Scalar mismatches in metropolitan water governance

A comparative study of São Paulo and Mexico City

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4. RIVER BASIN GOVERNANCE

4.1 INTRODUCTION

This chapter reviews the literature on river basin governance.[18] It addresses the secondary research question: What does the literature on river basin governance tell us about how to understand and address metropolitan water challenges? First, it examines the evolution of river basin governance over time, and more specifically its shift towards Integrated Water Resources Management (IWRM) and Integrated River Basin Management (IRBM) (see 4.2.1). It then describes the main characteristics of IWRM and IRBM (see 4.2.2), as well as the main drivers, institutions and instruments shaping these concepts (see 4.2.3). Subsequently, the chapter debates the strengths and weaknesses of IWRM/IRBM based on the literature reviewed (see 4.3). Finally, the chapter links back to the knowledge gaps identified in 1.2.3 and provide three main insights relevant for analysing metropolitan water challenges from an IWRM/IRBM perspective (see 4.4).

4.2 OVERVIEW

4.2.1 EVOLUTION OF RIVER BASIN GOVERNANCE

Water resources management (WRM) can be traced back to the first river basin civilizations, with water rules defined in the Indus Valley around 2500 BCE and flood management and irrigation techniques developed in Ancient Egypt (Dellapenna and Gupta, 2009). For many early civilisations, controlling rivers was part of the formation of the centralized state (Wittfogel, 1955). Already in prehistoric times, people learned to adapt to seasonal changes in water availability, and water management was crucial during the transition from hunting-gathering to farming (Mithen, 2010). Rivers and coasts have historically attracted populations, as they provide resources, allow for navigation and serve as natural borders.

From the early 20th century onwards, the hydraulic paradigm permeated water management worldwide, aiming to control the natural environment through human transformations at the service of society (Swyngedouw, 1999; Lopez-Gunn, 2009; Custódio, 2012). Water resources management practices developed mainly through the knowledge of technical experts working under the auspices of the state (Pahl-Wostl *et al.*, 2007). The assumption was that water resources could be controlled, especially through large-scale infrastructural. These engineering works required large investments and centralized coordination and management, and became synonymous with state-building and the emergence of powerful bureaucracies (Huitema and Meijerink, 2014). Different sectors requiring or impacting water were managed separately, leading to a 'silo effect' (Xie, 2006).

Only relatively recently, during the nineteenth century, did ideas emerge about the need to protect, preserve and conserve water resources, with the beginning of the conservation

[18] This chapter draws heavily on Brandeler *et al.* (2019).

movement in the United States (Agyenim, 2011, p. 31). The persistence and aggravation of a range of water-related problems (e.g. Wat&San, energy, food production, transboundary conflicts), increased awareness on the urgent need for water resources management (Agyenim, 2011: 32). Global climate change and its implications for water governance have further brought attention to this urgency.

Despite rising environmental awareness, water crises are often portrayed as issues of physical scarcity rather than the inadequate governance of a renewable resource (Biswas and Tortajada, 2010), or a deeply political challenge from global to local ('glocal') level (Gupta *et al.*, 2013a). This position reinforces technocratic approaches based on standardized large-scale technological solutions at the expense of more innovative and sustainable technologies and practices (Farrelly and Brown, 2011; GTT, 2014). However, persistent and worsening water challenges reveal the limitations of engineering to solve these problems (Li *et al.* 2015). Consequently, there is growing consensus that the global water crisis is first and foremost a 'crisis of governance' (Castro, 2007; Tortajada, 2008; Biswas and Tortajada, 2010; Vörösmarty *et al.*, 2010; Gupta *et al.*, 2013a).

IWRM is an empirical concept developed by practitioners from on-the-ground experience and promoted as early as at the first global water conference in Mar del Plata in 1977 (WWAP, 2009). It gained global attention during the International Conference on Water and the Environment in Dublin in 1992. During this event, participants defined the *Dublin Principles*, which call for integrated, participatory management (ICWE, 1992). The concept has since been adopted by international agencies such as the World Bank (Abers, 2007; Abers and Keck, 2013), contributing to its influence among academic and professional circles worldwide. The Hague Forum, in 2000, pushed IWRM further by including a wide range of water management stakeholders from around the world, as opposed to the Mar del Plata and Dublin events, where participants exclusively consisted of intergovernmental participants and experts (Rahaman and Varis, 2005). During this forum, participants suggested applying equity criteria in water management and called for collaboration and partnerships at all levels, meaningful participation and cooperation with international organizations and the UN (Rahaman and Varis, 2005). In 2001, the International Conference on Freshwater in Bonn suggested IWRM as the best approach for meeting the water-related needs of the poor and for promoting decentralization and new partnerships. It also recommended prioritizing efforts towards better governance, mobilizing financial resources, building capacity and sharing knowledge (Rahaman and Varis, 2005). The concept was also integrated into the European Union's Water Framework Directive of 2000 and subsequent programmes such as the EU Water Initiative (Wallington *et al.*, 2010).

