Climate Change Sensitive Cities

Edited by

Gian Carlo Delgado Ramos

Climate Change-Sensitive Cities:

Building capacities for urban resilience, sustainability, and equity.

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Climate change-sensitive cities
Editor's introduction

Gian Carlo Delgado Ramos

Growing ecological degradation, including anthropogenic emission of greenhouse gasses (GHG), the principal cause of climate change, with all its implications, is undoubtedly induced by economic growth in a far greater degree than population growth or other variables (IPCC, 2014).

This is confirmed by the strong correlation –observed for more than a century at least—between economic growth, energy consumption, and generation of waste (Kraussmann *et al.*, 2009; UNEP, 2016; Hoornweg and Bhada-Tata, 2012). In consequence, human beings are responsible for more than half the warming observed between 1951 and 2010, a period during which an increment has also been observed in extreme climatic events, such as heat waves, cold fronts, intense rains, cyclones and others (IPCC, 2014).

According to the Intergovernmental Panel on Climate Change (IPCC), each of the past three decades has been hotter than any other since 1850 (IPCC, 2014). The surface temperature of our planet has increased 0.85º C since 1880, and the oceans have warmed –considering depths up to 700 meters, the first 75 m of which registered increases of 0.11º C per decade—since 1971 (IPCC, 2014). Furthermore, the absorption of ever-increasing quantities of CO_2 by the oceans has caused their acidification (currently by about 26%), with negative implications for marine biodiversity, particularly in coral reefs where the intensity of bleaching suggests that the phenomenon might be irreversible as, for example, in the north section of the Great Barrier Reef in Australia (Hughes *et al.,*2017).

Also, as a result of climatic change, average sea level has increased 19 centimeters since 1901, the ice sheet in the Arctic and Greenland has lost part of its mass in every successive season, and North Hemisphere glaciers have also diminished (IPCC, 2014). The most recent major event of ice mass loss was the breaking away of a 5,800 square-kilometer iceberg with an estimated weight of roughly a billion tons from the Larsen C ice sector in Antarctica in July 2017. This is the third event of this importance to occur in recent years.

For these reasons, and considering that the risk of abrupt and irreversible changes grows in direct proportion with the magnitude of global warming (IPCC, 2014), international climate negotiations have established as their central objective an increment in temperature of no more than 2º C compared with the 1861-1880 period, which requires that CO_2 emissions accumulated since 1870 should not surpass 2,900 gigatons (GT) of CO_2.

Achieving the goal of 2º C established in the Paris Accord (UNFCCC, 2015) doesn't mean there will be no negative impacts at all, as those resulting from such temperature increments will continue for centuries, even if anthropogenic emissions of GHG stop. What this accord is thus trying to achieve is to minimize the adverse effects; in pursuit of this idea, the intention has been voiced to pursue efforts to limit the temperature increase to 1.5 º C above pre-industrial levels (Article 2.1a; UNFCCC, 2015). The necessary actions are pressing, because the estimated effects could be worse than previously calculated. On the one hand, the Accord itself is insufficient, based as it is on voluntary national contributions which, even if they were accomplished totally, would still allow an increase in temperature greater than 2º C (Delgado, 2016), and on the other, because of the implications to climate if the withdrawal of the U.S. from the Accord –the second global generator of GHG, after China— is actually carried out.

Recognizing that climate change is a shared concern –as established in the resolution of the 21st Conference of Parties to the United Nations Frame Convention on Climate Change—and that climate change is an unavoidable part of global environmental degradation, this collective publication is focused both on the analysis of the state of the situation, and on the necessary capabilities to gravitate towards scenarios which include sustainability and urban resilience.

In such a context, the urban element is a key factor, both in the evolution of what has been termed "the great acceleration" or global change (Costanza *et al.*, 2007; Steffen *et al.,* 2011) and in the search and construction of solutions and alternatives. It is there, in the cities, where 80% of world wealth is generated, where the vast majority of consumption is located, and where a great proportion of infrastructure is sited, which already represents a global stock of 792 billion tons of materials, absorbing around half of the material and energy extracted annually on a global scale for its renovation and expansion (Kraussmann *et al.,* 2017). Cities are thus, directly or indirectly, responsible for a considerable part of global environmental degradation, including the emission of between 71 and 76% of GHG (IPCC, 2014). And, given that the urbanization of existing space is proceeding at a rate never experienced before in history[1], the time frame for making adjustments and implementing corrective measures is undoubtedly getting shorter.

It is hardly a minor issue. Implications derive from both the deep transformations experienced by urban settlements themselves on a local-regional scale, and from those which result from accelerating urbanization on a global scale, associated with economic growth and the dynamics of capital

1 While some Latin American cities became well established over two centuries, European cities managed it in one and a half, American urban settlements (U.S.) in one century, and Chinese cities completed this process in little over 50 years.

accumulation, to the extent that the real estate sector already represents 217 trillion dollars, or almost 60% of the total value of global assets, including shares, bonds and gold (Savills, 2016). In this context, the historic urban "implosion-explosion" process described by Lefebvre (2003) becomes increasingly relevant in the search and construction of solutions. The implosion of activities, wealth, assets, production media, infrastructure, knowledge and population, along with the explosion of irregular settlements, suburbs, peripheries, dormitory cities, etcetera, with their diverse economic, political, social and environmental implications, becomes increasingly visible and will continue to do so in a business as usual scenario in which urban population will reach 66% of the world total by 2050 (United Nations, 2014). Taking this into account, the U.N.'s Eleventh Sustainable Development Goal (www.un.org/sustainabledevelopment/es/cities/) recognizes cities as the principal sites in which resilience and sustainability can be constructed. Urban settlements play a central role not only to face the ecological and climate crises, but to transform built up space as a whole, both in its biophysical complexity, but also in the function and logic of the socioeconomic, socio-ecological and socio-technical frameworks that support it; all this with the aim of conceiving socially just, viable and resilient human settlements.

This is undoubtedly a reflexive endeavor, and consequently political in that it depends on the context in which the multiple actors involved function, and on their diverse traits, interests, assessments and power quotas. Therefore, in building imaginary scenarios for urban transition-transformation, it is fundamental to establish who defines the agenda and what we mean by transition and transformation: of what, going where, to what end and in favor of whom, within what temporal and spatial scales, how and in exchange for what or in place of what (Meerow and Newell, 2016).

Given these uncertainties and complexity, the imaginary scenarios for transition-transformation could settle upon schemes which (1) are functional according to the existing model of production, (2) advocate important adjustments but do not affect structures, or (3) involve radical transitions and transformations, opening the way for reflection and action affecting structural, functional and relational aspects. Different initiatives take shape in diverse categories, such as: ecocities (Wong and Yuen, 2011), ecopolis (Engwicht, 1992; Downton, 2009), green cities (Campbell, 1996; Simpson and Zimmermann, 2013), resilient cities (Newman *et al.,* 2009; OECD, 2016); intelligent cities (Albino, Berardi and Dangelico, 2015), low carbon cities (Dhakal and Ruth, 2017), cities for good living (*ciudades para el Buen Vivir*; Delgado 2015-A; Cardenas, 2015), all the way to the suggestion of "green urbanism"[2] (Thomson and Newman, 2016)[2], among others.

This broad variety of imaginary scenarios is conducive to considering the concepts of urban sustainability and resilience –and urban transition in itself– as boundary objects from which it may be possible to generate the encounter of visions, actions, and eventually consensuses (Meerow and Newell, 2016; Delgado and Guibrunet, 2017). Of course, such boundary objects need to be assessed and contextualized, taking into account prevailing socioeconomic inequalities (including those involving gender), and all the logics, structures and power discourses which underlie them.

This book, therefore, is embedded in one of the greatest challenges of the twenty first Century: the setting in motion of what we understand as sustainability and resilience, to say nothing of equity and justice. The

2 According to Thomson and Newman (2016), green urbanism is structured within three temporal horizons: 1) *green design,* which improves upon conventional urban development or linear urban metabolism; 2) *sustainable urban development,* which strives for "zero impact"; that is, it views itself as a stationary state; and 3) *regenerative urbanism,* which aims to enable us to repair the biosphere by means of the functioning of a circular urban metabolism.

challenge is that, despite the fact that sustainability and justice –and, more recently, resilience and equity– are gaining presence in academic and political discourses and narratives, they are still general, and consequently vague ideas, because their aim is generally to establish points of agreement among different concrete interpretations emerging from distinct biophysical and sociocultural contexts, but very especially diverse worldviews. However, beyond narratives and discourses, these notions –when they materialize or are translated into policies or localized actions– may be pursuing very different environmental, economic, social, demographic and institutional objectives which, alternately, might reinforce the *statu quo* or stimulate radical transformations.

In such a panorama, despite the recognition that urban development does not meet the more elementary conditions of strong sustainability (Neumayer, 2003), the authors of this book generally agree on the notion of urban sustainability as a boundary object, referring to the dynamic state of a socially desirable operation, which persists over time without transgressing planetary frontiers (Steffen *et al.,* 2016) while it incorporates intra and intergenerational equity, in a context in which multiple natural, physical, economic, political and sociocultural traits of different spaces are taken into account, as well as the multiple forms and languages of valuation present (Delgado and Guibrunet, 2017). Urban resilience blends with this, bearing witness to the necessary ability on the part of urban systems to transform, shift, maintain and return quickly to *desirable functions* (whether they be socio-economic, political, ecological, or others) in the face of disturbances such as those derived from climate change and, more broadly, from global ecological change.

Although both ideas are closely related, they are not synonyms. In fact, an urban system can be resilient, but not necessarily sustainable; furthermore, the very actions which stimulate resilience, like redundancy of subsystems (i.e. water and energy infrastructure, etcetera), can be in contradiction with those that seek greater sustainability in terms, for example, of more efficiency. Nevertheless, and despite tensions existing between urban sustainability and resilience, both can coexist; for example, if resilience is considered as a notion focused on the process of change or transition, while sustainability is more involved with the expected or desired result. Thus, the contributions we present here visualize resilience in the framework of desirable functions of the urban, which in turn leads to the very discussion of sustainability.

Of course, for these visions to become politically significant or, in other words, to become "boundary objects" as places for the coming together of visions, actions, and eventually consensuses, they must revert the trend towards delocalizing the impacts and blurring the responsible actors and those affected, at the same time as they stress the importance of solutions which emerge from "bidirectional governance", a product of a profound recomposition of forces emerging from the constitution of a *social political body* which builds desirable imaginary scenarios both of the function and of the design, planning and production of space. This is a real challenge at local, regional and international levels, especially when taking into account the different realities of developed and developing countries, such as Mexico.

