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Managing Potable Water in Southeastern Spain, Los Angeles, and Sydney: Transcontinental Approaches to Overcome Water Scarcity

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Abstract
Climate change and the increase of population pose challenges to ensuring suitable water supply in water-scarce regions. This work presents a comparative analysis of the water-supply approaches adopted in Los Angeles, Southeastern Spain, and Sydney. Results show a decrease in per-capita water use in the period 2000–2020, which reflects an improvement in water conservation. Social factors in the domain of hydropolitics and economic efficiency explain the divergence of water policies adopted. The adaptation to water scarcity and growing population in three regions of developed countries located in different continents sheds light on challenges facing the achievement of water security worldwide.

Keywords Climate variability and change · Desalination · Water recycling · Water scarcity · Water supply · Water transfers

1 Introduction

Water scarcity is a growing challenge that affects an expanding population worldwide (Greve et al. 2018). Climate change impacts include the occurrence of more extreme weather, more severe and frequent heat waves, and droughts (IPCC 2013). Moreover, increasing water consumption means that by 2030 global freshwater resources will decline by 40% according to the projections by the United Nations World Water Assessment Programme (WWAP 2015). Therefore, there is a growing concern about which water systems are the most sustainable and resilient, with a variety of different approaches to achieving water security (Grison et al. 2023). However, few studies have analysed the consumption, reuse and sources of water, and none by comparing three case studies from different coun-

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tries with similar challenges, such as the United States, Australia, and Spain. This article's objective is to shed light on discerning strategies in the search for sustainable, comprehensive, and efficient urban water supplies. This objective is accomplished by presenting a three-case study of the evolution of water use over a twenty-year period. Extensive literature research was conducted to support the reasoning throughout the article. The study aims to diagnose specific case studies and contribute to the ongoing debate about overcoming water scarcity, and to stress the importance of achieving water security through the evaluation and comparison of water-related data. Los Angeles (California) and southeastern Spain feature semiarid climates with strong seasonality and inter-annual variability of precipitation, whereas Sydney (Australia) features a humid climate with long cycles of below-average precipitation. These three areas constitute a useful sample of climatic regions for comparison purposes regarding water-supply adaptation.

Desalination and water recycling are useful in overcoming water scarcity in arid regions (Loáiciga 2015). In Spain, these new resources have risen in recent decades (Bernabé-Crespo et al. 2019). Desalination has proven effective in augmenting the water supply in coastal regions and achieving water security, although it also may cause problems such as brine disposal and the construction of seawater intakes (Cooley et al. 2013), contribute to greenhouse gas emissions and disrupt of marine ecosystems (Lattemann and Höpner 2008; Backer et al. 2022; Sheibani et al 2023). Likewise, the unit cost of desalinated water may be twice or three times higher than water from conventional sources (Ziolkowska 2015). Renewable-energy desalination technology (Alkaisi et al. 2017; Zarzo and Prats 2018) reduces the carbon footprint and offers a viable solution to meet water supply needs while being environmentally benign. Further development regarding solar-power desalination is being made to reduce costs, being solar distillation the most common technique, which accounts for 70% of the renewable desalination plants (Shatat et al. 2013; Monteiro et al. 2020), although freeze desalination is making a contribution to water supply (Janajreh et al. 2023). It is also worth considering the use of brine in industrial applications and its value (Villar et al. 2023).

Purifying municipal sewage water for agricultural use and for urban irrigation is well established in many semi-arid regions, such as California. More controversial is the reuse of treated municipal sewage for human use. Although Rodríguez et al. (2009) found no evidence of correlation between the consumption of recycled water and increased health risks, debate is ongoing about direct potable reuse (Kesari et al. 2021). For instance, Deng et al. (2019) conclude that reclaimed water could not be defined as 'harmless'. Social acceptance of potable reuse is eased by effective and permanent public health education (Sokolow et al. 2019). Nonetheless, much remains to be done about overcoming the public's resistance to the 'yuck' factor (Schmidt 2008). Public perception, culture, and widespread acceptance are essential to IPR (Indirect Potable Reuse) or DPR (Direct Potable Reuse) projects.

Collection of rainwater in tanks and rain barrels is used as a household water source in many parts of the world; however, the water yield depends strongly on the local climate and average rainfall (Rahman et al. 2012). Stormwater constitutes a flood hazard in urban areas and it also carries pollutants to streams, lakes, and the sea, especially during the first heavy rains (Deletic 1998). Stormwater control measures based on green stormwater infrastructure (GSI) principles have gained popularity in California (Sadeghi et al. 2018) and other parts of the world (Boroomandnia et al. 2021) as a mean to enhance urban greening and for groundwater recharge under suitable conditions.

