Scalar mismatches in metropolitan water governance

A comparative study of São Paulo and Mexico City

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10. TOWARDS A THEORY OF METROPOLITAN WATER GOVERNANCE

10.1 INTRODUCTION

Large metropolitan regions are quickly multiplying and increasingly facing challenges in terms of water quantity, quality and adaptation to risk from extreme weather events. Although they generally have greater access to resources to address these challenges, their complexity increases exponentially with their size, as the number of actors and institutions involved directly or indirectly in metropolitan water governance also multiplies. The failure to reconcile metropolitan water governance across urban and river basin scales can translate into water policies that lead to a 'scalar mismatch'. In some cases, this can create redundancies that enhance resilience within overall water governance, as different actors and instruments work towards similar goals through different means. This is very necessary to cope with the impacts of climate variability and change. However, overlapping and disconnected policies and a lack of coherence and coordination between different levels of government and between urban and basin scales can also render measures ineffective or lead to externalities and conflicts over limited resources.

This thesis investigates river basin and urban water governance in relation to metropolitan water challenges through the following overarching question: **How do interactions between drivers and institutions at different spatial and institutional scales levels shape metropolitan water challenges, and how can policy instruments from river basin and urban water governance frameworks be (re)designed to foster more sustainable and inclusive metropolitan water governance?**

Section 10.2 reviews the lessons learned from the case studies in terms of the scalar mismatches that influence sustainable and inclusive metropolitan water governance. Section 10.3 highlights important considerations for metropolitan regions in federal states around the world. Following this, 10.4 identifies five elements that need to be considered individually and jointly to address scalar mismatches in metropolitan water governance. Section 10.5 then assesses the implications of this research for global policy and the SDGs.

10.2 TAKING STOCK FROM THE EXPERIENCES OF SÃO PAULO AND MEXICO CITY: SCALAR MISMATCHES IN METROPOLITAN WATER GOVERNANCE

The case studies illustrate the challenge of developing sustainable and inclusive metropolitan water governance as multiple levels of government and spatial scales are involved. This challenge translates into mismatches across scales.

10.2.1 MANAGING BULK WATER SUPPLY AND WATER CONTAMINATION AT THE MULTI-BASIN SCALE

Applying the spatial unit of the river basin to managing bulk water supply and water contamination does not internalize the two megacities' externalities on neighbouring

basins. Both the MVMC and MRSP are contained within one river basin (although the VMB is much larger than the MVMC, whereas the MRSP and ATB roughly overlap). However, the impacts of the two metropolitan regions in terms of water use and water contamination extend far beyond their basins and artificially interlink several basins. Water availability is insufficient: Between 39.4 and 47.9m^3/s are imported into the ATB from other basins out of the 81.25m^3/s that are used[91]; 20m^3/s are imported to the VMB out of 88m^3/s used and over 27m^3/s are estimated to be over-extracted within the VMB's aquifers (see 5.4.1 and 7.4.1). In both cases, higher levels of government intervene to ensure stable water supply to the megacities from other basins, thereby transferring the cities' water scarcity to donor basins, with impacts on the latter's communities, economies and ecosystems. Similarly, contamination from the MRSP flows down the Tietê River far beyond the borders of the ATB[92], while contaminated waters were reused in irrigation in the VMB's neighbouring basin until a large treatment plant was inaugurated in 2017. In fact, the impact of large cities extends much further as they tend to rely on 'virtual water' through the import of food and other goods, and local changes in the hydrological cycle can have repercussions far away. This regional approach may not fully account for these impacts.

A regional scale that includes all concerned basins can better account for these externalities. It is unrealistic for cities such as Mexico City and São Paulo to reduce their demands and impacts on surrounding basins in the short or medium-term. Centralized management of large-scale infrastructure for water supply (e.g. inter-basin transfers, metropolitan-scale integration of supply systems) at the multi-basin scale will remain in the short- and medium-term due to infrastructure lock-in, but is also more appropriate for cities of this size as it allows for economies of scale and integrates water scarce areas and areas without the means (or scale) to develop local infrastructure. The MRSP can learn from Mexico's restrictions on issuing new permits in low water availability zones. This does not address challenges of irregular water use and requires significant enforcement efforts, but it represents an effort to stabilize overall water use. The MVMC could adopt a water use fees system similar to the MRSP's, where funds are collected by the relevant basin entity and reinvested in projects that benefit the population and ecosystems within that basin. Wastewater discharge fees could also partly be used to compensate areas downstream of the metropolitan regions that receive contaminated water.

Nevertheless, the two cases show that **measures that reduce water demand, increase water use efficiency, integrate alternative sources of water and treat wastewater closer to the source can wean metropolises from their dependency on distant water resources and reduce contamination far beyond their borders.** Although they require long-term planning and regional coordination, they can often be managed locally. Decentralized management generally ensures more context-relevant responses and better user compliance (Xiao 2018). These initiatives exist but generally receive little support from governments or water utilities (e.g. rainwater harvesting for non-drinking water purposes, bioswales or artificial injections to

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[91] When needed, an inter-connection with the Paraíba do Sul basin allows to divert up to 8.5m3/s towards the Cantareira System (see 5.4.1).

[92] The river was contaminated 130 km downstream of the MRSP in 2015.

infiltrate surface runoff). While certain initiatives had clear benefits, utilities lack incentives to reduce the volume of water they supply or of wastewater they treat, as this affects their revenue. It also requires long-established actors to radically change their approach and is therefore met with scepticism.

In the longer-term, if these measures are effective, the spatial scale of managing bulk and water supply and water contamination can be reduced. However, parts of these metropolises may never become self-sufficient in terms of water supply, and some degree of intervention through inter-basin transfers might remain necessary in the long-term (see 7.4.1). The MVMC is expected to face a deficit of 25.1 m^3/s of water by 2030, even after importing water from the Cutzamala and Lerma systems and over-drafting the local aquifers (World Bank, 2013). These calculations do not account for the effects of climate change on precipitation, evaporation and water use. The over-exploitation of aquifers and the deficit would correspond to 51% of the water demand (of approximately 90m^3/s). Reducing the pressure on local aquifers and addressing the remaining gap of 25m^3/s could partially be done through reducing leaks (projected to be 28.1m^3/s in 2030 in a business-as-usual scenario) and commercial losses (projected at 6.8m^3/s in 2030) and other measures mentioned above. Nevertheless, these require significant investments by the government and households. Halting water imports from other basins would require supplying another 20m^3/s through water demand management and alternative sources, which is unrealistic to be achieved by 2030 and even beyond.

