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1

URBAN WATER CYCLE AND SERVICES

An integrative perspective

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1.1 Introduction

A civilization may be conceived as a set of infrastructure (Yevjevich, 1992). From that perspective, the interacting systems that allow societies to achieve sustainable development in terms of social, economic, and territorial cohesion assume a major, even vital, role (European Commission, 2017). The existing urban water cycles and services are crafted by the co-evolution over time and space of such natural and anthropogenic systems (Nace, 1975).

To frame the discussion on the interactions of water-human systems(e.g., water uses and related services), it is useful to take advantage of existing heuristic/conceptual representations. Thus, one may use the hydrological cycle (i.e., in broad terms, also known as the water cycle) to represent the material flow of water on our planet, i.e., through the biosphere, atmosphere, lithosphere, and hydrosphere (Sivapalan, 2018). This overall cycle has mainly two components that define the water flow between those spheres in all its states of matter (e.g., liquid, solid, gas): (1) movement and (2) storage. Those two components define the basis of water balance throughout the planet. The resulting water availability, in terms of accessible quantity and quality, constrains the possible water uses of the human population and, thus, the inherent services. Those services include water supply, wastewater collection and management, drainage, and recreation, among others (Jenerette & Larsen, 2006). If we consider the integration of these services in the water cycle, and its application to densely populated, built-up developed areas, while keeping the cycle's conceptual structure, we can characterize an urban water cycle (UWC). Figure 1.1 schematizes a possible representation of a UWC.

The UWC, similar to its parent cycle, undergoes constant change due to, often interlinked, impacts (Pan et al., 2018), namely: (1) environmental, as climate change and ecosystem degradation; and (2) anthropogenic, as population growth, urbanization (e.g., urban development and land use characteristics), and cultural aspects. Those impacts vary considerably across the territory and their understanding is paramount for effective water resources (and somehow UWC services) management (di Baldassarre et al., 2019).

The integrated UWC management (hereafter, IUWM) strains the relationship between supply and demand for the services required to enable the multiple water uses that exist in the UWC components (as in Figure 1.1). The IUWM allows for assessment of the resulting variation of

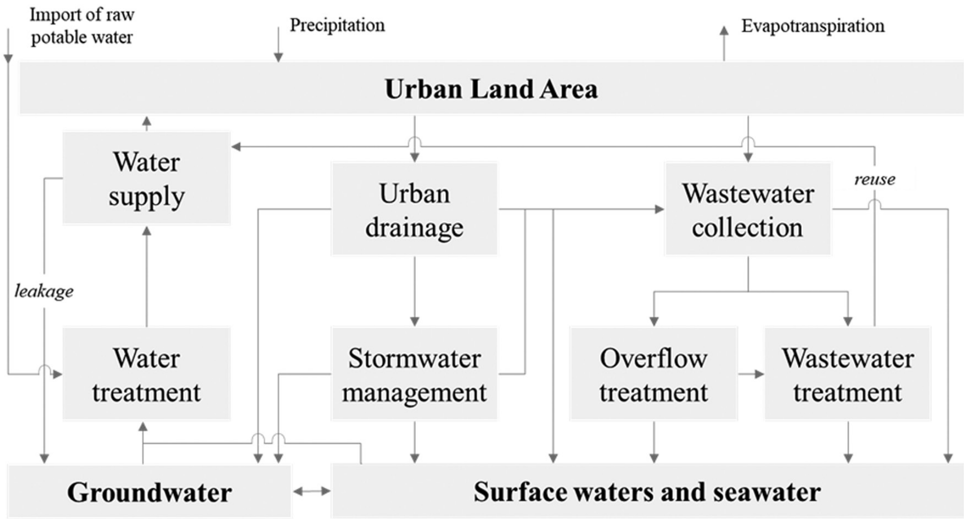

Figure 1.1 Possible schematic representation of UWC components and pathways. Source: Adapted from Marsalek et al. (2008).

water quantity and quality through the different UWC components while addressing climatic, hydrologic, ecological, land use, and engineering issues (Marsalek et al., 2008). To successfully achieve this supply/demand equilibrium, as well as suitable planning and development, identifying the interactions between the urban environment and the respective complementary neighboring areas, e.g., suburban, and rural environments (Bhaskar & Welty, 2012) is also required. In short, changing climatic, land, and human conditions often cause increased water stress that requires supply from outside the urban area or even another catchment, resulting in intensified resource movement, i.e., from source (resource abstraction) to effluent discharge into receiving waters.

In the end, the UWC services sustainability requires some questions to be clearly considered, depending on their rivalry and excludability (OECD, 2009): "who gets the service?" "when they get it?" "how (and how much) they get?" and "how (and how much) they pay for it?" Thus, for the sake of simplicity and worldwide comparison, we will focus on urban water supply and wastewater management, referring, when appropriate, to the remaining services (e.g., stormwater management and urban amenity).

As a starting point, in countries perceived as developed economies, access to safe water supply and sanitation (in which wastewater management is included) has largely been ensured following significant previous investments, mainly at the end of the last century. Nonetheless, considerable investments will still be required to rehabilitate existing infrastructure so as to bring it into conformity with stricter environmental and health regulations and to maintain service quality over time (Bo et al., 2021). On the other hand, in the remaining countries, referred to as transition or developing economies, the challenges are more daunting. A large share of the population has no access and many other residents have unsatisfactory services (Adelodun et al., 2021). An urban water crisis has persisted over decades even as the international community acknowledges these disparities and is committed to achieving milestones to counter problems such as poverty, inequality, and unequal power relationships as well as flawed water management policies that exacerbate the existing scarcity. Those goals that aim to reach sustainability are now defined as the Sustainable Development Goals (SDGs), where SDG 6 focuses on ensuring availability and sustainable management of water and sanitation for all.

