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URBAN WATER GOVERNANCE

Approaching a pressing environmental and social challenge

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0.1 Introduction

Do you drink water, take showers, water your garden? Do you live in a city? Have you considered whether your water consumption impacts the volume of available water, quality of waterways, the habitat of aquatic animals, or other people's use of water upstream and/or downstream? If you live in a rural area, do you think that the functioning of cities has an impact on your water uses or on the local fauna and flora? One single yes means you are concerned with and connected to urban water governance. Indeed, urban water is a smaller water cycle within the global water cycle, and governance contributes to determining how these two cycles co-evolve. Nevertheless, many cities around the world have experienced a "water crisis," and scientific evidence is growing that substantiates the argument that the current co-evolution is neither sustainable nor satisfactory.

Urban settings have long been important centres of economic, political, social, innovative, and cultural activities. Yet prior to 2005, scholarly attention directed towards understanding the nuances and challenges of urban water governance was limited. This has now shifted, with urban water governance regarded as a critical field of research (see, e.g., Figure 0.1). Access to water and/or wastewater disposal is a complex collective-action dilemma that faces environmental, socio-economic, and technical constraints. The recognition of the human right to water and the global monitoring of water access through the Sustainable Development Goals (SDGs) ([formerly the Millennium Development Goals]) emphasise how vital and inequal this access is worldwide. The decision-making and delivery contexts for urban water are rapidly changing, due, in part, to changes in patterns of precipitation, ageing infrastructures, decreasing water quality (occasionally due to lack of wastewater treatment), increasing water withdrawals/discharges (in volume, quality, and across space), and damage to water ecosystems, among others. The socio-economic and technical delivery of water services is costly, and it rests on network-related industries that are difficult to regulate, which limits the ability to offer universal access to water/wastewater collection. This issue affects both developed and developing countries, the former in renewing infrastructure and the latter in building it.

According to (Pahl-Wostl 2015), "water governance is the social function that regulates development and management of water resources and provisions of water services at different levels of society and guiding the resource towards a desirable state and away from an undesirable

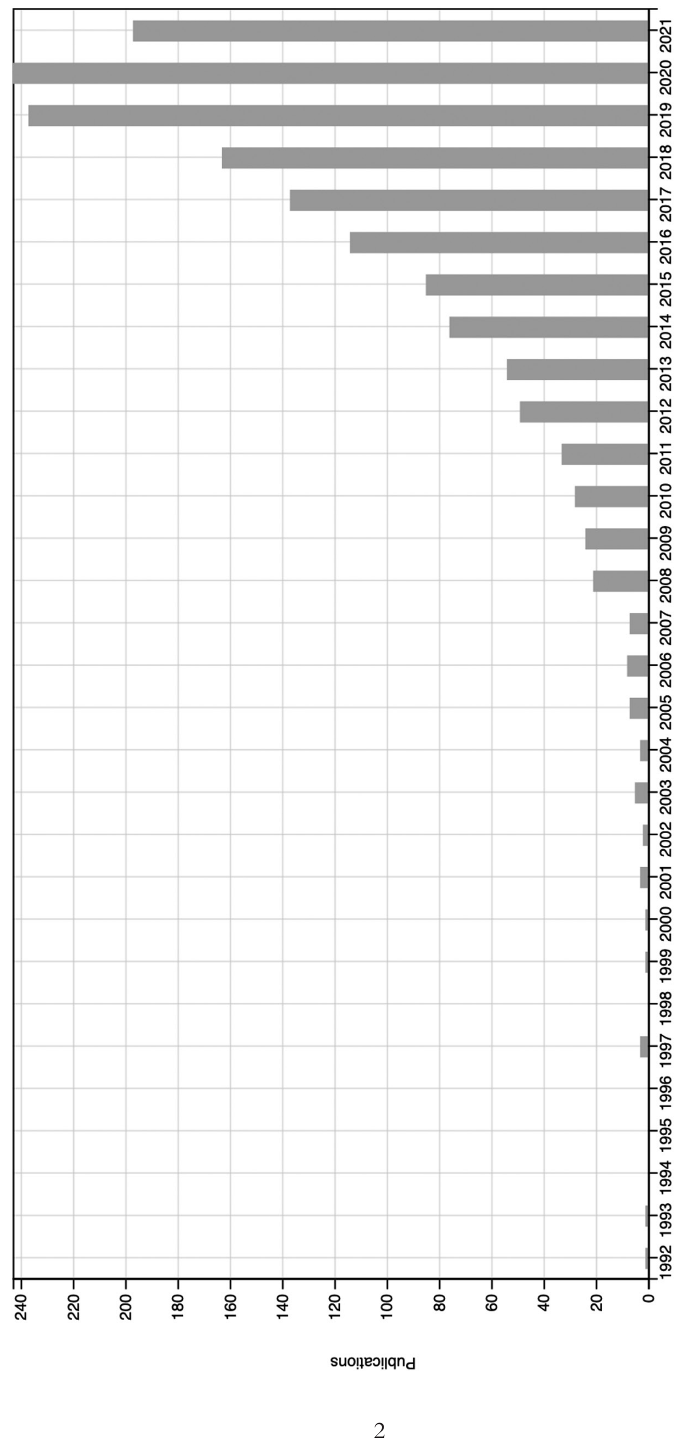

Figure 0.1 Total publications per year about urban water governance – We use data from web of sciences. The request is: TOPIC: (urban water governance); Timespan = 1992–2020; Indexes = SCI-EXPANDED, SSCI, A&HCI, ESCI.

