Environment, Development and Sustainability (2024) 26:7347–7375
https://doi.org/10.1007/s10668-023-03011-8

Assessment and Actions to Support Integrated Water Resources Management of Seville (Spain)

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Received: 20 January 2022 / Accepted: 2 February 2023 / Published online: 11 March 2023

Abstract

Integrated Water Resources Management (IWRM) of the city of Seville, Spain, located in the southern Guadalquivir River Basin is assessed applying the city blueprint approach (CBA). The trends and pressures framework identifies five major indicators reflecting 'concern' for Seville's urban water management: heat island effect, urban drainage flooding, river peak discharges, unemployment rate and economic pressure. The results indicate increased daytime and night-time temperatures and increased urban flooding due to sealed soil, and river rise from regional precipitation under climate change. The financial pressures are driven by the high unemployment rate and the low per capita income compared to other cities assessed. The city blueprint framework identifies three categories reflecting 'poor' performance for the urban water management of Seville: water infrastructure, solid waste and climate adaptation. An aging sewer network, low operational cost recovery and combined-sewer overflow systems dominate. Solid waste management is characterized by high waste generation, low recycling rate and minimal energy recovery. The percentage of green space is low, but growing. The Governance Capacity Framework identifies five conditions reflecting 'limited' governance of water scarcity: awareness, useful knowledge, continuous learning, agents of change and financial viability. The assessment of water governance reflects a low citizens' sense of urgency. Integrating citizens and stakeholders in a more participative governance will result in increased awareness of economic efforts required to face water scarcity, renewal of water infrastructure and climate adaptation. The blue city index (BCI) of Seville is 5.8/10, placing it highly among other Mediterranean cities, and in the top 20% of 125 cities assessed worldwide. Application of the CBA to the urban water resources of cities allows clear definition of water and resource management challenges and is the first step to becoming a 'water smart' city.

Keywords Urban water management · Climate change · Water scarcity · Water governance · City blueprint approach

Abbreviations

AEAS Asociación Española de Abastecimientos de Agua y Saneamiento

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AEOPAS	Asociación Española de Operadores Públicos de Abastecimiento y Saneamiento
APE	Aqua Publica Europea
BOE	Boletín Oficial del Estado
BOJA	Boletín Oficial de la Junta de Andalucía
CEDEX	Centro de Estudios y Experimentación de Obras Públicas
CITEAIR II	Common information to European air II
CONAMA	Congreso Nacional de Medio Ambiente
DAL	Disability-adjusted life years
EDAR	Estación Depuradora de Aguas Residuales
ETAP	Estación de Tratamiento de Agua Portable
EPI	Environmental performance index
EMASESA	Empresa Metropolitana de Abastecimiento y Saneamiento de Aguas de Sevilla
ETAP	Estación de Tratamiento de Agua Portable
GDS	Groundwater development stress
GPI	Gestión Patrimonal de Infraestructuras
GPS	Gestión Pública Sostenible
GWP	Global water partnership
IEA	Instituto Euromediterráneo del Agua
IECA	Instituto de Estadística y Cartografía de Andalucía
INE	Instituto Nacional de Estadística
PES	Plan Especial de Sequía
PGRI	Plan de Gestión del Riesgo de Inundación
SIMA	Sistema de Información Multiterritorial de Andalucía
SINAC	Sistema de Información Nacional de Agua de Consumo
WEI+	Water exploitation index
YACQUI	Yearly average common air quality index

1 Introduction

1.1 Water challenges

Demographic patterns attenuated by climate change alter water availability and quality. The world population is estimated to reach 8.6 billion in 2030 (United Nations, 2017). People will concentrate in urban areas, from the current 55% of the population to 68% by 2050 (UNDESA, 2018). Higher local surface temperatures in polluted regions will likely trigger regional feedbacks and emissions leading to an increase in peak levels of ozone and $PM_{2.5}$ particles (IPCC, 2014). The biggest water-related risks are water scarcity, poor water quality, flood risk, overexploitation of water resources, aging of the water infrastructures and risk of the future financing capacity for modernization (OECD, 2013).

In the European Union, the setting of a common framework to address water management resides in the Water Framework Directive (WFD) establishing the basic principles for river basin management, water quality of ecosystems, biodiversity, participatory governance and cost recovery (European Commission, 2000). Europe faces challenges by climate change, incorporates stakeholders into participatory governance, seeks to protects ecosystems and providing adequate financing (European Commission, 2000). Water security is threatened by water stress exacerbated by the effects of climate change, unsustainable abstraction, changes in consumption patterns and growing populations (Gawlik et al., 2017). Water security is challenged in the long term (sustainability) by inadequate financing of needed water infrastructures (Jha et al., 2012).

Climate change in closely linked with the availability of water for all uses. For Spain, an average rise of 2 °C may result in a loss of ~3000 Mm^3/year of groundwater, reflecting a reduction of 15% in the availability of irrigated groundwater (Bisselink et al., 2018). A 2 °C anomaly will increase water stress, measured by the water exploitation index (WEI+) based on studies by the European Environment Agency (2018).

The EU Drinking Water Directive regulating public water services (European Commission, 2018), and the safe reclamation and reuse of wastewater to protect environmental and human health in relation to the quality achieved Alcalde-Sans et al., 2017) are examples of EU efforts to address future water challenges. Water reuse is of particular relevance for Spain (Šteflová et al., 2018).

Major water challenges facing cities include water scarcity, increased flooding risk, water pollution (special emphasis on N and P), wastewater treatment, urban heat island effects (climate change) and aging of water infrastructures (Koop et al., 2015). During the last 30 years, water scarcity in European cities has increased from 6 to 13% (European Environmental Agency, 2012). European countries waste between 10 and 25% of abstracted cleaned water due to leakage in distribution systems and lack of metering (European Environment Agency, 2012). The number and severity of floods in Europe are expected to increase flood risk, particularly in northern and north-eastern Europe (Proença de Oliveira, 2018). In 2010, 178 million people were affected by floods globally. Urban areas may be impacted by river flooding, coastal floods and urban drainage flooding (Jha et al., 2012). Water pollution is worsened by population growth, industrialization, agricultural activities and climate change. In Europe, heat waves are estimated to have caused 70,000 premature deaths in Central and Western Europe during the summer of 2003 (European Environmental Agency, 2012). Although detailed statistics are not yet available, the record heat experienced in Western and Central Europe in summer 2019 certainly impacted the health of humans and animals (Gramling, 2019).

1.2 Water management in Spain

Water availability in Spain ranges from 53 L/m^2 per year in the Andalusian Basin in the southeast (Confederación Hidrográfica del Guadalquivir, 2015) to 969 L/m^2 per year in the Miño River Basin in Galicia in the northeast (Confederación Hidrográfica del Miño-Sil, 2015). Precipitation exhibits annual variability reflected in river flows from 1 m^3/s in summer to 50 m^3/s in winter. Fluctuation of river flows is large, so if flows are not regulated (dams and reservoirs), water availability would reach ~8% of the total natural water resources, compared to ~40% in rest of Europe (Pérez-Díaz, et al., 1996). Spain has adopted a policy of increasing water supply, but water scarcity challenges this policy; Hofste, et al., 2019).

Spain has a long tradition of water management at the river basin level led by the Spanish Hydraulic Administration (Fanlo Loras, 2007). River Basin Districts in Spain (Fig. 1) are managed by Spain, Portugal and France, but the Guadalquivir River Basin is a national River Basin District managed solely by Spain.