This chapter highlights the different characteristics of supply and demand of UWC services across the world and how environmental and anthropogenic impacts (un)balance this equilibrium. As a result of the preceding point, it is important to understand the relationship between competing uses, existing resources, and infrastructure requirements as well as the subsequent variability in costs and prices of UWC services in different contexts (Hukka & Katko, 2015). Finally, a demand assessment, detailing and categorizing the different water uses (both consumptive and non-consumptive) and "used water" characteristics, is required to understand worldwide differences in water allocations and wastewater management tendencies and acknowledge market and merit considerations.

After this brief introduction, we provide a detailed description of urban water uses and their financing requirements, addressing "who" and "how much," as well as the main worldwide trends. Lastly, we provide some policy implications, opportunities, and concluding remarks.

1.2 Urban water cycle, systems, and services

1.2.1 Insights into the UWC systems and services

To support the worldwide demographic, economic, and social (e.g., in terms of behavior) growth, a focus has been placed on production and cost efficiency, which has favored the "take, make, consume, dispose" concept. Due to those targets, the main components of UWC systems, and the provision of related services, were addressed separately, putting an increased stress on both ends of that linear economy approach, i.e., on resources and on the environment. Their interactions were often disregarded or underestimated, which is obviously unsustainable under limited resources. As an example, the demand for water supply has reached an alarming level, providing the motivation to assess the potential of "reducing, reusing, and recycling" those resources, and thus promote IUWM.

UWC systems need to reach subsistence and, perhaps, sustainability. At this stage, IUWM becomes extremely important to achieve the former and to enable the latter. In general, those systems should aim to: (1) continuously supply safe drinking water; (2) collect and treat wastewater for disease protection and prevention of environmental harmful impacts; (3) control, collect, and transport stormwater to protect from flooding and pollution; (4) reclaim, reuse, and recycle water and nutrients.

To achieve an IUWM, the system needs to be considered as a whole and a fuller role must be given for each element/stakeholder identified as nodes (e.g., treatment plants), due to possible dependencies (e.g., treated wastewater may be mixed with "drinking water supply"). Those dependencies can reach a relevant level of complexity; nonetheless, they allow for several synergies and gains (Figure 1.2).[1]

Indeed, the improved management of outputs (e.g., wastewater and stormwater) can offer positive-sum solutions to human societies and natural ecosystems. Some examples can be linked to energy generation, water reuse, and recovery of distinct constituents (Figure 1.2), namely: (1) reclaimed water for aquifer recharge; (2) water swaps with irrigators to deliver more freshwater to urban users; (3) treatment of wastewater for liquid or dry fertilizer and soil improvement (for an extensive list of possibilities, see Rao et al., 2017). In Figure 1.2, the "materials" and "energy" flows are defined by possible node inputs (as the consumption of recovered materials like biomass and energy), and node outputs (as the generation of energy).

1.2.2 Defining urban water uses

The UNSD (1997) defines water use as the "use of water by agriculture, industry, energy production and households, including in-stream uses such as fishing, recreation, transportation and

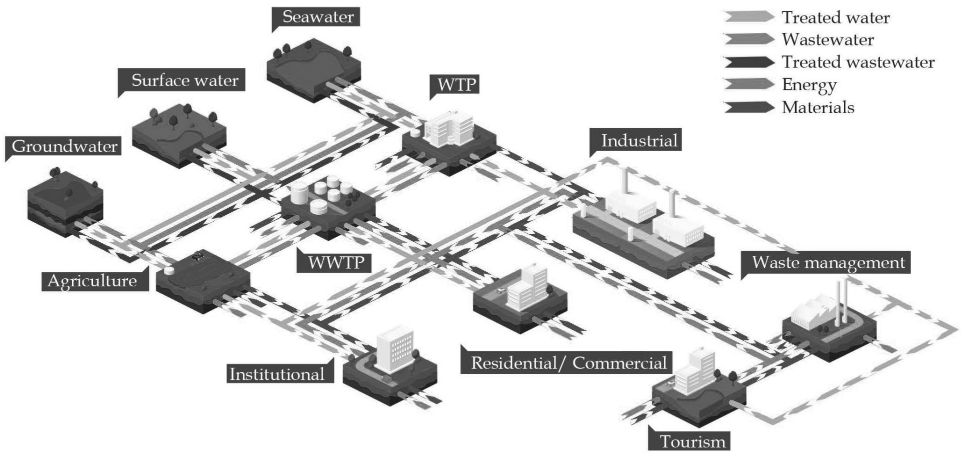

Figure 1.2 Possible general features of an integrated management process (and other related outputs).

waste disposal." Nonetheless, to clarify the concept, a differentiation of closely related terms, such as withdrawal, demand, or consumption, must be made. A withdrawal is defined as the removal of water from a water course (ground or a surface water source) for off-stream use. Demand for water is an economic concept used to describe the quantity that users are willing and able to purchase under particular circumstances. Consumption is the quantity of water withdrawn and made unavailable for reuse, including losses to evaporation or contamination (Gleick, 2003). As follows, a consumptive use is the part of withdrawn water that is "evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment" (Mays, 1996).

The relationship between water uses and natural hydrologic systems outlines the in-stream use, off-stream use, and return flow (Mays, 1996). The first is when water is used but not withdrawn from its course (as hydroelectric power generation, navigation, and recreation). The second is when water is withdrawn or derived from its course to supply different uses, not necessarily consumptive uses. The third is when water is released from a node of use and reaches a water source, becoming available for further use.