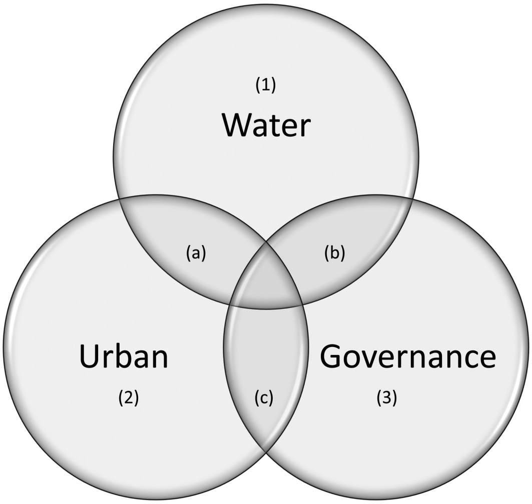

Figure 0.2 Delineation of the dimensions of urban water governance.

state." We define urban water governance as the organisation of the urban water cycle and of its interlinkages with directly interacting uses. We identify an urban water cycle that consists of the technological dimensions of water supply and uses. It is the object of the governance stricto sensu. Governance consists of the political-economic, institutional, and social dimensions that organise the urban water cycle. In this view, governance is the practice of interaction by actors to coordinate the urban water cycle, to engage in political and power relations, and to take into consideration technical and urban planning needs (Bakker 2010; Bolognesi 2018; Varone et al. 2013). This simple identification highlights that the relations are not unilateral; rather, they consist of numerous interlinkages and complex feedback relations.

Figure 0.2 depicts urban water governance as a particular *and* generic object. We use this combination of facets to structure our delineation of urban water governance. In the next section, we define the generic dimensions: (1) water, (2) urban, and (3) governance (Section 0.2). Then, we focus on associations of dimensions a, b, c (Section 0.3). Before concluding, we present the main ongoing challenges in urban water governance (Section 0.4).

0.2 Defining water, urban, and governance

(1) Water: Hydrology, ecology, and society

Water is a natural resource. Water has hydrological characteristics, which the "water cycle" heuristic scheme synthesises. The essential variables of the global water cycle are precipitation, evaporation, infiltration, and runoff. In the *Encyclopedia of Hydrological Sciences*, Beckie (2005) gives an overview of the fundamental principles of hydrological modelling. He writes that the water balance (S) results from precipitation (P) and evaporation and transpiration (ET), the net evolution of groundwater (G), and surface water (Q) for a given time (t) and catchment:

$$\Delta S = \left(P - ET + G_{in} - G_{out} + Q_{in} - Q_{out}\right)\Delta t$$

This equation shows that water quantity varies over time and space, and understanding this variability in the context of changing land, human, and climatic conditions remains a critical challenge for hydrology (Blöschl et al. 2019). Because of these conditional changes, the water cycle intensifies, i.e., more variation and extremes (Huntington 2006). Observations indicate that the subsequent changes in trends of water availability contrast dramatically over geographical areas (Rodell et al. 2018). The distribution of water scarcity and abundance, or events as floods and droughts, evolves significantly.

Water has ecological characteristics. Water serves as a habitat for 140,000 specialist freshwater species and is a condition for life (WWF 2018). Water availability and quality determine how liveable the habitat is, and, thus, they affect the state of and the interactions among ecosystems and finally biodiversity properties, i.e., ecosystem, community and species, intraspecific, genetic and functional diversity (Geist 2011). Freshwater ecology studies how these properties co-evolve within aquatic ecosystems. Aquatic ecosystems are diverse and are estimated to host about 6–10% of the existing animal species (Balian et al. 2008; Dudgeon et al. 2006). The diversity of water habitat and life depends primarily on "salinity, temperature, availability of light, dissolved gases and nutrients, along with biogeographic processes" (Geist 2011, p. 1508).

Water has social characteristics. Like other animals, humans use water and contribute to both the stability and the alteration of freshwater habitats. Even more, since the Anthropocene, humans are a primary driver of water characteristics, and, as such, water characteristics are both a social construct and a social context. For instance, dams are a significant source of disturbance for freshwater ecology and hydrology (Dudgeon 2019; Piégay et al. 2020); and they exist because the local water context was considered to limit local development (Flaminio, Piégay, and Le Lay 2021). Economic activity (production and consumption), demographic trends, technology, and models of organisation and coordination, among other social phenomena, affect water and vice versa. Concepts like social-ecological systems, socio-hydrology, and co-evolution place these nuanced relationships at the forefront of analysis (Baldassarre et al. 2019; Kallis and Norgaard 2010; Ostrom 2009). We place ourselves, and this handbook, in this tradition.

(2) Urban: People, infrastructures, and land

An urban area consists of a concentration of people in a built-up area. It consists of a centre and a periphery, the former being denser. Most of the world's population lives in urban areas. In 2020, urban population is estimated to represent 56.2% of the world's total population, and it is forecast to reach 62.5% by 2035 (UN Habitat 2020). Increasing urban populations typically result in the growth of urban areas. In 1950, there were 306 metropolises with more than 300, 000 inhabitants, including 1 with more than 10 million inhabitants. In 2020, 1,934 metropolises were counted with 34 hosting 10 million people. Thus, the share of 10-million-inhabitants metropolises within metropolises has been multiplied by more than five. Worldwide, urbanisation means a change in economic activity, way of life, and concentration of people. Urbanisation is not a homogeneous phenomenon (Figure 0.3). The location and size of cities are not uniformly distributed around the globe. This spatial heterogeneity comes with significant environmental, economic, and political consequences.