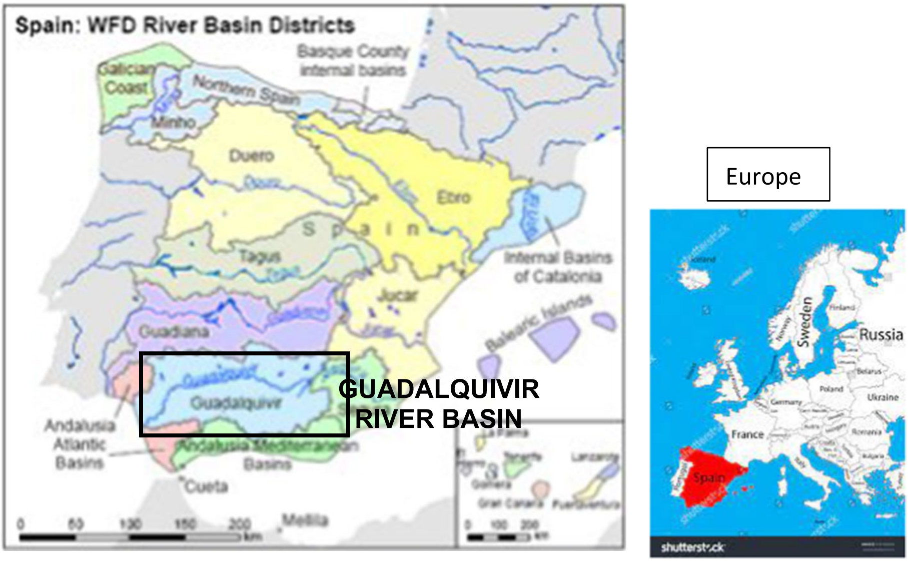

Fig. 1 River basin districts in Spain as specified in the river basin management plans as part of the Water Framework Directive (WFD). Source: European Commission (EC). (2015)

1.3 Basic water services in Spain

The provision of basic water services in Spain is universal and the water rate is affordable. The average cost for users is 0.9% of the family budget (Delacámara, 2017), far below the limits of affordability set by the UN (3% of the annual family budget for drinking water and 5% for sanitation; UN Development Program, 2006). The average water rate in Spanish domestic use is 2.2 €/m^3 (PwC, 2019) and does not fully cover the environmental and infrastructure replacement costs as embedded in the WFD.

The Spanish water sector has undergone a significant transformation in the last 40 years (Morcillo, 2017), focusing on improved response to droughts and floods (external phenomena) and the development of wastewater reuse. The water sector in Spain faces challenges from growing water scarcity aggravated by climate change and additionally by its breach of European legislation on water treatment (17% of wastewater is untreated) (PwC, 2018). Spain also faces a deficit of investment in new water infrastructures hindering the achievement of environmental objectives, the adaptation to climate change impacts and the improvement in the quality of water services (Albiol Omella, 2016).

1.4 The Guadalquivir river basin

The Guadalquivir River Basin, located in southern Spain, covers an area of 57,184 km^2 extended over 12 provinces belonging to Andalusia, Extremadura, Castilla-La Mancha and Murcia, with a total population of 4,361,469 inhabitants. The geographic space of the Guadalquivir river basin is confined by the Sierra Morena Mountains to the north, the Betic Mountain ranges to the south and the Atlantic Ocean to the west (Fig. 2).

Fig. 2 The Guadalquivir river basin. Source: (Confederación Hidrográfica del Guadalquivir, 2015)

The Guadalquivir River discharges into the Atlantic Ocean and has a total length of 666 km. The average annual runoff in the basin is 7022 hm^3/year. Average annual precipitation is 582 mm/year, with a range from 293 mm/year in the south to 1321 mm/year in the north. The average temperature is 18 °C within the Mediterranean climate (Confederación Hidrográfica del Guadalquivir, 2015). The main land uses are agriculture (56.4%), forestry (40.8%), wetlands (1.5%) and urban areas (1.3%) (Confederación Hidrográfica del Guadalquivir, 2013).

Water derives from surface and groundwater sources. Surface water resources are regulated through large dams with a total reservoir capacity of approximately 8104 hm^3 (Confederación Hidrográfica del Guadalquivir, 2013). The recharge of groundwater, 2720 hm^3/year, represents approximately 38% of the total water resources available. The main water quality pressures are point-source pollution (urban and industrial discharges), diffuse sources (agriculture (nitrates, pesticides) and erosion) and hydromorphological modifications. The main water abstractions in the Guadalquivir River basin are irrigation (88%), domestic uses (10%), industrial (1.1%) and energy production (0.9%).

2 Methodology

2.1 Study area

Our objective is to assess the Integrated Water Resources Management (IWRM) of Seville (Spain) and to provide options for actions for long-term water security. Seville is climatologically and culturally centered in the semiarid Mediterranean environment, and the capital of Andalusia located within the Guadalquivir River Basin. Seville experiences substantial weather variability and has a tradition of managing extreme phenomena, such as droughts and floods (Confederación Hidrográfica del Guadalquivir, 2015). Seville was chosen for this study because it resides in a climatologically sensitive region, is a major

Spanish city and offers decades in water management deserving of description and exchange with others. Seville water resources are specified in Fig. 3.

2.1.1 Seville water resources within the Guadalquivir river basin

Seville is the capital of Andalusia with a population of 689,434 inhabitants in 2017 (Diputación de Sevilla, 2018a, 2018b, 2018c), and per capita income of 18,477 €, compared to an average of 23,271 € in Spain (Instituto Nationacal de Estadistica, 2018). The management of the urban water cycle is carried out in the metropolitan area covering 12 municipalities and supplies water to 1,064,000 via the public water company EMASESA (2017b).

Surface water is the main source of drinking water to the Seville population. 95% of renewable water resources are for domestic water use, while the average is ~9% in the Guadalquivir River Basin which is dominated by agriculture (89% of renewable water resources) (Confederación Hidrográfica del Guadalquivir, 2015). The Seville water system has a low water stress level of ~16%, while the Guadalquivir River Basin as a whole has a water stress indicator of ~46% indicating moderate water stress.

The Seville water system consists of six reservoirs (Fig. 3), three drinking water treatment plants, and six wastewater treatment plants (WWTPs), of which four treat Seville's wastewater (EDAR Copero, EDAR Ranilla, EDAR Tablada and EDAR San Jerónimo). In 2017, reservoir volume was 402 hm^3 which represents 63% of reservoir capacity. Three hydroelectric dams generate 20,426 MWh. The water supply network is 3842 km long and the sanitation network is 2949 km long; effectively all combined-sewer overflows (EMASESA, 2017b).

Fig. 3 Seville water sources (rivers, dams and reservoirs) located in the Sierra Morena Mountains to the north of the City of Seville. (Location: 37.3891° N, 5.9845° W). ('Embalse' = Reservoir; 'Rio' = River). Source: (EMASESA, 2017b)

The average rainfall in Seville is 650 mm/year, compared with the Guadalquivir River Basin average of 582 mm/year (Confederación Hidrográfica del Guadalquivir, 2015). Rains occur mainly in autumn and spring; summer is the dry season when practically no precipitation falls. Severe droughts recur on average once every eight years (Confederación Hidrográfica del Guadalquivir, 2015), and the city has constructed infrastructures to minimize flood impacts.

2.2 The city blueprint approach

The city blueprint approach (CBA) is a diagnostic tool to assess of the sustainability of the urban water cycle (Van Leeuwen, 2012). The CBA is the first step in the process to advance a sustainable urban water cycle and services in a city (Van Leeuwen, and Koop, 2015). Recently, CBA methodology was applied in 125 municipalities and regions in 53 countries worldwide, including 32 Provincial capitals in China (van Leeuwen & Koop, 2020). Also, the CBA has been applied in comprehensive assessment of the urban water cycle in Seoul and tens of coastal cities in South Korea (Kim et al., 2018; Lee et al., 2022), and 45 cities and regions mostly in Europe (Koop & van Leeuwen, 2017), all to investigate their urban water cycles to identify challenges and potential solutions.

