In some places, builders of new housing developments are being obliged to provide a system for rainwater disposal. This is usually done through infiltration lagoons. Unfortunately, there have been cases where the lagoons are abandoned once the building permits have been approved, meaning that better control is required through municipalities and ministries to ensure the correct functioning of these lagoons.

It is essential to incorporate aspects related to projected climate change into water planning. Due to the uncertainty of climate change, it is essential to have a planning mechanism that includes adaptive water management, in which long-term climate projections will guide shorter term planning and after a number of years, short-term climate projections and planning must be reviewed in order to move forward.

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9. Acronyms

ASADAS: Aqueduct and Sewerage Administrators' Associations
AyA: Costa Rican Institute of Aqueducts and Sewers.
ECLA: Economic Commission for Latin America
CMIP3: Coupled Model Intercomparison Project 3.
CMIP5: Coupled Model Intercomparison Project 5.
GMA: Greater Metropolitan Area.
EF: El Financiero (Newspaper).
ENSO: El Niño-Southern Oscillation.
ESPH: Heredia Public Service Company
IDWS Improved drinking water sources.
INEC: National Institute of Statistics and Censuses.
IPCC: Intergovernmental Climate Change Panel.
IRI: International Research Institute for Climate and Society.
JICA: Japan International Cooperation Agency.
LNA: National Water Laboratory.
GCM: General Circulation (climate) Models
MINAET: Costa Rican Ministry of Environment, Energy and Seas
NCEP-NCAR Reanalysis: Meteorological database of the US National Center for Environmental Prediction/ National Center for Atmospheric Research.
PDO: Pacific Decadal Oscillation
OLE: Latin American Observatory of Extraordinary Events.
WMO: World Meteorological Organization
WHO: World Health Organization.
PCM: Joint Monitoring Programme.
RCOF Regional Climate Outlook Fora.
SPI: Standardized precipitation index.
TN10: Number of cold nights (below the 10th percentile).
TN90: Number of warm nights (above the 90th percentile).
TX10: Number of cold days.
TX90: Number of hot days.
UNICEF: United Nations International Children's Emergency Fund.
ITCZ: Intertropical Convergence Zone.

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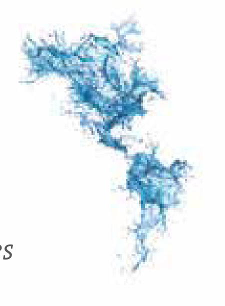
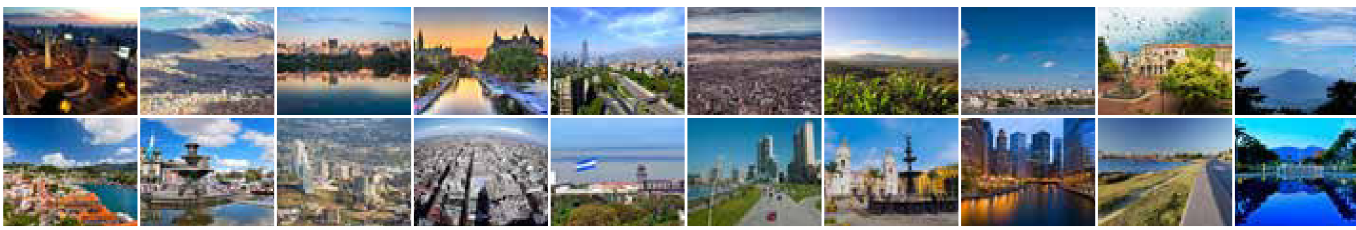
URBAN WATER CHALLENGES IN THE AMERICAS

A perspective from the Academies of Sciences





The Americas are among the most urbanized regions of the world (>80%). Urbanization goes hand in hand with intensification in the use of **water resources for human needs**; in turn, hydrological systems play a role in the development and growth of cities, not only as a source of drinking water but also for the deposition of wastes. ***Urban Water Challenges in the Americas*** describes and analyzes the problems of water in urban centers in 20 countries of the Americas: spanning from South America, Central America, Mexico and the Caribbean to the United States and Canada. This unique collection of experiences with urban waters in the Americas rests on a wide geographical representation that includes differences in water resource availability and levels of economic development.

The main challenges touched upon in this book of the IANAS Water Program are: Can the problems of urban water supply and sanitation be solved with better management? Can access to safe drinking water be improved? Can the challenge of improving sanitation and wastewater management be met? Can water related health problems and water-borne disease be better addressed in urban areas? What are the water related challenges in adapting to climate change for urban areas and how can they be met? What are good models and concepts for helping to improve water management in urban areas?

The goal of this volume is to look for different answers to these questions in the search for solutions to the challenges of properly managing water resources in urban areas.

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