Water Scarcity

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Keywords: water scarcity ; water cost ; water quality

1. Introduction

Water scarcity, defined as long-term water imbalances occurring when the level of water demand exceeds natural water availability and supply capacity, is expected to pose high risks to both societies and economies in the next decade [1]. According to Mehta [2], water scarcity is both 'real' and 'constructed', in which socio-political and institutional factors are at interplay. The constructive perspective fits well with a coexisting double narrative. On the one side, the water insufficiency narrative identifies the reasons for water scarcity in the limited supply or decreasing water resources and the factors increasing the demand side. This narrative comprises population growth, water transfers with neighboring regions, and climate change pressures [3]. On the other side, the water mismanagement narrative attributes water scarcity primarily to poor management and bad governance, and the lack of economic investment and development in water resources infrastructure [4]. Nevertheless, increasing water use due to population and economic growth is usually recognized as the primary driver of water scarcity because both factors lead to a growing demand for water-intensive goods and services (e.g., agro-food products) [5]. Moreover, hydroclimatic extremes (e.g., heat waves, droughts) intensify high consumptive water use [6]. The last three decades have successively been the hottest on the earth's surface compared to all the previous decades since 1850 [7]. Furthermore, rising temperatures have changed the balance of water resource revenue and expenditure, which, in turn, has caused widespread water scarcity and an uneven distribution of water resources. Land-use and land-cover changes [8], and changes in characteristics and patterns of precipitation and evaporation [9], have also contributed to maximizing the imbalance between water supply and demand, requiring investment in water infrastructures or water transfers to ensure water security [10].

Climate change will have a significant influence on water scarcity and water supply, both quantitatively and qualitatively. Severe impacts are reported to be water-related, with river ecosystems and agriculture often highlighted as sectors highly sensitive to change [11]. Agriculture, the world's largest water-consuming sector, accounts for 70% of water use on average, although it is estimated that the consumption of freshwater for agricultural irrigation accounts for 60%–90% of all water use, depending on the level of economic development and the climate of the area [12]. At the current growth rate of population and urbanization, the agriculture sector will have to produce 60% more food globally and 100% more in low-income nations [13]. However, a year with an anomalous rainfall regime, sudden temperature changes, or extreme weather events, have harmful effects on the performance in agricultural and livestock activities [14]. Consequently, ensuring food security and sustainable agricultural development is an urgent challenge because declining water availability or increasing water demand can harm cropland productivity [15]. Furthermore, although domestic and tourism water demands are relatively low compared to agricultural activity, tourism is heavily water-dependent, and the quantity and quality of water affect multiple facets of tourism sustainability [16]. At first glance, tourism appears to have a negligible impact on water resources, because global figures suggest that international tourism accounts for less than 1% of national water use in most countries, although in some others, such as Spain, this percentage could exceed 10% [17]. Nevertheless, tourism tends to be concentrated in dry and warm places and seasons, coinciding with high water demand from urban and agriculture users [18].

The competing water-related interests and the varying physical and socioeconomic drivers impacting specific sectors are increasing the challenge to address water supply in the near future [19]. In addition, water-related extreme events maximized by climate change will have indirect implications on social, economic, and environmental systems, thereby changing the spatial management and allocation of land and water resources [20]. This situation is particularly enhanced over semi-arid regions, where average precipitation is between one-fifth and one-half of the potential plant water demand [21]. Consequently, drying trends may occur most significantly in these regions, impacting the hydrological cycle, leading to changes in system response and increased drought risk and water scarcity [22]. According to Haghighi et al. [23], drought in semi-arid regions often starts with a meteorological drought (defined by lack of precipitation, possibly aggravated by hot temperatures, causing high evapotranspiration rates) [24], which leads directly to a hydrological drought (defined as a persistently decreasing discharge volume in streams and reservoirs over months or years) [25]. However, if the use of water resources exceeds the renewal of surface and groundwater, or if water demand outstrips supply, both agricultural and socio-economic droughts occur [26][27]. Exacerbating matters, a recent satellite-based study of Earth's freshwater resources demonstrated that this scenario based on drought severity was predicted for the end of the 21st century by the Intergovernmental Panel on Climate Change [28].

Although a consensus on long-term drought dynamics and their main drivers has not been achieved due to the complexity and difficulty with defining drought, different drought types, and difficulty providing an absolute assessment of the drought severity phenomenon [29], it is predicted that the frequency and intensity of droughts will increase under future climate change scenarios at the regional level, particularly in southern Europe [30]. Droughts are expected to be more severe over time and enduring, which poses a challenge for agricultural and urban-tourist water management in the Mediterranean region [31]. Mediterranean basins have a strong climate seasonality due to being dominated by alternating high- and low-pressure systems, and by depending on the water resources generated in other areas [32]. Future projections of climate trends show that Mediterranean countries will become drier and hotter, which might result in a severe decrease in agricultural productivity [33]. The need for irrigation water increases in these basins during the summer months as the growing season progresses, and the fluctuations in out-of-phase water availability and demands results in temporary or permanent water scarcity in the region [34]. Consequently, the Mediterranean region is one of the most vulnerable regions to climatic and anthropogenic changes, and hence it is a climate change hotspot due to the expected warming and drying of the region [35].