The CBA consists of three complementary frameworks (Fig. 4). The main challenges of cities are assessed with the Trends and Pressures Framework (TPF). How cities are managing their water cycle is assessed with the City Blueprint Framework (CBF). Where cities can improve their water governance is assessed with the Governance Capacity Framework (GCF). The CBA evaluates a total of 48 indicators and addresses 27 questions for each water-related challenge addressed (here, water scarcity).

This diagnostic tool was chosen because it provides the status of sustainable water management in a complete but clear way; reveals a city's strong and weak points on water sustainability; serves as the first step in strategic planning to become sustainable and water-wise; is an easy-to-understand interactive tool serving strategic decisions; and consists of a platform that enhances city-to-city learning and the exchange of best practices (Van Leeuwen, 2012). Recent examples of the application of the CBA to world cities is given in Chang et al. (2020) for China, and Huyghe et al. for Antwerp (2021), Kim et al., 2018; Lee

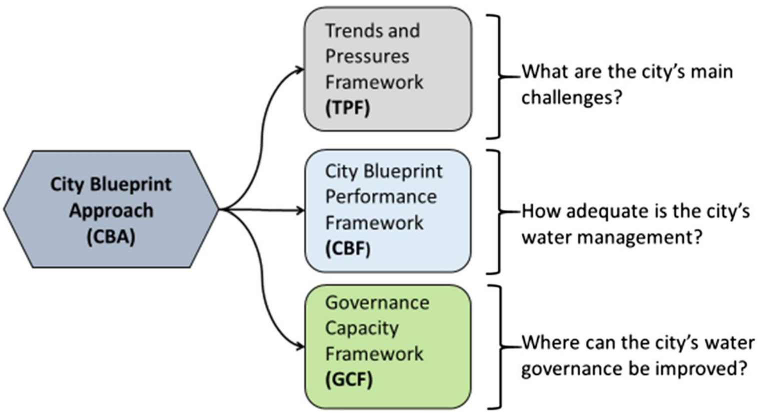

Fig. 4 The three complementary frameworks of the city blueprint approach (Koop & Van Leeuwen, 2020a, 2020b, 2020c)

et al., 2022 for Seoul and coastal areas, Koop and van Leeuwen (2017) for 45 cities mostly in Europe and the US, and Koop et al. (2022) for a 125 global cities.

2.2.1 Trends and pressures framework (TPF)

The TPF addresses pressures which the city faces in four general categories: social, environment, finance and governance, and assesses the main challenges of cities. This study introduces an air quality indicator to the TPF into the environment category because of its relevance to lifecycle, human health and smart cities management. The score of each indicator is calculated from 0 to 10 (Koop & Van Leeuwen, 2020a). All indicators are described in detail in Algaba (2019). Indicators of the "Trends and Pressures Framework" including definition, calculation method, data sources, numerical result and conclusion as to degree of concern.

2.2.2 City blueprint (performance) framework (CBF)

The CBF assesses how cities are managing their water cycle including aspects related to city management such as solid waste or climate change. The CBF consists of 24 indicators divided over seven main categories: (I) basic water services, (II) water quality, (III) wastewater treatment (WWT), (IV) water infrastructure, (V) municipal solid waste (MSW), (VI) climate robustness, and (VII) plans and actions (Koop & Van Leeuwen, 2020b). The indicators are scored on a scale from 0 to 10. The lower the score, the more room there is to improve its performance.

2.2.3 Governance capacity framework (GCF)

The GCG focuses on how to improve the governance capacity of cities while focusing on water-related challenges. The GCF is based on personal interviews and a questionnaire based on three dimensions: knowing, Wanting and Enabling (Koop & Van Leeuwen, 2020c). GCF identifies in which areas cities may improve their *water governance*. In this analysis, we focus on 'water scarcity' as this represents a critical regional challenge. The "knowing" dimension refers to the need for awareness, understanding and learning about the effects and risks of the decision-making process. The "wanting" dimension refers to the need of stakeholders for commitment, cooperation and action to find solutions. The "enabling" dimension refers to the government network, resources and policy instruments that stakeholders require to achieve their goals. (Šteflová, et al., 2018). A Likert scale is a rating scale used to measure opinions, attitudes, or behaviors consisting of a series of questions, followed by a series of five answer statements. Respondents choose the option that best corresponds with how they feel about the question. The results derive from a review of pertinent documents and in-depth interviews with three agents in the decision-making process. The score of each of the 27 GCF indicators is based on a Likert-type method specific for each indicator, scoring from very encouraging (++) to very limiting (--).

Three agencies were selected to prepare the GCF are: (1) Confederación Hidrográfica del Guadalquivir which is responsible for water resources management and planning in the Guadalquivir River basin, and specifically for the water supply system of Seville, (2) University of Seville, an institution generating knowledge and research in the field of water and society, and (3) EMASESA, the managing institution responsible for the urban water cycle in the Seville metropolitan area. These interviews were conducted in person at all three agencies and were recorded. To ensure the anonymity of the interviewees, the results presented reflect consensus conclusions of the three interviewees and the first author. Opinions did not differ significantly on the issues raised; however, when differences occurred, they are reflected in the text. Each question receives a rating ranging from very encouraging (++) to very limiting (--) according to the Likert-type method. Indicators and detailed questions answered by the three interviewees in Seville of the "Governance Capacity Framework", the Likert method analysis and data sources are included in Algaba (2019) and available upon request.

2.3 Data sources

Databases and information from the most credible local sources at different geographic scales are used. Only in those cases where it has not been possible to use local data, information at river basin, regional or national scope have been used. The following data sources were consulted:

- *Global scale*: United Nations, The World Bank, WHO, OECD, IMF, CIA, UNICEF.
- *European scale*: EEA, CITEAIR II.
- *National scale*: Instituto Nacional de Estadística, AEAS, AEOPAS, AGA, Ministerio para la Transición Ecológica, Ministerio de Obras Públicas y Urbanismo, Ministerio de Sanidad, Consumo y Bienestar Social.
- *Regional scale*: Junta de Andalucía, Instituto de Estadística y Cartografía de Andalucía, Consejería de Educación, Consejería de Medio Ambiente y Ordenación del Territorio, ASA-Andalucía.
- *River basin scale*: Confederación Hidrográfica del Guadalquivir (Guadalquivir RBMP).
- *Local scale*: Diputación de Sevilla, Ayuntamiento de Sevilla, EMASESA, LIPASAM, EMVISESA, Universidad de Sevilla, Gerencia de Urbanismo, Parques y Jardines, Turismo de Sevilla.

3 Results

3.1 Trends and pressures framework (TPF) of Seville

The TPF scores and degrees of concern for each indicator are provided in Table 1. Five indicators reflect concern or great concern for Seville: heat risk urban drainage flooding and river peak discharges, unemployment rate, and economic pressure (Fig. 5).