Water conservation is essential to improving water supply resilience, enhance resource efficiency, and reduce infrastructure investment and, thus, to lower the cost-of-service delivery

(Tapsuwan et al. 2018). The feasibility analysis of water sources must also address the costs of water conveyance, which generates greenhouse emissions. Consequently, any water conservation measure must address the reduction of greenhouse gases emissions, which would improve air quality and human health (Sokolow et al. 2016). In this respect, it is noteworthy that the largest single user of electricity in California are pumps applied to transfer water between regions (Cohen et al. 2004).

Cooley et al. (2019) calculated approximate costs for water sources, considering partial costs accrued from groundwater pumping, conveyance, integration in the distribution network, maintenance, and replacement. In their study, it is noticeable that if DPR becomes feasible (considering legal, social and health factors) costs would be significantly lower as costs of storage, conveyance, and pumping would be reduced compared to others. Likewise, desalination costs depend on several factors such as the technology used and the salinity of seawater. This affects the cost of water, which is also a driver of consumption (Grafton et al. 2011). An example of this is the study of Loáiciga and Renehan (1997), which showed that pricing residential water at its marginal cost coupled with an intense public-education campaign were effective in reducing residential water use by close to 50% during the California drought of 1988–1991.

2 Methodology

This work presents a geographical analysis applying diachronic, qualitative, and quantitative research, within the paradigm of water supply in arid and semi-arid regions, where new resources such as desalination or recycled water may contribute to water supply and have significant social and economic value.

This work's methodology consists of a bibliographic search to frame the background and status of water management at an international and regional level in Spain, USA, and Australia. Data were collected from the databases of different organisms: those related to rainfall were obtained from the American National Oceanic and Atmospheric Administration (NOOA), the Meteorology Statal Agency of Spain (AEMET), and the Bureau of Meteorology (Australian Government). The population projection was made according to the information provided by the US Census Bureau. Data related to water consumption and water reuse were collected from Los Angeles Department of Water and Power (LADWP), Sydney Water Company (SWC), and in the case of southeastern Spain, data collection implied the access of databases of MCT (Mancomunidad de Canales del Taibilla) for water consumption, and ESAMUR (Regional Entity of Sanitation) for water reuse. The period of analysis comprised from 2000 to 2020 in the case of water consumption, and from 2010 to 2020 in the case of water reuse. Along with the collection of data, meetings were held with managers of MCT, the Department of Water Resources of California in Sacramento, LADWP, and SWC. Fieldwork also included visits to facilities, such as desalination plants, reservoirs, sewage treatment plants and water-recycling complexes. Research work consisted in the comparative analysis, elaboration of graphics, and writing of conclusions and proposals, with the aim of highlighting the value of the different management models, and attempting to discern common patterns and improved approaches for water supply in each region. These approaches may serve as comparative examples for other water-scarce regions around the globe.

3 Area of Study

The Köppen-Geiger climate classification (Peel et al. 2007) indicates a temperate oceanic climate (Cfb) in Sydney, cold semi-arid climate (BSk) in Murcia, the largest city in southeastern Spain, and warm-summer Mediterranean climate (Csb) in Los Angeles. The three cities observe growing urban populations (southeastern Spain, Los Angeles, and Sydney experienced +0.84%, +5.65%, and +19.77% population growth rates, respectively over the period 2009–2019), strong economic development, and are currently debating plans to overcome water scarcity.

MCT is in charge of carrying water supply in southeastern Spain. It captures water from several resources: local freshwater from the Taibilla River, transferred water through the Tagus-Segura Aqueduct (TSA), and seawater desalination from 4 desalination plants belonging to the MCT, while it maintains agreements with other 3 desalination plants that produce water mainly for irrigation, reaching a production capacity of 880 MLPD. Other sources of water are groundwater and water exchanges with agricultural users of other basins, both used exceptionally during drought situations. The area supplied by MCT includes 80 municipalities. The population in this area has grown from 1,923,891 inhabitants in 2000 to 2,528,656 in 2019.

Los Angeles metropolitan area surpasses 20 million people. LADWP takes its water from several sources: Los Angeles Aqueduct (LAA), the Metropolitan Water District (MWD) of Southern California (which acts as a regional water wholesaler and supplies LADWP and other member agencies with water from the Colorado River and the State Water Project). LADWP also withdraws groundwater, which is polluted in some areas (Sokolow et al. 2016). Despite the great potential for desalination in California only two plants are built in California (in Santa Barbara and Carlsbad, with a combined production capacity of about 202 MLPD). LADWP supplies water to 4,041,284 inhabitants (2020), which represents an increase since 2000, when 3,740,515 people were counted.