Although it is not clearly apparent in the description of the IWRM principles, privatization and public-private partnerships are often considered to go hand in hand with IWRM, which can be considered as part of the neo-liberal trend (GWP-TAC, 2000; Rahaman and Varis, 2005; Gupta and Pahl-Wostl, 2013). In theory, privatization can bring many benefits to Wat&San services. It can increase the predictability of Wat&San investments and services, ensuring that they are properly maintained. The rationale is straightforward: Wat&San services are costly, long-term projects with few immediate political gains. By delegating services to private parties, governments can bring in capital they do not have, diminish costs by tapping into private efficiency and ensure that investments will be maintained despite potential political changes as companies are less subject to political influence (Wolff and Palaniappan, 2004). Nonetheless, privatization of water management may also have downsides as it can lead to fragmentation, single-purpose planning and management and a lack transparency, and make water unaffordable for the poor in developing regions through full cost-recovery (Rahaman and Varis, 2005).

Integrated River Basin Management (IRBM) is a subset of IWRM focused on the river basin scale. IWRM is a broader concept with an administrative logic, where the national level also plays a crucial role. A literature review of papers on IWRM focusing on the main trends within the period 2000-2011 showed that 44.4% of papers were dominated by a focus on the river basin management unit (Gallego-Ayala, 2013). Within IRBM, the basin is the main arena for building relations of collaboration, cooperation and coordination at different levels and scales of organization (Burgos and Bocco, 2014). The main idea behind this is to match the system's natural sphere, the "hydrologically-defined basin", to the management scale, thereby allowing for comprehensive problem analysis and the internalization of otherwise externalized problems (i.e. downstream effects of upstream activities) (Pahl-Wostl *et al.*, 2008; Lindborg *et al.*, 2017). A number of governments and institutions (e.g. EU Water Framework Directive) have adopted this principle (Molle, 2009a). In practice, water resources management at the basin level is carried out through River Basin Organizations (RBOs) often composed of representatives of a variety of interests and this can go beyond the level of the nation state and involve several states. Participatory processes that include marginalized groups may promote greater equity in water resources management, including in access to water (Swallow *et al.*, 2006).

4.2.2 MAIN CHARACTERISTICS

IWRM and IRBM have many characteristics found across the literature in terms of their goals, the spatial scale at which they are implemented, their approach to water resources, key actors and their mandates, water users, and what constitutes 'inputs' and 'outputs' of water (see Table 4.1).

Goals: As water resources management shifted towards IWRM/IRBM, its objectives moved from a pure resource exploitation ethic to include social equity and environmental sustainability (Hooper, 2005). IWRM and IRBM aim to integrate water uses for people (i.e. public/urban use), food production (i.e. irrigation), nature (i.e. maintaining ecosystems), industry and other uses (i.e. energy, commerce) ('GWP Integrated Urban Water Management', no date).

Approach: The modernist-inspired water resources management paradigm has a linear approach, focusing on supply augmentation rather than demand management, and addressing water resources concerns separately from matters of land use, planning and environmental management (Xie, 2006). Within IWRM/IRBM, water systems are considered as a whole, including surface (e.g. wetlands) and groundwater, upstream and downstream, as well as quantity and quality concerns through both supply and demand management (Chenoweth *et al.*, 2001; Jønch-Clausen and Fugl, 2001; Jones *et al.*, 2006; Savenije and Van der Zaag, 2008; Molle, 2009a; Butterworth *et al.*, 2010). Besides the natural system, IWRM/IRBM also integrate the human system, through a holistic institutional approach (Jønch-Clausen and Fugl, 2001; Abdullah and Christensen, 2004; Molle, 2009a), considering links to both land and water resources, including social and economic activities, and environmental management functions such as pollution control, development planning and biodiversity conservation (Abdullah and Christensen, 2004; Medema *et al.*, 2008; Savenije and Van der Zaag, 2008; Molle, 2009a; Molle and Mamanpoush, 2012; Koç, 2015). This involves integrating sectoral responses and blending viewpoints and objectives (Jønch-Clausen and Fugl, 2001; Medema *et al.*, 2008), and emphasizing stakeholder participation and cross-agency coordination for equitable allocation and the protection of ecosystems (Jønch-Clausen and Fugl, 2001; Hooper, 2005; Agyenim, 2011; Gain *et al.*, 2013). Furthermore, IWRM/IRBM treats water as an economic good, pricing it at levels that promote cost recovery and allocation to the most beneficial uses (Xie, 2006). Responses involve both hard and soft measures that go beyond technical solutions (Chenoweth *et al.*, 2001; Abdullah and Christensen, 2004).