The "heat risk" is an assessment of the severity of the urban heat effects on human health. This indicator is the arithmetic average of the number of combined tropical nights (>20 °C) and hot days (>35 °C) in the period 2071–2100 (European Environmental Agency, 2017) and the percentage of green and blue urban area. Data for Seville yields 50 days (maximum) for the sum of night and day exceedances. Today the percentage of green and blue area in Seville is 26% (European Environmental Agency, 2012). With these data Seville obtains an overall score of 8.4. The "heat island effect" is a great concern for Seville and the city is making significant efforts to increase woodland and green areas (EMASESA, 2018a, 2018b, 2018c, 2018d) (Ayuntamiento de Sevilla, 2019a, 2019b), as well as changing paving materials that absorb less solar radiation (Horizonte Sevilla, 2018a, 2018b, 2018c). A pilot project, CartujaQanat, aims to reduce air temperature and

Table 1 Indicators and scores of trends and pressure framework (TPF) and city blueprint framework (CBF)

	TPF				CBF	
Categories	Indicators	Sub-Indicators	Score	Categories	Indicators	Score
Social	Urbanization rate		**1**	Basic water services	Access to drinking water	**10**
	Burden of disease		**2**		Access to sanitation	**10**
	Education rate		**1**		Drinking Water quality	**10**
Environment	**Flooding**	**Urban drainage flood**	**8**	Water quality	Secondary WWT	**10**
		River peak discharges	**7**		Tertiary WWT	**10**
		Sea level rise	**0**		Groundwater quality	**6.3**
		Land subsidence	**0**	Waste water treatment	Nutrient recovery	**10**
	Water scarcity	Freshwater scarcity	**6**		Energy recovery	**10**
		GW scarcity	**0**		Sewage sludge recycling	**10**
					WWT Efficiency	**10**
		Salinization—seawater intrusion	**5**	**Water infrastructure**	**Stormwater separation**	**0.9**
	Water quality	SW quality	**1.7**		**Average sewer age**	**0**
		Biodiversity	**4**		Water system leakages	**7.5**
	Heat risk	Heat island effect	**8**		**Operation cost recovery**	**3.5**
	Air quality	**YACAQI**	**2**	**Solid waste**	**Solid waste collected**	**3.7**
Finance	**Economic pressure**		**5**		**Solid waste recycled**	**1.7**
	Unemployment rate		**7**		**Solid waste energy recovered**	**0**
	Poverty rate		**0**	**Climate adaptation**	**Green space**	**3.1**
	Inflation rate				Climate adaptation	**10**
Governance	Voice-accountability		**3**		Climate-robust buildings	**8**
	Political stability		**4**	Plans and Actions	Management and action plans	**9**
	Government effectiveness		**3**		Water efficiency measures	**10**
	Regularity quality		**3**		Drinking water consumption	**10**
	Rule of law		**3**		Attractiveness	**10**
	Control of corruption		**4**			

Areas of concern are highlighted in 'bold' implement new models of bioclimatic innovative solutions using the subsoil (Urban Innovative Actions, 2018) (Núñez, 2019).

The "urban drainage flooding" indicator is the risk of flooding due to intensive rainfall and is expressed as the fraction of urban soil that is sealed. Seville soil sealing is 63% (EEA, 2012), providing a score of 8.2, reflecting great concern. Seville is implementing Sustainable Drainage Systems (SuDS) policies throughout the metropolitan area, to achieve efficiency in rainwater management and improving natural recharge of the aquifers located below the sealed surface of the city of Seville (EMASESA, 2018a, 2018b, 2018c, 2018d) (Horizonte Sevilla, 2018a, 2018b, 2018c). Also, Seville has constructed new green areas with water retention ponds to deal with extreme rain (Ayuntamiento de Sevilla, 2019a).

The "river peak discharges" indicator reflects the vulnerability of urban flooding due to river level rise. Flash floods from outside the city are included. This indicator is the percentage of the city area that would flood with 1 m river level rise representing 24% of the city area making it a concern for the city. However, even if flooding risk exists, it is not a concern at present as the last important flood in Seville was in 1961 (Sevilla Secreta, 2019). Since 1970, there have been no floods in the nearby river channels due to the program protecting Guadalquivir riverbanks and defense of the metropolitan area (Confederación Hidrográfica del Guadalquivir, 2015) (Diario de Sevilla, 2001).

The "unemployment rate" is the percentage of population of the total labor force without a job. The annual average unemployment rate in Seville is ~ 24% leading to a score of 10, and of great concern for the city. The "economic pressure" indicator is the GDP per capita per year and represents the economic power of a territory. The GDP per capita per year in Seville is 18,477 €, which correspond to a score of 6.5, and of concern. The GDP/capita and the unemployment rate introduce uncertainty about the capacity of the city to finance the basic water services and promote sustainability in the medium and long term. The financing capacity of the different administrations and entities responsible for providing water services is aggravated by the effects of the recent economic crisis (Díez, 2017) (Albiol Omella, 2016).

3.2 City blueprint framework (CBF) of Seville

The scores and degrees of performance for all CBF indicators are provided in Table 1 and range from 0 (very poor performance) to 10 (very good performance). The spider chart diagram (Fig. 6) shows how Seville performs according to CBF indicators. The score and degree of performance of each indicator is proportional to the length of the 'spike'. Details are provided in the Algaba (2019).

Categories achieving good or very good performance are: basic water services water quality, wastewater treatment, climate adaptation and plans and actions. Those categories needing improved performance are water infrastructures and solid waste and are discussed below.

3.2.1 Basic water services

The regional government of Andalusia declares that drinking water and adequate sanitation are inalienable rights for all citizens of the Andalusian Autonomous Community (Junta de Andalucía, 2018). The company that manages the urban water processes offers a universal service for drinking water supply, sanitation and wastewater treatment. Since 2015, a policy of equitable redistribution of the charges that basic water services entail has been

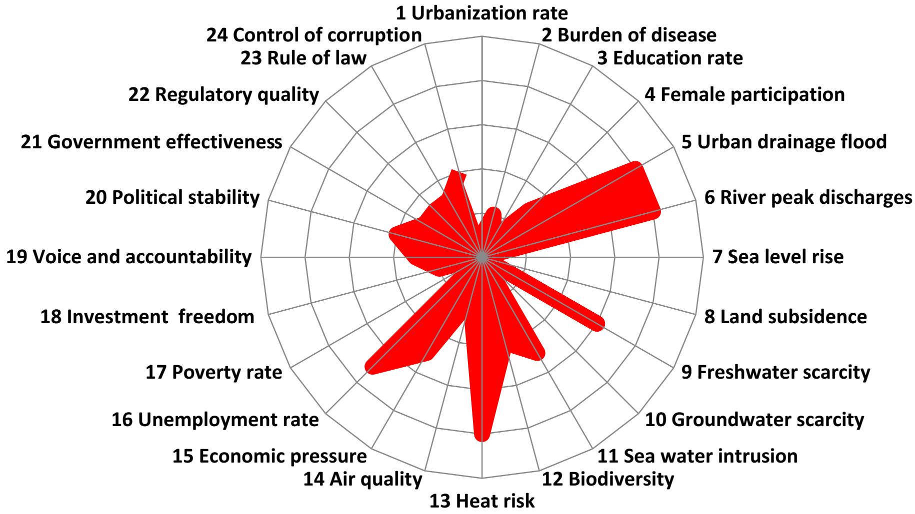

Fig. 5 Trends and pressure framework (TPF) in this spider chart diagram of the TPF of Seville, the length of the spider spike indicates the score and degree of concern. Indicator scores range from 0 (no concern) to 10 (great concern). The score and degree of concern of each pressure is proportional to the length of the spike

carried out, so that no family and no user is left without water services due to poverty. The percentage of the cost of the urban water cycle by family or user is far below the values established by the UN as affordable water (Delacámara, 2017) (EMASESA, 2017a, 2017b, 2017c, 2017d). Spanish regulations (Plan de Seguridad del Agua) require high-quality standards for drinking water quality, in-line with EU regulations.

3.2.2 Water quality

All municipal wastewater is subjected to at least secondary treatment (EMASESA, 2017a). All WWTPs have implemented techniques for P removal. The needed infrastructures are being implemented to remove N to acceptable levels. Only one of the WWTPs (EDAR Ranilla) has presently implemented N removal (EMASESA, 2018a). Seville does not use groundwater as a domestic water. In the Guadalquivir River basin, 54 out of 86 groundwater bodies achieve "good status" (quantitative and chemical); however, water availability is inadequate resulting from overexploitation of aquifers and leading to salinization (Confederación Hidrográfica del Guadalquivir, 2015).