SWC is in charge of water supply to more than 5.3 million people in the Sydney metropolitan area. Water stems mainly from nearby rivers and reservoirs, the Warragamba being the largest in Australia, which was completed in 1960 with a capacity of 2000×106 m^3. Despite the higher annual rainfall, Sydney also relies on a desalination plant built in 2010, the third largest in Australia (with a production capacity of 250 MLPD that can be extended to twice that amount under extended operation).

It is pertinent to consider annual rainfall in these three regions when examining water supply management and identifying weak spots. Figure 1 depicts the sum of deviations from the mean and the average annual precipitation in Los Angeles, Murcia, and Sydney for the period 1895–2020. Los Angeles and Murcia exhibit relatively low average precipitation in the last 130 years, the latter having the lowest (less than 300 mm per year). Sydney enjoys a more humid climate, with an average of near 1200 mm per year. However, the Australian city features long cycles of declining and increasing precipitation. Specifically, it is evident that from 1899 through 1948 Sydney endured an overall declining precipitation. From 1948 through 1999 its precipitation exhibited an overall increasing trend. Since 1999 the precipitation has shown an overall declining trend. In contrast, Los Angeles and Murcia exhibit less pronounced and shorter wet and dry cycles. Los Angeles endured its critical dry period between 1924 and 1945, whereas the critical dry period in Murcia took place between 1947 and 1977. Even relatively short droughts, lasting three to seven years in Los Angeles and Murcia, exacerbate dryness water scarcity because of their innately low-precipitation and large potential

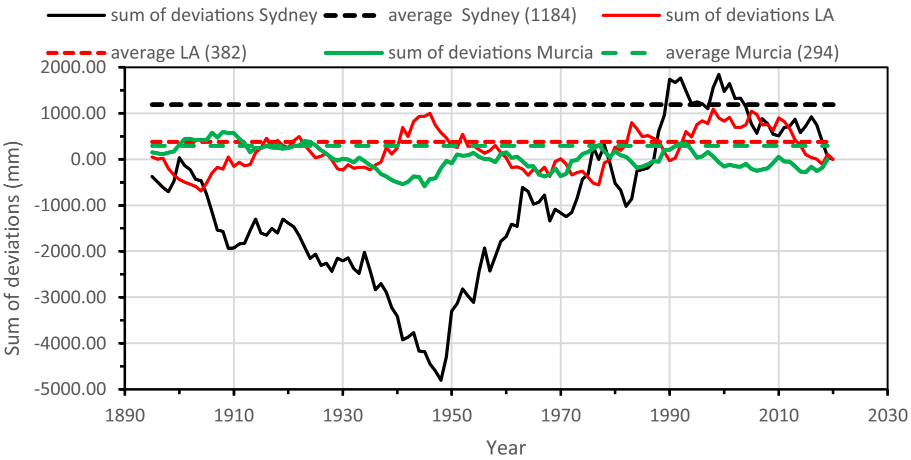

Fig. 1 Comparison of annual rainfall (1895–2020) in Los Angeles, Murcia, and Sydney. Source: own elaboration, data from NOOA, AEMET, and Bureau of Meteorology

evapotranspiration. Sydney features larger annual rainfall, but longer periods of below-average precipitation.

4 Results

In southeastern Spain, the annual volume of water distributed to users rose from 2000 (198,422,547 m^3) until 2005, when it reached a maximum of 227,284,806 m^3. It declined from 2005 until 2014, when it attained a minimum value of 183,174,411 m^3. There were 583,101 more inhabitants in 2014 than in 2000; yet, there was a reduction of 15,248,136 m^3 consumed, which means a decline in per capita use and more efficient supply: 103 m^3/(person·year) (2000) and 73 m^3/(person·year) (2014). However, since 2014 water use has risen until reaching a maximum of 197,948,297 m^3 and an increase in per capita use, 78 m^3/(person·year). Water use is related to the size of the permanent population and the tourist influx, urban typology, economic cycles, and the performance of water distribution companies, which aim to reduce water loss and improve conveyance efficiency. Conveyance efficiency in this area reaches on average 85.6%, though it varies from one municipality to another (Bernabé-Crespo et al. 2021).

Figure 2 shows the long-term declining and increasing contributions to water supply by transferred water and desalination, respectively, in southeastern Spain since 2000. At the beginning of the 21st century water transferred from the Tagus-Segura aqueduct (TSA) was the main water source for human consumption in southeastern Spain, accounting 72.93%. The first desalination plant started operating in 2003. Seawater desalination reached 47.62% of the total in 2018, in a year when the TSA was paralyzed due to a severe drought. Thus, in recent years desalination has moved from being a marginal to becoming a significant water source.