The water uses themselves can be defined through different categories. If we take into account Figure 1.2, the "treated water" edges flow into "water use" nodes, categorized through its broad water use features, e.g., the residential use covers water use in or around a house, including indoor (as shower, faucets, toilets) and outdoor (as watering lawns and gardens) household uses. Water uses have been aggregated in multiple ways, following economic, geographic, or engineering backgrounds. Examples are: (1) municipal water uses that cover residential, commercial, industrial, and other uses, where "other" also includes water leaks and unaccounted-for water uses (e.g., firefighting); and (2) urban, periurban, and rural water uses, a territorial typology, where each category may include several water uses (see Figure 1.2) depending on their predominance.

The definition of water uses is important in understanding the overall perspective of demand under competing uses, stressing "who gets" and enabling discussion of "when," "how much," and "how is it financed," among other important issues. Naturally, each water use has distinct impacts in terms of resource quantity and quality variations. Examples are "in-stream navigation" water use, which does not impact quantity variations but may imply quality changes through pollution (as leakages of dangerous substances), and water supply for sanitation (as toilet flush), which implies quantity and quality variations (due to excludability and rivalry of water supply and the resulting wastewater stream).

1.2.3 Measuring urban water uses

To evaluate the UWC water balance, we have to measure the different flows within the UWC (Xenochristou et al., 2020). However, systematic collection of usage data remains scarce, with strong regional disparities, leading to recurrently inadequate and incomplete data. A significant share is not measured or is not quantifiable, as the evaluation of recreational uses or ecosystem services (Bolognesi, 2018). Therefore, we will focus on water supply and wastewater management, in which two issues stand out: the first is how water uses are measured, the second is data quality. If we consider water supply and wastewater management services, utilities often use meters, e.g., in the edges of Figure 1.2 for leakage control as in district metered areas or to charge their consumers. Nonetheless, several utilities may question their use due to increased costs and resulting prices to customers (Barraqué, 2011). Thus, in several cases, water usage data are estimated rather than accurately measured as: (1) wastewater management services being charged at 90% of water supplied, or (2) at supply nodes (Figure 1.2), consumption being influenced by unknown water leaks or infiltration (mostly in wastewater flows).

Situations may exist where we have distinct types of water volumes, covering (Pinto et al., 2021): (1) production (costs, water withdrawn); (2) consumption (benefit, user consumption); and (3) billing (revenue, what utilities charge). The relation between them depends on water losses (real, apparent, and unbilled, i.e., non-revenue water) and tariff structure (e.g., guaranteed consumption).

When it comes to comparing costs and the price of water, the difficulties deepen due to decreased availability (e.g., commercial/trade secrets) or increased complexity (e.g., to consider purchasing power parities). In a seminal study, OECD (2010, p. 34) states that:

> (1) pricing, cost and other relevant data on water-related services is fundamentally local, that any aggregation or averaging exercise implies a loss of information; (2) choices regarding sampling and aggregation affect national values; and (3) extreme care should therefore be taken in proposing cross-country comparison on such variables.

Therefore, interpreting or comparing distinct studies or databases, with certain different assumptions, requires careful analysis.

Overall, the collection and interpretation of water use and related data are challenging; however, it is fast improving as several databases are emerging, fostering continuous improvement toward modernization and rationalization of water management.

1.3 Financing urban water cycle services

1.3.1 Project feasibility – no solution fits all

IUWM usually focuses on the actual/projected UWC services demand. Imbalance from supply and demand mostly covers changes in traditional water resources (e.g., surface and groundwater) availability, increases in demand, and infrastructure requirements (Grant et al., 2012). Therefore, implementing IUWM depends to a large extent on climatic, topographical, and socioeconomic conditions (among others: landlocked cities vs. coastal cities, altitude, and social inequality), which may require different governance, technical, and financing approaches.

An important feature in IUWM is its cyclic approach, where wastewater and stormwater must be considered as more than undesirable commodities that should be discharged and disposed of in a prompt and efficient fashion (Angelakis & Snyder, 2015). Several cases of their reuse can be found in the United States and in Australia, and increasingly across the world, even if stormwater reuse shows a comparatively slower growth (Global Water Intelligence, 2017).

In the end, the feasibility of IUWM projects will surely depend on possible funding structures within a variety of physical and socioeconomic circumstances.

1.3.2 Key concepts from water economics

Understanding UWC service costs were developed over time to assess existing constraints. They include the cost of forgone options, possible alternative uses (the non-accounting ones), and the costs (or benefits) imposed due to the "mutually interfering usage." From the previous statement, four concepts stand out: costs, value, price, and tariffs. A sensible definition of those concepts can be found in Table 1.1.

Drawing from the previous concepts, cost does not, in general, drive economic value, neither does price measure it, and items with no market price can still have a positive economic value. The different dimensions of value are well characterized in Smith's (1776) quote comparing diamonds and water. Now, if we compare the cost (Equation 1) and value (Equation 2) components of water, as a function of different components (adapted from Rogers et al., 2002), there is an easier assessment of its possible price.

← externalities (ext.) →

$$\text{Full cost} = f\left(\text{O \& M costs, capital charges, opportunity costs, economic ext., environmental ext.}\right) \quad (1)$$

Table 1.1 A definition for cost, value, price, and tariff

Concept	*Definition (reference)*
Cost	"O&M costs, capital costs, opportunity costs, costs of economics, environmental externalities. From a different perspective several support costs may have to be included in (or differentiated from) the classical cost outlays, as institution building, human resources development, information systems, monitoring and assessment, regulation, planning and strategy development." (Cardone & Fonseca, 2003)
Value	"Value to users of water, net benefits from return flows, net benefits from indirect use, adjustments for societal objectives and intrinsic value." (Rogers et al., 1998)
Price	"Amount set by the political and social system to ensure cost recovery, equity and sustainability. The price may or may not include subsidies. Prices for water are not determined solely by cost." (Rogers et al., 2002)
Tariff	"A tariff is the system of procedures and elements which determines a customer's total water bill (any part of that bill can be called a charge, measured in money/time units or money units alone; and any unit price can be called a rate, usually measured in $\text{money}/\text{volume}$ units)." (OECD, 1999)

← Full supply →
← Full economic costs →

← Net benefits from →

$$\text{Full value} = f\left(\text{users of water, return flows, indirect uses, societal objectives, intrinsic value}\right) \quad (2)$$

← Economic value →

additional concepts are required to analyze UWC services, as their delivery achieves a distinct status from the delivery of other commodities, since those services entail vital functions and externalities. For that purpose, the reader is redirected to Berg and Tschirhart (1995) for a listing of topics addressed in the literature on utility pricing and capacity, covering concepts such as price elasticity, price discrimination, and marginal cost pricing.