10.2.2 Coordinating Surface and Groundwater Management

The river basin scale is also too restrictive to think about bulk water management and water contamination as it mainly focuses on surface water dynamics. The MVMC and MRSP cases highlight that **groundwater, that is not part of a basin system, is not adequately integrated with basin management**. Significant uncertainty remains around groundwater dynamics. In the MVMC, groundwater use is very high, but little is understood about recharge rates, groundwater flows and quality levels. In the MRSP, it is not clear how much groundwater is used, but it is estimated to be significantly higher than official rates. There may be potential for expanding groundwater use in certain areas, thereby decreasing the need for water imports, but this would require more studies. This translates into an absence of groundwater management in the MRSP and the absence of effective groundwater management within basin management in the MVMC. Although rules and restrictions are in place in the MVMC to reduce groundwater over-exploitation, the relevant authorities lack capacity and incentives to enforce these (see 7.4.2).

The invisibility of the aquifer hinders the sense of a shared resource among users across a larger spatial scale. It is harder to monitor, and users tend to feel more strongly that the water beneath their feet belongs to them. Water use permits and fees do not consider interlinkages between surface and groundwater. However, the consequences of inadequate groundwater management can spread far beyond water extraction wells. It can lead to land subsidence and dried up springs and wetlands. In the MVMC, efforts to recharge local aquifers exist (e.g.

artificial groundwater recharge, retention reservoirs in the mountains surrounding the city). Their effects on the groundwater table are uncertain and depend partly on the speed of groundwater flows. However, as they also mitigate flood risks it is worthwhile to further assess such options and scale them up.

10.2.3 Retaining and reusing greywater: Semi-decentralized stormwater and wastewater management

The approach to stormwater and wastewater has focused on metropolitan-scale infrastructure to rapidly evacuate these effluents, ignoring downstream effects. This centrally managed linear approach is disconnected from local mandates and basin dynamics. Local responsibilities are not made coherent with a basin vision and plan. This has led to flood control infrastructure in one municipality that aggravates flood risks for a neighbouring municipality. Erosion or inadequate sewage treatment upstream affects downstream municipalities. In addition, this linear approach **consolidates a dependence on water imports.**

The ATB's macro-drainage plan defines a shared vision with **differentiated measures implemented at sub-basin levels** according to local characteristics, and vertical coordination between the state and municipalities to ensure that local stormwater measures are coherent with the regional plan. This combines local and metropolitan-scale measures that address soil-sealing, sewers and the occupation of floodplains, as well as basin-scale measures to reduce erosion and siltation upstream and maintain or rehabilitate wetlands and floodplains and retain stormwater upstream. Smaller-scale measures (e.g. warning systems, civil defence emergency measures, green infrastructure) can be more effectively implemented locally within a regional plan. To avoid a lack of coordination between municipalities – resulting, for instance, in stormwater being pushed to neighbours – it is crucial that local stormwater plans are made coherent with the ATB's plan. Meanwhile, government agencies at state or national levels can more efficiently coordinate large-scale infrastructure, such as deep drainage systems, and monitor large rivers.

While CONAGUA and state actors in the MVMC also coordinate large drainage infrastructure, this is not part of a regional plan that includes local governments or basin management principles. Groundwater depletion has caused severe land subsidence in certain areas, making these more vulnerable to flood risks. Existing measures, such as artificial groundwater infiltration that address flood risks and recharge aquifers, can be implemented in densely urbanized areas, while green infrastructure measures to retain stormwater in the MVMC's surrounding mountains naturally recharge aquifers and reduce urban floods. Scaling up rainwater harvesting can also contribute to reducing surface runoff and provide a source of water for non-drinking uses. The MVMC could therefore benefit from a regional plan such as the ATB's macro-drainage plan, which considers local needs, implements measures within sub-basin or aquifer units and promotes regional collaboration.

Wastewater management can also be better addressed through a multilevel framework. Decentralized wastewater management allows for discharging treated wastewater closer to the source, recharging aquifers or replenishing local wetlands, or it can supply industries and other users, according to local needs. Designing wastewater treatment measures at sub-basin level can allow for better consideration of local characteristics (e.g. population density, local hydrology, potential demand for recycled wastewater, lack of land tenure and physical obstacles that prevent the connection of informal settlements to the sewage network) to design context-appropriate measures. Meanwhile, regional coordination remains necessary as mega-treatment plants and large sewage mains will remain in place for decades, and the failure to treat sewage has a regional impact.

In the longer-term, retaining stormwater and (treated) wastewater within the cities' sub-basins can restore ecosystems and reduce the need for external water resources. As climate change will bring more irregular but more intense rains, such measures will enhance urban resilience.

10.2.4 Water services are fragmented across the metropolis and disconnected from water resources and environmental management

Whether the services are provided by a local or a state utility, metropolitan municipalities generally depend on shared water resources and inter-linked infrastructure. However, different utilities do not coordinate in terms of planning, which leads to fragmented infrastructure and inefficiencies and downstream impacts from inadequate sewage treatment. In the MRSP, municipal governments remain responsible for developing Wat&San plans, even when they have delegated this service to SABESP. However, these plans are often not (adequately) designed and/or implemented and SABESP *de facto* elaborates state planning for water services. In addition, there is no requirement for neighbouring municipalities to harmonize their plans or seek synergies. On the other hand, as SABESP has control of planning it could – in theory – ensure greater coherence across municipalities. In the MVMC, the total vacuum in terms of Wat&San policy at national level meant there are no shared standards and goals between local and state governments. This hinders the ability of local actors to coordinate actions on shared challenges.

While municipal provision may enable greater proximity to consumers and knowledge of the local context, **some degree of regional planning and or management can better address the dependence on shared water resources and infrastructure and the regional impact** from a lack of wastewater collection and treatment. This would allow for economies of scale (e.g. water purification and wastewater treatment plants can often be shared between multiple municipalities), greater technical capacity (local utilities often struggle to hire and retain skilled professionals, especially in poorer municipalities) and cross-subsidies between municipalities. Moreover, in Brazil, the Supreme Court decided in 2013 that services of common interest (such as Wat&San services) should be managed by both the state and local governments within metropolitan areas. This represents a recognition of the need for regional cooperation in the management of Wat&San services, due to shared benefits and externalities. However, this ruling fails to address the reliance of Wat&San services on distant water resources and the externalities transferred beyond the metropolis.

Even with regional planning, utilities cannot control local factors such as land use and land tenure, which often restrict the areas where they can provide Wat&San services. Utilities face great obstacles to expanding drinking water provision and sewage collection services to informal settlements, and the consequences are felt at a regional level (e.g. leaks from clandestine connections, sewage discharge into local streams and reservoirs). This was even more problematic in Protected Areas, but environmental actors rarely collaborated with utilities and local governments to find common ground. Overcoming this requires inter-sectoral coordination, sometimes between government agencies at different levels.