The high human density in urban areas stresses carrying capacity, i.e., the ability of an environment to sustain its population size. Urban ecological footprint indicators aim at measuring the extent to which human pressures affect carrying capacity. Such indicators compare the city surface to the land surface theoretically required to support its population. The discrepancy is sizeable. For instance, Rees and Wackernagel (1996) estimated that the ecological footprint of Vancouver in 1991 was 180 times larger than its administrative size. As per capita urban

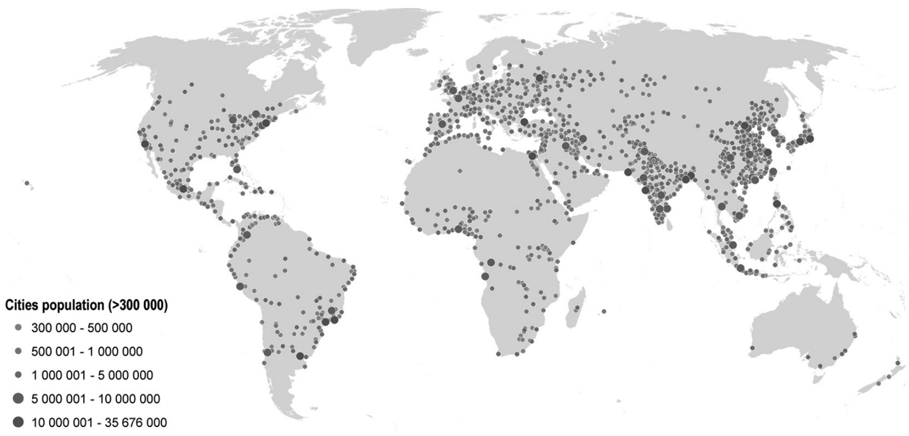

Figure 0.3 Urbanisation of the world: location and size of cities with more than 300 000 inhabitants (Authors' elaboration with the support of Stéphane Kluser).

ecological footprint tends to be greater than per capita national ecological footprint, urbanisation poses severe sustainability challenges (Ortega-Montoya and Johari 2020). Consequently, more and more research focuses on the factors favouring the introduction of sustainability measures in the policy agendas of cities (Reckien et al. 2018; Swann and Deslatte 2018).

Heterogeneity in urbanisation also reveals asymmetric development dynamics and power distribution, reflecting the multiplicity of embedded urban systems (e.g., energy, water, mobility, etc.) (Nielsen and Farrelly 2019). Not all cities are equal, nor are the spaces and people within an urban area. Some cities concentrate economic or political power, which affects their own capacities to organise their development. Consequently, cities are not isolated; rather, they are part of networks and systems that structure cooperation and competition. Zipf's law ranks cities according to their size, facilitating a determination of the hierarchical distribution of cities within national urban systems (Cura et al. 2017; Gabaix 1999).

(3) Governance: Problems, coordination, and strategies

Governance involves multiple actors and typically involves a coordinative approach, thus implying the need to examine coordination mechanisms through their effectiveness, legitimacy, and power struggles (Ostrom 2005; Pierre and Peters 2020; Rhodes 2007; Williamson 1996). The notion is polysemic, but we can distinguish conventional (e.g., top-down and market-based modes of governance) from non-conventional (e.g., network and/or hybrid governance) approaches. Consequently, numerous approaches alternatively emphasise economic, political, or sociological processes. To navigate this diversity and make sense of it, instead of rejecting some approaches, we refer back to Knight's (1992) recommendation for considering a "building block approach" to governance, starting from a simple perspective to an increasingly more sophisticated position that includes significant, but hard-to-measure, phenomena, such as power and/or cultural mechanisms.

A governance system consists of actors that create coordination using formal and informal institutions with a particular allocation of decision and control power. The actors in the system are people or public/private entities that make choices to achieve a goal (e.g., drinking water) and that interact through transactions (e.g., water delivery) (Commons 1924). Actors are boundedly rational (Simon 2000). They do not intend to maximise any utility optimally but rather choose a satisfying option using imperfect information and values (i.e., they primarily focus on drinking water, not on drinking the cheapest water with equal quality). To enable (water) transaction and (water) use satisfaction, actors coordinate by creating and crafting formal institutions (like laws, contracts, and any written rules) as well as informal institutions (like habits, values, and unwritten codes of conduct). These institutions are multilevel, which means they concern more or fewer people, overlap, are complex, and rely on different enforcement mechanisms, from trust to policing.

There are a plethora of governance system structures. A governance system structure is qualified as a complex and hybrid form that mixes the characteristics of three ideal types: hierarchy, market, and self-organisation (Ostrom 2010). These institutions are nested across multiple levels from the local to the global, shaping a polycentric system (Carlisle and Gruby 2019). A polycentric system combines multiple decision centres that are interdependent, more or less autonomous, and hierarchical. Interdependency and nestedness are critical characteristics because they imply complementarities, conflicts, and externalities between institutions. Institutional complementarity, conflicts, and externalities cause consequential non-linearities in coordination processes, and thus, they are pivotal to understanding governance systems' functioning and effects (Aoki 2007; Bolognesi and Nahrath 2020). From a dynamic perspective, power struggles and contextual changes contribute to the evolution of governance systems, with the components evolving at varying frequencies and speeds (Mahoney and Thelen 2009; North 2005; Roland 2004).

0.3 Urban water governance: Assembling water governance, urban water, and urban governance

(a) Urban water

Studying urban water relates to three questions: where does water come from? what are the different uses? and how are they delivered? Responding to these questions relates to economic and infrastructure development and spatial interlinkages between cities and their hinterland. Urban water withdrawals are largely dedicated to municipal water, i.e., mainly households' consumption of water for drinking, showering, and washing as well as other uses depending on the public distribution network. On average, in 2018, countries used 28.25% of their total water withdrawal for municipal water use. There is a large diversity in the share of municipal water use ranging from 0.46% in Afghanistan to 100% in Monaco. Noticeably, 50% of countries use less than 20% of their water withdrawal for municipal use. Two key drivers of national disparities in the share of municipal water are economic development and the importance of agriculture in the national gross domestic product (GDP).