Due to unique features of water-related industries (e.g., higher capital intensity and technical characteristics, institutional status, environmental importance) that are connected to the public/ private economic nature of those services and their social value, UWC services require the assessment of several sources of finance. If we distinguish the economic nature of some WSS in line with the rivalry in consumption, as well as the "excludability" in accessing the "good"/ "service" and to whom the benefits are accrued (i.e., to direct users or to a pool of beneficiaries), diversified sources of financing can be adopted (OECD, 2009). When a UWC service resembles a private good, as traditional water supply, the provider may require a payment from users (inducing the user-pay and polluter-pay principles). On the other hand, if a UWC service falls into the common pool/club/public good categories, it will be increasingly more difficult to do so, consequently reinforcing the integration of transfers and taxes. For all UWC services, a different share of those sources may be required, achieving distinct 3Ts (tariffs, taxes, transfers) policies (OECD, 2010). Nonetheless, additional sources, such as loans and bonds, must be explored due to flexibility benefits and to allow for large upfront investments normally required in the water sector (Pinto & Marques, 2017a).

1.3.3 Revenue streams

In the case of IUWM, decision-makers may have to compare water supplies besides the traditional ones, which are usually less costly. To discuss the feasibility of IUWM projects, it is useful to adopt a financing decision framework, in which, after measuring the costs and benefits to check if it is justifiable, a judgment is made whether the project is mandatory or not. If it is mandatory, the financing framework can cover customer charges below the water supply network charges, and the remaining funding can be shared by other beneficiaries. In case it is not mandatory, commercial viability must be assessed, and charges may vary between a cost-sharing model proportional to the benefits received and customer willingness to pay (WTP). The pivotal point is the requirement to achieve an appropriate mix between 3Ts (with potential external funding partners) and repayable mechanisms (Byrnes et al., 2006).

Since there are several possible funding avenues, and particularly when projects do not pay for themselves, it is of paramount importance to discuss the most appropriate financing structure and how it may vary. In fact, besides the direct beneficiaries, the wider utility customer base should also be considered, as state or national governments (Pinto & Marques, 2017b). Occasionally, funding for these projects can be charged to property developers (Lazarova et al., 2001) or to relevant industrial customers (e.g., in the Municipality of Constância, Portugal, 75%

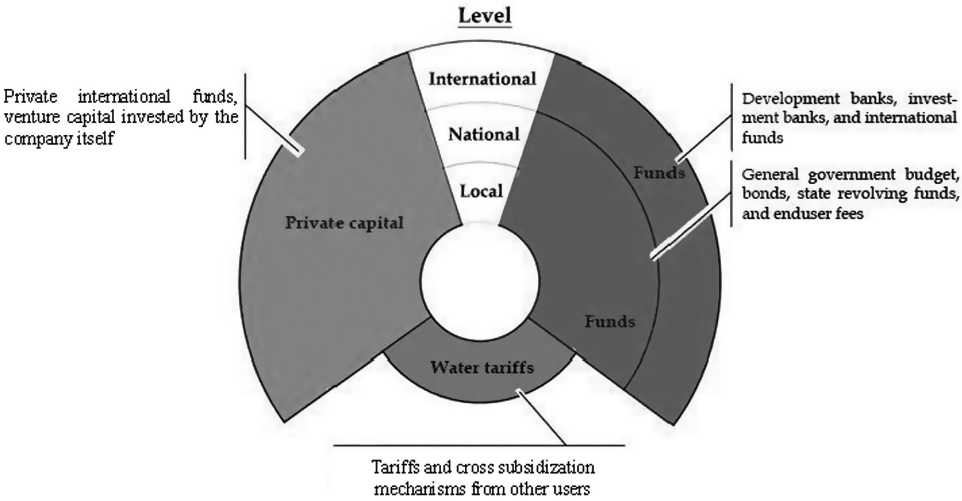

Figure 1.3 Financing sources classified according to type of funding and geographical level. Source: Adapted from de Paoli and Mattheiss (2016).

of municipal wastewater collected is treated for free at the wastewater treatment plant of a pulp [paper] production company). Thus, when deciding upon the most appropriate financing structure, different types of funding at distinct levels should be considered (see Figure 1.3).

Furthermore, and relying on the broad set of benefits brought by IUWM projects, the possibility exists to allocate the source of payment outside the direct beneficiaries. For water reuse schemes, some possibilities are:

- fees paid by developers;
- recreational fees (fishing licenses, park entrance fees);
- stormwater management fees;
- wastewater user charges; and
- donations or dues made to nonprofit groups and associations.

Finally, it is important to identify a concern for customer charges affordability, where there is a need to consider local knowledge of low-income households' expenditures, ability and WTP, although caution should be used in interpreting WTP estimates. In the absence of this information, tariff levels and structures may be based on erroneous assessments of affordability constraints that may not match WTP. In cases where tariffs are kept too low, the result may be a vicious circle of underfinanced services, lower than needed investment and maintenance, and lack of access to water services.