Table 4.1 Main characteristics of IWRM/IRBM

Main characteristics	IWRM/IRBM
Scale	Basin (for IRBM) and national (for IWRM)
Goals	Integrate water uses for people, food, nature, industry and others. Balance economic, environmental and equity goals
Approach	Integrate all water resources and related concerns within the basin. Integrate sectors and multiple interests
Actors	Basin organizations (for IRBM), national and state/provincial departments for (IWRM)
Mandates	Water allocation and bulk supply; wastewater/water quality; flood mitigation; participatory planning; monitoring/evaluation; conflict resolution; community development
Users	All users within a river basin. Agriculture is often the biggest user
Water 'inputs'	IWRM/IRBM aim to consider all water resources in the basin (including within urban areas), but focus is on blue water
Wastewater / stormwater 'outputs'	Concern for impacts downstream communities and ecosystems. Efforts to regulate and reduce pollution (industrial and urban, and diffuse pollution). Climate change adaptation increasingly considered (focus on droughts)

Source: Author

Spatial scales of IWRM and IRBM: IWRM/IRBM emphasize the river basin unit as the ideal management level[19], although IWRM also has a spatial national focus through the integration

[19] The boundaries of surface watersheds are generally delineated from topographic maps based on land elevations (Vaughan *et al.*, 2016). The rain and snow that falls within this area is stored, filtered, seeped or drained into a common water body through a network of streams that drain the surface area and the groundwater that contribute to those streams.

of its principles in national-level legislation, policies and institutions (Abdullah and Christensen, 2004; Watson, 2004; Hooper, 2005; Rahaman and Varis, 2005; Jones *et al.*, 2006; Butterworth *et al.*, 2010). While the river basin level dominates, IWRM can be implemented from the local to the transboundary and global levels (Butterworth *et al.*, 2010). Moreover, the large size and population of some catchments means that management at the scale of polders, wetlands or aquifers may be more logical (Butterworth *et al.*, 2010). Transformations of the natural environment, for instance, through irrigation schemes and inter-basin transfers, and the administrative boundaries of different government levels further complicate basin management (Butterworth *et al.*, 2010; Moss and Newig, 2010).

Organization: Conventional WRM is hierarchical, centralized and top-down, with central governments often directing water supply development, water service provision and water use regulation (Xie, 2006). IWRM/IRBM embraces (a) decentralization and subsidiarity, with preference for the basin or sub-basin level (Xie, 2006; Molle, 2009a); (b) transparent participatory decision-making, including access to information (Rahaman and Varis, 2005; Jones *et al.*, 2006); and (c) implementation through special purpose organizations, such as RBOs, rather than general purpose government layers (Molle, 2009a; Huitema and Meijerink, 2014). A diverse range of actors can be involved, including user associations, environmental NGOs and affected communities.

Mandates: Conventional WRM's mandates are limited to river basin planning and policy "with no enforcement, regulatory or water-resource development functions, and no direct representation of local interests and stakeholders, other than through state agencies" (Molle, 2009a: 490). As IWRM/IRBM aims to integrate stakeholder needs and interests at basin level, its mandates concerns all water-related activities (e.g. basin-wide evaluation, planning, strategy implementation, monitoring, water allocation mechanisms, water quality maintenance, basin guidelines, negotiation/ dispute resolution mechanisms, flood warning and mitigation, and community development) (Chenoweth *et al.*, 2001). These mandates are shared between actors, including RBOs and other multi-stakeholder platforms, but are often blurred (Jønch-Clausen and Fugl, 2001; Grigg, 2008). IWRM/IRBM supporters argue that adequate implementation requires clearly delimited responsibilities that match to authority and capacities for action (Jønch-Clausen and Fugl, 2001). In some cases, government bodies are responsible for regulating water uses but do not have the administrative and political power needed to oppose traditional line agencies (Molle, 2009a; Agyenim, 2011). In other cases, quantitative functions (e.g. water supply, irrigation, flood mitigation) are managed separately from qualitative functions (e.g. water pollution, land use), and a single organization may facilitate an integrated approach (Abdullah and Christensen, 2004).

Users: IWRM/IRBM considers all users and economic interests within a river basin, including domestic, agricultural, industrial and recreational users (Savenije and Van der Zaag, 2008). The agricultural sector is the largest user of water resources in most countries, followed by the energy sector (i.e. hydropower), making the water/food/energy nexus crucial for integrated water management, particularly in the context of climate change (Biswas, 2008; OECD, 2016). Domestic and recreational users represent a relatively small portion of total water use.

In river basins with low population densities, ecosystems such as grasslands or woodlands may be major water users (Harrington *et al.*, 2009). However, in heavily urbanized basins, water resources' allocation can be a source of competition and conflict between urban and rural users (Butterworth *et al.*, 2010; Molle and Mamanpoush, 2012; OECD, 2016). Downstream users are particularly vulnerable to variations in the water regime occurring in upstream areas (Molle, 2009b). Users also differ in their access to natural or financial resources and in their political power (Swyngedouw *et al.*, 2002; Molle and Hoanh, 2007; Molle, 2009b). Effective and legitimate norms and instruments for water allocation among users are therefore crucial in heavily urbanized basins, but are often lacking, especially in cases with large informal economies (Watson, 2004; Butterworth *et al.*, 2010; OECD, 2016).