In fiscal year 2000/2001, a total of 812.65 million m^3 of water were consumed in Los Angeles, which rose to a maximum of 850.44 million m^3 during 2003/2004. Since then, the trend is overall declining with interspersed maxima in fiscal years 2006/2007, 2013/2014,

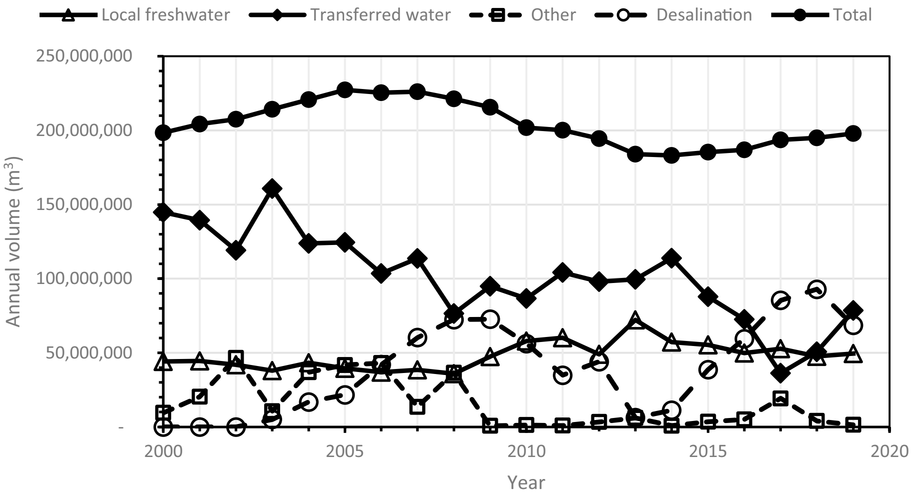

Fig. 2 Evolution of water supplied by MCT, by origin of source (2000–2019). Source: data from MCT (2020)

and 2017/2018 (see Fig. 3). The City of Los Angeles fiscal year extends from July 1st of a year through June 30th of the following year. Per capita water use fell from 217 m^3/(person·year) in 2000/2001 to 149 m^3/(person·year) in 2019/2020. The largest use occurred in 2003/2004 (224 m^3/person·year). The smallest per capita consumption took place in 2016/2017 and in 2018/2019, with 148 m^3/(person·year), which implies a stabilization of per capita water use in recent years. LADWP does not have water supplies from desalination, and relies almost entirely on transferred water by the LAA, water imported via MWD. It is seen in Fig. 3 the long-term decline of total water consumption in Los Angeles,

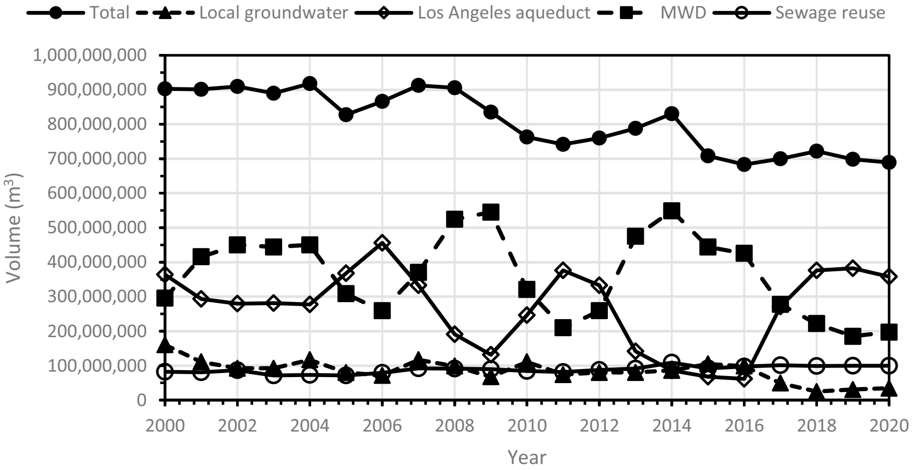

Fig. 3 Evolution of water supplied by source (2000–2019). Source: LADWP Urban Water Management Plan, 2020 Draft

while the MWD contribution increased whenever the LAA's contribution declined. Local groundwater exhibits a long-term decline and sewage reuse has increased slightly since 2000.