The title of this book, *Climate Change-Sensitive Cities,* refers to a broad range of issues. Naturally, to the biophysical features of climate change and to the growing vulnerability of urban settlements, stemming not only from the increase in population and built up space, but also from the entirety of economic, sociocultural and political variables, spatially and temporarily diverse and distinct. Similarly, it refers to the necessary transition-transformation towards courses of action which are more sustainable, resilient and fair, which is supposed to be the result of a sustained and robust awareness process, both on the part of individuals and institutions, ever more sensitive to the role the urban element plays, for better or for worse. It also refers to advances in the development of capacities, not only for diagnoses, but also for designing and executing actions which are appropriate to the dimension of the challenge we face, which includes a broad range of transversal issues and approaches.

Stressing the fact that the human agency plays and will play a role of growing importance in the future, this book seeks to open a venue for discussion on empirical and regulatory, even on epistemological aspects concerning the human agency as such and its drivers, as well as the "languages of valuation" in play, the visions, expectations and imaginaries of the future, challenges, limitations and opportunities.

In recognizing the shared responsibility for overseeing the planet (the so-called *planetary stewardship*) –by means of the human agency–, all within the planetary frontiers and in a context of important socioeconomic inequalities, it is relevant to broaden the incidence of local, national and international organisms in the adoption of decisions and actions for sustainability, especially in times when science has ceased to be relevant to political activity of governments like, for example, that of the U.S. which chooses to believe in "alternative facts" while setting in motion a profound environmental deregulation.[3]

This submission is, therefore, timely, at a juncture in which regional and local instances acquire a more crucial role *vis à vis* the already mentioned

3 The expression "alternative facts" was used by Kellyanne Conway, council to the sitting president of the U.S., when she justified the statement that the President's inauguration ceremony had had the largest audience in the country's history, notwithstanding photographic evidence to the contrary, in stark contrast with the inauguration of the previous government in 2009. The concern of organized scientists is considerable, not only about the political discourse related to science (i.e. environmental and climate issues), but also about the questionable designations for key posts, such as the Environmental Protection Agency, and the potential cuts in budgets assigned to science and technology, in parallel with important increases in military spending. This has been expressed in several communication media, including journals such as *Science* and *Nature*, as well as with the formation of the 314 Action coalition (www.314action.org). What is not an "alternative fact" is the environmental deregulation achieved in the firsts months of Trump's administration (Davenport, 2017).

withdrawal of the U.S. from the Paris Accord: a country which, to make matters worse, calls for –in words of its Federal Government– the "clean and efficient use of fossil fuels, and the chief of the U.S. Environmental Protection Agency (EPA), Scott Pruitt, advocated ending the regulatory assault which has declared war on this country's economy (Davenport, 2017).[4] Facing this situation, and the undoing, delay, or blocking of more than 30 environmental laws –a regulatory rollback never seen before in the 47 years of EPA's history– it is expected that state and local governments will become the only governmental actors in this country who will be able to exercise some sort of counterbalance to the dynamics of the Federal Government, including actions which could water down the *Clean Power Plan* and, in general, federal research and technological development related to the efficiency and decarbonization of the American economy; in the previous administration, this effort had concentrated on a reduction of GHG emissions by 2025 of 26 to 28% below the levels registered in 2005.

This situation is undoubtedly relevant, both for the planet and for Mexico, particularly in the border zone where, in many cases, joint efforts are not only desirable but necessary too. Nevertheless, on a regional scale, without dynamic action on the part of government actors and others, these efforts could be undermined easily.

The mitigation potential on an urban scale, and the need to set in place appropriate adaptation measures, have been analyzed in the Fifth Report

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4 Concerning schemes to capture and stockpile carbon, it is worth mentioning that Robert E. Murray, CEO of Murray Energy, the largest coal mining company in the U.S., considers them a fantasy while they are not practical nor economically viable (Romm, 2017). This statement was made days after the U.S. Federal Government cut the research budget in this field, and not long after the shutting down of the leading carbon capture project, the Kemper plant of the Southern Company in the state of Mississippi which, after an investment of 7.5 billion U$S, decided to forego coal and convert to gas (*Ibid*).

by IPCC, as well as by other influential international actors, like the C40 (a network of 40 cities committed to reducing carbon emissions and adaptation to climate change), which estimates that cities can contribute as much as 40% of the reductions necessary to reach the goal established in the Paris Accord (C40, 2016)[5]. Part of this potential can be found in the structuring of non-conventional planning, capable of overcoming the traditional silos of design and execution of urban policy which, simultaneously, requires a systemic and territorially based approach. This sort of approach –intrinsically interdisciplinary– is increasingly requested in the specialized literature as it figures as endeavors to reveal the links existing between, for example, water and energy, land use and climate change, among other "urban nexuses". This potential is precisely what we are trying to shore up in the immediate future, but there is more; there are other actions and synergies that would emerge from compliance with the SDGs (UN Sustainable Development Goals) (www.un.org/sustainabledevelopment) and the implementation of the New Urban Agenda (http://nua.unhabitat.org). All this implies that the urban transition-transformation towards more resilient, sustainable, inclusive and low carbon modes, requires a multidimensional, multilevel and multitemporal effort by the largest possible number of actors.

Contextualizing the book

We focus on Mexico, including bi-national comparative readings between Mexico and the U.S. Mexico is considered vulnerable because 15% of its territory, containing 68% of its population and 71% of its GNP, are exposed to

5 The estimation assumes all cities with a population greater than 100,000 inhabitants will carry out all the actions proposed in the C40 report (C40, 2016). The report proposes 410 possible actions grouped in 62 programs which cover five sectors: energy, buildings, transport, waste and urban planning.

adverse effects of climate change. Out of a total of 2,457 municipalities, it is estimated that 824 municipalities, with a population of 61 million inhabitants, are exposed to flooding; 283 municipalities, with 4 million inhabitants, are at risk of landslides; 1,292 municipalities, with 54 million inhabitants are prone to agricultural drought; 585 municipalities, with 29 million inhabitants could suffer reductions in rainfall; 545 municipalities, with 27 million inhabitants, may experience a loss in agricultural productivity due to temperature fluctuations; 1,020 municipalities, with 43 million inhabitants, are exposed to more and more frequent heat waves; and 475 municipalities, with 15 million inhabitants, could become victims of infectious vectors, particularly of tropical diseases.

This is a consequence of several causes. The country is exposed to climatic events on both coasts (Atlantic and Pacific, including phenomena such as *El Niño* and *La Niña*); its economy, considered in the "developing" class, is weak and to a considerable extent informal, which results in that the majority of the population live in poverty or extreme poverty, and are, in consequence, even more vulnerable. Furthermore, given that the country is highly urbanized, with nearly 80% of its population living in cities, the majority of this population is dependent on local, regional or international flows of energy and materials, such as food, that are imported from Mexican agricultural regions or from abroad. While imports of food from abroad are growing, including corn and beans, which are the staple foods in this country[6], national production lacks the necessary support, and its productivity is increasingly affected because a

6 Between 1991 and 2011, yearly imports of corn rose from 1.4 million to 9.4 million tons, of which 8.4 million tons came from the U.S., and these figures have continued growing in recent years. In the same period, imports of dried beans rose from 30,000 tons to 106 thousand tons, of which 96 thousand came from the U.S. The increase in food dependence, measured as the proportion of foreign, as compared with domestic supply, in terms of total consumption, went from 8.4% in 1991 to 33.3% in 2011 in the case of corn, and from 0% to 36.5% in the case of

considerable portion of it is rain fed. This is a situation which, in a context of climate change, may increase the country's vulnerability in terms of food security and sovereignty (Delgado, 2013).

Furthermore, Mexico's infrastructure is limited, partly expired or close to the end of its useful life, a situation that is not made easier by the fact that the country is highly dependent on imported technology, from that which is involved in renewable energy, all the way to machine tools, electric and medical equipment, medicines, etc. Any attempt at a transition towards more sustainable and resilient approaches could find itself hamstrung by difficulties in endogenous development of science and technology, but also due to limited access to transfers of technology and know-how (Delgado, 2016). To all this we must add a whole array of limitations, covering from the financial aspect to the restricted autonomous capacities of a developing country, which range from governance, transparency and accountability, to research in climate change, particularly in modelling and prediction capacity on a local-regional scale, which constrains but doesn't necessarily thwart the capacity for effective planning, including the prevention and management of disasters[7].

Other limitations are related to research into sources of pollution, propagation of infectious vectors and preventive measures, among others, like gender aspects, or education for sustainability initiatives, including education for climate change which is still very weak. For these reasons, and given

beans (based on information from FAOSTAT).

7 In Mexico, the capacity to plan, monitor and on occasion provide an early alert and coordinate preparations to face disasters which result from the correlation between natural and dangerous phenomena with determined socioeconomic and physically vulnerable conditions (Romero and Maskrey, 1993), is still in its early stages (Aragon, 2016), all this in a context of lack of financing and restricted consolidation (Aragon, 2016). Besides, there are a series of inequalities, like those associated with gender, that are not usually taken into account. At least, not in any effective way.

the great sociocultural differences in the country, the need is palpable for a concentrated effort to achieve a successful, multicultural and multilingual education and communication, including the main indigenous languages, as speakers of these languages are usually poor and highly vulnerable. In addition, and to complicate matters, those indigenous communities possess many of the most bio-diverse territories in the country under a social property regimen. This trait must be understood as an advantage in the context of seeking the implementation of novel schemes of hybrid governance; that is, one that integrates vertical (top-down and bottom-up) and horizontal (between different relevant issues) approaches to governance by means of the coproduction of knowledge and integral decision-making, to the purpose of advancing towards more sustainable, resilient and just human settlements (Delgado, 2015B; Delgado and Guibrunet, 2017). This overview takes into account those urban settlements in the country where social property and, above all, community management practices that assume the existence of cooperation networks for planning, prevention and action, still exist.

Thus, it is in this complex and diverse context that we must seek ways to advance in the commitments pledged by Mexico within the framework of the Paris Accord, where a national contribution was proposed for the reduction of 50% of GHG emissions by 2050 from a 2000 baseline. Of this general figure, 25% of the reduction of GHG and short life polluting emissions was established unconditionally for 2030, with up to an additional 15% conditioned to international aid, for a total of up to 40% GHG reductions.