Inputs and outputs: IWRM/IRBM consider the hydrological cycle as a unitary whole, and are therefore concerned with all water resources within a river basin (including rainwater and snowmelt) (Savenije and Van der Zaag, 2008; Harrington *et al.*, 2009). They call for awareness on how different types of water (blue water, green water, grey water) interact and how this interaction impacts equitable use and the distribution of costs and benefits (Savenije and Van der Zaag, 2008). However, IWRM/IRBM have largely focused on 'blue water' (i.e. surface and groundwater), often ignoring 'grey water' (i.e. water after basic treatment), and 'green water' (i.e. water in the unsaturated zone of the soil and plants which has critical ecosystem services, and is sensitive to land degradation) (Jewitt, 2006; Molle and Mamanpoush, 2012; Hayat and Gupta, 2016). 'Rainbow water' (i.e. atmospheric moisture) is not included in IWRM/IRBM, yet perturbations in moisture recycling, often linked to changes in land use, can affect precipitation in distant locations. Water availability in one river basin can therefore be modified due to activities (i.e. deforestation, irrigation) in regions on the other side of the planet (Wang-Erlandsson *et al.*, 2018). Furthermore, IWRM/IRBM does not address virtual water, through which the import of items, such as food, reduces the need to use water resources for their production locally (Dalin *et al.*, 2017).

The linear approach of conventional WRM facilitates the contamination of water downstream, with little concern for the environmental impact. The focus is on economic development, especially following World War II, and water quality is not a priority for the industrial and agricultural sectors (Xie, 2006). IWRM and IRBM call for protecting water resources and ecosystem services through adequate wastewater management (i.e. collecting and treating wastewater before discharge, wastewater recycling, and waterway restoration) (Martinez-Santos *et al.*, 2014). This may involve (de)centralized infrastructure, but also regulating and reducing diffuse pollution, most of which derives from agricultural activities (Xepapadeas, 2011).

4.2.3 Drivers, institutions and instruments

The rise of IWRM and IRBM was in part spurred by drivers of water resources challenges such as increasing competition for water resources through population growth and economic development, climate change and variability, and land use changes due to human interventions or natural processes (Hooper, 2005; Gallego-Ayala, 2013; Wang-Erlandsson *et al.*, 2018). Major shifts in societal behaviour have also played an important role in driving a shift in WRM

(Hooper, 2005).

Political, legal and institutional factors also play an important role in the shift towards IWRM/IRBM (Tortajada, 2001; Grigg, 2008; Agyenim, 2011). Institutions rooted in centralized structures, sectoral fragmentation and weak local capacity, with low political awareness or will and inadequate data and information management hinder the successful implementation of IWRM/IRBM (Jønch-Clausen and Fugl, 2001; Medema *et al.*, 2008; Molle, 2008). Latin American countries that adopted IWRM/IRBM principles all shared strong support for decentralization policies within political reforms more broadly (Lee, 2000; Tortajada, 2001). User representation and public participation in river basin institutions balance the power of public sector institutions and may prevent bureaucratic infighting (Lee, 2000). Weak implementation of IWRM/IRBM in the Global South may also be explained by the fact that it requires a stable political context and institutional environment (Agyenim, 2011; Cameron and Katzschner, 2017). Property rights regimes may be different from those in the Global North and stable financing and administrative capacity is more likely to be lacking, as is the ability to enforce laws and regulations (Agyenim, 2011). On the other hand, in the Global South, IWRM can be compatible with local water rights that are participatory, self-regulatory, sensitive to the vulnerable and able to contain conflicts (Agyenim, 2011; Agyenim and Gupta, 2012).

IWRM/IRBM institutions are often designed at the basin level, under the premise that they "fit" their context and are therefore more effective (Young *et al.*, 2008; Agyenim, 2011). Nonetheless, institutions shaping IWRM/IRBM have been developed at multiple levels, combining central-local, river basin specific and public-private organizations (Medema *et al.*, 2008). At global level, International Financial Institutions (IFIs) have financed large-scale water resources development projects in the global South (Lebel, 2005). The national level is crucial for IWRM through the design and implementation of laws, norms, regulations and rules (Gallego-Ayala, 2013). National governments set standards for water quality and water allocation. Some nations also possess a water regulatory agency at the national level (OECD, 2011). The national level is often the level for hydropower planning and management as this enables better distribution and economies of scale. When water becomes an issue of national security (i.e. during drought), governments may take control over water resources (Gupta *et al.*, 2013b). A literature review of papers on IWRM focusing on the main trends within the period 2000-2011 showed that 22.5% adopted the country level as the scale of analysis. The allocation of water policy roles and responsibilities across national and sub-national levels varies significantly, making it impossible to capture a "national model" with comprehensive institutional mapping (OECD, 2011). Additionally, in federal countries significantly more water policy responsibilities are devolved to subnational governments. States usually have sovereignty over water resources within their territory and establish the basic rules about how individuals and groups can access these (Gupta *et al.*, 2013b).