Figure 4 shows that freshwater represents the main source of water supply for Sydney, and desalination only operates when reservoir storage drops below certain levels. Sydney desalination plant was commissioned in 2010 and it has supplied water in 2010, 2011, 2012, and 2019 to present. Desalination supply reached a maximum of 15.67% of total water supply in 2010–2011, and it amounted to 13.36% during 2019–2020, in coincidence with droughts in NSW. Total water use reached a maximum in 2002–2003, with 634,742,000 m^3, and a minimum of 480,733,000 m^3 in 2011–2012. Overall, water consumption declined since 2000, during a period of population growth (4.02 million in 2000 and 5.3 million in 2019), but the recent years do not follow a clear trend, which makes per capita consumption fluctuate from 100 m^3/person·year in 2019 to almost 116 m3/person·year in 2017.

Water recycling is common for agricultural use in Southeastern Spain (Gil et al. 2019); yet, treated sewage reuse as potable water has not been contemplated yet, although a few studies propose pilot projects (Bernabé-Crespo et al. 2022). Los Angeles, Sydney, and Murcia reuse between 15–17%, 7–10%, and 89–95% of their treated sewage (see Table 1). The former two discharge most of their treated sewage to the ocean, thus bypassing the opportunity to recycle it.

5 Discussion

Comparing the conditions concerning water supply in Los Angeles, southeastern Spain, and Sydney reveals the different approaches to cope with unique natural and societal conditions. The city of Sydney has succeeded in harnessing supply water for

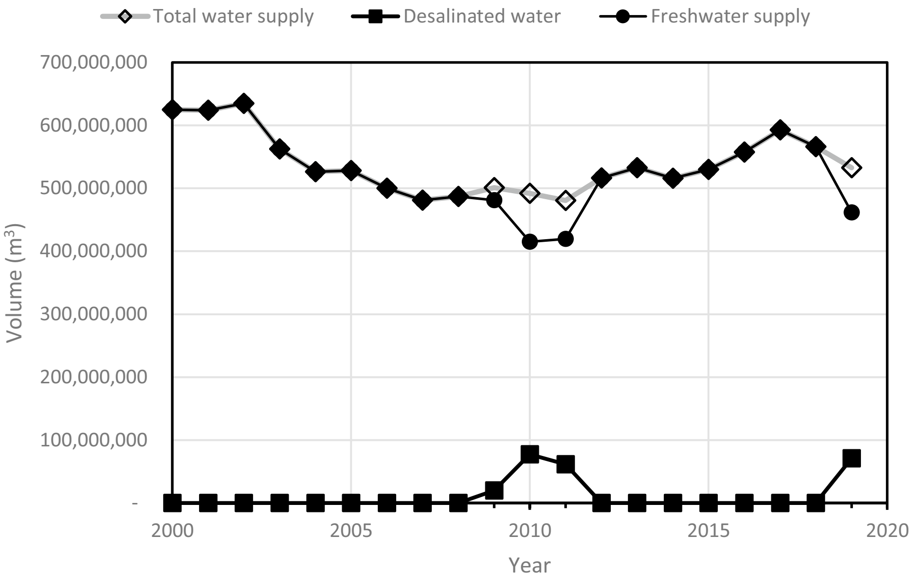

Fig. 4 Water distributed by the SWC by source, 2000–2019. Source: data from Sydney Water (2021)

Table 1 Water recycling in Los Angeles, Murcia, and Sydney (in 10^6 m^3)

YEAR	MURCIA			SYDNEY			LOS ANGELES		
	treated volume	reused volume	% reused	treated volume	reused volume	% reused	treated volume	reused volume	% reused
2010	110.981	104.646	94.29	472.267	33.683	7.13	526.711	84.855	16.11
2011	115.082	107.020	92.99	509.435	47.521	9.33	480.141	81.689	17.01
2012	109.407	100.678	92.02	587.294	45.929	7.82	509.615	87.876	17.24
2013	110.855	102.091	92.09	496.575	46.951	9.45	568.018	91.125	16.04
2014	104.245	95.292	91.41	469.579	46.943	10.00	713.709	109.228	15.30
2015	105.010	99.619	94.87	562.476	43.075	7.66	574.291	91.801	15.99
2016	104.348	92.755	88.89	546.605	43.341	7.93	619.808	97.541	15.74
2017	105.491	98.053	92.95	564.154	38.339	6.80	650.149	101.479	15.61
2018	103.364	96.356	93.22	463.191	42.834	9.25	603.123	99.361	16.47
2019	109.307	101.944	93.26	518.000	44.000	8.49	620.899	99.977	16.10
2020	117.293	112.550	95.96	536.140	46.919	8.75	637.761	99.944	15.67

Source: own elaboration, data from ESAMUR, LADWP and Sydney Water

a population of millions of people and a dynamic economy depending on surface water storage which mainly comes from an extensive network of reservoirs. Nonetheless, frequent droughts and the effect of climate change pose risks to water security for a growing urban population. Desalination acts as a resource only used when required, a type of insurance against a future shortage of surface water. In this sense, Sydney has adopted a strategy to cope with drought, which in this area is a known hazard due to the long cycles of declining precipitation that it endures.