3.2.3 Wastewater treatment

Management of the urban water cycle in Seville is conducted in conjunction with the agricultural sector surrounding the city (EMASESA, 2017a, 2017b, 2017c, 2017d). P is removed by biological by coagulation-flocculation in secondary treatment and the sludge is used as commercial fertilizer. In spring and summer, the sludge produced in WWTPs is used in agriculture (50% of the total sludge) and in autumn and winter the sludge is composted for summer use. Thus, 100% of the sludge produced is directly or indirectly utilized in agriculture.

The Seville water company has combines water management with energy recovery (EMASESA, 2017a, 2017b, 2017c, 2017d). The four Seville WWTPs have implemented biogas recovery from the anaerobic digestors (EMASESA, 2018a, 2018b, 2018c, 2018d). Cogeneration produces electric energy and heat. Also, three of WWTPs (EDAR Copero, EDAR Tablada and EDAR San Jerónimo) have implemented a co-digestion process (EMASESA, 2017a, 2017b, 2017c, 2017d). The main advantage lies in the capability to mix waste of different composition to optimize co-digestion. Additional advantages of the process are enrichment the sludge to be used as an organic amendment and sharing treatment facilities, reducing investment and exploitation costs (EMASESA, 2017a, 2017b, 2017c, 2017d).

3.2.4 Water infrastructure

Seville has a long history of urban planning and infrastructure development. The separation of wastewater and stormwater is a relatively modern concept; however, most sewerage networks are combined, so-called CSOs. The degree of separation of the networks is small, despite new policies that are being implemented. In new urban developments, separated networks are mandated via the update of the EMASESA regulations (EMASESA, 2018a, 2018b, 2018c, 2018d).

The water distribution network has an average age of 28 years, much better than that of the sanitation network (90 years). This is the result of efforts in the construction of the Melonares dam, which reduced water system leakages to less than 15% (Hernández, 2006). This entailed a significant annual investment in the modernization and renovation of the

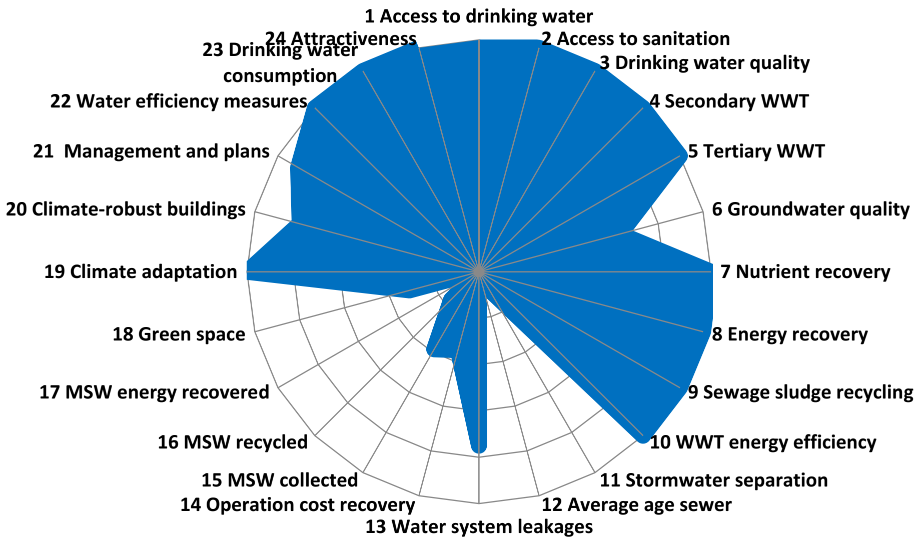

Fig. 6 City blueprint framework (CBF) of Seville. The length of the spider spike indicates the performance score ranging from 0 (very poor performance) to 10 (very good performance). The score and degree of concern of each pressure is proportional to the length of the spike

water distribution network to achieve this objective, which has been achieved with a percentage of ~12% in 2017 (EMASESA, 2018b) Improvements in the sanitation network has been slow as a result of the priority given to the water supply network. The need to intervene in the replacement and modernization of the sanitation system is evident but costs are high.

At the root of the problem of the longevity of networks and water infrastructures is that the water tariff does not comply with full cost recovery. In fact, the price of water in Spain is 2.2 €/m^3, compared with the European average of 3.20 €/m^3 (PwC, 2019). This prolonged situation results in the aging of water infrastructures and is regardless of whether the Seville water company has a positive operating cost recovery ratio of 1.03 (EMASESA, 2019a).

3.2.5 Solid waste

The populace is aware of water scarcity as a result of frequent droughts. The citizen knows that water management must include using drinking water efficiently and wastewater reclamation and reuse. In contrast, Spain does not have a culture supporting reduction of solid waste volume, promoting its reuse and establishing energy recovery protocols. Seville has initiated a policy of solid waste treatment and recycling and society is changing its habits. In 2018, the Seville population recycled 16.6% of its total solid waste (LIPASAM, 2019), as compared to the EU average of ~27% (LIPASAM, 2018a, 2018b). Recycling has increased in Seville by 23% from 2014 to 2018.

Incineration of solid waste is not widespread in Spain due to difficulties in processing and environmental authorization. Instead of incineration, solutions proposed are controlled landfills, recirculation and energy use of leachates produced (LIPASAM, 2018a, 2018b).

Mass tourism in Seville, 2.9 million tourists in 2017 (Consorcio de Turismo de Sevilla, 2017), generates an additional volume of solid waste to that generated by the resident population and not included in the "solid waste collected" indicator.

3.2.6 Climate adaptation

Green and blue space in Seville in 2012 covered 26% of the urban area. Since then, the city has made a concerted effort to increase the green space by adding more wooded areas and public parks (Bonells, 2019). In July 2019, Seville approved the Climate Emergency Declaration (Ciccaglione, 2019) to address adaptation to climate change. Seville is the first major city in Spain to declare a climate and ecological emergency, similar to cities such as New York, San Francisco, Sydney, Paris and Amsterdam (Ellsmoor, 2019). This declaration establishes a public transport network powered by electric energy with the corresponding improvement in the city's air quality (Ameneiro, 2019).

Important impacts of climate change are severe droughts and floods. Seville and the Guadalquivir river basin have implemented water planning and management for decades, with satisfactory results. Confederación Hidrográfica del Guadalquivir has developed two plans: "Plan de Gestión del Riesgo de Inundaciones (PGRI)", regarding flood risk, and "Plan Especial de Sequía (PES)", concerning water scarcity and droughts. The principal objective of the PGRI is to ensure that flood risk is not increased and, if possible, reduced through different action programs, taking into account flood risk management, focusing on prevention, protection and preparedness, including flood forecasting and early warning systems. The overall objective of the PES is to minimize environmental, economic and social impacts from eventual drought (Confederación Hidrográfica del Guadalquivir, 2015).

Air temperature is increasing in the Seville region as climate change intensifies (CEDEX, 2017). Seville is conducting pilot projects on how to reduce air temperature by applying innovative technological solutions with the help of EU-funded pilot projects. The WATERCOOL Project (LIFE) aims to develop new strategies for urban adaptation to climate change, from public and private sectors (EMASESA, 2018a, 2018b, 2018c, 2018d). The Seville project CartujaQanat, part of the Urban Innovative Actions 3rd call, aims to reduce air temperature and implement new models of bioclimatic innovative solutions using the subsoil (Urban Innovative Actions, 2018). EMASESA has defined a strategic plan with actions for adaptation to climate change focusing on the heat island effect, flood risk and droughts. Relevant projects include: co-digestion process in WWTP, electrification of the fleet of vehicles, mini-hydroelectric power plants, rainwater retention tanks, environmental improvement of El Gergal dam, SuDS in Avenida El Greco, investment plan for networks obsolescence, ecological corridor in the canalization of river Guadaíra, heat stress campaign for EMASESA operators and participative reforestation in Rivera de Huelva river (EMASESA, 2018a).