In some cases, multiple institutions are superimposed onto each other, such as communal irrigation institutions combined with more recent water use allocation systems (Lebel, 2005). The multiple actors involved have differing objectives, responsibilities, and interests, which can lead to conflicts (Koç, 2015). The institutional integration expected of IWRM may not be realistic, and fostering coordination, cooperation and collaboration may be a more adequate alternative (Biswas, 2004; Koç, 2015).

The 'Dublin Principles' defined four principles that aim to guide concerted action from the international to the local level. The first principle defines fresh water as a "finite and vulnerable resource, essential to sustain life, development and the environment" (ICWE, 1992: Guiding Principles). The second principle emphasizes that water governance should be participatory and that decisions should be taken at "the lowest appropriate level with full public consultation and involvement of users in the planning and implementation of water projects" (Ibid). Participation is also seen as essential for balanced and sustainable water use (Jønch-Clausen and Fugl, 2001). The third principle recognizes the central role that women play in water governance and aims to empower them so that policies can better answer their needs. The final principle defines water as an economic good, under the auspice that giving water an economic value will prevent wasteful and environmentally damaging uses.

Table 4.2 Instruments of IWRM/IRBM

Types of instruments	IWRM/IRBM
Economic	Bulk water use fees; PES programmes; pollution fees, and economic and financial tools for investment, cost recovery and behaviour change (e.g. subsidies for water efficient technology and infrastructure, royalties)
Regulatory	Bulk water use permits; Transfers of bulk water use permits; land use regulation within basin (restricting development); Licensing (of polluting activities); Conservation measures (e.g. easements and zoning)
Suasive	Anti-pollution campaigns; Public awareness and education programmes on environmental protection; Water resources assessment and information
Coordination	Pollution monitoring systems; Meteorological monitoring systems; Participatory spaces for negotiation and conflict-resolution on water resources management

Source: Author

From these principles, the IWRM/IRBM frameworks derive a variety of possible instruments to address water challenges (see Table 4.2). Among their key instruments are policies concerning water (re-)allocation among users. In particular, *who* has priority to use water resources in water scarce environments (in many cases, but not all, the priority is granted to domestic water use) (Butterworth *et al.*, 2010; Agyenim, 2011). Other influential instruments include regulatory and economic instruments to manage pollution, such as wastewater discharge fees for Wat&San utilities, industries and other bulk water users), the identification and licensing of polluters (i.e. permits for wastewater discharge), effective monitoring systems, identification and responses to infringements of laws, regulations and permits, and regulations and incentives to preserve areas with important ecosystems (i.e. conservation areas, compensation to municipalities for conservation efforts, PES programmes). Other crucial instruments, especially in water scarce areas, are those that establish rules for water diversions from streams, rivers, lakes and groundwater (Agyenim, 2011). IWRM/IRBM instruments interfere at national and basin levels, and focus on environmental and economic dimensions, with social and relational goals appearing more secondary.

4.3 IWRM/IRBM FOR SUSTAINABLE AND INCLUSIVE DEVELOPMENT

4.3.1 Steps forward

The shift from conventional WRM approaches towards IWRM/IRBM create conditions for more inclusiveness. IWRM/IRBM can challenge centralized expertise and decisions when water-related challenges require adaptive, polycentric (Sneddon *et al.*, 2002; Molle, 2009a) and contextual solutions (Jønch-Clausen and Fugl, 2001; Xie, 2006). Decentralization and participation, by integrating actors with knowledge of the local environment and local users' needs, may lead to superior equity and efficiency in resource management (Andersson and Ostrom, 2008). By emphasizing the need to blend different viewpoints, they enable a more holistic and inclusive approach to water-related issues (Grigg, 1999, 2008; Medema *et al.*, 2008). IWRM/IRBM strives for a fair allocation of water resources among upstream and downstream users within a basin or sub-basin, between current and future generations, and for both human and ecosystem needs (Harrington *et al.*, 2009; Molle, 2009b; Molle and Mamanpoush, 2012).

IWRM/IRBM may enhance sustainability by recognizing the role of ecosystems in WRM (Molle, 2009a) and promoting demand management (Grigg, 2008). In the context of population growth and the overexploitation of water resources, IWRM/IRBM have the potential to restore a vision that considers both humans and ecosystems (Molle, 2009a).

4.3.2 Lingering obstacles

Continued environmental degradation, including of water systems, in areas where IWRM/IRBM has officially been implemented highlights the limitations of these principles for fostering ecological sustainability. There is no consensus on how to implement IWRM/IRBM. Moreover, the focus of IWRM/IRBM has been on 'blue water', to the detriment of 'grey water', 'rainbow water', 'green water', and the 'embedded water' or 'virtual water' in imported food products and other goods (Molle and Mamanpoush, 2012; Hayat and Gupta, 2016; Dalin *et al.*, 2017; Wang-Erlandsson *et al.*, 2018; Brandeler *et al.*, 2019). An understanding of 'green water' flows can lead to more efficient irrigation for instance. There is also no consensus on whether IWRM/IRBM enhances adaptability, which is problematic in a context of climate change (Medema *et al.*, 2008; Foster and Ait-Kadi, 2012; Gain *et al.*, 2013).