Statistics on municipal water use cover water delivered through pipes, which should not hide the considerable diversity in how people access water for basic needs. SDG 6 monitors the types of access to basic water needs, including sanitation. Despite significant progress since 1990, worldwide "one in three people do not have access to safe drinking water" and "two out of five people do not have a basic hand-washing facility," according to UNICEF and WHO.[1] If, in general, households in developed countries have tap-water access, that is certainly not the case in many developing countries and in slums in many countries. The type of access and required infrastructure strongly affect how people use water, e.g., building new pipes or investing in renewing old infrastructure (Bolognesi 2018; Vasquez et al. 2009). Essential drinking water and sanitation are not the only urban water uses. Fire protection, urban agriculture, hydrothermal

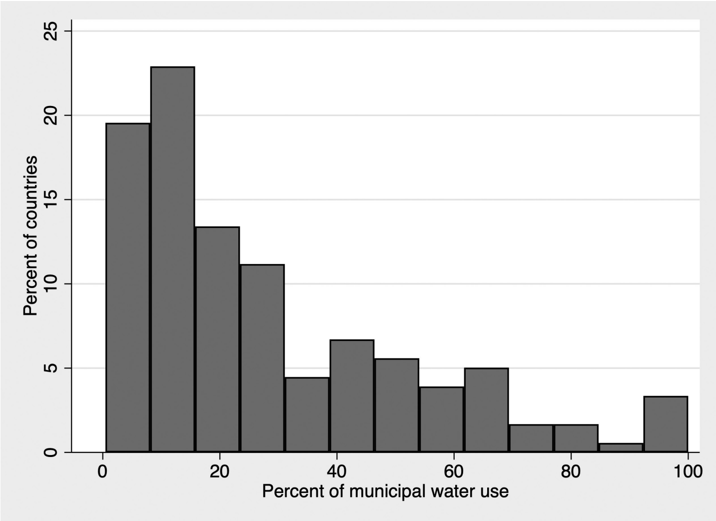

Figure 0.4 Countries distribution regarding the share of municipal water use in total water withdrawal (Authors' elaboration using Aquastat data. The data covers 179 countries in 2018).

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power, refreshment, leisure and bathing, and protection against floods are other types of urban water use and are likely to increase in the near future. Due to the increase in anthropogenic use and social-ecological feedback loops, aquatic habitat quality and water flows are likely to be more and more threatened.

As seen with the urban water footprint, cities are not large enough to get their water from themselves. Water used in urban areas has sources, mainly outside the urban areas. Linking sources to the end of the pipes implies the use of significant infrastructure outside cities, generates interdependencies between cities and hinterland, and political and economic factors shape these relationships. Las Vegas is a typical example. Located in a desert, the city pumps water from more than 400 kilometres to the north, limiting water use drastically near the source. Such spatial interlinkages have consequential redistributive effects on water access, economic development, and environmental inequalities. Therefore, determining the volume of water transiting to cities becomes increasingly relevant (Garrick et al. 2019; McDonald et al. 2014). McDonald et al. (2014) estimate that 10–14% of large cities transfer water from another watershed, corresponding to 83,000 million litres per day (±15 000 million litres).

(b) Water governance

Water governance is pivotal in shaping water resource dynamics and uses (Ostrom 2009). While often grouped together, it is of primary importance that governance processes maintain water resources distinct from water uses to improve system sustainability (Bolognesi 2014; Gerber et al. 2009). It allows for defining and monitoring environmental conditions for sustainability and making explicit sociopolitical trade-offs that grant water access and uses. Combining water resources with their uses causes severe difficulties in defining the governance perimeter that are fit for purpose (Ingold et al. 2018; Varone et al. 2013). Should it be based on spatial, sectoral, or actors configurations? Many normative approaches to water governance have emerged depending on the principal perspective, and academia and practitioners' views often meet (van de

Meene, Brown, and Farrelly 2011). A common trend is a search for integration and for finding a fit between environmental and social dimensions because it increases both the range of possible solutions and the soundness of the analysis (Gleick 2018; Hering and Ingold 2012). Integrated water resource management (IWRM), nexus, water security, adaptive management, and economic regulation of infrastructures are among the most influential approaches.

IWRM, a concept that is more than 80 years old, reemerged during the 1990s and was put at the forefront of the international water governance agenda by the Global Water Partnership in 2000 with its technical report defining IWRM as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystem" (Biswas 2004). It is a vague definition but two aspects are noteworthy and common to most IWRM approaches. First, IWRM considers water as a complex system and takes into account the different components of the systems and their interrelations jointly. Consequently, it is cross-sectoral and multidimensional (like economic efficiency, environmental preservation, political decision making, inclusiveness, legitimacy, and equity). Second, it is assumed that implementing IWRM will lead to more sustainable outcomes. However, IWRM has been routinely found to be significantly constrained in its implementation (Biswas 2004).