Furthermore, **water tariffs can be a tool for facilitating more equal access to Wat&San services at a regional level.** Affordable tariffs in metropolitan regions are crucial to ensure social inclusion, but still need to enable cost-recovery on average – where some consumers pay more to compensate for the lower costs to others – and reflect regional water availability. Cross-subsidies across São Paulo State enable SABESP to apply the same tariffs (including subsidized rates) to all its consumers. In the MVMC, tariffs are highly subsidized for all consumers, despite water shortages, which leads to irrational water use and transfers costs to future generation and donor basins, as well as to taxpayers nation-wide. The poorest did not benefit as they live in informal settlements and spend much more buying water from water trucks. The spatial scale for designing water tariffs therefore involves a solidarity component that considers who benefits and who pays within the utility's jurisdiction but also beyond it. The adequate scale for water tariffs also has a water availability component (i.e. how is water consumption affected, where is water taken from, at what cost). People and water resources beyond a utility's jurisdiction are often affected by its water tariffs but not considered in their design. The presence of an independent regulator at regional or higher level was therefore found to be crucial for sustainable and inclusive tariffs (see 9.7.3).

10.2.5 Linking Water Management, Ecosystem Services and Land Use/Spatial Planning

A great challenge is the **disconnect between both UWM and IWRM/IRBM and land use and spatial planning**. While WRM responsibilities are at basin, state and national levels, the mandates for land use and spatial planning are mainly at municipal level, despite some attempts at regional planning. However, the effectiveness of WRM instruments is determined significantly by local factors. In particular, land use and building regulations and commercial or industrial developments – generally overseen at local levels – drive increases in water demand. Corruption, clientelism and weak human and financial capacity at local level facilitate unsustainable economic activities and irregular urbanization, including into Protected Areas. Harm to ecosystem services is directly linked to such land use changes, yet there is no regional planning that adequately addresses it. Strategic Environmental Assessments are not conducted at river basin or aquifer scale, even when impacts on water resources were significant. Some respondents argued for the creation of a regional planning body with actual influence over land use and zoning.

Both the MVMC and MRSP have Protected Areas that are crucial for producing ecosystem services and protecting nature's contributions. For municipalities (or districts in the case of Mexico City) that have a significant part of their territory under such status, this represents significant restrictions on their urbanization potential, economic development and tax revenue. **The metropolis (usually) relies on peri-urban or rural municipalities to monitor and prevent irregular occupations and preserve vital ecosystem services – even when these municipalities lack financial and administrative resources and economic incentives to do so.** Measures that acknowledge the dependency of the metropolis on ecosystem services from its rural hinterlands and align incentives (e.g. laws and zoning regulations, PES programmes) are limited, unenforced or absent.

Land ownership further complicates land use and spatial planning. In Mexico, most land is privately owned, making government interventions very difficult. The land of indigenous communities and communal landowners is established and protected by the National Agrarian Law, requiring municipalities to deal with federal institutions for any land and water-related matters in these areas. Moreover, many residents of metropolitan municipalities work in the urban core, consuming water, producing waste and wastewater, and being exposed to flood risks. Despite this, they have no influence on decisions relating to these challenges and do not pay for the costs they create, as they live and vote in the neighbouring municipalities (and even neighbouring states in the case of the MVMC).

10.3 IMPLICATIONS FOR METROPOLITAN SYSTEMS IN FEDERAL STATES AROUND THE WORLD

Urbanization in Mexico and Brazil is expected to continue in the next decades but at a much slower rate than experienced during the second half of the 20th century. Other countries, especially in Asia and Africa are still in earlier stages of this radical transformation of their societies, and many of their cities are expected to mushroom in the coming decades. For those in federal states, in particular, the cases of Mexico City and São Paulo can provide a number of lessons for addressing metropolitan water challenges. The particularities of metropolitan regions in federal regimes have implications for the provision of urban water services, for water resources management, the link between the two and the role of land use management.

10.3.1 METROPOLITAN AREAS IN FEDERAL STATES

Metropolitan 'government' is usually not an option

Federal regimes have more than one level of government, each with specific responsibilities defined within the Constitution. Arrangements at intermediary levels (e.g. metropolitan, basin) generally cannot have administrations with executive power. Unitary states can more easily redefine territorial boundaries for different purposes (e.g. creation of Grand Paris as a metropolitan area). Therefore, metropolitan regions in federal states usually cannot form a metropolitan government with powers that compete with or exceed those of other levels of governments.

The Federal Constitution of both Mexico and Brazil define metropolitan regions and highlight the importance of regional action on issues of common interest. In 2013, the Supreme

Court in Brazil stated that, in metropolitan regions, the state government and municipalities concerned must jointly address functions of common interest. In Mexico City, a Law for Metropolitan Coordination aims to establish guidelines for a metropolitan planning strategy. In both cases, these efforts are met with resistance by those who see it as a threat to the federalist regime or to the decentralization of power to municipalities, which followed democratization.

Metropolitan water challenges are better addressed at different spatial scales and through different levels of government or non-state actors depending on the nature of the challenge (e.g. bulk water at multi-basin scale). Metropolitan entities are therefore not necessarily an adequate response, and metropolitan regions can better address water-related challenges through a range of arrangements across multiple scales.

Multi-scalar water governance in metropolitan regions

The Constitution in a federalist regime determines to a large extent the balance of power between levels of government. In Mexico more power is concentrated at central level, whereas states have significant power in Brazil and many responsibilities have been decentralized to the municipal level. This contributes to shaping water governance regimes in metropolitan regions and determining the levels at which policy instruments are designed. The types of jurisdictions included within a metropolitan region also play a role. As the MVMC includes multiple states, the national government is involved, controlling major infrastructure that crosses state borders and supplies several states. In addition, through inter-basin transfers both metropolises include multiple states and therefore also the federal government. The complexity of their water governance regimes is therefore much greater than the jurisdictional composition of the metropolitan regions themselves.

To address metropolitan water challenges, it is essential that the Federal government and Constitution define the 'metropolitan region', its boundaries and expectations regarding what functions can be carried out at that territorial scale and by whom. Nevertheless, the metropolitan region is not necessarily the ideal spatial scale to address all metropolitan water-related challenges. Depending on the nature of these challenges, different spatial scales may be relevant for designing policies and policy instruments.

10.3.2 Implications for Urban Water Management

Water services are often considered of local interest and carried out by local actors. The research shows that while some challenges and solutions within metropolitan water governance are local, many are shared, as externalities spread beyond jurisdictions. Three factors suggest that (partially) managing UWM functions at a higher level in metropolitan regions can promote more inclusive and sustainable development:

- First, many metropolitan regions have severe inequalities, including in access to adequate drinking water. Peri-urban municipalities tend to have less capacity for providing these services independently, and their form of urbanization may make it more costly (and therefore less attractive) to utilities. Fragmented service provision is also linked to clientelism at local levels. If managed at a larger spatial scale, Wat&San services can benefit from cross-subsidies that allow for more affordable water tariffs and enable provision in marginalized areas.