In addition, the principle of water as an economic good is frequently criticized as it may foster the notion of water as a commodity, ignoring its non-monetary value and shifting perception away from water as a common good that brings shared duty and responsibility (Rahaman and Varis, 2005). Pushing for cost recovery in areas with large pockets of poverty, such as nations in the Global South, can lead to eliminating vital subsidies for basic water infrastructure and services (Rahaman and Varis, 2005).

Furthermore, IWRM/IRBM aims to move from a fragmented to an integrated and coordinated approach to resources planning and accommodating the needs and interests of all stakeholders within the basin (Chenoweth *et al.*, 2001). Yet, while this idea has become mainstream, its implementation is still lacking (Chenoweth *et al.*, 2001; Medema *et al.*, 2008; Jacobi *et al.*, 2015). There are several reasons for this. For example, the integration goals are ambitious as they assume political will and the adequate availability and sharing of data and knowledge (Allan, 2003; Molle, 2008). However, they ignore uncertainty (Agyenim, 2011), tensions between developing basin-wide approaches and more decentralized resource management[20] (Miller and Hirsch, 2003), the antagonistic nature of IWRM goals (Efficiency, Equity and Environmental sustainability) and their necessary trade-offs (Molle, 2008), and the jurisdictional complexity of river basins that cross national or even state borders (in the case of federal regimes) (Choudhury and Islam, 2015).

Also, the Dublin statement on IWRM does not provide suggestions on how to implement effective participation mechanisms (Rahaman and Varis, 2005, p. 16). While integrating different views is generally considered a positive aspect of IWRM/IRBM, by allowing for greater social inclusiveness, in practice it requires significant resources and time-commitments (i.e. time spent in meetings, travel time and costs of attending meetings), and participants lacking expert knowledge often struggle to follow and intervene in discussions (Brandeler, 2013). Decision-making spaces are often still dominated by state-affiliated experts and traditional power relations, and the broad goals of IWRM/IRBM can lead some groups to hijack these to legitimize their own agendas (Wester and Warner, 2002; Molle, 2008). For instance, urban elites and state bureaucracies may use it to facilitate upstream interventions by downstream stakeholders (Molle, 2009b). Marginalized voices and interests struggle to gain representation and negotiate on equal footing (Swyngedouw *et al.*, 2002; Molle, 2009b; Brandeler *et al.*, 2014; Varis *et al.*, 2014). This especially concerns indigenous and rural communities as well as the urban poor (Boelens, 2009; Brandeler *et al.*, 2014). Besides a lack of representation and participation of diverse interests and stakeholders, RBOs often struggle with limited enforcement, regulatory or water-resource development functions (Molle, 2009a). IWRM/IRBM cannot be established in contexts of war and conflict and require stable democratic processes and institutions (Hooper, 2005), but beyond that it is not clear how to address unequal power relations (Jønch-Clausen and Fugl, 2001; Brandeler *et al.*, 2019). This may require broader political reforms beyond the scope of water management institutions.

4.4 Scalar limitations of IWRM/IRBM

4.4.1 The "naturalness" of the river basin scale as a social construction

The spatial scale of the river basin has been framed by the IRBM and, to a large extent, by the IWRM literature, as the ideal unit for water resources planning and management (see 4.2.2). However, this simplifies hydrological dynamics. First of all, river basins are generally formed

[20] Although the river basin management approach has often been framed as one of decentralization, it represents a scaling up from municipalities (Cohen and Davidson, 2011).

by multiple watersheds nested into each other, as each tributary forms a sub-division, so deciding where to draw the boundaries for a management area can be a challenge in itself (Cohen and Davidson, 2011; Perreault, 2014).[21] These boundaries are constantly shifting as our understanding of surface and groundwater flows and GIS technology improve (Cohen and Davidson, 2011). Second, the hydrological cycle is not restricted to the boundaries of the river basin. Land-atmosphere feedback, such as local and regional land use change and moisture recycling patterns can have effects on remote precipitation and, thereby, on distant river flows (Wang-Erlandsson *et al.*, 2018). Model simulations have suggested that complete deforestation of central Africa could decrease February precipitation by 35% in the Great Lakes region (Avissar and Werth, 2005), while irrigation in India may support up to 40% of the precipitation in some arid regions in eastern Africa (Vrese *et al.*, 2016). Third, river basins usually share the same boundaries as granular, unconfined aquifers (i.e. just below the surface), but the recharge areas of karstic and confined aquifers mostly do not match those of river basins (Demiroğlu, 2017). Aquifer boundaries may be the more appropriate spatial framework to address groundwater management and protection in the latter case (deep aquifers in arid regions) (Garduno *et al.*, 2006; Foster and Ait-Kadi, 2012).