1.4 Urban water worldwide trends

1.4.1 Key water databases

Water-related data can be exported from different sources. Without conducting an extensive analysis, we will present important apps that maintain a continuous effort to include more granular data, higher resolution, new and aggregated data sets, and indicators from different sources.

The first is the AQUASTAT (https://www.fao.org/aquastat/), FAO-UN's global information system on water resources and their use. Established in 1960, it includes over 180 variables and indicators by country. The second is the WHO/UNICEF JMP database (washdata.org/), which, since 2000, includes estimates of progress in household drinking water, sanitation, and hygiene from data produced by national authorities. These databases are complemented by UNstat (https://unstats.un.org/) which is the core UN statistics division data portal, with a focus on the SDGs. To follow SDG's six updates, a dedicated data portal (www.sdg6data.org) draws data from UNstat and other sources.

The Organisation for Economic Co-operation and Development (OECD) also has its own water data portal (https://data.oecd.org/environment.htm#profile-Water) with data and indicators on water withdrawals and wastewater management, among others.

The Aqueduct Water Risk Atlas (https://www.wri.org/applications/aqueduct/water-risk-atlas/) from the World Resources Institute gathers data to measure water-related risks by aligning different indicators, such as physical quantity, quality, and regulatory and reputational risk categories. This app uses open-source, peer-reviewed data to help informed decision making based on best practices in water resources management and to enable sustainable growth in a water-constrained world.

The Water Peace Security partnership initiative is led by IHE Delft and draws considerably from the Aqueduct's database. The app (https://waterpeacesecurity.org/map) aims to help local stakeholders identify, understand, and address (i.e., mobilize, learn, and promote dialogue) water-related security risks.

World Bank Water Data Portal (https://wbwaterdata.org/) is the app for all water-related open data from World Bank–funded initiatives, such as the IBNET, the SIASAR, and the GFDRR, supplementing these with dozens of quality data sources, such as the OECD, the UN, WRI, WWF, and a number of governments. It contains more than 2650 data sets under three pillars (Build Resilience, Deliver Services, and Sustain Water Resources).

Our World in Data (https://ourworldindata.org/clean-water-sanitation) is an app developed at Oxford University to make the knowledge accessible and understandable. This app focuses on research and data (e.g., UNICEF/WHO JMP data and AQUASTAT) to build reports and make progress in dealing with problems related to, in this case, water resources and services.

EEA's databases (https://www.eea.europa.eu/data-and-maps/), including the Waterbase and the Water Information System for Europe (WISE) Water Framework Directive database, deal with the status and quality of Europe's surface and groundwater bodies and with the quantity of Europe's water resources and water withdrawals and discharges, among others.

GWI WaterData (https://www.gwiwaterdata.com) is a market-oriented app produced by Global Water Intelligence and covers high-value business information for the water sector.

In the end, water data analyses must still confront of comparability. Improvements have been made, but the harmonization of definitions or calculation methods between the different indicators in the existing data is (more frequently than desired) found to be lacking.

1.4.2 Water risk, sectoral perspective, and access

By using the Aqueduct Water Risk Atlas to disclose potential impacts that may threaten water quantity, quality, and accessibility and therefore constrain its sustainable use, an overall current situation or a baseline is illustrated in Figure 1.4. To reach this baseline, we consider a combination of water risk indicators selected from the Physical Risk Quantity (water stress, inter-annual and seasonal variability, groundwater table decline, riverine and coastal floods, and droughts, accounting for 70%),

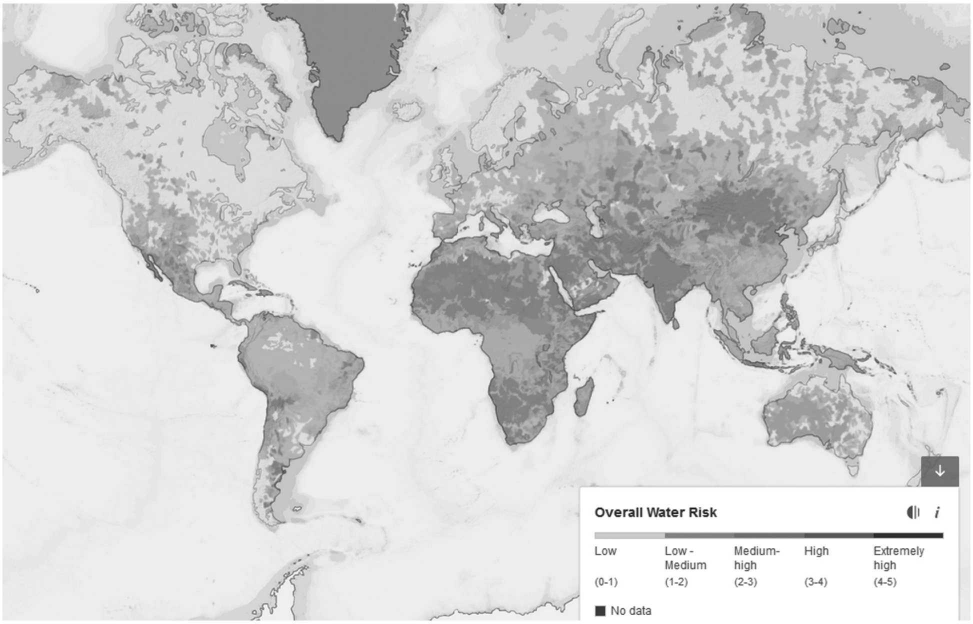

Figure 1.4 Overall water risk baseline (water quantity, water quality, and regulatory and reputational indicators). Source: WRI Aqueduct, www.wri.org/applications/aqueduct/water-risk-atlas, accessed on 05 January 2022.