- Second, metropolitan regions tend to be densely urbanized and share water resources used in water provision. There can be potential gains from combining financial and human resources from multiple municipalities and scaling up the provision of certain services (e.g. shared water and wastewater treatment plants). Coordinating water supply also enables municipalities with insufficient water resources within their borders to respond to local water demand. As water resources are often imported from beyond metropolitan boundaries, managing at least certain aspects of Wat&San services (e.g. regulation, housing) at a higher level can better address potential externalities.
- Third, surface water runoff is not restricted by administrative boundaries within metropolitan regions. Actions in one municipality may aggravate flood-related risks in a neighbouring jurisdiction. Implementing basin principles and harmonizing local stormwater plans involve a certain amount of coordination at higher levels.

The autonomy of local governments, as well as competition and tensions between them, can hinder the formation of this type of collaboration. For example, the fact that **opposing political parties control the State and Municipal governments in the MRSP is a hurdle to integrate Wat&San policies in the area.** Scaling up services is also often associated with centralized, top-down decision-making. Arrangements where metropolitan municipalities must share responsibilities with the State government, as was pushed by the Supreme Court in Brazil, can allow for a balance between local autonomy and regional interest. The State (through a regulatory agency, for instance) can define criteria for municipal Wat&San plans and verify their compatibility and overall coherence at regional level. Instruments such as cross-subsidies and redistributive policies benefit from economies of scale and can reduce inequalities across the metropolis (and beyond, depending on the reach of the provider). Meanwhile, many actions can be decentralized and may be more effective at local level, such as billing, pipe repairs, monitoring of small-scale stormwater and flood infrastructure, or flood evacuation strategies. The Subsidiarity Principle supports governance at the lowest adequate level, but in large metropolitan areas the adequate level for certain water governance functions may not be the local level.

10.3.3 Implications for Water Resources Management

In federal regimes, authority over water resources is generally shared (to different degrees) between central and state governments. Local governments may be responsible for streams, small rivers and other water bodies contained within their borders. WRM therefore requires vertical coordination between government agencies at different levels. It also involves horizontal coordination between states, and between municipalities. Furthermore, where IWRM has been adopted, river basin organizations (RBOs) must also navigate this complex web of interactions. RBOs have been relatively successful in Brazil, but, in both cases, they have struggled to counter the weight of state institutions as they lack executive power. In metropolitan regions, WRM can therefore involve the three levels of government, the basin level and the metropolitan level. In fact, this research highlighted that metropolitan regions often involve multiple river basins and sometimes more than one state through the supply of bulk water and, in some cases, the discharge of contaminated waters.

Metropolitan regions often have large-scale water infrastructure managed by the state or central government. If water bodies belong to the state or federal domain, the involvement of higher levels of government is inevitable. To include the interests of communities and protect ecosystems in donor basins, it is crucial to involve all jurisdictions concerned with the transfer of water resources and the discharge of wastewater and stormwater management within and beyond the metropolitan area. Mechanisms are key, however, to ensure accountability and transparency, as higher levels of government may have interests and favour certain jurisdictions, both within the metropolitan regions and in relation to its rural hinterlands.

For sustainable and inclusive water governance, actors in a metropolitan region must assess which water resources and respective ecosystems are used, affected or implicated one way or another. Metropolitan regions can then develop plans and instruments that consider these interdependencies and the spatial scale(s) for their design. For instance, returning funds from water use fees to the basins (or even sub-basins) where they originated from strengthens the ties between the metropolis and basin(s) it relies on. A sense of a shared regional identity with awareness about the importance of surrounding ecosystems for the metropolis can help increase public pressure for regionally coordinated action.

Due to the interconnections between metropolitan regions and water systems beyond their borders, utilities and other UWM actors should be involved in WRM and held accountable if the aim is to achieve sustainable and inclusive development. While water for human consumption is a priority within WRM, mechanisms can ensure that utilities strive for efficient water use. Flat rates, impunity for consumers who lack metres and highly subsidized water tariffs encourage excessive use. As the case studies in this thesis demonstrates, this may ultimately hurt the poorest within the metropolis and in its rural hinterlands, who remain excluded from formal services and pay much higher prices. Involving a regulator or third party that can link the services to their water resources would facilitate relational and social inclusiveness.

10.4 Understanding and overcoming scalar mismatches in metropolitan water governance

Addressing scalar mismatches in metropolitan water governance is necessary, although not sufficient, in order to increase sustainable and inclusive development. This research concluded that considering five key elements in institutional and policy design can enhance policy effectiveness.

10.4.1 Defining Metropolitan Water Governance

Due to their concentration of people and economic activities, metropolitan regions have a water footprint and impact on people and ecosystems that expands far beyond their own borders. Identifying the demands and impacts of the metropolis locally and on the surrounding (or relatively distant) rural hinterlands may foster a shared conceptualization of the metropolis and its interlinkages with water systems. The concepts of 'metropolitan water' and 'metropolitan water challenges' are not static, but rather moving targets, as cities continue to expand and increase their demands and impacts. Over time, institutional frameworks and instruments can become irrelevant or ineffective. This is the case of water allocation quotas for Mexico City and Mexico State based on the MVMC's characteristics in the 1970s (see 7.4.1). In addition, 'metropolitan water' can involve different spatial scales, and therefore different stakeholders, institutions and policy instruments, according to which challenges are addressed. Both IWRM/IRBM and UWM embrace the principle of subsidiarity, albeit to different spatial scales (i.e. basin and municipal) and bringing these actors together within a metropolitan water governance framework therefore enhances complexity. These different IWRM/IRBM and UWM actors have different approaches to water related challenges and their policy responses, different types of knowledge and unequal power. This complexity is further enhanced by party politics across the metropolis and its rural hinterlands and between levels of government. Reluctance or inability to act at different levels can lead to problems of 'fit' between legal and policy frameworks for cities and basins. The experience of RBOs, for instance, has demonstrated that municipal representatives typically maintain localist stances and require incentives to act towards the interest of the river basin. In metropolitan regions, this is further complicated by the tensions between regional interest and political-administrative fragmentation. In this complex scenario, there are no one-size-fits-all solutions.

Metropolitan water governance actors are generally understood as those within the metropolitan region or at higher levels of government that act on the metropolis. However, it also includes actors of neighbouring areas that are interlinked in water governance – for instance, because they influence water resources exported to the metropolis, or shape land use management in areas that produce these water resources.

To address scalar mismatches, metropolitan water governance requires:

- Identifying the relevant spatial scale to address various metropolitan water challenges;
- A sense of a common interest and a shared commitment to its challenges;
- A recognition of the importance of knowledge- and data-sharing at the relevant scale;
- Clear mandates and guidelines for joint action, when this is beyond an actor's traditional attributes. Due to institutional inertia, actors do not easily change behaviour;
- Developing planning mechanisms at the relevant spatial scales (i.e. municipal, metropolitan, macro-metropolitan, (sub-)basin, multi-basin) with synergies between local concerns and interests and those at larger scales, such as ecosystem protection. These plans are not an amalgamation of local plans but are coherent with these while

taking the regional interest as a basis. This can be facilitated by creating a set of common standards at local levels.