To go beyond the vagueness of IWRM, authors have focused on specific aspects. The nexus approach emphasises the cross-sectoral interlinkages, initially between water and energy with food now increasingly included in the analyses (Bazilian et al. 2011; Hussey and Pittock 2012; Liu et al. 2018). Others wanted to detach from the normative perspective of the IWRM and propose a cohesive and objective measurement of the water multidimensions. Water security aims at simultaneously addressing the water resource and its main uses, e.g., freshwater biodiversity, drinking water consumption, agricultural uses, and floods and droughts. Many place-based studies have been conducted and, nowadays, research is moving towards large N studies and reproducible measurements to identify patterns of water security improvements (Gerlak et al. 2018; Hoekstra, Buurman, and Ginkel 2018; Vörösmarty et al. 2010). Others scrutinise the process of water governance per se. The adaptive management approach pays serious attention to the fact that social-ecological systems are unpredictable (Huitema et al. 2009). Consequently, it is how people adapt and make decisions in different situations that matter. Authors argue that multi-types of learning, experimentation, and participatory processes are pivotal and should be part of water governance (Jager et al. 2020; Reed et al. 2010). The regulation approach focuses on economic mechanisms and incentives to design water governance. This approach is often applied to the regulation of drinking water supply and wastewater management. Authors question the effectiveness of economic regulation as well as regulatory agency organisation and control mechanisms, such as performance indicators and price-setting (Bakker 2010; Pinto, Simões, and Marques 2017; Porcher and Saussier 2019).

(c) Urban governance

Cities are nodes within a more extensive (territorial) development system. As a node, they concentrate not only people, but also economic and political resources. While they depend on their hinterland, they attract people and resources. City development results from both synergies and competition with a city's hinterland or with other cities (Fujita, Krugman, and Venables 1999). Consequently, the dynamics of city development and the governance of cities are specific. Cities balance costs and gains from agglomeration. On the other hand, within each city, the need exists for coordination to shape sustainable development and to consider the fact that actors within cities both conflict with each other and coalesce to benefit from urban resources (Stone 1993). Consequently, urban governance deals with allocation of resources, including water, between a city and its hinterland and within a city. For instance, Los Angeles secures 8,895 million litres of water per day from other water basins (McDonald et al. 2014). Within Los Angeles County, water rights and water rates vary significantly, causing unequal access to water (Pincetl, Porse, and Cheng 2016).

Decentralisation is a second reason for urban governance specificity. Cities have more and more responsibilities and are in charge of implementing national policies. While theoretical governance mechanisms are not changed, the urban perimeter should be accounted for. Due to decentralisation and territorial competition, cities have developed competencies and planning strategies. It raises the question of the effect of urban management and organisation on urban sustainability. For instance, interlocal collaboration, stakeholder support, and membership in a global network that offers support (e.g., ICLEI) have a significant positive effect on implementing environmental measures (Swann 2017). More broadly, organisational environment, stakeholder participation, and urban population attributes (e.g., political preference and growth) affect a city's likelihood of adopting sustainability measures (Swann and Deslatte 2018). Those results emphasise that urban governance has a lot to do with governing fragmentation and enabling cooperation with multiple partners (Kim et al. 2020).

Studies have found non-linear relationships, which stress that with governance, context matters. Therefore, many advocate that experimenting with reforms and sharing knowledge within and across cities is essential to conduct transitions and transformative changes in urban areas with consideration given to multilevel embeddedness. Farrelly and Brown (2011) highlight the conflict between change and path-dependency in urban areas. They show that local-scale experiments are an essential source for learning but that their ability to influence the more extensive system faces inertia due to traditional urban water management. They have identified a list of 36 factors that favour or impede such experiments, encompassing agency, regulatory environment, politics, and belief in technology. As urban governance is also about establishing cooperative arrangements with rural areas, this aspect is of major importance. For instance, in the 1990s, Munich conducted an innovative reform of its drinking water supply by implementing financial support for upstream farmers to turn to bio-agriculture (Grolleau and McCann 2012). Nowadays, it is a standard scheme.

0.4 Ongoing challenges

We are experiencing global changes that challenge urban water governance sustainability and understanding. These challenges relate either to social transformation, environmental changes, or the ability to handle complex problems. These phenomena intensify stress on water resource allocation among ecosystem and people, and they require consideration of the social, hydrological, and environmental dimensions of water simultaneously both in academic analysis and in practice (Baldassarre et al. 2019; Vollmer et al. 2018).

First, with increasing urbanisation and inequalities, competition for water within an urban area, such as in Los Angeles, and with the immediate environment and rural regions is likely to intensify dramatically. In addition, inequalities increase heterogeneity and complicate finding inclusive solutions. For instance, in Rio de Janeiro, wealthy neighbourhoods with private swimming pools sit adjacent to the *favellas*, which have poor access to drinking water. Inequalities associated with urbanisation are likely to increase the complex configuration of urban areas that are still poorly addressed in the water management literature (van den Brandeler, Gupta, and Hordijk 2019). Innovation through technological change and systematic thinking to invent and build non-conventional urban water systems are needed; and the effects of systems must be anticipated to avoid misadaptations or unanticipated indirect perverse effects (Hoffmann et al. 2020; Larsen et al. 2016). Integrative and adaptive urban planning is pivotal to design and craft systems that address multidimensional constraints, e.g., topography, density, or socio-economic characteristics.

Second, environmental changes, including climate change, biodiversity loss, and ecosystem degradation, reveal the limits of our current systems and limit our ability to plan. Indeed, non-linearities and irreversibility are intrinsic to these changes, altering the predictability and understanding of social-ecological systems, which pose new challenges (Baldassarre et al. 2019; Dudgeon 2019). For instance, climate change is likely to mean more frequent and more intense droughts and floods in the same place, and urban development must respond in view of the vulnerabilities posed by these hazards (Berbel and Esteban 2019; Bolognesi 2015).

Third, those social and environmental changes require novel ways of thinking and instruments to devise coherent, legitimate, and effective urban water governance measures (Pahl-Wostl 2020); some talk of a complexity paradigm (Balland et al. 2022). To reach improved outcomes, integrated modelling must be developed to take advantage of the digital era by aiming at combining different dimensions of social-ecological systems; for instance, to set realistic and effective water tariffs (Pinto, de Carvalho, and Marques 2021). Another approach consists in exploring how governance integrates different sub-systems to improve the outcome of polycentric systems (Berardo and Lubell 2019; Trein et al. 2021). Finally, local experimentation should not be denied. It could serve as an incubator for new and effective practices (Farrelly and Brown 2011).