Quality (untreated connected wastewater and coastal eutrophication potential, accounting for 12%), and Regulatory and Reputational Risks (unimproved/no drinking water, unimproved/no sanitation, Peak RepRisk country in "environmental, social, and governance," accounting for 18%) categories; the relative importance of those indicators was kept at default levels. For more detail on the assembly of those indicators, see Hofste et al. (2019).

For a clear understanding of how the future will unfold, we focus on water stress changes from the baseline (projections for 2040 considering societal water demand divided by available water) in Figure 1.5. We present a business-as-usual scenario[2] to promote a sensible impact.

Figure 1.5 shows that most urban areas will experience a significant increase in water stress changes, which is expected to take a toll on the overall water risk and, thus, impose constraints on urban water uses. Regarding the main off-stream water uses worldwide (i.e., agricultural, industrial, and municipal), they are measured through the quantity withdrawn due to their water demand, with significant differences around the world (Table 1.2).

The "hidden" uses through private boreholes or illegal network connections (as in informal settlements) bring an additional difficulty. Nonetheless, we can still raise awareness to potential shifts in consumption patterns, considering improved supply and sanitation services. In Figure 1.6, we draw attention to the evolution of drinking water supply coverage between urban and rural areas throughout approximately the last 20 years (2000–2020).

Regarding access to safe sanitation in urban areas (mostly wastewater management), in Figure 1.7, we highlight, for particular groups of countries, their evolution over the 2000–2020 timeframe.

1.4.3 In-depth urban water uses

To achieve SDG6, and possibly establish a lower boundary on IUWM, we need to consider the requirements to achieve access to drinking water and sanitation, to counter industrial and

Figure 1.5 Water stress changes from baseline, timeframe 2040. Source: WRI Aqueduct, www.wri.org/applications/aqueduct/water-risk-atlas, accessed on 05 January 2022.

agricultural pollution, as well as to obtain water scarcity and improve water management. To understand what the inherent costs would entail, WRI prepared an "Achieving Abundance: Understanding the Cost of a Sustainable Water Future" data set for display on "Resource Watch." In this data set, the cost of action required to close the gap between current and desired conditions is calculated for each country, as highlighted in Figure 1.8. Major cities were also introduced and were categorized according to the "Economic Capacity Categorization of Cities" data set. It categorizes 769 cities into four groups based on: (1) their current economic strength (through their income), and (2) their projected population and economic growth (income growth relative to population growth, between 2015 and 2030). Those four categories are defined according to their high and low grades, respectively: struggling (low, low), emerging (low, high), thriving (high, high), and stabilizing cities (high, low). This categorization can help to identify cities that will likely face challenges in providing urban services in the future, possibly UWC services.

The daunting situation that several cities may face will certainly increase abstraction costs (as in withdrawals from greater distances and at greater depths). In general, they may also confront greater water and wastewater treatment costs. In such cases, Noiva et al. (2016) suggest that they must increase water use efficiency, demand management, reuse, and recycling. Still, to effectively achieve sustainable practices, utilities need to have detailed information so as to understand water use patterns and the myriad factors that influence them (for a household-level analysis, see Abu-Bakar et al., 2021). Some reports aggregate some databases to that end (Larson et al., 2021), but unfortunately, they are still too few in number and heterogeneous (di Mauro et al., 2021).

Table 1.2 Water withdrawal by sector, from sdg6data database latest data available (accessed on 05 January 2022)

Region	*Agriculture (%)*	*Industry (%)*	*Municipal (%)*	*m^3 / pop*	*Urban pop (%)*
Asia	**82.2**	**8.6**	**9.3**	**585.9**	**49.6**
Central Asia	87.7	8.4	4.0	1716.5	48.2
Eastern Asia	64.6	21.1	14.3	447.5	62.5
Southeastern Asia	85.1	6.4	8.5	771.3	48.8
Southern Asia	91.2	1.9	6.9	589.0	35.8
Western Asia	84.0	6.3	9.6	632.0	71.9
Europe	**29.4**	**43.4**	**27.2**	**409.0**	**74.5**
Eastern Europe	22.9	54.1	23.0	378.7	69.7
Northern Europe	11.9	41.1	47.0	203.9	82.1
Southern Europe	59.1	21.4	19.5	639.2	71.7
Western Europe	5.4	56.6	38.0	381.0	79.9
Oceania	**59.0**	**18.2**	**22.8**	**554.0**	**69.5**
Australia and New Zealand	60.1	17.8	22.1	714.0	86.1
Melanesia	10.7	37.1	52.2	50.3	17.2
Latin America and the Caribbean	**71.0**	**12.1**	**17.0**	**512.4**	**80.6**
Caribbean	57.6	24.8	17.6	567.7	70.3
Central America	74.8	9.3	16.0	568.1	74.5
South America	70.7	12.0	17.4	484.0	84.1
North America	**37.3**	**49.5**	**13.2**	**1317.9**	**82.2**
Sub-Saharan Africa	**75.5**	**6.6**	**17.9**	**93.0**	**40.4**
Eastern Africa	88.1	2.7	9.2	113.3	27.7
Middle Africa	45.7	17.4	36.9	22.0	49.5
Southern Africa	64.2	10.0	25.8	260.2	63.9
Western Africa	65.0	9.6	25.4	73.4	46.4
Northern Africa	**82.2**	**5.3**	**12.5**	**572.6**	**52.0**
World	**71.6**	**16.3**	**12.1**	**529.4**	**55.1**

Source: FAO AQUASTAT / UN-Water, www.sdg6data.org/tables, latest year with data is 2018 (last accessed on 5/1/2022).