Scalar mismatches within metropolitan water governance are reflected within four key elements. First, scalar mismatches concern the water resources that are currently used or impacted in the metropolitan region, or that could be in the future (see 10.4.2). Besides blue water (i.e. surface and groundwater), this also involves green water and grey water. Second, metropolitan water management involves infrastructure at different spatial scales, from small-scale infrastructure catering to the local level, to metropolitan-wide and beyond (see 10.4.3). Even small-scale infrastructure may be interconnected with other infrastructure at a larger scale rather than operate in isolation. It is important to consider these interconnections and how infrastructure in one area may impact another area of the metropolis. Third, it is necessary to connect water resources (of different types) to the ecosystems and ecosystem services that sustain them (see 10.4.4). Often, little is understood about these ecosystems and the crucial role that they play in metropolitan water governance. Finally, although municipalities have clear borders, there is more ambiguity about metropolitan regions' boundaries, especially as they are constantly evolving, and this has implications for how they manage land use and contain sprawl (see 10.4.5).

10.4.2 Considering different types of water

Large metropolitan areas have heavy footprints on different types of water, including blue, green and grey water. Sustainable and inclusive metropolitan water governance must aim to increase efficiency of use of different types of water and to diversify among them.

Blue: Towards multi-basin coordination and conjunctive use

Bulk water supply is based on surface and groundwater resources from within and beyond metropolitan boundaries. Regions exporting (surface or ground) water to the metropolitan region are often side-stepped in decision-making processes, as state and national-level actors make top-down decisions. Inclusive and sustainable bulk water management therefore requires a framework with fair rules and a shared responsibility for water allocation that incorporates the multiple basins and aquifers concerned, and the interests of local stakeholders. In addition, it is necessary to address differences in cost structures and subsidies that lead to water uses inconsistent with overall water resources optimization (e.g. subsidies on inter-basin transfers that make water imports cheaper than more sustainable alternatives) and disincentivize water saving (e.g. utilities' revenue depends on maximizing water sales). Efforts could be made to reduce megacities' impact on other basins through demand management measures. These include: (i) consistent use of water metres (for bulk use and for retail services) that must be installed within a set deadline to avoid a fine; (ii) leakage detection and repair programmes; (iii) incentives for installation or retrofitting of water saving equipment and the use of more efficient irrigation systems in cities' rural hinterlands; and (iv) the use of alternative sources such as recycled wastewater and rainwater harvesting (for non-drinking water purposes, including artificial groundwater infiltration). This last one is particularly important to help "close the loop" sub-basin and basin levels and reduce the spatial scale of bulk water use. This implies strengthening coordination with Wat&San utilities, the industrial sector and rural water users.

Although IWRM/IRBM promotes the integration between surface and groundwater sources, many large metropolitan areas that rely on both do not address these together. Reliable knowledge on groundwater resources (including recharge rates, actual extractions and contamination risks) is limited, preventing adequate planning of groundwater use. Groundwater extraction infrastructure is also often privately owned, as opposed to infrastructure for surface water abstraction, and monitoring groundwater extraction is resource-intensive, which further prevents it from being effectively integrated in a regional strategy. Consistent application of fines for water use infractions – instead of tacit acceptance and impunity – could support more widespread monitoring and enforcement.

Moreover, the boundaries of aquifers and river basins do not necessarily overlap. Aquifers may spread over more than one basin and vice versa. However, IWRM/IRBM promotes river basins as the unit for analysis and management, adding to the uncertainty regarding how to manage groundwater resources. The consequence can be unregulated groundwater use, with conflicts arising once the wells run dry.

Overcoming the mismatch between ground and surface water management requires switching to conjunctive use that integrates all river basins and aquifers used and affected by the metropolitan region. This can increase climate change adaptation, as diversifying water resources will provide reserves during droughts or relieve pressure on over-exploited aquifers (Pincetl *et al.*, 2019). With conjunctive management, an allocation framework can be implemented that sets limits on water use permits to sustainable abstraction levels. In times of heavy precipitation, measures such as green infrastructure and artificial aquifer recharge can store groundwater and complement water reserves in dams (which have drawbacks such as evaporation, sedimentation, and the use of valuable land) (Porse *et al.*, 2015). The effectiveness of this measure depends on aquifers' storage capacity and their potential discharge. In periods of water scarcity, users could trade their surface water permits for groundwater permits. Conjunctive management may require a single institutional framework for both types of resources, with structures at multiple spatial scales.

Grey/black: Switching blue water for grey water

As metropolitan water demand rises and the accessibility of affordable and sustainable blue water decreases, another alternative is to recycle and reuse (the increasing volume of) grey (and sometimes black) water for uses that do not require high water quality. Many industries that require water for industrial processes (e.g. cooling) can use grey water with no effect on the quality of their output. Win-win arrangements are possible if they transfer their (blue) water use permits to users requiring higher-quality water. Public water utilities, for instance, can sell treated wastewater to these industries at a much lower cost than the original bulk water fees they are paying or for free in exchange for their water use permit. A challenge is that blue water and the cost of abstracting and distributing it is often subsidized or even not paid for by the user, which makes a switch to grey water – and its related costs – significantly less attractive. To increase grey water recycling and reuse it is therefore important that blue water is priced adequately and fairly.

Many grey water use measures are small-scale (e.g. grey water in toilets, rebates on water saving technology) and can be implemented in (new) houses, hotels, office buildings, schools and factories; retrofitting is more expensive and may need to be subsidized. They often rely on private initiative but are much more likely to spread if there are incentives or regulatory measures that promote this shift (see 9.7.2).

Green: Towards understanding the links between land use, green water and blue water

As cities expand, agricultural land, forests and other ecosystems are converted into urban land. This impacts blue water (e.g. disappearance of springs) and green water flows (soil moisture). The role of green water, including its links to blue water, is still often misunderstood or ignored by water managers, and it is generally not integrated within IWRM/IRBM strategies in practice. A better understanding of green water could reduce the need for irrigation or increase its efficiency and free up blue water for other uses. It would also highlight the link to land use management and the protection of crucial ecosystems. Although IWRM/IRBM promotes the integration of water and land, water managers typically have no influence on land use management.

10.4.3 Metropolitan water infrastructure

Thinking small (when possible): Incremental shift towards a new approach to water use

To a large extent, the modernist paradigm that promotes society's control of nature through hard engineering and a linear approach to water remains in place. The financial model of water management institutions also often favours a linear approach to water supply. Their revenues are mainly based on water sales and they therefore have a structural disincentive to reduce water supply. Larger, consolidated utilities are more capable of revising revenue strategies. Incentives and regulations could be designed at regional level with a medium to long-term perspective.