0.5 Urban water governance: How to take stock from the literature?

Urban water governance is multifaceted, resulting in a fragmented scholarship. This handbook seeks to put together widely accepted pieces of this fragmented knowledge. It offers a panorama of various approaches that might be combined to understand and address current issues. Indeed, while simple, some basic questions remain timely, both for academics and for practitioners: how does urban water governance work? How is it shaped? What are its impacts? These questions are important for practitioners because, as noted, there are considerable challenges ahead. They are important for academics because these simple questions reveal that urban water governance figures as a privileged field for testing theories. This handbook seeks to (1) offer a state-of-the-art perspective on these questions, taking into account the disciplinary fragmentation of the field; and (2) pave the way for future research going beyond this disciplinary fragmentation in order to favour knowledge accumulation.

The handbook is structured in presenting a progressive entry into the complexity of urban water governance, starting with technical dimensions and including more and more layers of the social phenomena. Each concept and dimension is exemplified by taking advantage of the current processes of urban water governance reform worldwide. Five aspects of urban water governance structure the handbook: (1) deliverance of urban water, (2) wastewater collection and treatment, (3) utilities regulation, (4) political-economic aspects, and (5) sustainability. Parts 1 and 2 deal with the technical means by which water services are delivered in distinguishing between traditional and urban systems as well as drinking water and sanitation (chapter 1–10). Part 3 addresses how institutions and economic regulation shape urban water governance organisation and outcome (chapter 11–15). Part 4 depicts the policy and political processes of urban water governance in considering network, power, and change (chapters 16–19). Part 5 addresses different sustainability issues of urban water governance, echoing previous chapters but in specific contexts such as slums, infrastructure management, pollution, or integrative approaches (chapters 20–25). This structure facilitates a progressive understanding of urban water governance, which relies on an iterative approach to the urban water system, focusing alternatively on the "urban water cycle" and the "water institutions."

Note

1 Information on SDG 6 is accessible from: https://www.un.org/sustainabledevelopment/water-and-sanitation/, accessed 23/12/2021.

References

Aoki, Masahiko. 2007. "Endogenizing Institutions and Institutional Changes." *Journal of Institutional Economics* 3(1): 1–31.

Bakker, Karen. 2010. *Privatizing Water: Governance Failure and the World's Urban Water Crisis*. Ithaca: Cornell University Press.

Balian, E.V., H. Segers, K. Martens, and C. Lévéque. 2008. "The Freshwater Animal Diversity Assessment: An Overview of the Results." In *Freshwater Animal Diversity Assessment, Developments in Hydrobiology*, eds. E.V. Balian, C. Lévêque, H. Segers, and K. Martens. Dordrecht: Springer Netherlands, 627–37. https://doi.org/10.1007/978-1-4020-8259-7_61.

Balland, Pierre-Alexandre et al. 2022. "The New Paradigm of Economic Complexity." *Research Policy* 51(3): 104450.

Bazilian, Morgan et al. 2011. "Considering the Energy, Water and Food Nexus: Towards an Integrated Modelling Approach." *Energy Policy* 39(12): 7896–906.

Beckie, Roger. 2005. "Fundamental Hydrologic Equations." In *Encyclopedia of Hydrological Sciences*. John Wiley & Sons, Ltd. https://onlinelibrary.wiley.com/doi/abs/10.1002/0470848944.hsa004.

Berardo, Ramiro, and Mark Lubell. 2019. "The Ecology of Games as a Theory of Polycentricity: Recent Advances and Future Challenges." *Policy Studies Journal* 47(1): 6–26.

Berbel, Julio, and Encarna Esteban. 2019. "Droughts as a Catalyst for Water Policy Change. Analysis of Spain, Australia (MDB), and California." *Global Environmental Change* 58: 101969.

Biswas, Asit K. 2004. "Integrated Water Resources Management: A Reassessment." *Water International* 29(2): 248–56.

Blöschl, Günter et al. 2019. "Twenty-Three Unsolved Problems in Hydrology (UPH) – a Community Perspective." *Hydrological Sciences Journal* 64(10): 1141–58.

Bolognesi, Thomas. 2014. "The Paradox of the Modernisation of Urban Water Systems in Europe: Intrinsic Institutional Limits for Sustainability." *Natural Resources Forum* 38(4): 270–81.

Bolognesi, Thomas. 2015. "The Water Vulnerability of Metro and Megacities: An Investigation of Structural Determinants." *Natural Resources Forum* 39(2): 123–33.

Bolognesi, Thomas. 2018. *Modernization and Urban Water Governance: Organizational Change and Sustainability in Europe*. London: Palgrave Macmillan UK. http://link.springer.com/10.1057/978-1-137-59255-2.

Bolognesi, Thomas, and Stéphane Nahrath. 2020. "Environmental Governance Dynamics: Some Micro Foundations of Macro Failures." *Ecological Economics* 170: 106555.

van den Brandeler, Francine, Joyeeta Gupta, and Michaela Hordijk. 2019. "Megacities and Rivers: Scalar Mismatches between Urban Water Management and River Basin Management." *Journal of Hydrology* 573: 1067–74.

Carlisle, Keith, and Rebecca L. Gruby. 2019. "Polycentric Systems of Governance: A Theoretical Model for the Commons." *Policy Studies Journal* 47(4): 927–52.

Commons, John Rogers. 1924. *Legal Foundations of Capitalism*. New York: MacMillan.