To achieve this, several assumptions must be met: the application of environmental protection and climate change adaptation regulations in planning, designing, constructing, operating and even for the abandonment of [certain] tourist installations in coastal ecosystems; the sustainable management of urban water (savings, recycling, rain harvesting), plus other unspecified actions which can be inferred from generic mentions of actions such as efficient use of energy in industry and transport, and the management of waste. Apart from other mitigation measures linked to adaptation, the improvement of our capacity to adapt and the reduction of vulnerability by means of tools for territorial planning and risk management (National Vulnerability Atlas and National Risk Atlas) have also been proposed; the convenience of inverting the expense ratio between reaction to disasters and prevention of disasters, to give more weight to the latter has been examined; further measures include: guarantee the safety of dams and hydraulic infrastructure; protect at least 50% of the municipalities catalogued as most vulnerable to climate change; relocate irregular settlements from disaster-prone areas by means of regulating the use of land, and relocate vulnerable infrastructure in tourist zones; increase resilience of strategic infrastructure (including technologies to make transport infrastructure more resilient, and to protect coastal and riverside infrastructure); reinforce early alert systems; ensure both water supply and urban and industrial water treatment to guarantee sufficient quantity and quality in urban settlements with more than 500,000 inhabitants, among other actions.

It is, then, an overall picture in which the urban factor is clearly central. Nevertheless, given the generic character which so far infuses the greater part of our national commitments to the Framework Convention, the concrete part of these good intentions is still to be seen, not only in political discourse, but also in the actual work which includes diagnoses and construction of local scale propositions where territorialities in a broader sense (biophysical, sociocultural, political and economic), are intrinsically heterogeneous all over the country.

In this vein, situational and propositional analyses become pertinent and necessary. *Climate Change-Sensitive Cities* seeks, from the point of departure of collective reflection, to approach this issue, including the complex border dynamics which demand a bi-national endeavor which, in practical terms, has become more difficult since the already mentioned withdrawal of the U.S. from international efforts to deal with climate change. Given this, and considering that local/regional actions can provide a sort of counterbalance to this undesirable situation in which the U.S. Federal Government supports the continuance of an energy matrix based on fossil fuels (with projections of exporting crude in greater quantities than most OPEC countries today by 2020, that is, an estimate of 2.25 million barrels daily; Mayer, 2017), along with a relatively lax environmental regulation, contributing authors from both sides of the border explore and analyze cases in Mexico and the U.S. with the aim of revealing, by means of comparative analysis, the advances, challenges and contradictions existing in urban transition-transformation.

The collection of works, although far from representing a comprehensive and rounded review, seeks to advocate the necessary continuity of an analysis on different spatial and temporal scales, always keeping in mind the diversity and complexity of the urban challenge; it follows that the analysis should be holistic, interdisciplinary and integrated, approaching issues that range from land use, management and prevention of disasters, water governance and the advancement of so-called green infrastructure, to financial matters, gender issues, and education for climate change initiatives. The motivation of the chapters is, on the one hand, to take on some of the principal challenges and resistances against the paradigm shift taking place in urban management, and on the other, explore the possible paths of transition-transformation towards more sustainable, resilient, inclusive and fair settlements.

Structure of the book

In the first part, the contributors reflect on the sensitiveness toward the generation of a multifactorial environment of risks, which is accentuated by climate change and urban expansion.

Noting the close links between social, economic and environmental factors, and the reduction of urban vulnerability in Mexico *vis a vis* extreme hydrometeorological phenomena, Angles calls for the adoption of integrated policies based on land management, to proceed from there to approach the integral management of risks from a perspective that incorporates environmental and land use regulation. With this in mind, the author describes the existence or non-existence of instruments for the integral management of risks, specifically conceived to reduce the vulnerability of cities in the face of climate change. She dedicates special attention to three issues: environmental regulation, the Atlas of Risks, and land use regulation which, she considers, are fundamental for reducing vulnerability and strengthening the transition towards inclusive, participative, safe, sustainable and resilient cities.

In a similar vein, Escandon reviews the same case study, Mexico City, emphasizing the need to undertake a systemic and interdisciplinary study on the link between climate change, international cooperation and local policies, to achieve a better construction of the problem and its possible solutions. To this end, the author focuses on the issue of land use regulation as a means for reducing the causes of climate change and the impacts of environmental transformation under way; he does this by studying conservation sites as hybrid entities, that is to say, entities with a material dimension and other representational dimensions in which different actors participate in their production. In his analysis, while suggesting that in the present climate change policy, particularly Mexico City's *Climate Change Action Program 2014-2020*, he observes what he calls an "asymmetric ignorance" as it generalizes contexts that are very dynamic from environmental, social, cultural and economic points of view, Escandon proposes instead a hybrid form of governance.

In the second part, contributors approach the links between adaptation and water management from an integral point of view, identifying challenges and opportunities in urban governance which not only exceed sectorial outlooks but impact the urban in a broad sense, generating synergies and co-benefits in matters that range from urban health to land use planning, design of built up space, and growth of green areas.

In this line of thinking, Jimenez *et al* apply technical arguments and a multidisciplinary outlook to reveal how Mexico City could be affected by climate change as a consequence of changes in the quality of water. Warning that Mexico City's climate action plan should broaden its water-related objectives to include risks associated with the quality of the liquid (apart from leak control, conservation and development of infrastructure), the authors analyze three issues: (1) the impact of extreme hydro-meteorological events on the quality of water, in this case the Xochimilco aquifer; (2) the effect of increasing temperatures on the decontamination capacity of water sources, for which they examine the case of the Magdalena river; and (3) the assessment of the vulnerability of the population to waterborne diseases in a climate changing context, and the relationship between the quality of water and acute diarrheal illnesses. As a result, the chapter enumerates the principal challenges and potential adaptation and mitigation measures for the different study cases and actors involved, as well as the limitations or information gaps that hamper assessment and decision making.

In a further chapter, Ruiz analyzes adaptation to climate change and urban water management in an environment of natural hydric abundance, as is the state of Chiapas. In her critique of the technocratic and depoliticized visions of water management, the author reviews the dominant paradigm of water management in dialogue with the leading vision of climate change adaptation.

She argues, on the one hand, for the need to take into consideration local dynamics which affect urbanization processes in order to be able to design climate policies more suited to local contexts and, on the other, that future climate change adaptation strategies should incorporate the political dimension of the water resource, as well as its subjective dimension, thus to be able to strengthen its effectiveness and reduce social conflicts over water.

Zuñiga examines the case of arid and semiarid zones, giving an account of potential urban adaptation strategies in the face of climate change, on the base of the development of green infrastructure in walkable neighborhoods, as a way to both reduce vulnerability, and strengthen urban hydric safety. Green infrastructure is advocated by the author as an alternative to traditional "grey infrastructure" for the management of storm water, arguing that it reduces damages to both socioeconomic and ecological systems. Furthermore, she views it as an opportunity to redesign urban space, making it walkable, green and inclusive. The proposition of green infrastructure for arid zones is undoubtedly important, because climate change, in general, will worsen droughts and extreme storms, thus adding its contribution to the heat island effect, with its implications for human health plus, in coastal cities, the added problem of the increase in sea level. Zuñiga underpins her analysis with examples of experiences in Los Angeles, California, and Scottsdale, Arizona, in the U.S., and Hermosillo, Sonora, in Mexico.

In the third part, both contributions review the multiple factors that render cities sensitive to the access, management, consumption and waste of energy and materials in a climate change context.

Specifically, these two chapters focus on water, energy, land use, and existing synergies.

The work of Muñoz *et al* examines the links between water and energy in the case of coastal cities in the semiarid region of California and Baja California which, on the one hand, share hydric resources already under pressure and, on the other, they commercialize electricity. The aim of the authors is to define the links between water and energy as interdependent and shared resources in that coastal region between Mexico and the U.S. They advocate an integral reading, including such cross-cutting factors as social, economic, environmental, political and physical aspects. From there, the comparative analysis they propose describes the characteristics of the water and energy sectors in both states, existing regulations, potential regional impacts of both sectors under study, the relevant factors which could affect the links between them, and some alternative management options which could improve energy efficiency and enable the diversification of alternative sources of water (including bi-national cooperation schemes).

Delgado and Blanco, in recognizing the modern hydro-social cycle that is characteristic of contemporary cities, including their economic, political and socio-environmental implications, reflect upon the existing transformation of the management and infrastructure of water in a context of climate change. To do so, the authors present a comparative analysis of two megacities: Los Angeles and Mexico City. Apart from reviewing general features and presenting the urban hydric metabolism of both case studies, the chapter explores –from the point of view of a critical notion of urban water governance– the present and expected challenges in both mega urbanizations to the process of guaranteeing the human right to water and reaching the 6th Sustainable Development Goal (which proposes to achieve universal access to clean water and sanitation). The comparative analysis provided enables the authors to perceive similarities and asymmetries in the more complex technical, technological, ecological, sociocultural, political, institutional and financial challenges –present and predictable– from a holistic perspective which endeavors to create a picture of the "water nexus", including the relationships between water-energy-carbon, and water-land use.

The fourth part of the book approaches a group of subjects that have been termed in the literature as "cross-cutting" such as risk management and disaster prevention, land use planning, management and renovation of infrastructure, and others like financing, gender issues, and education. These are matters that are far from being of secondary importance. They can turn the policies and actions of a climate change-sensitive city into successful and long-lasting experiences, or indefensible disasters, with implications over multiple time scales.

In the reflection on the so-called "green financing" for cities, or the necessary financing to make cities "sustainable, resilient and intelligent", Ivanova provides a broad exploration of the present situation of urban infrastructure and its necessary renovation, as well as some of the existing financial options, some ways to improve existing mechanisms, and future challenges. Specifically, intergovernmental transfers are reviewed –loans, public-private partnerships, and international aid– revealing that there are no firm rules on which is the best way to govern and administer finances; political options are established in terms of a set of advantages and detriments, which imply important costs and benefits. The reading here is from an international point of view.

De Luca and Gay Antaki approach the issue of gender and climate change examining the case of Mexico City, underlining the dearth of studies on this issue in an urban context. Their work is an important testimony on an unequal city, in which women are among the less favored actors. It is the city, the authors claim, where spatial fragmentation which segregates and excludes women, can be clearly observed, frequently hampering their mobility, and their social, political and economic participation. The objective of this chapter is to reveal this situation in a context of vulnerability in the face of climate change, and to open new venues for participation and change. Keeping this in mind, the authors review the present state of public policies regarding gender and environment in Mexico City, as well as a specific program called "Mujer Huerto" (orchard woman). They conclude, among other contributions, that the point of view of gender requires an exercise in reflection in which gender becomes an analytical category which enables the redesign of policies and actions (or programs) in such a way that, apart from advancing towards sustainability, they should also promote a genuine empowerment of women. In this sense, urban climate policies would have to consider all the complexity associated with the gender issue, including gaps in the generation of information and knowledge, with the aim of preventing the growth of existing asymmetries and, better still, closing the remaining gap.