Shifting towards a more socially inclusive, ecologically sustainable approach that attempts to 'close the loop' of the urban water cycle is essential. Reducing pressure on donor basins can decrease regional inequalities and environmental stress. This requires the adoption of small-scale (sometimes disruptive) solutions at local level that can be scaled up (e.g. water metres, artificial recharge, reuse of treated wastewater, and rainwater harvesting), that empower local actors and strengthen a multi-scalar water governance approach. However, this is generally thwarted by institutional inertia, path-dependency, transitioning costs and stranded assets, and it is therefore not always realistic in the short-term. An incremental shift that combines large and small-scale infrastructure can allow for slowly phasing out or reducing mega-works that are neither sustainable nor inclusive. Both large and small-scale infrastructure must be integrated in regional planning, as small-scale measures may impact the effectiveness of large-scale measures if they are scaled up. Although some large infrastructure will remain indispensable in established metropolitan regions, there is an opportunity to avoid mistakes in rapidly growing cities, especially in the Global South. In cities of the Global North, there is a window of opportunity with aging infrastructure to switch to a new system.

Avoiding white elephants: Wastewater treatment

The linear approach to wastewater management affects the replenishment of waterways and aquifers within urban areas. Large wastewater treatment plants allow for economies of scale and mean that fewer plants are needed, at least in theory. However, they can also become white elephants, operating far below capacity as sewage from distant neighbourhoods does not reach these plants due to topography, the extensive piping needed and the inability (for practical or legal reasons) to connect informal settlements. Localized sewage treatment can be a solution for certain housing complexes and industries (especially as these are privately financed), but not across the city as they occupy extensive space. However, large metropolitan areas offer sufficient scale for several medium to large-sized treatment plants. It can make sense to distribute these by sub-basin or sub-region within a large city, so that treated wastewater is discharged closer to the source – reducing the length of pipes needed – and recharges local stream flows. With sewage treatment plants spread out across the metropolitan region, opportunities also arise for wastewater recycling and reuse as treatment facilities are located closer to the demand. In addition, it can lead to savings in the transportation of both untreated (plants are closer to wastewater producers) and treated wastewater (plants are closer to potential users of treated wastewater). It also means that treatment involves smaller quantities and can more easily be adjusted to the level of treatment necessary for different uses. In the city it can be reused in industrial processes and large buildings (e.g. toilet water) and in peri-urban/rural areas it can be reused for agricultural irrigation.

Combining local and regional-scale approaches: Adaptation (in particular to flood risks)

As the proportion of urban land in high-frequency flood zones is increasing and climate change is making extreme weather events more frequent and intense, inadequate urban stormwater and flood management will have severe consequences (Güneralp *et al.*, 2015). Adopting measures that allow for redundancy and fast responses increases adaptation to climate-related risks, such as floods and mudslides is critical. This is the case of small-scale measures such as green infrastructure, warning systems, or civil defence departments and community networks, which can be context-relevant and managed locally. Green infrastructure (e.g. parks, bioswales, green roofs) can complement conventional stormwater systems, and provide additional ecosystem services (e.g. aesthetic, climate regulation, water quality regulation).

However, in metropolitan regions, actions in one area can cause or exacerbate flood risks in other areas (e.g. dykes that redirect flood waters to neighbours, erosion upstream causing siltation downstream, regional and global processes such as climate change). Local adaptation measures must therefore be supported by a metropolitan- or basin-scale plan that identifies and addresses externalities and shared risks across the urban space. Such a plan can tailor strategies to different areas of the metropolis. For instance, grey infrastructure is more cost-effective in densely urbanized centres, whereas infiltration is viable in peri-urban areas. Municipal governments or private actors can implement small-scale measures, while larger-scale measures may require involvement from higher levels of government.

Municipalities tend to be reluctant to spend resources for results felt outside their borders but may be encouraged if funds are made available for actions of larger-scale impact identified within a metropolitan or basin plan. Funding could be based on the user-payer or polluter-pays principles (e.g. a risk creator-payer mechanism), where developers that remove vegetation, increase soil-sealing or enhance flood risks in any other way must pay proportional compensation. The use of water fees for basin projects, including flood-related projects, in the case of São Paulo shows that this has potential to mobilize stakeholders around common-interest actions. Adding stormwater charges to the water bills could also be an option, even if only during the rainy season, although this represents an additional financial burden for poorer households. Construction permit approvals can require developers to plan for on-site stormwater retention. In Washington D.C., stormwater retention credit trading enables developers to meet their on-site requirements or buy 'credits' for stormwater retention from other developers who voluntarily retrofit their properties through a stormwater credit-trading programme (DOEE, no date; Cardona, 2019). This creates flexibility for developers according to available space and relative cost of foregoing development for stormwater retention, and this can provide incentives for preserving green areas in poorer parts of the metropolis. These credits can only be sold within the (sub-)basin where they are generated. This project is now expanding to other cities, such as Chicago, which is also dealing with stormwater flooding and a lack of financial resources (DOEE, no date; Cardona, 2019).

Without a regional approach, municipalities have no incentives to adopt stricter building and zoning regulations in a unilateral manner, as developers can simply move to the neighbouring municipality. Therefore, regulations pushing for adaptation in urban and housing development must be enforced at metropolitan or regional level.

10.4.4 Sharing and Compensating for Ecosystem Services/Nature's Contributions

Ecosystem services produced within and around metropolitan regions are highly valuable as they support large populations and major economic centres. Ecosystem approaches can be integrated in both water services and risk management and WRM. This can foster a system of sharing and compensating the use of ecosystem services.

Upstream effects

Surface and groundwater bodies that depend on healthy and productive ecosystems sustain water supply to metropolitan regions. The role of these ecosystem services is often misunderstood and undervalued. Even in contexts of (relative) water scarcity, bulk water supply is often wasteful (e.g. heavy water losses, inefficient irrigation practices, high industrial water use for non-essential products). This is linked to the linear approach to WRM that assumes water's inexhaustibility and ignores ecosystems' limitations. Even when water allocation systems recognize the discrepancy between supply and demand and impose restrictions, these are rarely associated with environmental preservation measures.

Sustainable bulk water management requires defining the relevant ecosystems' boundaries of all the aquifers and the multiple basins that supply water to the metropolis. Identifying and mapping these areas allows for assigning legal protections and responsibilities to enforce these. Although local actors can enforce these measures, recipients of these ecosystem services (metropolitan water users and others) can fund these through water use fees, compensation mechanisms, Payments for Ecosystem Services and other mechanisms.

In addition, to ensure sustainable water supply, water allocation should not exceed what these systems can provide sustainably. Preserving minimum environmental flows and recharge rates within water allocation regimes is therefore crucial.