Cura, Robin et al. 2017. "The Old and the New: Qualifying City Systems in the World with Classical Models and New Data." *Geographical Analysis* 49(4): 363–86.

Di Baldassarre, Giuliano et al. 2019. "Sociohydrology: Scientific Challenges in Addressing the Sustainable Development Goals." *Water Resources Research*. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018WR023901.

Dudgeon, David et al. 2006. "Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges." *Biological Reviews* 81(2): 163–82.

Dudgeon, David et al. 2019. "Multiple Threats Imperil Freshwater Biodiversity in the Anthropocene." *Current Biology* 29(19): R960–67.

Farrelly, M., and R. Brown. 2011. "Rethinking Urban Water Management: Experimentation as a Way Forward?" *Global Environmental Change* 21(2): 721–32.

Flaminio, Silvia, Hervé Piégay, and Yves-François Le Lay. 2021. "To Dam or Not to Dam in an Age of Anthropocene: Insights from a Genealogy of Media Discourses." *Anthropocene* 36: 100312.

Fujita, Masahisa, Paul R. Krugman, and Anthony Venables. 1999. *The Spatial Economy: Cities, Regions, and International Trade*. Cambridge, MA: MIT Press.

Gabaix, Xavier. 1999. "Zipf's Law for Cities: An Explanation." *The Quarterly Journal of Economics* 114(3): 739–67.

Garrick, Dustin et al. 2019. "Rural Water for Thirsty Cities: A Systematic Review of Water Reallocation from Rural to Urban Regions." *Environmental Research Letters* 14(4): 043003.

Geist, Juergen. 2011. "Integrative Freshwater Ecology and Biodiversity Conservation." *Ecological Indicators* 11(6): 1507–16.

Gerber, Jean-David, Peter Knoepfel, Stéphane Nahrath, and Frédéric Varone. 2009. "Institutional Resource Regimes: Towards Sustainability through the Combination of Property-Rights Theory and Policy Analysis." *Ecological Economics* 68(3): 798–809.

Gerlak, Andrea K. et al. 2018. "Water Security: A Review of Place-Based Research." *Environmental Science & Policy* 82: 79–89.

Gleick, Peter H. 2018. "Transitions to Freshwater Sustainability." *Proceedings of the National Academy of Sciences* 115(36): 8863–71.

Grolleau, Gilles, and Laura M. J. McCann. 2012. "Designing Watershed Programs to Pay Farmers for Water Quality Services: Case Studies of Munich and New York City." *Ecological Economics* 76: 87–94.

Hering, Janet G., and Karin M. Ingold. 2012. "Water Resources Management: What Should Be Integrated?" *Science* 336(6086): 1234–35.

Health: The Freshwater Health Index'. *Science of The Total Environment* 627: 304–13.

Hoekstra, Arjen Y., Joost Buurman, and Kees C. H. van Ginkel. 2018. "Urban Water Security: A Review." *Environmental Research Letters* 13(5): 053002.

Hoffmann, Sabine et al. 2020. "A Research Agenda for the Future of Urban Water Management: Exploring the Potential of Nongrid, Small-Grid, and Hybrid Solutions." *Environmental Science & Technology*, 54(9), 5312–5322 https://doi.org/10.1021/acs.est.9b05222.

Huitema, Dave et al. 2009. "Adaptive Water Governance: Assessing the Institutional Prescriptions of Adaptive (Co-)Management from a Governance Perspective and Defining a Research Agenda." *Ecology and Society* 14(1). http://www.ecologyandsociety.org/vol14/iss1/art26/.

Huntington, Thomas G. 2006. "Evidence for Intensification of the Global Water Cycle: Review and Synthesis." *Journal of Hydrology* 319(1): 83–95.

Hussey, Karen, and Jamie Pittock. 2012. "The Energy–Water Nexus: Managing the Links between Energy and Water for a Sustainable Future." *Ecology and Society* 17(1). https://www.jstor.org/stable/26268988.

Ingold, Karin et al. 2018. "Misfit between Physical Affectedness and Regulatory Embeddedness: The Case of Drinking Water Supply along the Rhine River." *Global Environmental Change* 48: 136–50.

Jager, Nicolas W., Jens Newig, Edward Challies, and Elisa Kochskämper. 2020. "Pathways to Implementation: Evidence on How Participation in Environmental Governance Impacts on Environmental Outcomes." *Journal of Public Administration Research and Theory* 30(3): 383–99.

Kallis, Giorgos, and Richard B. Norgaard. 2010. "Coevolutionary Ecological Economics." *Ecological Economics* 69(4): 690–99.

Kim, Serena Y. et al. 2020. "Updating the Institutional Collective Action Framework." *Policy Studies Journal* (Early view). https://onlinelibrary.wiley.com/doi/abs/10.1111/psj.12392.

Knight, Jack. 1992. *Institutions and Social Conflict*. Cambridge University Press, Cambridge.

Larsen, Tove A. et al. 2016. "Emerging Solutions to the Water Challenges of an Urbanizing World." *Science*. https://www.science.org/doi/abs/10.1126/science.aad8641.

Liu, Jianguo et al. 2018. "Nexus Approaches to Global Sustainable Development." *Nature Sustainability* 1(9): 466–76.

Mahoney, James, and Kathleen Thelen, eds. 2009. *Explaining Institutional Change: Ambiguity, Agency, and Power*. Cambridge: Cambridge University Press.

McDonald, Robert I. et al. 2014. "Water on an Urban Planet: Urbanization and the Reach of Urban Water Infrastructure." *Global Environmental Change* 27: 96–105.

van de Meene, S. J., R. R. Brown, and M. A. Farrelly. 2011. "Towards Understanding Governance for Sustainable Urban Water Management." *Global Environmental Change* 21(3): 1117–27.