Finally, Vazquez advocates the need of education on climate change, as a catalyst for acquiring new knowledge and abilities to mobilize responsible actions and achieve significant behavioral changes, on the base of informed decisions that contribute to strengthen resilience in people facing the risks related to climate change which, simultaneously, encourages participation and commitment. Providing follow-up for one of the objectives stated in the Mexican Climate Change General Law, which decrees promotion of education and dissemination of culture in matters concerning climate change, the author provides an empirical review of the state of the situation in Mexico, reviewing educational measures proposed in a set of climatic action plans in Mexican urban municipalities. The author winds up with a warning that, for education on climate change to have real transforming effects, it is necessary to go beyond the mere provision of information, and, additionally stimulate relational, integrating, empathic, anticipatory and systematic reflection.

The body of work we present in this book seeks to encourage the increasingly necessary reflection on the urban transition-transformation. As we said before, it is not a comprehensive review, but a collective contribution by academics and expert advisors operating within and without decision-making spaces, both in government and in other spheres. We hope this effort will be useful for the coproduction of imaginaries, planning and actions capable of supplying more sustainable, resilient, just and fair urban spaces.

As a group, we hope to continue contributing, in this way and in others, seeking a continuity of our analysis and reflections about the implications of climate change and environmental deterioration, especially on the urban scale.

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I. Cities sensitive to climate change associated risks

Chapter 1

An approach to integral risk management associated with climate change in Mexican cities

Marisol Angles Hernandez

Introduction

According to the Intergovernmental Panel on Climate Change's report (IPCC, 2013), the warming of the climate system is unequivocal, and it has been worsening since the Fifties due to an increase in the concentrations of anthropogenic greenhouse gases (GHG)[1]; which has provoked, among other things, the warming of the atmosphere and oceans, the decrease in volumes of snow and ice, and a rise in sea level. Hence, climate change, understood as climate variations due directly or indirectly to human activity that disrupts the composition of the atmosphere and which adds to the natural variability of climate observed over comparable periods of time, constitutes a threat to ecosystems, society and economic development (Peña and Neyra, 1998). This provides ample cause for the emergence of a comprehensive risk management strategy as a central issue in cities, whose expansion is driven by capitalist modernization, always in need of more space for its consolidation; in many cases, with complete disregard for climate or environment.

On the one hand, formally established real estate developments fostered by

1 The main greenhouse gases are: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), ozone (O_3) and chlorofluorocarbons (CFC); these gases, in the atmosphere, absorb and emit infrared radiation.

neoliberal governance and guided by the logic of commodification (Lefebvre, 1983) and speculation, require State support. Land use modifications and natural capital destruction, to the detriment of supporting services of innumerable ecological functions vital to sustainable urban development, are "justified" by the generation of jobs and new sources of investment; in addition to the possibility of increasing availability of housing.

To this we must add irregular human settlements, generally established in peripheral areas that degrade the environment and, paradoxically, because of these conditions and due to the lack of basic public services, increase their vulnerability[2] to climate change (UNDP, 2011: 6). This situation increases the probability of disasters occurring. It is noteworthy that what turns a natural event into a disaster is the degree of vulnerability; in other words, to what extent a geographic area, a community or a structure is able to cope with the negative effects of the event to which it is exposed (UN-Habitat, 2012: 124). At present, approximately 70% of disasters are related to climate, a percentage that has doubled over the last 20 years (UN, 2013).

Due to the close relationship between social, economic and environmental aspects, and to the reduction of vulnerability to extreme hydrometeorological phenomena, governments should adopt comprehensive policies based on land management, both from an ecological and urban[3] perspective, which is

2 Vulnerability: State of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt. (Adger, 2006: 268).

3 Within the framework of the UN-Habitat Program, in July 2016 Mexico included the following towns in the Resilient Cities Network: Ensenada, La Paz, Ciudad del Carmen, Tapachula, Ciudad Juarez, Saltillo, Manzanillo, Durango, Aculco, Leon, Acapulco, Puerto Vallarta, Guadalajara, Tepic, Monterrey, Atlixco, Solidaridad and Mazatlan. It is worth mentioning that the Resilience Strategy for Mexico City states that "a crucial issue is the inclusion of information from the Risks and Dangers Atlas, to strengthen urban planning in relation to risks and tensions that the city faces ". In a similar vein, it adds: "In the CDMX (Mexico City), the greater urban expansion has occurred in the Soil Conservation Zone, exerting pressure on

congruent with the new United Nations Agenda for Sustainable Development, whose goal number 11 is to ensure that cities and human settlements are inclusive, safe, sustainable and resilient (www.un.org/sustainabledevelopment/sustainable-development-goals).

From this perspective, this paper highlights the need to address comprehensive risk management from a perspective involving ecological and territorial management, based on the identification of risks undertaken by the respective risk atlases. All this is necessary to provide some elements of articulation that may contribute to reduce the vulnerability of Mexican cities, considering that urban development policies in the country lack the technical support contained in the risk atlases and, in many cases, the risk atlases themselves are non-existent. This contributes to the social construction of risk, which is exacerbated by the effects of climate change.

To that end, we rely on the descriptive method as to the gathering, integration and evaluation of data about the existence, or absence, of the proposed comprehensive risk management tools, which are fundamental for the decision-making process concerning urban development. Undoubtedly, this is an exploratory approach that highlights the lack of public policy instruments, and the absence of their systematization if they do exist. Although there are enough studies on urban planning in Mexico, there are few contributions that integrate into their analysis the components that we propose as means to reduce the cities' vulnerability to climate change.

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the environmental services that this area provides". In this context, SEDUVI (Mexico City Department of Urban Development and Housing) collaborates with SEDEMA (Mexico City Department for the Environment) to integrate policies to protect the Soil Conservation Area and its environmental services in the new General Program for the Urban Development of the CDMX, in order to standardize them with those of the ecological order. However, the POEL dates back to the year 2000 and the referred atlas is non-existent (SEDEMA, 2016).

Climate vulnerabilities in mexican cities

When referring to the composition of climate risk in cities, that is, to the probability of sustaining losses at a specific location at any given time, it is necessary to consider a function that includes climate-related threats (intense rains, droughts and winds), the cities' vulnerability (livelihoods, infrastructure, public services, sustainability and governance systems), as well as their exposure to climate threats (adaptation of UN, 2004).

Consequently, we understand that urban vulnerability in relation to climate change implies cities' tendency or susceptibility to suffer damages and losses when they are impacted by extreme climatic events, as well as their ability to recover on their own. While climate events are not controllable, vulnerability can be managed; therefore, it is vital to work on its reduction, particularly when we are facing anarchic and unsustainable urbanization schemes. Such is the case of many Mexican cities, where the process of urbanization which started in the '50s, responded, as in other parts of the world, to the social division of labor. Industrial activities required important concentrations of population which, in return, demanded goods and utilities, unleashing the excessive growth of cities, especially in suburban areas lacking public services and infrastructure.

In the '80s, Mexico was already a predominantly urban country. By the year 2000 there were 343 cities with more than 15 thousand inhabitants, which housed 63.3% of the national population. in 2010 the number of such cities reached 384, with 71.6% of the total population of the country (PNDU, 2014-2018) and it is expected that by 2050 the urban population in Mexico will reach 82.6% of the total (ECLAC, 2016). However, we must consider the situation of irregular settlements in our country, which responds, fundamentally, to the lack of territorial planning and to the absence of a cautious approach to comprehensive risk management. On the other hand, the concentration of job opportunities in large cities is a further contributing factor, to which we must add the provision of services such as education, finance, recreation, etc. All this is required by people whose demand for housing and services is covered by two routes: 1) middle and high-income households, that are commonly catered to by urban developers and lending institutions which have concentrated their efforts on the provision of confined buildings that operate as a closed cell, totally separate from its regional environment, from which it voraciously extracts the inputs that sustain it, and excretes, as in a metabolic process, all kinds of waste (Wolman, 1965; Delgado *et al.*, 2012); and 2) low-income households which, in the absence of accessible housing and loans, have to settle on unsuitable land which may involve risk areas, thus incentivating the construction of excluded and marginalized spaces that increase social inequalities, vulnerability and other factors associated with poverty.

This is why Vilhena (2011) argues that in these contexts, law and rights may be seen as a mere farce, a power struggle between the fortunate few who negotiate the terms and conditions for those excluded. In Mexico, the so called "excluded" are increasing; from the year 2012 to 2014, the number of people in poverty increased from 53.3 to 55.3 million; from which 69.2% of them lived in urban areas (CONEVAL, 2015), breaking the historic pattern according to which the poorest people lived in rural areas. In addition, of the 31,374,724 housing units existing in 2014 (INEGI, 2015), 11% were located near or over a river bed; 2.3% were built on landfills, caves or mines and 9% next to slopes (PNDU, 2014-2018), thus compromising the safety of these people and, at the same time, affecting the conservation of ecosystems and increasing climate change vulnerability.

This becomes even more complex if we take into account that by the year 2015, 9 out of every 10 disasters in Mexico were related to extreme hydrometeorological phenomena. From which, 44% of the impact was due to heavy rains, 28.4% to tropical cyclones and 18.4% to floods (SEGOB, 2015).

In 2016, the damages and losses caused by natural disasters were estimated at 11,947.9 million pesos (639 million dollars).[4] The most destructive disaster was originated by Tropical Storm Earl, in the state of Puebla, due to torrential rains; which inflicted damages worth 2,092 million pesos (Garcia *et al.*, 2016).

Given the evidence available, a more adequate use of land in combination with natural resources preservation becomes unavoidable; because natural resources contribute to mitigating the negative effects of climate change, risk of floods and landslides and, among others, serve as a natural barrier against extreme hydrometeorological events. On the contrary, practices such as deforestation, overexploitation of natural resources and inadequate urbanization increase the risk of disasters (UN-Habitat, 2012: 126).

Facing this reality, it is imperative to work toward the establishment of more inclusive, participatory, safe, sustainable and resilient cities (Angles, 2015). This implies reducing the vulnerability of human settlements from the ecological and climate perspectives. Especially those where people live in precarious conditions,[5] since after a disaster, the degree of poverty increases and the welfare and human development of the affected population regresses (ISDR, 2009).