Downstream effects

Ecosystems upstream of the metropolis are crucial for metropolitan water provision, but those downstream are negatively affected by untreated wastewater, contaminated stormwater and other diffuse pollution. The spatial scale of this contamination may extend beyond the immediate river basin and stakeholders downstream. Pollution reduction mechanisms such as wastewater discharge fees often fail as they are weakly enforced or because they are cheaper than reducing contamination. Wastewater use discharge fees are often reinvested in wastewater treatment within the metropolis or even in other areas and downstream jurisdictions do not necessarily receive any type of compensation. In some cases, compensation is obtained through courts. Provisions can also be implemented to redirect (part of) the revenue from wastewater discharge fees to affected jurisdictions.

Water and sanitation services

Wat&San providers lack incentives to consider the sustainability management of the water resources they rely on or to address externalities from service provision onto other jurisdictions (e.g. lack of sewage treatment contaminating rivers). This disregard for the value of ecosystem services is reflected in the pricing of Wat&San services, such as highly subsidized tariffs for all consumers. Often subsidized tariffs are given to the poor, but the poorest remain entirely excluded from access. In rural areas this is because their water is taken away, while in urban areas it is because they are in marginalized settlements. Measures that ensure access for all enhance social inclusion, but water tariffs should also relate to water availability and the cost of bulk water supply to consider environmental and economic sustainability. This will incentivize water savings by both consumers and utilities.

10.4.5 Addressing urban sprawl as a regional phenomenon

Land use

Urban growth drives land use and ecosystem changes in the periphery and rural hinterlands. The city exercises significant influence over rural areas, through its economic and political power, to obtain and monopolize water resources and export wastewater downstream. The challenge is that urban policies (i.e. land use, zoning, housing, infrastructure) are disconnected from environmental and water-related policies. As cities expand, farmland and green areas are converted into urban land and farmland respectively. While urban demand for water resources and agricultural products rises, the land available for food production either shrinks or shifts to more distant areas, expanding the spatial scale on which the metropolis depends. This threatens both food and water security for metropolitan areas. In addition, urban expansion is a less conspicuous form of reallocating water from rural to urban areas, as water allocated to agricultural use is then (formally or informally) reconverted into water for urban uses.

Although IWRM/IRBM acknowledges the need to integrate water resources and land, it does not provide concrete tools for spatial planning. These are the mandates of municipalities and states, or even of the federal government, and RBOs do not have any say on land use, zoning, or spatial planning. Land ownership also affects what measures can be implemented to control sprawl (e.g. difficulty from preventing private landowners to sell land to developers). Meanwhile, ineffective water allocation mechanisms can facilitate urban expansion despite (relative) water scarcity if water use permits originally issued for agricultural use are adopted for urban use. At metropolitan or regional level, the policies of one municipality may be incoherent with those of a neighbouring municipality, or even negatively impact them. A regional land use policy is necessary to curb unregulated sprawl, push for densification and offset negative impacts. This is supported by the push for 'Compact Cities', promoted by the United Nations' Habitat III report, with the aim to prevent the spread of suburbs and preserve crucial ecosystem services (United Nations, 2016a).

Environmental protection

Although certain areas valuable for their ecosystem services are protected on paper, this can be difficult to enforce near large urban areas. If land is privately-owned, landowners face an opportunity cost by preserving the area rather than selling it or developing it themselves. Expropriating this land for environmental protection involves significant compensation payments. Very restrictive legislation to protect areas can backfire without constant monitoring (which is also costly) and lead to informal occupations. Local governments are often responsible for land use, including preventing the occupation of protected areas, but municipalities in the periphery – where the pressure on land is highest – generally lack capacity to enforce these measures. As Wat&San companies are often not allowed to provide services in informal settlements, residents install clandestine water connections and discharge their wastewater *in natura*.

Nature-based solutions need greater support, but basing these on a regional strategy rather than exclusively piece-meal initiatives by local governments is more effective. This can involve protecting green belts that provide ESS such as water recharge and water production, and linear parks that cross the metropolis. In addition, compensation mechanisms designed at regional level may reduce the disproportionate burden on municipalities in the periphery that must protect green areas on limited budgets. Although IWRM/IRBM actors have limited influence on land use and spatial planning, they may have indirect influence through other instruments, such as the classification of water bodies (see ANNEX G – ADDITIONAL INSTRUMENTS). By influencing the degree of protection granted to water bodies, RBOs can restrict the type of activities and land uses that can (legally) be developed near them.

Housing

As metropolitan regions expand, the demand for housing leads to the occupation of floodplains and areas of springs and aquifer recharge through both formal processes (i.e. real estate developments) and informal processes (i.e. informal settlements). Besides threatening crucial ecosystems, this often leads to inadequate housing for residents (e.g. exposure to flood risks). Low-density sprawl causes environmental degradation and increases inequality between periphery and core, as low-income residents are increasingly far-removed from employment opportunities. It also impacts water and wastewater infrastructure as pipes must cross greater distances.

In response to these challenges, a regional plan can identify areas adequate for development and aim for densification rather than sprawl. This may involve adjusting zoning regulations and building codes, addressing real estate speculation and regenerating or upgrading inner cities and informal settlements. Where legalization is unlikely to ever happen (e.g. settlements in areas at risk of floods or mudslides or crucial for ecosystem services), relocating residents through inclusive and participatory processes are necessary. Besides reducing the negative impacts from sprawl, densification reduces water consumption (e.g. smaller/no gardens needing watering, fewer appliances) and the unit costs for water utilities. Compact cities can host growing populations while minimizing impacts on the habitats that provides them with ecosystem services.

10.5 THE SUSTAINABLE DEVELOPMENT GOALS: INCLUDING A REGIONAL APPROACH INTO IWRM

The 2015 Sustainable Development Goals (SDGs) are likely to play an important role in shaping future metropolitan water governance regimes. Metropolitan water challenges relate directly to three of the 17 SDGs (see 1.2.2): SDG 6 on water and sanitation, SDG 11 on cities and human settlements and SDG 13 on climate change.[93] Therefore, even if metropolitan water governance regimes do not explicitly adopt sustainable and inclusive development as a normative framework, shifts in related policy areas may influence how actors and institutions

[93] And indirectly to many more (e.g. SDG 15 'Life on Land', SDG 10 'Reduce Inequality').