Desalination is heavily contested in California, and, despite its potential, it remains underdeveloped, with only two desalination plants currently operating, and neither one supplying the City of Los Angeles. The major obstacle to desalination is the opposition by well-organized groups who see increased water supply as a precursor to urban sprawl, and other fears dealing with coastal and ocean harms (O'Neill 2023). In contrast, water politics have directed investments to expand recycled water for potable reuse, in relation to managed aquifer recharge (MAR).

Water transfers are fundamental to California's water distribution system, which also cause tensions between regions exporting and importing water. Ecologic concerns such as diminished streamflow reaching the San Francisco Bay Delta, the intensification of aridity in the Owens Valley, and water diversions in the Colorado River harming its delta are of prominent. These transfers enable potable and agricultural water supply; yet, these freshwater resources depend greatly on variations of the Sierra Nevada and Rocky Mountains snowpacks, which are threatened by climate change impacts (Swenson and Famiglietti 2014; Udall and Overpeck 2017).

Southeastern Spain displays a more diversified portfolio of water sources. Desalination has been developed as a reliable supply, and water transfers remain important despite their controversy. Drought cycles are mitigated by desalination plants operating at full capacity to meet human water demand and irrigators contracts, while in humid years desalination plants function at low capacity.

Local water supply is adapted to each area's conditions, such as precipitation, availability of water resources, and population. These adaptations produce water-supply schemes with variable contributions of surface water, water transfers, desalination, and sewage reuse. In general, regional schemes of water supply must be founded on decision making that is democratic and encourages social participation. Managers and stakeholders play an important role in the decision-making about water supply, which must be transparent and participative, but they also need to be assisted to improve their decisions (Loucks 2023). In this regard, relevant water authorities may be progressive and adapt to changing patterns of demand, or remain inertial and unable to respond adequately to changes.

Climate change poses threats to guarantee water supply. Subsequently, a diversified portfolio of water supplies combined with strategies pursuing water conservation are needed to face the risks derived from both climate change and urban growth. The experiences in Los Angeles, southeastern Spain, and Sydney demonstrate that it is essential to reduce water demand by using water more efficiently. This means reducing water losses in the distribution system and reducing the per capita unit consumption of water in the municipal/industrial and agricultural sectors. Water (conveyance) losses depend on the age of distribution system, materials used, and the performance of the agencies in charge of its maintenance. In the three study regions, per capita consumption has dropped since year 2000 (Fig. 5), showing that water conservation, renewal of the distribution networks, and public education about water conservation have worked well. These measures must be maintained and periodically revised to improve water-use efficiency. Promoting water conservation is the most cost-effective, non-structural, strategy to achieve an efficient water supply system, as it involves lower costs than investments in infrastructure for water storage, withdrawal, treatment, and distribution. Regulation of landscape irrigation has also been implemented to save water. Figure 5 highlights that Los Angeles' residents used twice the per capita volumes used in southeastern Spain, although there has been a declining

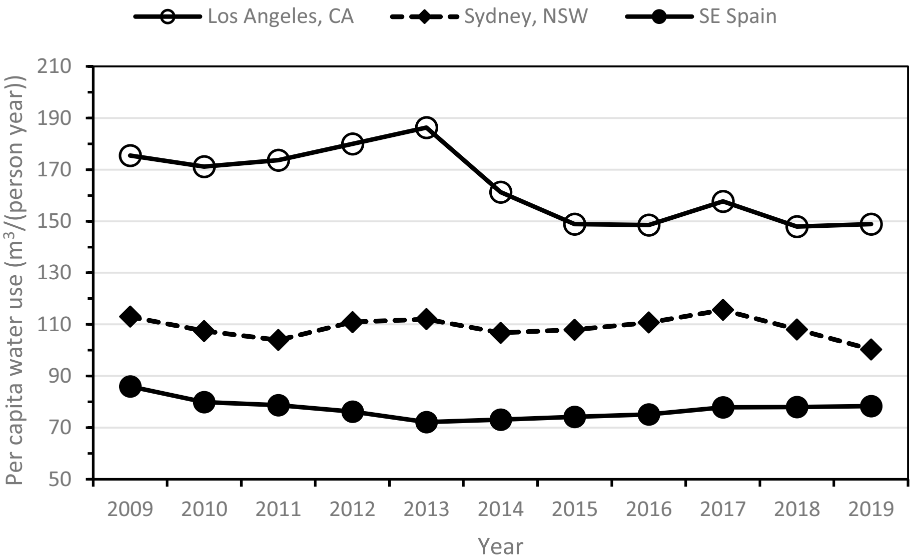

Fig. 5 Per capita water use in Los Angeles, Southeastern Spain, and Sydney (2010–2019). Source: own elaboration

trend in per capita water use in Los Angeles. Specifically, the most recent data indicate per capita water uses equal to 149, 78, and 100 m^3/ (person·year) in Los Angeles, southeastern Spain, and Sydney, respectively. These data establish that substantial improvements in water-use efficiency could be made in Los Angeles and Sydney considering what has been achieved in southeastern Spain.