The Seville Strategic Plan 2030 identifies measures to adapt buildings to climate change and reduce energy use (Ayuntamiento de Sevilla, 2019a, 2019b) by decarbonization of the city, sustainable urban planning and bioclimatic architecture. Seville is improving the energy efficiency of public and private buildings with the development of distributed renewable energy production, and buildings that produce photovoltaic electricity. Also, urban planning and construction in Seville will be based on bioclimatic and healthy parameters, making good use of plants, water, materials, colors, research and technological innovation, which should characterize the future design of the city, its public spaces, buildings and infrastructures (Ayuntamiento de Sevilla, 2019a, 2019b) (Horizonte Sevilla, 2018a, 2018b, 2018c).

3.2.7 Plans and actions

Water management follows the guidelines of the UN and the EU's WFD in relation to IWRM. Water challenges are addressed in conjunction with public participation. Seville has established the Sustainable Public Management Strategic Plan (Plan Estratégico de Gestión Pública Sostenible (GPS)) 2017–2021 implementing social, economic and environmental measures to satisfy necessities without compromising future progress and protecting Seville's natural heritage.

Water efficiency measures are in place to protect against water scarcity and the loss of biodiversity caused by climate change. There has been a continuous move to improve water efficiency of the water supply networks (12% of leakages) and at the same time an awareness and responsibility campaign has been implemented to raise awareness of the citizens in relation to adopting habits that promote responsible urban water consumption (113 L per person per day) (EMASESA, 2017a, 2017b, 2017c, 2017d) (EMASESA, 2018b).

The city is keenly aware of the importance of water-related landscapes and improving the attractiveness of the city and well-being of its inhabitants with surface water features. The attractiveness of Seville in relation to its surface water elements dates to 1946, when the Alfonso XIII canal, known as the Guadalquivir dock, was built. The last constructive modification of the Guadalquivir dock took place on the Universal Exposition of 1992 in

Seville (Sevillapedia, 2014). Many projects have been developed to promote tourism and leisure and business activities. A recent example is Torre Sevilla, a commercial and business complex, and Magallanes Park (Torre Sevilla, 2019a, 2019b) (Consorcio de Turismo de Sevilla, 2017). In addition, the initiative “Ciudad Saludable” aims to add surface water features and green space and to reclaim efficient use of water (Horizonte Sevilla, 2018a, 2018b, 2018c).

3.3 Governance capacity framework (GCF) of Seville

The results of the governance capacity of Seville are provided in Table 2 and in Algaba (2019). This spider chart diagram depicts areas where Seville can improve its water scarcity governance according to GCF indicators. The score of each indicator is proportional to the length of the spider spike.

Figure 7 Spider chart diagram of the Governance Capacity Framework of Seville. The Likert-scores range from very encouraging (++) to very limiting (--).

3.3.1 Condition 1: awareness

Overall, the city of Seville and stakeholders have knowledge gained from historical droughts. The population is aware and adopts active positions, such as moderate water consumption (113 L per person per day). However, the population does not have a clear sense of the need to urgently address future challenges that may arise due to climate change. Long-term strategies must be explained, and the population must appreciate that the solution to water challenges comes from anticipation. Interviews suggested there is a difference in awareness and commitment among the populace, who in general are less aware of water scarcity, and the stakeholders, who have a higher degree of knowledge and commitment more in-line with the challenges of water scarcity.

3.3.2 Condition 2: useful knowledge

The responsible agencies of Seville and Andalusia provide abundant information on water scarcity. This information is clear, but sometimes is presented in a too technical manner, which hinders its understanding by the general public. The available information covers different areas of knowledge of the drought phenomenon. Information is offered regularly and transparently. However, knowledge about water scarcity in Seville is scattered across agencies. The agencies hosting the data on water scarcity base their views on their competencies, and integration into a single field of knowledge is not successful.

3.3.3 Condition 3: continuous learning

Water scarcity is well monitored and real-time data are publicly available. These data reflect the availability of different water resources, societal water consumption habits and forecasts of future availability. Climate change, however, is not well integrated into future resource forecasts because no water resources restriction scenarios are developed. Currently, there are drought plans by river basin (Confederación Hidrográfica del

Guadalquivir, 2018) and emergency drought plans for all water systems with more than 20,000 inhabitants (EMASESA, 2018a, 2018b, 2018c, 2018d). A follow-up evaluation of these plans is carried out every year and the drought plans are renewed every 6 years as part of the RBMPs. However, evaluation and monitoring of the water management planning is not carried out in conjunction with the population and the stakeholders. Despite a network of stakeholders with clear objectives and defined policies, there is no culture of interaction between them, making it difficult to reach agreements and commitments in the long term.

3.3.4 Condition 4: stakeholder engagement process

The stakeholders are duly informed and actively participate in the participatory institutional framework. Participation processes are clear and transparent and decision-making

Table 2 Scores of the governance capacity network (GCF) applied to Seville. The Likert-scores range from very encouraging (++) to very limiting (--)

Dimension	Condition	Indicator	Score
Knowing	**Awareness**	**Community Knowledge**	0
		Local sense of urgency	0
		Behavioral internalization	+
	Useful Knowledge	**Information availability**	0
		Information transparency	0
		Knowledge cohesion	0
	Continuous learning	Smart monitoring	+
		Evaluation	+
		Cross-stakeholder learning	-
Wanting	Stakeholder engagement process	Inclusiveness	+
		Protection of core values	+
		Progress/variety of options	++
	Management ambition	Ambitious and realistic management	++
		Discourse embedding	++
		Management cohesion	++
	Agents of change	Entrepreneurial cohesion	+
		Collaborative agents	0
		Visionary agents	++
Enabling	Multi-level network potential	Room to maneuver	++
		Clear division of responsibilities	++
		Authority	++
	Financial viability	Affordability	+
		Consumer willingness to pay	+
		Financial continuation	0
	Implementing capacity	Policy instruments	++
		Statutory compliance	++
		Preparedness	++

Areas in bold represent areas identified as needing improvement

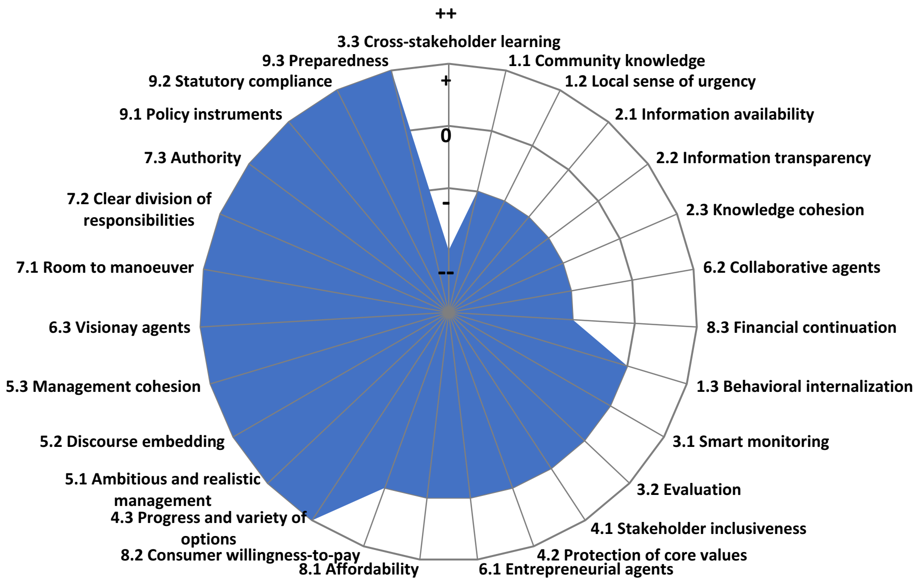

Fig. 7 The governance city framework CBF and spider diagram. The Likert-scores range from very encouraging (++) to very limiting (--). The score and degree of concern of each pressure is proportional to the length of the spike

is usually carried out by agreement between the different parties seeking consensual decisions. However, many times the representatives of the stakeholders do not have the mandate to make decisions, which complicates the procedure. The stakeholders employ processes that are clear and transparent leading to agreements, but commitments focus on short-term results. The decision-making procedures are carried out with representatives of interest groups with public participation and exposing different alternatives so that the agreed solution can be chosen while improving the expected result.