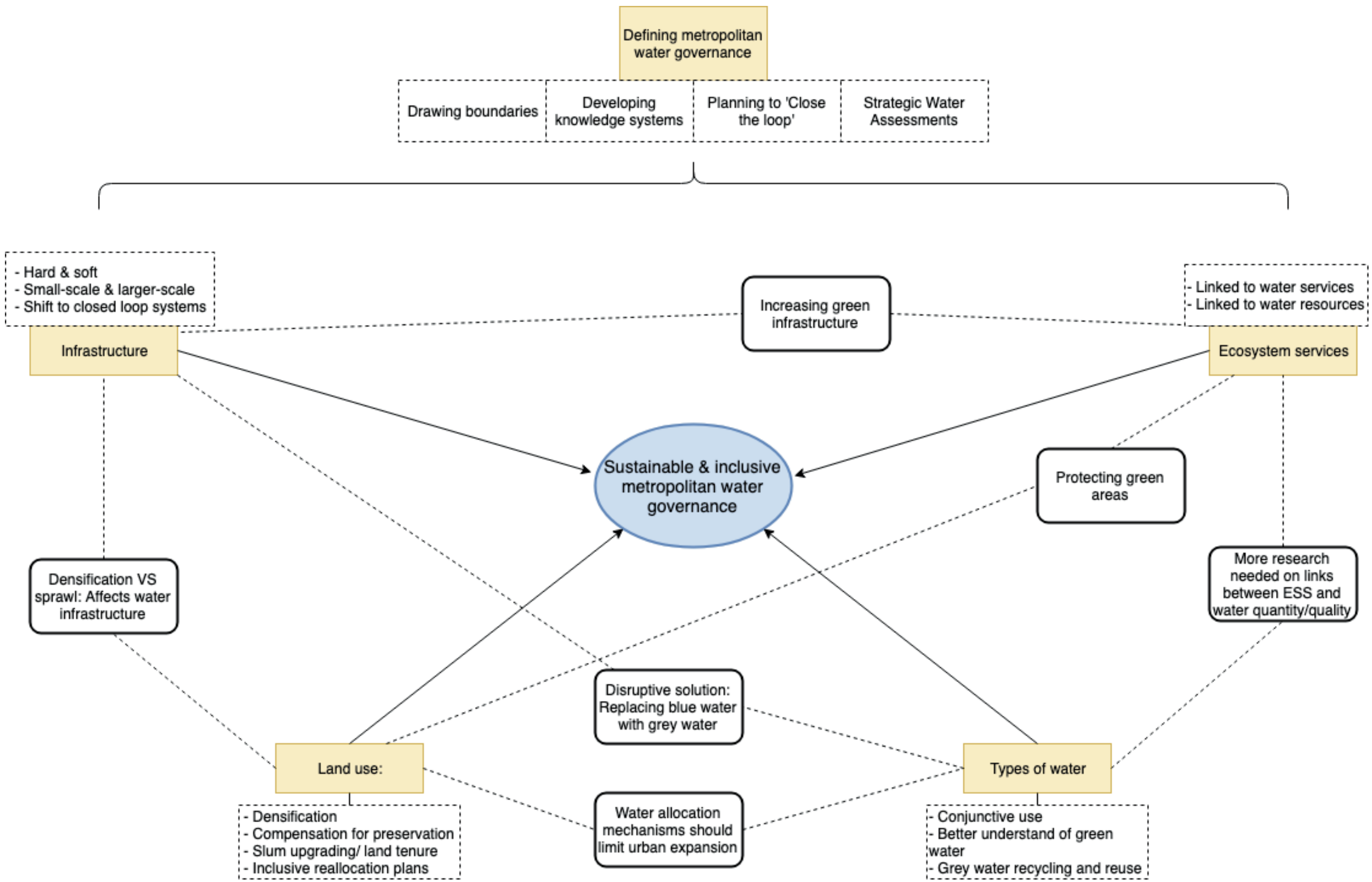
respond to metropolitan water challenges. This study's aim in relation to policy was to consider how interlinkages between SDGs impact these challenges and how synergies can be harnessed for win-win strategies.

Metropolitan water governance requires a multi-level approach with coordination across levels of government, but this thesis emphasized the need for regional spatial planning. Many of the challenges concern land use changes (i.e. urbanization, agriculture) and involve multiple municipalities, as well as trade-offs and externalities between municipalities within the metropolitan region or between the urban and rural areas. It is essential that the spatial scale of implementation and effects of instruments are coherent with the scale of the issues they address. Otherwise, the costs (economic, social, environmental or relational) are likely exported elsewhere. A regional approach for addressing metropolitan water challenges should involve the following steps:

- *Drawing boundaries*: Defining the urban area; Identifying at least the blue, grey and black water systems that are used or impacted by the urban area; Delimitating the areas that provide ecosystem services crucial to the city's water systems; Mapping the relevant macro-infrastructure for water management.
- *Developing knowledge systems*: Collecting and sharing urban data across megacities and their rural hinterlands. Data is typically kept within organizations, sectoral silos and municipal or state governments.
- *Elaborating a regional plan* to 'close the loop' of the urban water cycle. Coordinating river basin plans (including groundwater management) with city plans and providing guidelines for local governments. Outlining measures to reduce sprawl, create buffer zones around water bodies to reduce contamination and protect ecosystems, and promote a shift towards decentralized grey and green infrastructure.
- *Developing Strategic Water Assessments* for plans and programmes centred around water and related ecosystems. This could integrate metropolitan water and spatial planning through a focus on the changes necessary within the planning processes.

SDG 6 combines water services and IWRM, which is an important step forward in overcoming mismatches between urban and river basin scales. To support the integration of UWM and IWRM/IRBM, this thesis proposes an additional indicator under 6.5 ("Implement IWRM at all levels") that promotes developing regional water plans for cities with more than one million inhabitants. Such a plan would be based on the four steps above. This regional planning framework for integrating urban and basin concerns in large cities can then be used to design, implement and evaluate policies and policy instruments related to different types of water, infrastructure, ecosystems and urbanization (see Figure 10.1). Such an approach recognizes and addresses the multiple spatial scales involved in water-related challenges in metropolitan regions, thereby facilitating more inclusive and sustainable responses.

Figure 10.1 Regional approach for integrating urban and basin concerns



10.6 Final Reflections

This research explored the ways in which spatial scales in policy design play a role within metropolitan water governance and either hinder or support inclusive and sustainable responses to water-related challenges. Over the past decades, the complexity of water resources in major metropolises has been addressed through two main governance approaches – river basin governance and urban water governance. Although these approaches have promoted greater inclusiveness and sustainability, they focus on river basin and urban systems separately, which prevents each governance regime from addressing all relevant drivers and policy effects. This thesis proposes the concept of 'scalar mismatches' and develops the framework of 'metropolitan water governance' to bridge this gap.

By selecting the case studies of Mexico City and São Paulo, two megacities that grew rapidly during the 20th century, I was able to examine what each could learn from the other, but also what lessons could serve cities in the Global South more broadly. As cities multiply and expand in the coming decades, and climate change puts additional stress on urban water systems, governance regimes must carefully consider where they draw boundaries and what as well as who these include. With adequate resources, political will and public support, policy (re)designs in metropolitan water governance can overcome potential 'scalar mismatches' and support sustainable and inclusive development. These new concepts are open to further contributions from researchers and policymakers.