Local resources such as rainwater should be promoted and used when available. It constitutes a cheap resource that helps meeting the demands for gardening and other functions, such as firefighting, and also prevents from flooding. The storage of stormwater can be dedicated to aquifer recharge and watering of vegetation (Sadeghi et al. 2018). Water transfers frequently cause tensions among communities. Although the investment cost of water transfer is high, it has been the most cost effective alternative when compared with other supply alternatives, although, as stated above, there may be adverse environmental impacts associated with water transfers (Abdi-Dehkordi et al. 2021). The viability of water transfers may be compromised by projected decline of precipitation associated with climate change in many regions, which may affect export and import basins. The confluence of climate change and the contentions surrounding water transfers may render them impractical in the future (Mirzaei-Nodoushan et al. 2021), for instance, the TSA was paralyzed in Spain in 2017–2018, proving it is not a sustainable strategy in the long term.

Desalination has significant water-supply potential because coastal areas harbour most of the population in the study areas. It may be the only viable alternative to sustain tourism activity in islands or hydrographically isolated coastal zones, and it can act as a backup water supply during drought periods, as is the case in southeastern Spain and Sydney. In the former, desalination has become a cornerstone of water supply, and it reached near 50% of the total water supply recently; whereas in the latter it has become part of a strategy for long-term adaptation to climate change and drought, although it is currently under-used. It is noteworthy that sustainability is a key issue when considering desalination as a durable option. It must avoid environmental impacts on the sea, and achieve energetic efficiency. This energy input is a key issue because it affects the cost of water, and, if obtained from fossil fuels, it contributes to greenhouse gas emissions that exacerbate climate change. Research on desalination is a strategic issue because of its potential to water supply. Brackish desalination should also be considered in certain environments as it requires less energy, proven effective in inland communities.

The reuse of treated sewage is a feasible option relying on technology. Current search for water security calls for all the municipal sewage to be devoted to agriculture and municipal irrigation to avoid the waste of water resources. Moreover, sewage can be treated to become potable water. In this respect, one large utility in California hosts one of the first systems of sewage reuse combined with river water imports in a complex MAR and IPR scheme practiced by the Orange County Water District (OCWD) that produces an average annual 247 million m^3 of potable water. Sewage reuse as a water source is cost effective and can generate a nearly constant volume of water. Hence, it is needed to overcome the public's rejection and include recycled water as part of water planning and management. OCWD's successful experience is being exploited to advance public acceptance of treated sewage reuse.

Recycled water requires less energy input than desalination, imported water, or groundwater, although health risks must be monitored. Current regulation in California only allows IPR, though several studies agree that DPR would be a more feasible option in terms of sustainability, both economic and environmental (Leverenz et al. 2011; Ghernaout et al. 2019). It is therefore timely to educate the public about the possibility of PR to carry out public campaigns to raise awareness on non-conventional sources of water.

This paper has shown that three regions in developed countries located in three different continents have so far managed to adapt through the application of technology and water transfers to achieve water security as population increases and the Earth climate warms up. Water reuse, seawater desalination, and interbasin water transfers are capital- and energy-intensive means that have allowed California, southeastern Spain, and Sydney to achieve water security. Water conservation has proven helpful during periods of extreme water scarcity. Could these means applied in the three study regions be implemented in developing countries with limited economic wherewithal? The challenge facing the world insofar as reaching water security is concerned is revealed in Fig. 6.