Three-prongued proposal for comprehensive climate risk management in cities

Although vulnerability intertwines with many other features, for the purposes

4 At the average exchange rate of 18.69 pesos per dollar in 2016.

5 In Mexico, the multidimensional poverty index considers the following elements: income, educational backwardness, access to health services and social security, basic spaces and services in the home, nutritious and quality food, social cohesion and access to paved roads. (LGDS, 2013).

of this work we focus only on three of them: ecological regulation, risk atlases and territorial planning. Those three were chosen because they have a direct impact on the comprehensive risk management of any given human settlement. Hence, they are crucial to reduce cities' vulnerability while strengthening their climate change resilience.

According to the (Federal) *Ley General de Protección Civil* (Civil Protection General Law), comprehensive risk management consists of a set of actions aimed at the identification, analysis, evaluation, control and reduction of risks, considering them according to their multifactorial origin. It should be embedded in a continuous development environment involving the three levels of government (Federation, States and Municipalities), as well as civilian society, in order to facilitate the implementation of actions aimed at the creation and execution of public policies, strategies and procedures integrated into the achievement of sustainable development guidelines, addressing the structural causes of disasters and strengthening society's resilience (Article 2, XXXVIII, LGPC). Correspondingly, resilience is understood as "the capacity of a socio-ecological system subject to some kind of stress (in the most basic sense of the term) or to a profound change —which is not necessarily negative— to regenerate itself without substantially altering its form and functions, hence accomplishing some sort of creative conservation" (Escalera and Ruiz, 2011: 111). Thus, resilience transforms the analytical perspective, and allows it to move from simple causal models to more complex systems with non-linear relationships, building on the scalar dimension between time and space (Davidson-Hunt and Berkes, 2003: 76).

Under this premise, territorial planning, both ecological and urban, must be integrated and articulated through horizontal processes within a framework of participatory democracy in order to serve as an axis for environmental protection planning. Otherwise, by continuing with the current unsustainable development model, we will contribute to the social construction of disaster risk related to climate change; as a result, national development will be compromised in the medium and long-term; and it will undermine the exercise of multiple human rights, including the right to a healthy environment, safe housing and the dignity of those who live in cities.

This approach is based on a comprehensive view that conceives the environment as a systemic whole rather than a set of isolated components; this is an essential mindset which should guide political-administrative organization and sustainable territorial planning of human settlements at national, state, regional and local level in harmony with economic development.

However, because the climate change threats that Mexico is facing will increase in frequency and intensity, it's urgent to develop and implement some adaptation measures which will enable the country to reduce its vulnerability through an articulated, strategically planned, dynamic and interactive framework (CICC, 2009). That includes the development of ecological regulations, risk atlases and territorial planning programs based on the importance of land use and the protection of natural resources (INE, 2006) in order to ensure the rational and sustainable use of space and those same natural resources.

In this line of reasoning, the *programa de ordenamiento ecológico local –POEL* (local ecological management program) is an environmental policy instrument aimed at regulating and inducing land use and productive activities, in order to achieve environmental protection as well as the preservation and sustainable use of natural resources. It is based on the analysis of deterioration trends and the potential for their use. Therefore, the *Ley General de Equilibrio Ecológico y Protección al Ambiente –LGEEPA* (General Law for Ecological Equilibrium and Protection of the Environment) considers POEL as a basic instrument to be incorporated into national development planning (Article 3, XXIV, LGEEPA). However, by 2016 only 79 of the 2,456 municipalities in the country (barely 3.2%), had decreed a POEL (INEGI, 2010; SEMARNAT, 2016); their absence can encourage the expansion of cities in areas of high environmental value, which implies the destruction of ecosystems (Topalov, 1979), which sometimes include public assets or protected natural areas.

At the same time, the risk atlas is a documentary and technological system at the municipal level that integrates information of probable damages or losses on an affected agent, resulting from the interaction between its vulnerability and the presence of a disturbing agent to which the community and its environment are all exposed. Thereby, it serves to guide the development of human settlements toward physically suitable areas and, when needed, to establish adaptation or risk mitigation measures necessary to ensure that Municipalities are safe, sustainable and resilient spaces (SEDESOL, 2012). In this context, it makes sense for the *Ley General de Cambio Climático – LGCC* (General Law on Climate Change) to mandate the implementation of adaptation measures throughout many channels such as: comprehensive risk management; ecological territorial planning; determination of the natural use of the soil; protection of wetlands and arid zones; development of risk atlases and programs on human settlements and urban development (Articles 28 and 29, LGCC).

Finally, to speak of territorial planning from a sustainability perspective refers us to Article 27, third paragraph, of the Federal Constitution, which empowers the Nation to impose, at any given time, modes of use of private property that best serve the public interest, as well as to regulate, on behalf of social benefit, the use of any natural element susceptible of appropriation, in order to, among other things, ensure its preservation, achieve a sustainable development and improve the living conditions of the rural and urban population. Accordingly, a set of required measures to organize human settlements and establish adequate provisions, uses, reserves and suitable purposes for any land, waterbody and forests will be implemented, in order to carry out public works according to plans and regulate the foundation, conservation, improvement and growth of population centers. It is also necessary to preserve and restore the ecological balance and to avoid the destruction of natural elements and damages that property may suffer to the detriment of society.

Accordingly, the *Programa Sectorial de Desarrollo Agrario, Territorial y Urbano,* 2013-2018 (Sectoral Program for the Development of Land, Territorial and Urban Development) (PSDATU, 2013) developed a strategy to strengthen risk prevention and disaster mitigation, from which a line of action derives aiming to incorporate comprehensive risk management in the planning and programming for the territory's development and its territorial planning.

As a starting point, the *Instituto Nacional de Ecología y Cambio Climático* (National Institute for Ecology and Climate Change) integrated several studies in order to determine which municipalities were the most vulnerable to climate change; they identified 480, which stands for 20% of the National total (INECC, 2016). In 2014, reacting to new evidence, the *Secretaría de Desarrollo Agrario, Territorial y Urbano –SEDATU* (Ministry of Agrarian, Territorial and Urban Development) created the program: *Reubicación de la Población en Zonas de Riesgo* (Relocating Population from High-Risk Areas) as a means to establish some guidelines for a planning that supports the development of ecological management programs and studies that, in return, would determine the feasibility of relocating populations living in areas at risk. By the following year this program changed its name to *Programa de Ordenamiento Territorial y Esquemas de Reubicación de la Población en Zonas de Riesgo* (Territorial Planning Program and Schemes for the Relocation of the Population Living in High-Risk Areas); and by 2016 the *Programa de*

Prevención de Riesgos (Risk Prevention Program) was created to strengthen and promote planning, prevention and adequate occupation of the territory, with the main objective of reducing the vulnerability of human settlements.

In addition to this, efforts have been made to finance the elaboration or updating, as the case may be, of the risk atlases of 975 municipalities, as well as the territorial jurisdictions in Mexico City, which are part of the *Sistema Urbano Nacional* (National Urban System), and which have been rated with a high and/or very high risk of exposure to natural disasters (SEDATU, 2016).

This situation is critical because, according to data from the *Centro Nacional de Prevencion de Desastres* (National Center for Disaster Prevention), only 327 municipal risk atlases that were developed with support from SEDATU are integrated into the *Atlas Nacional de Riesgos* (National Risks Atlas) (SEGOB, 2017); to which 239 municipal risk atlases elaborated within the framework of the state civil protection systems should be added, thus accounting for 566 instruments (23% of the total municipalities of the country), highlighting a lag in the elaboration and, therefore, use of these preventive instruments.

In line with this, the *Estrategia Nacional de Cambio Climático – ENCC*, (National Climate Change Strategy), published in 2013 by the Federal government, establishes some medium to long-term strategic adaptation axes aiming to reduce vulnerability and increase resilience of a social sector threatened by climate change. among its main lines of action it is worth mentioning: a) to strengthen the identification and attention of priority areas for vulnerability reduction, and to enhance resilience of human settlements; b) To improve the application of land use regulation in order to reduce or even eliminate irregular settlements located in areas at risk of natural disasters; c) To ensure the environmental protection of ecosystems facing public works projects or any other industrial and services activities, incorporating climate change criteria into the planning instruments, such as environmental impact and ecological territorial planning (SEMARNAT, 2013-A).

In addition, Objective 1 of the *Programa Especial de Cambio Climático* 2014-2018 (Special Climate Change Program) urges authorities to establish strategies that inhibit urbanization of those areas with high-risk potential (SEMARNAT, 2014); for which a risks atlas will be necessary as a means of identifying such areas.

Although adaptation actions require the commitment of authorities in all three levels of government –Federal, State and Municipal– it is at this last level where they make the most sense, as it is here where threats materialize and the first actions of response and resilience are implemented.

According to this logic, it is very important that municipal authorities should issue and enforce local ecological planning programs, risk atlases and urban planning, as well as monitoring and controling the land uses established in them (Article 8, LGEEPA). These instruments are decisive for the protection of natural resources and critical areas of high environmental value; hence, they're fundamental for the design and implementation of policies and actions conceived to address climate change, manage risk and enhance urban resilience.

Consistent with this, whenever a building license, land use modification or any other permit regarding the use of land is granted, it should be adjusted to comply with the regulated planning and prevention tools (Risk Atlas, Ecological Planning Programs and Urban Programs) as part of comprehensive risk management in the cities.

As noted, the social construction of risk has an important institutional component in which the State stands as an accomplice to the practices that generate it by neglecting the exercise of its authority in matters of ecological management, risk management and territorial planning. On one hand, the State fails to issue the proper tools; on the other, if those tools actually exist, the State could disregard its obligations concerning monitoring, inspection and compliance control. All of which calls into question the viability of sustainable and inclusive urban development. As we have seen, cities are built amid the exercise of many collective rights that rely on environmental conditions. This requires us to take measures to prevent pollution, disorderly occupation, and to protect environmental areas, as well as to recover high-environmental value zones and to expand green spaces in order to generate physical, biogeochemical (Crutzen, 2002), social and institutional interactions and arrangements that consider the ecosystems' carrying capacity and space security for human settlements.

Without a doubt, applying a comprehensive and practical view when developing territorial planning to support municipal urban development programs demands the inclusion of risk atlases and POELs for their technical formulation, execution and monitoring. If this approach is ignored, the consequences will be experienced by the cities themselves, their inhabitants and their authorities in a reactive manner, which implies high economic, material and human costs.