The problem facing society today goes beyond the lack of water resources to meet the world's growing needs and requires a change in the way that water is used, managed, and shared according to conflicting interests between water uses and functions [36][37]. This means considering water as both a biophysical and a social resource because water and society are (re)making each other: social conflict over water resource allocation affects the resource, and the hydrological features affect who has access to water, when, where, and at what cost [38]. Therefore, the strong competition between agriculture and urban-tourism water demands indicates the existence of 'structural' or 'permanent' water scarcity [39]. This scenario has motivated scientific communities to search for different (and complementary) solutions to increase water supply for both water-related sectors [40]. There are multiple environmental benefits associated with the agricultural use of reclaimed water, including: (a) reduced pressures on overstressed aquifers; (b) successful groundwater recharge; (c) reductions in fertilizer applications and expenses due to nutrients remaining in reclaimed water; and (d) higher crop yields for some crop types that are grown with reused water [41].

Conversely, lack of widespread public support (addressing the displeasure related to the perceived risk to human health and the environment), and technical and economic implementation (ensuring quality standards and energy efficiency at low cost), are some of the main barriers identified by reclaimed wastewater promoters [42]. Similarly, desalination is controversial because of its direct environmental consequences (high energy consumption and impacts on marine ecosystems) and for its consideration as a supply-oriented solution (creating a sense of security based on an unlimited resource that can reduce attention to water demand, enabling further consumption and pressuring local water systems) [43][44]. However, desalination provides a high-quality water supply [45] and is climate-independent, although this can thereby be seen as shifting problems from one scarcity (freshwater) to another (energy), thus postponing problem-solving [46]. On the contrary, the use of reclaimed (also called recycled) water for indirect potable reuse is mainly focused on landscaping (urban wetlands to improve water quality, green areas to mitigate the urban heat island effect, and better living environments for residents) [47], although the main obstacle for landscape water replenishment is its high nutrient concentration. Furthermore, potable reuse is limited to those contexts with severe water scarcity patterns, in which water is too precious to use just once [48]; for example, in 2002, Singapore became the first country to blend reclaimed water with fresh water in a reservoir to be used as recycled drinking water, called NeWater [49]. Similar efforts have been proposed in other water scarcity regions and cities to achieve net-zero urban water (conceived as the ability to sustain a population's water needs by replacing unsustainable practices with alternative, long term, locally sustainable sources). However, public perception, rather than water quality, has halted these projects [50].

2. Water Scarcity in South-East Spain

The region of south-east Spain has one of the largest structural water deficits in Europe. This is partly due to its semi-arid climatic characteristics, with mean annual rainfall values less than 400 mm, a great intra-annual variability, with a marked dry season in summer, in addition to inter-annual variability, with the occurrence of frequent episodes of drought and punctual episodes of intense precipitation. In this region, therefore, there is low availability of surface water resources because most of the rivers have a marked seasonal regime and their channels remain dry for most of the year. In addition, urban-tourist development, especially linked to residential tourism in coastal areas, and, above all, the development of an export-oriented irrigation model, explains not only the pressure on water resources but also the competition for water resources between agriculture and urban-tourist users [51]. This high-water demand has been fueled for decades by the Tajo-Segura transfer (TST) water flows, which since 1979 have conveyed water to the south-east from the Tajo River Basin headwaters located in the Iberian Peninsula hinterland. However, the volume transferred has not fulfilled users' expectations because the operation of this infrastructure has not prevented the irrigable surface from extending beyond the water availability limits [45]. This water deficit has been partially solved thanks to the extraction of underground water resources and the overexploitation of most of the aquifers in south-east Spain. Moreover, the need to diversify supply sources to guarantee demands has driven the development of non-conventional water resources in this region. In this sense, it should be noted that for several decades the reuse of wastewater has been especially intense in the south-east of Spain, where are located the highest percentages of wastewater treatment and reclaimed water use at the national level, mainly for agricultural irrigation [52].

Similarly, during the past two decades, desalination has also played a key role in guaranteeing water demand. In 2004 there was a change of direction in the Spanish water policy, which entailed the dismissal of future inter-regional water transfer projects for the benefit of desalination development in those Mediterranean regions that presented water deficit problems, such as south-east Spain, which experienced the greatest development of this infrastructure [53]. Although the use of this water source was initially focused on urban uses, recently the demand for desalinated water for agricultural irrigation has undergone significant growth. This expansion in desalinated water use has been driven by the modification of the TST legislation between 2014 and 2015 (Royal Decree 773/2014 and Law 21/2015) and the establishment of greater ecological flows on the Tajo River, which further restricted the approval conditions to enable water transfers to the south-east [45]. Faced with this situation, there has been an escalating trend in the consumption of desalinated water for agricultural uses that will continue in the future, according to the recent applications for desalinated water concessions by irrigators, which exceed the current production capacity of desalination plants [51].

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