World population rose from 2.54 billion people in 1950 to 7.8 billion people in 2020, for a 207% increase, while the world's freshwater annual use rose from 1230 km^3 in 1950 to 4050 km^3 in 2020, a 229% increase. The 2020 water-use volume reflects a short-term decline cause by the economic slowdown associated with the shutdowns caused by the coronavirus pandemic. Global freshwater use and population are projected to rise respectively to 5500 km^3/year (Boretti and Rosa 2019), and 9.74 billion by 2050, implying increases equal to 36% and 25% in freshwater use and population, respectively, between 2020 and 2050. Most of the population growth is projected to occur in Africa and Asia, which feature predominantly developing countries with fledgling economies. Massive amounts of capital investment and energy inputs would be required to achieve water security in the developing world in the next decades. There would be increased reliance on fossil fuels unless the energy is derived from renewable sources, a conversion of energy sources that has proven elusive (Loáiciga 2011). The latter statement is corroborated by Fig. 6, which depicts the CO_2 equivalent emissions worldwide in the period 1950–2020. The emissions equalled 6.0 billion metric tons in 1950 and 34.81 billion metric tons in 2020, for a 480% increase in CO_2 equivalent emissions. Figure 6 also shows that in 2021 the CO_2 equivalent

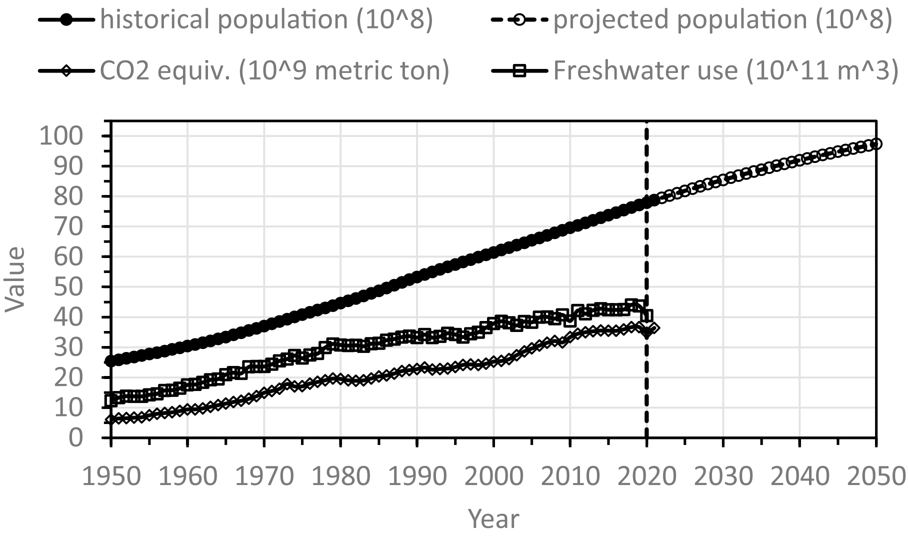

Fig. 6 Historical and projected population (in 10^8) (Source: US Census Bureau, https://www.census.gov/library/visualizations/2011/demo/world-population--1950-2050.html), freshwater use worldwide (in 10^{11} m^3) (Source: Boretti and Rosa 2019; https://www.statista.com/statistics/1199817/annual-freshwater-withdrawals-worldwide/), and CO_2 equivalent emissions (in 10^9 metric tons, https://www.statista.com/statistics/276629/global-co2-emissions/)

emissions (36.4 billion metric tons) recovered from the 2020 value as the world economy recovered from the pandemic. The emissions data demonstrate that fossil fuels remain the main energy source worldwide.

6 Conclusions

Climate change is projected to render precipitation more variable and scarcer in certain regions of the Earth, thus, affecting water supply. Even more challenging is that urban growth and rising consumption have larger influence on water scarcity, what makes it unavoidable to turn to smart strategies aiming to develop sustainable water supply systems and undertake actions that increase the efficient use of water resources.

This study assessed the conditions governing water supply, the trends in water use, and the strategies implemented to achieve water security in three diverse regions which share similar challenges.

The annual water use and the per-capita water use in the three study areas have declined in the first part of the 21st century. However, Spanish per-capita water use is lower than Los Angeles' and Sydney's. Local conditions influence the approach undertaken to achieve water security. Southeastern Spain has a diversified portfolio of water sources: it depends on local resources, transferred water, and desalination for potable consumption, and water recycling taps most of treated sewage. A strong commitment must be made by policymakers to maintain or achieve a diversified portfolio of water sources that is environmentally sustainable.

Los Angeles relies primarily on imported water. This makes it vulnerable to the threat of reduced precipitation and higher surface temperatures projected by climate-change assessments. A strategy for the large-scale development of desalination seems timely, and so is taking advantage of long experience to expand MAR and water recycling. Sydney's situation reveals that, although local freshwater is usually sufficient to meet the water demand, the reduction of these water sources by recurring droughts has led to greater reliance on desalination. This water supply strategy could be expanded to include a greater role for water recycling.

Efforts must be made in order to reduce water loss in distribution networks, and promote a more efficient use of water through reliance on water-saving smart appliances. Last but not least, public education concerning water use would encourage conservation and improve the acceptance of water recycling for human use. People's support and understanding of what it takes to achieve water security is imperative for its success.

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Declarations

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