Toward reducing urban vulnerability to climate change

The reduction of urban vulnerability to climate change requires strengthening cities' capacity to cope with extreme weather events, in order to respond and reorganize to preserve their key functions and structure, while maintaining their adaptation, learning and transformation capacities.

Consequently, the reduction of cities' vulnerability to extreme hydrometeorological phenomena needs to be strengthened through the articulation and implementation of ecological territorial planning, risk atlases and urban planning; these tools must be updated in order to remain congruent with prevailing reality and with the established sustainability objectives. In this regard, it should be clarified that the power to elaborate all these tools rests with municipal authorities; but in most cases, there are different public bodies whose purpose of action, far from being supportive is, in practice, opposed. For this reason, it's important to underline, preserve and enforce constitutional provisions toward sustainable development, as is stated in the following case law thesis of the *Suprema Corte de Justicia de la Nación* (Mexican Supreme Court) which states:

> [...] although it is true that Municipalities have the authority to formulate, approve and manage the zoning and municipal urban development plans, as well as to authorize, control and monitor land use within the scope of their competence [...], it's also true that the *Programas de Desarrollo Urbano Municipal* (Municipal Urban Development Programs) have to be consistent with Federal and Local ecological ordinances, since municipal authority must be understood to be subject to the guidelines and formalities set by Federal and State laws, and never as an exclusive preserve, isolated from federal regulation [...] (SCJN, 2011).

In this area, the Plan Nacional de Desarrollo (National Development Plan) 2013-2018 incorporates a strategy to deploy a broad development policy, through the promotion of comprehensive territorial planning, based on ecological regulation and territorial planning. This strategy combines with another, which is aimed at expanding the coverage of infrastructure and environmental programs that guarantee the conservation of ecosystems and natural resources, as well as to achieve the ecological regulation of the territory, especially in those areas with greater climate vulnerability (Gobierno de la Republica, 2013).

The *Programa Sectorial de Medio Ambiente y Recursos Naturales 2013-2018* (Sectoral Program on Environment and Natural Resources) presents a strategy to increase ecosystem resilience and reduce the vulnerability of population, infrastructure and services alike to climate change. Hence, it promotes the incorporation of climate change criteria in the POELs and other territorial planning tools, the creation of wildlife management units in municipalities that are vulnerable to the effects of climate change and, among others, the strengthening of comprehensive risk management (SEMARNAT, 2013-B).

However, to ensure the elaboration and coherence of the different tools for comprehensive risk management in the cities requires preferential treatment for the most vulnerable groups of the population and for the areas of greatest risk exposure; otherwise, efforts will be wasted within a context of organized irresponsibility (Beck, 2004).

As can be seen, local authorities are the ones in charge of making human settlements compatible with the guidelines of ecological territorial planning and risk atlas criteria, through the incorporation of the corresponding forecasts in the territorial planning procedures or programs and, therefore, of urban development in order to reduce urban vulnerability. As the Sendai Framework for Disaster Risk Reduction 2015-2030 states, disasters worldwide are often exacerbated by climate change; nonetheless, the exposure degree of people and assets has increased more rapidly when compared to vulnerability reduction.

Definitely, urban development based on territorial planning, risk atlases and unconditional respect for the environmental conditions of non-developable areas are essential conditions for comprehensive risk management, which should be included as a priority within public policies for the sustainability, security and resilience of cities.

Conclusions

Mexico's vulnerability to climate change demands actions toward its reduction, which cannot be left to the existing broad list of disjointed legal instruments. On the contrary, a political will, oriented to comprehensive risk management, is necessary in order to elaborate and implement the urban planning instruments issued from an ecological management of the territory as an adaptation strategy to climate change.

The identification and reduction of climate vulnerability corresponds to all levels of government, but primarily to the municipal level. Thus, it's imperative that municipalities exercise their powers with the object of constructing safe, sustainable and resilient cities in the face of climate change, which requires the articulation of territorial planning and environmental protection.

The Mexican government must reassess its role and responsibility for the increasing risk of extreme weather events in cities. This situation implies a deconstruction of its current role as a business agent, based on market logic, which has allowed the development and expansion of cities in response to capital flows. In this way, the State has neglected its decisive role in the sustainable planning of the territory, through the lack of expedition, implementation and verification of the legal systems so that all people can fully exercise their right to a healthy environment and adequate housing, while fostering private actions aimed at guaranteeing the rights of only a few with a certain purchasing power. That sector's demands lead to the destruction of habitat, natural resources and the environmental services they provide, as well as to the exclusion, marginalization, inequality and increased vulnerability of many other people.

The expansion of irregular or vulnerable settlements in terms of their construction characteristics or location, often associated with poor households, increases urban vulnerability to extreme climatic phenomena and highlights the insufficiency of the rule of law in the country.

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Chapter 2

Climate change, urban expansion and conservation in mexico city's periphery: between ignorance and good intentions

Jorge Escandon Calderon

Introduction

Although research on climate change policy started more than twenty-five years ago in Rio, the issue of environmental changes linked to urban dynamics is much more recent, motivated by the approach of the deadlines set by the Kyoto protocol (Ricci, 2016).

According to the United Nations Framework Convention, directly or indirectly, climate change refers to human activity, altering the composition of the global atmosphere and influencing the natural climate variability observed over comparable periods. Working Group II of the Intergovernmental Panel on Climate Change (IPCC) uses the term *climate change* to describe any modification in climate over time as a result of natural variability and anthropogenic activity (IPCC, 2014: 45). From this perspective, climate change observed at present, is the combined result of the processes that generate changes in the concentration of greenhouse gases (GHG) by increasing burning of fossil fuels and the release of aerosols into the atmosphere, solar radiation and characteristics of land surface uses (soil and ground cover).

Systemic analyses of the relationship between climate change, international cooperation and local urban policies is a difficult framework to resolve, even before attempting to integrate the perspectives of both the "hard" and the social sciences. The multiplicity of actors and agents involved, the amount of environmental programs available, the heterogeneous international financing for climate change study and mitigation, the large amount of rules and regulations for environmental protection and conservation, determine an extremely complex context that needs integrated visions (Lucatello, 2015), from the construction of the problem all the way to the possible solutions.

Although some areas have reached a significant consensus, such as the IPCC scientists regarding the effect of human activities on increasing emissions and their relation to the rise in temperature (IPCC, 2014), other agreements, such as those related to issues of collective action and cooperation for mitigation of GHG and adaptation to climate change from the global to the local scale, however, have not been achieved, because each national government has incentives to let other countries take the initiative and bear the burden of leadership, while they wait for some of the benefits of climate negotiations. It is also worth mentioning that the conservation of the environment has never been a priority of States, because they observe that they have survived quite well without this priority (Dryzek *et al.,* 2003).

The city as a cause of change

Many of the environmental changes under way are driven by the onslaught of rapid urbanization worldwide. The use of about 80% of resources and the generation of most of the world's waste are related to contemporary urbanization (Swyngedouw and Kaika, 2013). Many studies argue that cities are the major contributors to GHG, and even more in the cases of high income cities (Satterthwaite, 2008, Romero-Lankao, 2007; Dodman, 2009). Some authors (Satterthwaite, 2008) show that anthropogenic emissions are linked to the consumption patterns of middle- and high-income groups located in cities. Many global challenges arise from the ways in which cities grow and change, especially emerging megacities in developing countries, where massive social and environmental problems can be found in their peripheral zones (Ravetz *et al.,* 2013). A number of cities around the world are taking institutional measures to deal with the driving forces and consequences of climate change. Many urban authorities are perceiving that, unless they develop effective and meaningful initiatives to mitigate and adapt to climate change, cities may face conditions of risk and vulnerability, as well as deteriorating health conditions and welfare (Hoornweg *et al.,* 2011; Romero-Lankao and Dodman, 2011; Satterthwaite *et al.,* 2007).

Despite the incipient consensus between nations in terms of mitigation of GHG at an international level, some cities such as Mexico City have taken initiatives related to climate change policy.

Policies and strategies to address environmental changes in the cities of countries like Mexico, are aimed at reducing the vulnerability of people by approaches related to land management, which seeks reduce the causes of climate change (mitigation) and, especially, the relief of environmental impacts that are already under way (adaptation).

Delgado *et al* (2015), on the basis of the fifth IPCC report (Chapter 12, WG III) and adopting them as key factors for climate governance on an urban scale in Mexico, submit the following propositions:

- Allow a multilevel governance framework that empowers cities and promotes urban transformation.
- Encourage spatial planning skills [for land use] and the political dynamics to support land use policies.

In the case of Mexico City, spatial planning defines 63.946 hectares (ha) as Urban Zone and 88.442 ha as Conservation Zone (CZ). The CZ represents about 59% of the total territory of Mexico City, and the legal instrument related with policy is the General Ecological Management Program (PGOE) for Mexico City (2000). The social development index, which is an indicator used as a tool for quantifying social inequality and the degree of compliance with social rights, taking into account the inclusion of economic, social and cultural variables (Evaluates, DF, 2011) linked to the CZ, reveals a consistent pattern type of “center-periphery” in Mexico City. The municipalities located in the periphery that have territory in the CZ, are characterized by the increased presence in their territorial units of groups of low and very low social development (Escandon, 2014).

Another policy instrument, which we will analyze carefully is the Climate Action Program for Mexico City 2014-2020 – CAPMC (2014) in its fundamental actions which mention five strategic areas, of which two are directly linked to the CZ: Axis 2: *Containment of urban sprawl and creating a program that integrates environmental territorial planning and urban policies*. And Axis 4: *Sustainable management of natural resources and conservation of biodiversity through the creation of the Law for the Protection, Conservation and Sustainable Use of Biodiversity, as well as soil and water conservation infrastructure in the CZ*, among others (CAPMC, 2014: 15).

Analysis from another perspective

The magnitude of environmental modification related to climate change amplifies and emphasizes the inadequacy of the interpretative approaches adopted so far, in which a perspective prevails which focuses on analyzing institutional policies as instruments related to these institutions, and actions related to these interpretive approaches. Many expressions of political culture in society are omitted, in spite of not being totally dominated by the individualistic, competitive and instrumental logic of the rationalist models of modern capitalist institutional thinking.There are many inherent risks in interpretive approaches to the analysis of institutional capacity and policies, because they reflect only one part of territorial reality, and generally are accompanied by the consequent imposition of inadequate development models, which renew and exacerbate old conflicts which also become amplified in the context of climate change.