Nielsen, Joshua, and Megan A. Farrelly. 2019. "Conceptualising the Built Environment to Inform Sustainable Urban Transitions." *Environmental Innovation and Societal Transitions* 33: 231–48.

North, Douglass C. 2005. *Understanding the Process of Economic Change*. Princeton: Princeton University Press.

Ortega-Montoya, Claudia Y., and Arpan Johari. 2020. "Urban Ecological Footprints." In *Sustainable Cities and Communities*, ed. Walter Leal Filho et al. Cham: Springer International Publishing, 812–24. https://doi.org/10.1007/978-3-319-95717-3_76.

Ostrom, Elinor. 2005. *Understanding Institutional Diversity*. Princeton: Princeton University Press. http://www.jstor.org/stable/j.ctt7s7wm.

Ostrom, Elinor. 2009. "A General Framework for Analyzing Sustainability of Social-Ecological Systems." *Science* 325(5939): 419–22.

Ostrom, Elinor. 2010. "Beyond Markets and States: Polycentric Governance of Complex Economic Systems." *American Economic Review* 100(3): 641–72.

Pahl-Wostl, Claudia. 2015. *10 Water Governance in the Face of Global Change*. Switzerland: Springer.

Pahl-Wostl, Claudia. 2020. 'Adaptive and Sustainable Water Management: From Improved Conceptual Foundations to Transformative Change'. *International Journal of Water Resources Development* 36(2–3): 397–415.

Piégay, Hervé et al. 2020. "Remotely Sensed Rivers in the Anthropocene: State of the Art and Prospects." *Earth Surface Processes and Landforms* 45(1): 157–88.

Pierre, Jon, and B. Guy Peters. 2020. *Governance, Politics and the State*. Bloomsbury Publishing, New York.

Pincetl, Stephanie, Erik Porse, and Deborah Cheng. 2016. "Fragmented Flows: Water Supply in Los Angeles County." *Environmental Management* 58(2): 208–22.

Pinto, Francisco Silva, B. de Carvalho, and R. Cunha Marques. 2021. "Adapting Water Tariffs to Climate Change: Linking Resource Availability, Costs, Demand, and Tariff Design Flexibility." *Journal of Cleaner Production* 290: 125803.

Pinto, Francisco Silva, Pedro Simões, and Rui Cunha Marques. 2017. "Raising the Bar: The Role of Governance in Performance Assessments." *Utilities Policy* 49: 38–47.

Porcher, Simon, and Stéphane Saussier. 2019. *Facing the Challenges of Water Governance*. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-98515-2_1.

Reckien, Diana et al. 2018. "How Are Cities Planning to Respond to Climate Change? Assessment of Local Climate Plans from 885 Cities in the EU-28." *Journal of Cleaner Production* 191: 207–19.

Reed, Mark S. et al. 2010. "What Is Social Learning?" *Ecology and Society* 15(4). https://www.jstor.org/stable/26268235.

Rees, William, and Mathis Wackernagel. 1996. "Urban Ecological Footprints: Why Cities Cannot Be Sustainable: And Why They Are a Key to Sustainability." *Environmental Impact Assessment Review* 16(4): 223–48.

Rhodes, R. A. W. 2007. "Understanding Governance: Ten Years On." *Organization Studies* 28(8): 1243–64.

Rodell, M. et al. 2018. "Emerging Trends in Global Freshwater Availability." *Nature* 557(7707): 651–59.

Roland, Gérard. 2004. "Understanding Institutional Change: Fast-Moving and Slow-Moving Institutions." *Studies in Comparative International Development* 38(4): 109–31.

Simon, Herbert A. 2000. "Bounded Rationality in Social Science: Today and Tomorrow." *Mind & Society* 1(1): 25–39.

Stone, Clarence N. 1993. "Urban Regimes and the Capacity to Govern: A Political Economy Approach." *Journal of Urban Affairs* 15(1): 1–28.

Swann, William L. 2017. "Examining the Impact of Local Collaborative Tools on Urban Sustainability Efforts: Does the Managerial Environment Matter?" *The American Review of Public Administration* 47(4): 455–68.

Swann, William L, and Aaron Deslatte. 2018. "What Do We Know about Urban Sustainability? A Research Synthesis and Nonparametric Assessment." *Urban Studies*, 56(9), 1729–1747. 0042098018779713.

Trein, Philipp et al. 2021. "Policy Coordination and Integration: A Research Agenda." *Public Administration Review* 81(5): 973–77.

UN Habitat. 2020. *World Cities Report 2020. The Value of Sustainable Urbanization*. UN Habitat. https://unhabitat.org/sites/default/files/2020/10/wcr_2020_report.pdf.

Varone, Frédéric, Stéphane Nahrath, David Aubin, and Jean-David Gerber. 2013. "Functional Regulatory Spaces." *Policy Sciences* 46(4): 311–33.

Vasquez, William F., Pallab Mozumder, Jesús Hernandez-Arce, and Robert P. Berrens. 2009. "Willingness to Pay for Safe Drinking Water: Evidence from Parral, Mexico." *Journal of Environmental Management* 90(11): 3391–400.

Vörösmarty, C. J. et al. 2010. "Global Threats to Human Water Security and River Biodiversity." *Nature* 467(7315): 555–61.

Vollmer, Derek et al. 2018. 'Integrating the Social, Hydrological and Ecological Dimensions of Freshwater

Williamson, Oliver E. 1996. *The Mechanisms of Governance*. New York: Oxford University Press.

WWF. 2018. *Living Planet Report 2018: Aiming Higher*. eds. R. E. A. Almond, and M. Grooten. Gland, Switzerland: WWF--World Wide Fund for Nature.