3.3.5 Condition 5: management ambition

Water resources management policies in different work areas and organization levels (local, river basin, regional or national) are ambitious. The objectives are set by analyzing the mistakes made in the past and defining by consensus what kind of service a twenty-first century society requires. Indicators and process control points are defined to evaluate the effectiveness of the programs and plans adopted. Also, policy development considers the uncertainty inherent in water management. Planning is carried out in a time frame that does not coincide with the electoral periods, so that the political processes do not overly affect planning. The elaboration of plans and policies considers the historical hydrological record, the cultural behavior of the population and the need to have a normative context. At the national level, a regulatory framework has been established to coordinate and bring together the different administrations and agencies responsible for carrying out the water scarcity prevention policy. These policies result in coordinated planning and establish common objectives and time horizons. This procedure is also set at the river basin, sub-basin and local level (indicator 5.3).

3.3.6 Condition 6: Agents of change

The emergence of challenges such as climate change that aggravates water scarcity, as well as citizen demands for water services are an opportunity for the appearance of entrepreneurial agents, to optimize the use water resources through new technologies. Spain and the EU have an important network of public (business and university) and private entrepreneurs. The current limitation to this process is normally the initiatives are small-scale pilot projects, thus slowing down the possibility of solving the problems in the short term. Collaboration has been initiated between the Seville water company, the Seville City Council, University of Seville and private companies to work on joint projects that take advantage of the knowledge and techniques of the different actors to address water scarcity. This policy targets the medium-long term. Actors involved in water scarcity management understand what citizens demand for twenty-first century water services permitting the integration of short-term objectives with long-term strategies and goals.

3.3.7 Condition 7: multi-level network potential

Spain and Andalusia have many associations and stakeholders to defend the public and private interests in the water sector. Thus, there are associations of public companies (AEOPAS), and associations of public and private companies (AEAS, AGA, ASA Andalucía) to address and influence decision-making processes in relation to water scarcity. In Andalusia and Seville, the roles and responsibilities of managers addressing water scarcity are clearly delineated. This clear division of responsibilities is the result of well-embedded authority, based on the competences distribution made by regulations at national, regional and local scale.

3.3.8 Condition 8: financial viability

In Spain, drinking water and sanitation services are universal. The Andalusian Parliament has declared water as a human right (Junta de Andalucía, 2018), in-line with the declaration of United Nations (UN, 2010), so that it is forbidden to cut water to users, including Seville, who cannot afford it. EMASESA has lines of credit and financing to address these kinds of water poverty issues (EMASESA, 2017a, 2017b, 2017c, 2017d). However, future uncertainty that comes with climate change and its impact on water rates on the economy of the most disadvantaged classes must be addressed. The inevitable rise in the water rate to decrease water demand and increase efficiency can cause distrust and rejection by citizens, although traditionally the number of defaults in the Sevillian population is one of the lowest in Spain. The fact that the water rate does not recover operational costs raises doubts about the financial viability of the water service in the long term. Water infrastructure replacement in Seville is a slow process and is urgently required.

3.3.9 Condition 9: implementing capacity

The frequent droughts experienced by Seville in the past have led a water culture that guarantees adopting credible and reliable policies to solve problems. The water rate plays an important role in deterring misuse and waste of water resources. The implementation of plans to manage the impact of droughts (Plan Especial de Sequía) has been effective in anticipating negative effects of water scarcity. Legislation regarding water scarcity is ambitious and statutory compliance is effective. There is a good relationship between authorities and stakeholders. Each eight years on average severe drought comes to Seville. Since 1994, there have been no restrictions or penalties on the population and industry locally, which shows that the city is prepared for water scarcity and has a plan in place to implement different action scenario.

4 Discussion

4.1 Trends and Pressures Framework—Seville

The TPF assessment shows that the main pressures acting on the city are environmental: heat island effect and flood risk; and financial: unemployment rate and economic pressure. Water scarcity is also identified as a relevant environmental pressure from the interviews conducted for the GCF, especially in the medium-long term. This is highlighted in the spider diagram below:

Seville's position within the Mediterranean climate and the Guadalquivir River basin make the city more susceptible to droughts and water scarcity. Seville addresses flood risk through a plan to manage urban drainage flooding, including implementation of rainwater retention tanks and Sustainable Drainage systems (SuDS), development of an investment plan for renewal and replacement of water infrastructures, optimization and modeling of the sewer system for a return period of 15 years and a significant budget. Addressing urban drainage flooding in older cities where changing combined sewers to separated sewers is costly.

The heat island effect is addressed by utilizing materials to pave and decorate the streets to store as little solar radiation as possible, planting trees in the streets and the terraces of buildings, and using bioclimatic qanat to cool public places with groundwater (Urban Innovative Actions, 2018) (Horizonte Sevilla, 2018a, 2018b, 2018c). The challenge will be to draw conclusions from these pilot projects and develop an appropriate plan for the city. To combat CC, the Seville Strategic Plan 2030 foresees a greenhouse gas reduction program (transport system) and development of green areas (Ayuntamiento de Sevilla, 2019a).

Seville has implemented efforts to reduce water leakage in the distribution system and water consumption and enhancing dams and reservoirs. Seville has a Water Exploitation Index (WEI) of ~ 16% against an average of 29% in Spain (Food and Agricultural Organization, 2016). However, climate change makes it necessary to adopt flexible and adaptable solutions to achieve a sustainable water system. The fact that all water supply for Seville comes from surface water bodies constitutes an important risk to the metropolitan area. Seville is exploring protocols to abstract water sustainably from groundwater bodies. The combination of water supply from surface water (rivers) and groundwater bodies (aquifers) will provide flexibility and resilience against water scarcity (Sahuquillo Herráiz, 2009).

Wastewater reclamation and reuse constitute a sustainable strategy to face water scarcity. This strategy has been implemented through wastewater reuse legislation (Ministerio de la Presidencia, 2007) and the EU has developed a new Directive that regulates safe reclamation and reuse of wastewater in agriculture (European Commission, 2020). Seville will assess the implementation of wastewater reuse for irrigation of green areas and street cleaning. This strategy aims to protect the environment by reducing abstraction of natural quality water resources and wastewater discharges that impact river ecosystems. This process must ensure minimum quality requirements for water reuse (Alcalde-Sans et al., 2017). Implementing wastewater reuse for irrigation of green areas and street washing would not be difficult, reaching an adequate balance between wastewater quality and costs of the process.

All these strategies will entail significant economic investments and necessarily greater fiscal pressure on the Seville citizens. Based on the TPF results, financial pressures such as unemployment rate and purchasing power are also main concerns for Seville. The recent economic crisis has worsened the financial situation, and particularly in southern Spain. The national unemployment rate is 17.2% and income per capita is 23,271 €/year (INE, 2018). In Seville, the unemployment rate is 24.1% and income per capita is 18,477 €/year (Instituto de Estadistica Cartografia de Andalucia, 2018). Since adaptation to climate change is necessary, water distributions should be implemented justly such that climate adaptation and water services are affordable, especially for the most disadvantaged of society.

4.2 City blueprint framework (CBF)—Seville

Seville has faced serious water-related problems for decades and has successfully implemented policies and actions in: access to basic water services, water quality, WWTP efficiency and management and action plans for climate adaptation, and IWRM. However, the CBF analysis identifies two categories needing performance improvement: water infrastructure and solid waste management (Fig. 6).