To rethink an alternative perspective of climate change policies related to the city, specifically those related to the CZ of CAPMC in Mexico City, we briefly describe the concept of political culture (Tejera, 1996 and 2003; Alvarez, Dagnino and Escobar, 1998; Gledhill, 2000), and we formulate another complementary approach to the institutional perspective, analyzing the concept of governance and its application to the Mexican case. This chapter suggests that interpretive approaches like CAPMC, rather than relying on multilevel governance, are based on "*asymmetric ignorance*"[1], applied from consulting government agencies and developing solutions that ignore or generalize contexts that are very dynamic from an environmental, social, cultural and economic point of view.

To contrast the *asymmetric ignorance* of the institutional perspective and enrich the analysis, we further propose a description of THE CZ as a hybrid entity, and additionally take into account the stated ideas of two key player, to explain briefly what counts in political culture (everyday practices) as well as their perceptions of the problems of urban sprawl, trying fill in the gaps in the general and simplistic description of the urban sprawl problem contained in the CAPMC.

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1 Based on Robinson (2003). In the Geographic sphere, the universalism assumed by many of the theoretical claims within the discipline, has developed in ignorance of the wide range of social contexts which are totally different from the Anglo-saxon background, and which are typical of many Western Geography texts. In this case, I refer to the ignorance of social factors and action platforms, which determine the management dynamics of natural resources, many of which have been preserved to this day, by officials or consultants who design policy instruments.

Political culture

Since the second half of the 80´s in Latin America, some intellectuals and opinion circles began to widely use the notion of "political culture". With this notion, they have addressed a rather broad and heterogeneous range of phenomena, issues and problems. In recent years, cultural historians, anthropologists and social psychologists have become interested in a different phenomenon, which also has to do with the political culture: the "speculations", "mentalities", and "social representations" which different groups create around reality in general and politics in particular, trying to explain how different groups of society (Alvarez, Dagnino and Escobar, 1998; Lopez de la Roche, 2000; Paulson and Gezon, 2004) are perceived.

Other perspectives (linguists, semiologists, anthropologists) have understood the political culture as a series of symbols of power, paying particular attention to speeches, either as rhetorical devices from which political authority is constructed or legitimized, or rituals and ceremonies through which political ties are renewed in a society (meetings, demonstrations, celebrations) (Alvarez, Dagnino and Escobar, 1998; Hajer, 1995; Lopez de la Roche, 2000; Dryzek, 2003; Paulson and Gezon, 2004).

Following political discourse analysis, they have also developed approaches to the notion of political culture. Various disciplines have researched political discourse and its various genres; for example, the ways in which a society describes or represents itself from a politically-discursive viewpoint: how it represents the workers, the nation, professional politicians, institutions, history, national political traditions, etc. (Alvarez, Dagnino and Escobar, 1998; Hajer, 1995; Lopez de la Roche, 2000; Dryzek, 2003; Paulson and Gezon, 2004).

The participation of individuals and social groups will respond and have its starting point, in the construction of ways in which each individual internalizes political discourse, with its significance, symbols and meanings, thus giving form to the way in which social actors contribute to the functioning of institutions and accept the rules of the political order, or reject them, as the case may be (Mendez *et al.,* 2009). Considering this framework, the question that arises here is: according to the formulation of axes 2 and 4 of CAPMC (2014), which cultures are politically at odds?

Governance

The first thing to be mentioned about the CAPMC is that it assumes a description of governance. By rules (the "should be" dimension according to the World Bank, 1992 and 2015), assuming that the processes of coordination and cooperation between different stakeholders are given without any conflict, omitting the power relations between them and the different scales in which the actors interact.

From a conceptual point of view, governance is defined as "relational government" or "interactive government" (Kooiman, 2004), which means that the act of governing is shared, decentralized, fragmented and resolved in cooperation between public, private and social actors through what have been named networks or political communities (Natera, 2005; Aguilar, 2005; Geddes, 2005).

For Mexico, like many other countries, the concept arrived at its normative dimension through the *structural adjustment* reforms of the last two decades of the twentieth century, promoted by the World Bank and the International Monetary Fund, which were aimed at stabilizing the economy and overcoming the fiscal crisis as well as inserting the country into economic and financial globalization (Paz, 2015).

The World Bank identified a number of indicators of good governance such as: 1) voice and accountability; 2) political stability and absence of conflict; 3) government efficiency; 4) regulatory quality; 5) law enforcement, and 6) control of corruption (World Bank, 2015).

Given these indicators, there would seem to be few objections; however, these seem to address government action exclusively, which is important; but for the approach to environmental problems, amplified by climate change, it is not enough.

A more democratic and inclusive vision of governance would have to envisage not only the economic agents, but also the interplay of social agents, together with the government in a more active role, with the performance of institutions (through rules), as well as in the definition, implementation, execution and evaluation of public policy. It also means transparency, accountability, efficiency and effectiveness as well as horizontal interaction, and this forcefully refers to the redistribution of power and the strengthening of civil society (Paz, 2015).

However, there is still a complaint from civil society organizations that the incorporation of society into public order matters is still limited to simulated consultation, exchange of information and some cases of management, but not in fundamental decisions (Berrios, 2005; Blauert *et al.,* 2006).

CZ considered as a hybrid

The CZ harbors about 2.2 million people of which about 700,000 are linked to the agro-ecological area (Aguilar, 2013) and about 21,000 were dedicated to agricultural activities (INEGI, 2006 and 2010). Almost 80% of land holding in the CZ is collective (communal and *ejidal*[2] property), and distributed amongst 36 rural communities settled there (Rodriguez *et al.,* 2015). Understanding the CZ as territory of urban, rural and environmental interaction in the peripheral

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2 *Ejido* is a slightly restricted form of collective ownership of land, originally designed to benefit peasants and stimulate agricultural production, but recent reforms of the respective law have rendered it relatively similar to a straightforward form of ownership.

area of the city, means that the political dimension of space, includes not only that material dimension, but also has representational dimensions in which various actors are involved in its social construction.

Conceptually, the ideas of Latour (1993, 1998, 2004) are expressed in a nutshell. Latour strongly rejects the notion of nature as something "pure" and introduces the concept of "hybrids", defined as "mixtures (...) of nature and culture" (1993, 10). Swyngedouw (2004) goes deeper and affirms that hybrids are formed by a variety of biological, physical and chemical "natural" processes, as well as material, cultural and discursive practices of different actors, and also the social relations among actors. With this approach, the CZ is a "hybrid" with a biophysical part, another part integrated by material and commodified practices, as well as discursive dimensions constructed differentially. Other key hybrid features are: the relationships of the actors with natural resources, socioeconomic and cultural heterogeneity, rural-urban migration and bidirectional interdependence, among others.

Taking a stance on the framework in which we will be analyzing what the CAPMC says, we will adhere to the tenets of Urban Political Ecology (EPU), which defines the environment as a constructed and dynamic space in dispute, where different social actors with asymmetries in political power are competing for access and control of natural resources (Bryant and Bailey, 1997). EPU advocates a more refined understanding of how discourse, politics and human actions shape the environmental change and control of natural resources (Von Bertrab, 2013). It´s important to say that, when talking about discourse in this paper, we are referring to the proposal by Hajer (1995) who, building on the legacy of Foucault, defined it as a specific set of ideas, concepts and categorizations that are produced, reproduced and transformed to give meaning to physical and social relationships.

Since one of the main discursive elements of CAPMC is the containment of urban sprawl, but described in a simplified and even apolitical way, we propose to examine in closer detail, some of the views of two key actors who interact daily in this territory (officials and land-holding communities) regarding this issue.

What the actors say: current visions, reflecting a more complex reality for the CZ.[3]

In the eyes of the established communities, urban sprawl in the CZ, has the following causes: lack of planning and surveillance work by government authorities, promotion of irregular settlements by legislators and other politicians, migration of people from other regions who arrive as "settlers", as well as the natural demographic growth of *ejidos* and communities by the regular dynamics of the native peoples of the CZ (Escandon, 2014).

Concerning lack of planning and surveillance work by the authorities, the established communities perceive changes in the performance of activities between the different teams of public officials who come and go with every administration change, and express some skepticism about government actions, revealing lack of faith in the authorities. Violations of the regulation of land use according to planning is an issue that community land-holders point out as one of the main deficiencies of the governmental entities with jurisdiction in the CZ, in terms of surveillance work. They blame both municipal governments and the Mexico City administration, alleging that such violations are committed with their consent, and this discourages community members from filing complaints related to violations of land use (Escandón, 2014).

The green areas are disappearing and are being replaced by lumber

3 This section is based on Escandon, 2014.

> *mills or car repair garages...Where it´s assumed, for example, that there are areas where land use regulation says it is low density rural residential, which is described as including 70% of open areas, and 30% occupied by buildings with not more than two levels. Yet we see and we have as our neighbors, 2000m² plots 100% under construction. So then: ¿Where are the 70/30 specifications, and the restriction to two levels? But we didn't want to report it because it seems that everything is backed by municipal authorities or maybe worse, by central authorities, because no one stops them (Common land-holder).*

The issue of irregular settlements promoted by legislators and politicians, adds another component of great complexity because it involves other actors. The slums associated with irregular settlements show that there are political actors who seek to generate support groups during election periods to positions on government and county councils, and exchange votes for solving aspects of permanence in the CZ territories, with the provision of services and infrastructure which improve the living conditions in the slums associated with irregular settlements. The chaos caused by the lack of definition in the appropriation of land lots, involves corrupt local leaders who illegally appropriate land whose ownership is unclear. The ambiguity of boundaries of land according to soil characteristics (topography, rocky terrain, land located in gullies), often implies lack of knowledge by the owners of the precise limits of their lots, creating overlaps between lots, which increase the possibility of conflict between settlers and the community, and between the community and authorities (Escandon, 2014).

> *Basically, the most serious problem is the politicians who protect people who have been moving in little by little and illegally settling in this part of the urban sprawl, and the urban sprawl also grows, sponsored, encouraged and protected by politicians. I'll tell you about just one case in my* ejido*, San Andrés Totoltepec: In a zone we know as "Los Hornos", some common holders decided to settle around lands*

> *occupied by these irregular slums, and the government decided to evict the landowners but leave the settlers in peace, people who aren't owners of land, nor have cared for the forest (Common land-holder).*

Another issue involves actors from high socio-economic levels who introduce themselves as buyers of land. They are urban dwellers whose motivation is to acquire lots in places with natural conditions and landscape and which ensure scenery and privacy. Then, they offer developments close to the city, whose names (Mountain Meadows, Forest Glens) imply natural attractions near the city, brandishing the fact that the measures aimed at protecting nature (or avoiding urban sprawl) are not practiced, although they are on paper in planning programs for protected natural areas located in the CZ, as well as the CAPMC. One can say that here economic interests have subordinated environmental policies (Escandon, 2014). Here is an example of this.