Moreover, the view of river basins as closed ecological systems characterized by stability and predictability has lost relevance in the context of human interventions (e.g. climate change, pollution, loss of wetlands) that lead to increased uncertainty, change, complexity and conflict (Holling, 1978; Watson, 2004). As Europe's river basins are now linked by canal networks, inland navigation no longer relies on natural waterways and is coordinated nationally and regionally rather than at basin scale (Muller, 2018). River flows have also been altered to allow for water supply in expanding human settlements through inter-basin transfers, the drilling of deep wells and desalination (Cohen and Davidson, 2011; Perreault, 2014; Muller, 2018). Unintended human interventions, such as the accidental introduction of invasive species into a river basin, can also have devastating biological and economic impacts (Cohen and Davidson, 2011).[22] As these transformations and challenges, as well as the governance systems that respond to these, transcend across spatial scales, effective solutions are beyond the reach of any single agency or organization (Watson, 2004; Varis *et al*., 2014). An exclusively basin-scale approach may therefore limit flexibility and lead to transboundary problems.

Ultimately, the choice of scale for water resources management is socially produced and inherently political, emerging from social practices, perceptions and relationships over time (Molle, 2009a; Perreault, 2014). Treating the river basin as the 'natural' scale can lead to a technical approach that ignores political struggles and power relations (Perreault, 2014). On the other hand, territorial governance units based on conventional electoral boundaries (i.e. municipal, provincial, state, or national boundaries) rarely correspond to hydrological

[21] For instance, the US Geological Survey (USGS) divides the United States into 21 regions, 222 sub-regions, 370 basins, 2,270 sub-basins, approximately 20,000 watersheds and around 100,000 sub-watersheds (USGS, 2013).

[22] The introduction of zebra mussels into the Great Lakes, from ship ballast water, is estimated to have cost the North American economy over US$ 100 million and wreaked havoc on food webs and water supply systems (Cohen and Davidson, 2011), requiring States around the region to spend significant sums trying to address the problem.

boundaries, leading to a mismatch between institutional and hydrological logics that blurs the allocation of responsibilities across multiple scales and complicates the relationships between elected representatives, local authorities, water agencies, resource managers and end users (Bahri, 2012; Söderbaum and Granit, 2014; OECD, 2015b). Government participants in river basin initiatives are more likely to be responsive to the concerns of the jurisdictions where they were elected and to which they are accountable (Cohen and Davidson, 2011). This creates obstacles for coordinating different actors, particularly for financing (Newig and Fritsch, 2009) and land use management (Tucci, 2007), and may contribute to management failures within water governance, such as a lack of cooperation, participation and transparency (OECD, 2015b). Additionally, the socioeconomic drivers and power relations that shape WRM are not necessarily contained within the basin (Molle, 2009a).

4.4.2 IWRM/IRBM IGNORE THE URBAN

While basin-level management has become the dominant paradigm within the water governance literature, River Basin Organizations (RBOs) struggle in heavily urbanized environments, raising doubts about the adequacy of the basin as the spatial scale for addressing urban water challenges (Formiga Johnsson and Kemper, 2005; Jacobi and Francalanza, 2005; Rahaman and Varis, 2005; Alvim, 2006; Roggero and Fritsch, 2010; Brandeler, 2013; Freitas and Fracalanza, 2013). The IWRM and IRBM literature do not clearly address how water management at basin scale can be reconciled with the urban scale. A search within ScienceDirect for articles on IWRM published between 1970 and 2015 revealed that only around 14% contained any of the terms 'urban', 'city', 'cities', 'megacity', 'megacities' or 'metropolitan' in their title, abstract or keywords (Brandeler *et al.*, 2019). The same search within IRBM articles gave a result of 10%. Many of the IWRM/IRBM publications that do refer to the urban context have a narrow focus (e.g. urban demand management, pollution abatement tools, leakage control, wastewater recycling, public-private partnerships), and ignore IWRM's broader dimensions (Rees, 2006; Bahri, 2012). The particular challenges for IWRM implementation in large metropolitan centres, including coordinating across urban jurisdictions that may have competitive or conflictive relations, have also not been clearly addressed.

A straightforward explanation for this is that in most basins most of the water use is for agricultural use (i.e. irrigation). The purpose of WRM entities has often largely been to regulate flows for irrigation (70% of the world's water withdrawals, even reaching 90% in countries of the Global South) and power generation, with little influence over water quality management (Lee, 2000; Molle, 2008). In addition, irrigation's heavy water use is often also inefficient, with more than half of the water deliveries percolating into groundwater or returning to streams without watering crops, evaporating or otherwise lost (Molle, 2008). However, when demand within a basin exceeds supply, surface and groundwater resources become over-exploited, which affects development prospects (Tortajada, 2008; Barrios *et al.*, 2009). As basins urbanize and industrialize, and rural and urban water users compete for increasingly limited water resources, appropriate supply and demand management and water resources allocation mechanisms are crucial (Butterworth *et al.*, 2010; Molle and Mamanpoush, 2012).