1.5 Policy implications and opportunities

In general, IUWM can target several issues in following a more sustainable approach to dealing with rural poverty, water-food-energy security, health and environmental protection, climate mitigation and adaptation, and natural resources management (WWAP, 2017). In fact, the desired outcomes of healthier people, increased prosperity, more equitable societies, protected ecosystems, and resilient communities can be promoted through such key impact pathways as (UN-Water, 2014): (1) improved access to safe drinking water, sanitation and hygiene, increasing water quality and higher service standards; (2) new revenue, income, investment, cost saving, services, and human development outcomes; (3) robust and effective water governance with more effective institutions and administrative systems; (4) improved water quality and resource management within carrying capacity of ecosystems; and (5) reduced risk of water-related disasters to protect vulnerable groups and minimize economic losses.

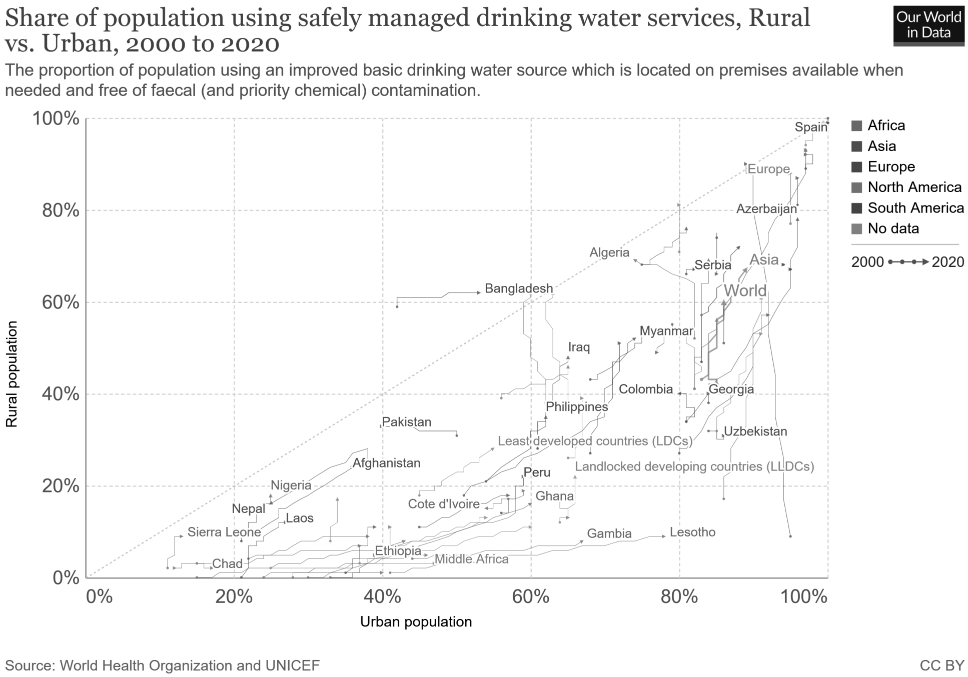

Figure 1.6 Share of population using safely managed drinking water services, rural vs. urban, 2000 to 2020. A safely managed drinking water service is one that is located on premises, available when needed, and free from contamination. Source: WHO and UNICEF, Our World in Data, https://ourworldindata.org/water-access, accessed on 05 January 2022.

For an effective IUWM, several urban and institutional design challenges can be cited. To solve those challenges, coherent participation from multiple actors is required, from water sector to strategic urban planners, environmental and economic regulators, as well as local governments (Marques et al., 2016). As seen in Section 1.4, water supply and wastewater management services are somehow already provided within contextual boundaries; however, that is not the case when you include stormwater management and other outcomes like urban amenity. For an effective delivery of those services, clear guidance in required.

Along those lines, the roles and responsibilities for appropriate IUWM need to be further clarified. In the end, if governments want to obtain stormwater management and urban amenity as outcomes of IUWM, then land and water planning have to be linked and targeted at a variety of scales, both spatial and time. The former from national to regional to local scale and the latter at the appropriate time to cover a project life cycle viewpoint (Loubet et al., 2016). Water planners, local governments, and water policy and statutory land planners need to collaborate, as a different suite of agencies are required through planning, construction, implementation, and ongoing management phases.

All services in an IUWM require consistent institutional and funding arrangements; yet, we can clearly draw a line of decreased maturity and definition within water supply, wastewater, stormwater management, and urban amenity services. The nature of those services highlights different (and increasing) funding challenges. Examples can be linked with health improvements through accessibility to improved UWC services, as quality green space, or the inherent uplift in property value due to improved livability.