Solid waste management in Seville lacks sustainable performance. By comparison, a recent CBA assessment of Antwerp (BE) shows that 66% of solid waste is recycled or composted and 30% is incinerated in Flanders (BE) (Huyghe, 2019). In Seville 16.6% of solid waste is recycled and incineration plants have not been constructed. Seville will improve solid waste management noting that Spain still disposes 56% of waste in landfills (LIPASAM, 2018a, 2018b) and encourage the citizens to reduce the volume of waste generated and should be reoriented to a solid waste as a resource. Combining solid waste companies of municipalities in the metropolitan area will guarantee resources economy and will reduce the environmental impact of the activity.

Seville water services and infrastructures are aging and the low operational cost recovery pose a sustainability problem in the medium-long term. The average water rate in Spain for domestic use is 2.2 €/m^3 (PwC, 2019) which makes Seville and Spain unsustainable in the medium-long term compared to the EU average of 3.2 €/m^3. This is a serious issue that is not exclusive to Spain as can be seen in the results of the CBA applied to other cities worldwide (Gawlik, et al., 2017).

Seville faces sustainability challenges in relation to environment and climate change and aging water infrastructures will require a rise in water tariff to be able to satisfy its adequate renewal and replacement. The pressure on citizens will intensify in the short-medium term and, to avoid social tensions an adequate governance system must be implemented, where stakeholders are integrated in the decision-making process in a climate of transparency and accountability.

4.3 Governance capacity framework—Seville

The governance capacity analysis of Seville conducted through interviews with local agencies involved in water scarcity results in conclusions as follows: insufficient community knowledge and low local sense of urgency; sharing of technical information and insufficient knowledge cohesion; weak cross-stakeholder learning and lack of collaboration agents and financial continuation (Fig. 7).

Although Seville citizens are aware of water scarcity through frequent droughts in the past, there is insufficient urgency about future water scarcity in a climate-changed world. To address community knowledge, the city launched the "Observatorio del Agua", a new advisory and water participation organization to include stakeholders and citizens in the decision-making process (Observatorio del Agua EMASESA, 2018a, 2018b, 2018c, 2018d). Knowledge brokers are needed to inform the science-policy interface. Research can be translated into tangible benefits for society if knowledge brokers facilitate exchange of technical information between agencies and stakeholders involved in decision-making (Holgate, 2012). Shared information should be "packaged" that is understandable by the general public and policy-makers.

Seville is part of the cross-EU Aqua Publica Europea (APE) focusing on the monitoring of household water consumption (EMASESA, 2017b). The objective of the program is to establish the water use habits of families in order to carry out awareness programs and water consumption policies, to implement a new water culture and to see the results of these policies in reduction of water consumption.

Seville should continue to encourage cross-stakeholders learning and collaborations between university, business and citizenship to address the challenges of water scarcity. Despite the low score obtained in the water infrastructure category (CBF) and the financial continuation indicator (GCF), Seville has launched a water infrastructure renovation planning carried out by a mixed team between the University of Seville and EMASESA technical staff (Cátedra del Agua EMASESA, 2017). The objective is to guarantee the operational, economic, technical, social and environmental sustainability of the service provided, always ensuring that it remains above the quality threshold that is considered enforceable.

In conclusion, the application of the city blueprint approach (CBA) to Seville has identified significant environmental pressures acting on the city related to the effects of climate change (droughts, urban floods and heat island effects), the need to react to solve the problems of solid waste management and water infrastructure replacement; the financial pressures that complicate the financial viability of water services and infrastructures; and finally, the need to improve water governance by encouraging citizens and stakeholders interaction in the decision-making process.

4.4 Blue city index

Population growth and urbanization together with the impacts of climate change place significant pressures on the urban water cycle in municipalities. Since cities worldwide need to address important water-related challenges, governance agencies, authorities, stakeholders and decision-makers must be equipped with tools that allow them to assess water resources and challenges (Trommsdorff et al., 2018). The CBA is applied as the first step in the process to advance a sustainable urban water cycle and services in a city. The main goals of the CBA are raising water awareness in cities, connecting potential partners, promoting collaboration and city-to-city learning and sharing best practices in urban water management among municipalities and regions (Koop & Van Leeuwen, 2015).

The CBA has been applied to more than 125 municipalities worldwide and now includes six US cities (Feingold et al., 2018) and 32 major cities in China (Chang et al., 2020). The CBF identifies strengths and weaknesses in IWRM and develop actions toward sustainability in urban water resources. The blue city index (BCI), the geometric mean of the CBF indicator scores, is 5.8/10, placing the city in the top 20% that have been currently assessed.

First common area found for all cities compared is the "solid waste" category, which must be improved in view of the low score obtained. Access to safe drinking water and sanitation follows the widespread positive pattern in Europe and universal access. Regarding the "sewage sludge recycling" and "WWT energy efficiency" indicators, there is a concordance at the Spanish level where the three cities stand out in performance, calling the attention to Genova still having much to do. Another common aspect is the low score obtained in the "operation cost recovery" indicator for the four cities assessed in the Mediterranean area. The percentage of "water system leakages" needs improvement in Mediterranean cities except Seville, which has an acceptable level (~ 12% of leakages). "Stormwater separation", which is a common problem for "historical" cities, is deficient in the three Spanish cities (CSOs) but satisfactory in the city of Genova (Gawlik, et al., 2017).

The CBA encourages cooperation for cities of similar cultural and climatic scope to take advantage of best practices of urban water management. Mediterranean and Central Northern Europe concur in "good performance" in areas such as access to drinking water and sanitation, sewage sludge recycling, management and action plans regarding IWRM and climate adaptation and water efficiency measures. Since full cost recovery is necessary to finance water services and renewal of water infrastructures and poses a great challenge for water sustainability to other European cities assessed by the CBA (Gawlik, et al., 2017), full cost recovery should be assessed.

5 Summary

The TPF identifies five major indicators reflecting concern or great concern for the urban water cycle of Seville: *heat island effect, urban drainage flooding, river peak discharges, unemployment rate and economic pressure.* For Seville, this results in increased daytime and night-time temperatures and increased urban flooding due to sealed soil and river rise from regional precipitation under climate change. The financial pressures are driven by the high unemployment rate (24%) and the low per capita income (18,477 €) compared to cities assessed.

The CBF identifies three categories reflecting poor performance for the urban water cycle of Seville: *water infrastructure, solid waste and climate adaptation*. An aging sewer network, a low operational cost recovery and combined-sewer overflow systems dominate. Solid waste management is characterized by high waste generation, low recycling rate and minimal energy recovery. Although adaptation is active in other areas, the percentage of green space is low.

The GCF identifies five conditions reflecting limited governance of water scarcity: *awareness, useful knowledge, continuous learning, agents of change and financial viability*. This results in insufficient community knowledge, low local sense of urgency, sharing of technical information, insufficient knowledge cohesion, weak cross-stakeholder learning and lack of collaboration agents and financial continuation. The assessment of water governance reflects a low citizens' sense of urgency. Integrating citizens and stakeholders in a more participative governance will result in increased awareness of economic efforts required to face water scarcity, renewal of water infrastructure and climate adaptation. Seville should continue encouraging collaborations between agencies, business, university and entrepreneurs to improve cross-learning and achieve water sustainable solutions against urban water challenges.

The agencies responsible for water management in Seville share technical information; oftentimes the scientific evidence is too technical and not well understood by the citizens and policy-makers. Seeking interlinkages between scientific evidence and policy making to address the issues raised is urgent (UNEP,2018). Science and policy in Seville can be strengthened by enhancing the flow of information and knowledge to inform the science-policy interface. This capacity should consist of experts of each knowledge field with a technical understanding and background experienced in the marketplace, so that they also know how policies can be effectively implemented. Scientific evidence well integrated into policy making can better adapt to climate change and future water scarcity in sustainable ways.

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