Furthermore, implementing IWRM/IRBM in heavily urbanized river basins is a significant challenge as integrated decision-making processes must address trade-offs and externalities between rural and urban areas. One key trade-off concerns the allocation of scarce water resources between public/urban users, other sectors as well as the environment. This is especially pertinent in basins where all available water is committed, and new developments require reallocation (Rees, 2006). As domestic water use typically has priority over other uses, this translates into reallocation from agricultural to urban uses (Rees, 2006). The import of water from other basins allows actors and users within the recipient basin to avoid this contentious, and potentially conflictual decision. Although this may increase the economic efficiency of water use, such transfers also imply economic, social and political costs to the donor basin (Rees, 2006). Large cities around the world are increasingly relying on neighbouring basins.

The IWRM/IRBM literature promotes integration between water and land resources and management. However, land use changes in rural areas (e.g. deforestation) of river basins and diffuse pollution from agriculture are difficult to regulate and their impacts on cities cannot easily be traced to specific sources. The expansion of human settlements and intensification of their use of land and water resources in urban areas strengthens interlinkages between spatial planning and water management (Hartmann and Spit, 2014). Nevertheless, there seems to be no comprehensive analytical framework for assessing the coordination of IWRM/IRBM with urban and territorial planning (Neto, 2016). RBOs often have some (limited) influence over land and water uses upstream and across the basin, but little leverage over policy fields that directly impact water quantity, quality and risks, such as land use planning, agriculture, hydropower, stormwater management, conservation, economic development and more (Moss, 2004: 85). The mismatch between hydrological and political-administrative borders may further lead to poor cooperation, particularly in basins with large metropolises and megacities, and many stakeholders and interests (Aguilar, 2008; Feiock, 2009; Sorensen, 2011; Li *et al.*, 2015). In addition, climate variability and change can also lead to droughts or floods, impacting both river basins and the cities within them. If IWRM/IRBM measures do not take steps to prepare for and adapt to these risks, cities may be left struggling to cope, or these frameworks may be overruled by urban water frameworks, as major cities gain prominence in water management. Droughts impact water supplies, and in basins with large cities even short droughts can have significant impact.

4.5 Inferences

This chapter reviewed the water resources management literature to gain insights on how it understands and addresses metropolitan water challenges. It explored this in relation to two knowledge gaps identified in 1.2.3, namely (a) how the literature relates to the local context and integrates urban water concerns such as water services and water-related risks, (b) how the literature relates to the metropolitan context as a multi-jurisdictional and often heterogeneous urban environment. Several factors were identified by the IWRM/IRBM literature review that may facilitate or hinder sustainable and inclusive development.

Sustainable and inclusive development

First, the literature review highlights a shift from WRM based on modernist ideals towards IWRM, and its subset of IRBM, that embrace sustainable and inclusive development principles. IWRM and IRBM aim for decentralization to the river basin level and stakeholder participation, which can lead to the design of institutions and instruments that foster the inclusion of multiple viewpoints and interests, greater efficiency in resource management for multiple users, the protection of ecosystems and the promotion of water demand management. The review identified aspects of IWRM/IRBM that could hinder sustainable and inclusive development, such as limited considerations for types of water other than 'blue water' and for water as a hazard (water is defined as a resource). Participatory processes may struggle to include diverse, and particularly under-represented voices, as they require significant time commitments, finance (Anggraeni *et al.*, 2019) and as expert knowledge dominates to the detriment of local, tacit knowledge. Municipal representatives involved in these participatory processes are also likely to defend their constituents' interests, even at the expense of the general interest within the basin. The approach to water as an economic good can also lead to the exclusion of the poor and marginalized. The empirical chapters of this thesis evaluate whether such measures were part of the responses to metropolitan water challenges in São Paulo and Mexico City, and if so, how effective they were.

The river basin scale may not always be ideal

One of IWRM/IRBM's core principles is the idea that the river basin is the ideal unit for water resources management, as this allows for overcoming the mismatch between hydrological and administrative scales. However, the literature review points out important limitations when parties take for granted the superiority of the river basin as a planning unit. This thesis recognizes that choosing the basin as a unit for water resources planning and management is a social construction and attempts to consider other relevant scales (for drivers, institutions and instruments) into a broader framework for understanding metropolitan water challenges. This includes scales related to elements of the hydrological cycle (e.g. groundwater dynamics, atmospheric water, green water) and scales that gain relevance due to human interventions on the 'natural' environment. For this purpose, a governance framework that addresses metropolitan water challenges must therefore go beyond the main characteristics of IWRM/IRBM identified in 4.2.2.

Influence of basin entities over specifically urban drivers and institutions

IWRM/IRBM has had a strong focus on agriculture and rural areas, even though it promotes balancing the needs and goals of all users. However, in heavily urbanized basins, a significant or even dominant proportion of water uses are for urban uses and water-related challenges are different (e.g. important water quality challenges, such as contamination from solid waste and domestic and industrial wastewater, reductions in aquifer recharge due to soil sealing, tensions between users). For IWRM/IRBM institutions and instruments to have an impact on these challenges they must address the relevant drivers and actors. This is even more complex in metropolitan regions, due to the larger number of actors involved and their sometimes conflicting political and administrative interests.