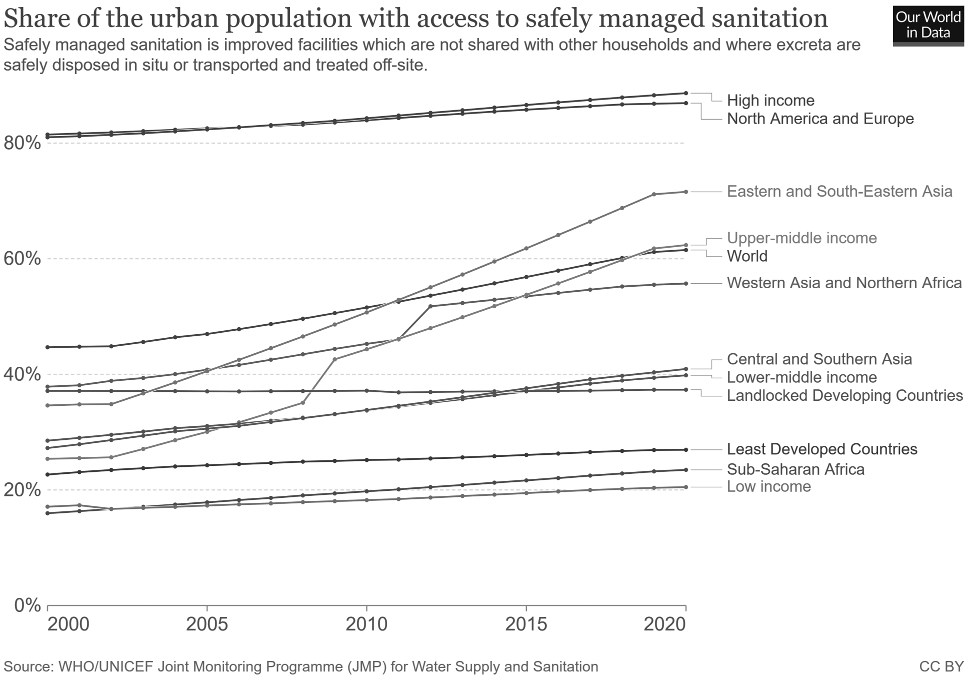

Figure 1.7 Share of the urban population with access to safely managed sanitation. Safely managed sanitation is improved household facilities where excreta are safely disposed in situ or transported and treated off-site. Source: WHO and UNICEF, JMP, Our World in Data, https://ourworldindata.org/sanitation, accessed on 05 January 2022.

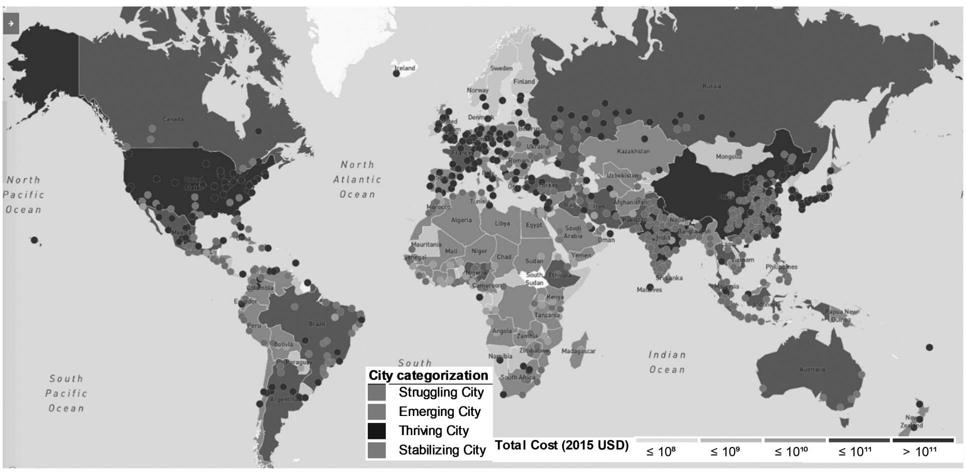

Figure 1.8 Total cost of sustainable water management (2015 USD) and city categorization. Source: WRI, www.wri.org/data/achieving-abundance-understanding-cost-sustainable-water-future-data, and Oxford Economics/WB/UN/WRI, datasets.wri.org/dataset, accessed on 05 of January 2022.

The different "rivalry" and "excludability" characteristics of UWC services render it difficult to understand who benefits and who should pay for what, hindering investment selection. This resembles a catch-22 situation, which often leads to the selection of the lowest cost option that will generally exclude the livability or the environmental options.

Those options may also be forgone in transboundary situations, where upstream vs. downstream water supplies (shift in withdrawals and discharges may lead to resource displacement) or polluting discharges (compliance among regulations and standards) may provoke conflict and hamper development efforts (Earle et al., 2015).

To reach IUWM, a long list of stakeholders must be included in the decision-making process at different levels, perhaps with rules and contracts to fulfill certain outcomes over a timeframe. In fact, these constraints may actually foster network-based governance toward sustainable synchronous regimes (Renou & Bolognesi, 2019).

1.6 Concluding remarks

We have examined the relationship among competing uses, existing resources, and infrastructure requirements, as well as the subsequent variability in costs and prices of UWC services in distinct contexts. The assessment of current knowledge reveals that there are no silver bullet solutions to balance supply and demand as well as anthropogenic and environmental sides of UWC. In short, even if water resources may be displaced elsewhere through appropriate infrastructure, they have a local nature and so do water stress issues (e.g., supply–demand imbalance).

Climatic and hydrologic conditions, infrastructure, and water demand in a given time and space are factors that shape those issues, requiring solutions tailored by location. Additionally, we are aware of the difficulties inherent in an international comparative assessment, which is why we report the parameters limiting the comparability of data (both measured and estimated), allowing an improved discussion.

The gap between research and practice remains difficult to overcome. Conflicts exist between developed scientific principles and popular thought about preferred solutions (e.g., lowest cost option). Usually, the latter carries multiple biases and noise, lacking full information and allowing for a possible continuous misapplication of, perhaps, interesting solutions.

As far as solutions go, a multitude of forces point in new directions, with a heightened emphasis on institutional advance through improved policy design and policy choice, as opposed to technological advances and further structural investments. Yet costly structures continue to be proposed and occasionally undertaken, and public interest in more dams and conveyances perseveres despite the highly harnessed water environment. For all these reasons, the potential role of engineering and management professionals remains high. To end this chapter, we would highlight in the words of Hanemann (2006):

> In short, while there clearly are some distinctive emotive and symbolic features of water that make the demand for water different, there are also some distinctive physical and economic features which make the supply of water different and more complex than that of most other goods. This fact has often been overlooked.

Notes

1 For such a system, see the case of Kalundborg Symbiosis at: www.symbiosis.dk/en/ (last accessed on 16/12/2021).

2 Scenario SSP2 RCP8.5, represents a world with stable economic development and steadily rising global carbon emissions, with CO_2 concentrations reaching ~1370 ppm by 2100 and global mean temperatures increasing by 2.6–4.8°C relative to 1986–2005 levels.

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