> *... In this zone, the land is not protected because, up there, wealthy and powerful people have arrived. They bought five hectares and built them up and filled them with people. But unfortunately, I have seen these people buy up land to sell it later. This is very serious. Although conservation areas are established, and this is fair, the government does not give us enough financial assistance for protected land, and if a speculator comes along and offers me $2000 per m^2 of land, I would consider selling it (Common land-holder).*

According to the group of government officials, the causes of urban sprawl are related to: municipal programs as instruments of legitimation to regulate slums; no effective problem-solving policy; lack of access to low cost housing in urban areas; promotion by political groups of irregular slums; economic interests related to speculation and sale of land; the natural population growth of native peoples, and because agreements with settler leaders are not respected.

One item to note is that even though the CZ is recognized by officials as a measure to prevent urban sprawl with an adequate legal basis ruled by the PGOE as an instrument of environmental policy, other administrative instruments such as Municipal Urban Development Programs, are used by the authorities to legitimize and regularize human settlements. Also, the dynamics of land occupation and the legitimacy of this occupation under the Urban Development Programs, suggest that environmental instruments, in fact, are subordinate to urban development and human settlements regularization. Such regularization is used as a measure to attenuate social discontent and political clientelism[4] (Escandon, 2014).

> *Settlements, which were recognized as irregular, before the new municipal programs, now are being processed according to some new instruments to somehow legalize them under updated municipal programs. There is already an instrument that will allow you to do that. What will happen to the conservation zone? Well, obviously, some of it will be lost. There will no longer be 88 thousand hectares. Perhaps there'll be something like 70 thousand, or 65 thousand (Government official).*

Efforts to revise both instruments to seek compatibility between environmental and urban criteria that intermingle in the CZ, carried out in the delegations of Xochimilco (Wigle, 2014) and Tlalpan (Aguilar and Santos, 2011) have been unsuccessful.

> *What is now in effect causes clashes between environmental law and the urban development municipal program. They collide because they were conceived with different objectives, one with a planning vision of urban housing. The other with a totally environmental planning vision: "I do*

4 Clientelism is a prevalent form of political strategy which comprises favors dispensed by an incumbent authority to determined groups (or political leaders) in exchange for votes. Not unlike what is known in the U.S. as "pork barrel politics".

> *not care if there are people, they have to go (the irregular inhabitants)." The collision between these two is inevitable (Government official).*

Another important issue mentioned by government officials is related to the absence of popular housing policies in the urban area of the city, resulting in a demand for land in the urban periphery, particularly in the CZ, first by low income groups, and second by more wealthy groups. The real estate developers are mentioned by government officials as an important issue in the CZ, but are seldom mentioned by owners of communal land. Real estate developers do not act alone; they are actors who interact with communal authorities as well as so-called owners, in agreement and complicity with political actors, with high economic interests that benefit certain individuals, over green lands preservation interests that benefit the whole city (Escandon, 2014).

> *It´s the need (of the people) to have house and home… because up there in the CZ they can get land at low prices: $300, $400 per sqm. The financial advantages that the people have in the CZ allow them to make payments little by little, between 7 and 10 years, without a guarantor, as we have demonstrated in the files that we have here. For example, here in the urban area, for someone who wants to buy an apartment, or a house, the institutional and financial system presents too many obstacles, and the real estate is very expensive. Having access to a home is very complicated in the urban part of Mexico City (Government official).*

Axis 4 of CAPMC, which mentions *sustainable management of natural resources and biodiversity conservation,* is considered to be too simplistic because community land-holders argue that government policies and programs were poorly designed, ineffective and insufficient; without relation to community needs and dynamics, excluding the local community land owners, imposing conservation policies restricting agricultural activities, not to mention inefficiency of the monitoring programs by officials (Escandon, 2014).

About the idea of poorly designed and ineffective programs, one that is mentioned recurrently by community land owners is the reforestation program, being criticized because much of the work of the authorities is incomplete and ineffective.

The reforestation program of the Environment Ministry (SEDEMA-CDMX) has certain similarities with the National Forest Program promoted by the National Forestry Commission, in financial terms. If we take into account the operating rules in the components of forest restoration and reconversion, as well as the environmental services component, we observe that the maximum amount spent per hectare is \$14,800.00. If this amount is compared with the selling prices of lots offered by urban developers (\$300-400/m^2 prices mentioned by an official, or \$2,000/m^2 reckoned by a member of the community), it is obvious that it cannot compete with real estate speculation. The minimum environmental subsidy required would be in the order of \$3 million pesos per hectare to discourage the illegal sale of land (Escandon, 2014).

For government officials, conservation policies and programs are poorly designed and implemented; with lack of financial and human resources; obsolete and outdated legal instruments; with excessive rules and complex operation; lack of continuity; inefficient use of economic resources; and with few benefits to community landowners.

To this must be added the lack of coordination between authorities and power struggles between various governmental bodies with juristictions in the CZ.

In the narratives of officials, a recurrent idea in terms of conservation programs it is that they are categorized as poorly designed and applied. Thus, Government officials express that it is very difficult in terms of maintaining credibility and trust with communities, since some programs that are promoted during an administrative period are dismantled in the next one, because they are evaluated as more harmful than beneficial under environmental criteria. Government officials also mention that lack of continuity in conservation programs operating in the CZ is a problem that reveals, among other things, the absence of evaluation of administrative activities. Administrative changes every three years in the municipal administration, and every six years in the Mexico City government are often accompanied by changes to institutional structures. This has involved a juxtaposition of government policies with regard to issues of agricultural production and forest conservation, which detonates an acute competition over human resources, facilities and vehicles (material resources), new budgets (financial items), and operational rules which duplicate efforts toward the accomplishment of projects. This shows that the difficulties for government officials are mostly institutional issues (little communication, inefficient policy instruments, absence of coordination) and lack of awareness of what the CZ means for urban dwellers.

Government officials try to apply their perspective of conservation through control of financial resources, the use of technical information from academic institutions as part of policies, and “normative” planning practices in order to obtain advantageous framings in the negotiation process with *ejidos* and communities. On the other hand, the prospect of conservation for established populations is linked to land ownership, community organization, identity as an instrument to reinforce legitimacy, and sometimes peaceful protest and active resistance such as closing the entrances to government offices and blocking roads so that their demands can be fulfilled.

Discussion and conclusions

To begin the discussion, let’s return to the question: In formulating axes 2 and 4 of CAPMC, which cultures are at political odds? It can be said that the conception, design and potential mechanisms of implementation and execution of the CAPMC, framed in the global culture rules of governance related to mitigation of greenhouse gases, and more specifically the complex environmental problem of urban sprawl, are pitted by exclusion against the culture of indigenous people, whose main problem can only be solved by finding a way out of the situation of poverty and marginalization in which they live. Some authors attribute the inefficiency of urban planning to inadequate interpretive approaches (Ricci, 2016). This includes persistence in the regulatory field, impregnated by the "asymmetric ignorance" approaches and the hegemonic dominance of Western scientific production, which often assumes or produces universalizing strategies and exclusionary practices of knowledge production (Ricci, 2016). This is evident in the CAPMC where the coordinator of that academic document is the Mario Molina Center which, as possessor of "scholarly" knowledge, does not even consider local wisdom, ignoring and omitting many of the strategies that have allowed the preservation of the territory in the CZ and that are contrary to urban sprawl. These strategies are associated with a series of community initiatives driven by day-to-day actions coordinated by community meetings and working groups of local authorities.

For landowners involved in the community decision, one of the major problems in managing the CZ, is the lack of a broad consultation with the communities to build agreements and decisions by consensus between communities and the authorities. According to interviewees, the authorities are decision makers determining what and where preserved territory is, and they do not have detailed knowledge or thorough understanding of what happens in the CZ. Decisions –explain the landowners– are taken based on prejudice by the authorities of the CZ, and these decisions rarely match reality as it is experienced by the inhabitants of the communities located in the CZ. This deepens the absence of legitimacy of government decisions, and key players who inhabit this territory feel excluded, distrustful of authority and its willingness to meet local demands and concerns.

The lack of inclusion strategies on the part of the authorities towards the inhabitants of the CZ is revealed in the narratives of the land owners of this territory. Integrating local people in conservation involves a social and political process that falls within the scope of social construction generating participation strategies. It also involves permanent communication channels between officials and community, which often are rancorous due to the number of lawsuits and mutual accusations of noncompliance between the two groups. The asymmetrical balance of power between officials and the community is expressed in exclusionary practices, starting with the conception, design, and establishment of the CZ, as well as most programs operating in this territory. This fits the description by Garcia Frapolli (2012) called participatory exclusion. However, other groups such as scientists and environmental organizations have been included and participated actively in the development of diagnoses, biological, ecological and socioeconomic databases and programs, just as relevant as the CAPMC.

The establishment of four successive lefy wing governments in Mexico City, where the direct relationship of consultation with society became manifest from the first administration in 1998, promoted a broad agenda aimed at different types of organizations and approached a vast range of issues, highlighting the aim of establishing a comprehensive policy relationship between government and civil society organizations (Alvarez and Sanchez Mejorada, 2013). This, however, is completely omitted by the technocratic vision dominant in the CAPMC.

The CAPMC 2014-2020, is again a design policy document impregnated with "asymmetric ignorance", because of the way in which it uses concepts such as governance, and the simplified manner with which it approaches urban sprawl, in addition to visualizing the ZC as a monolithic entity which only needs monitoring, totally omitting the perspective of social development that is very necessary in terms of vulnerability mitigation measures and adaptation to climate change.

This territory is strategic to Mexico City in terms of adaptation and mitigation of climate change; therefore, if participation of land owners is not invigorated, starting from platforms of action that strengthen the capability to decide on the management and use of their property, aiming at a more dignified consideration of the activities related to the management of natural resources on the part the *comuneros* who inhabit the CZ, as criteria to break the mold of "asymmetric ignorance" and the inertia that prolong processes of political clientelism for managing peripheral urban poverty, then territorial planning policies related to adaptation and mitigation of climate change will remain bogged down in pretty documents, full of good intentions.

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II. Adaptation and integral management in climate change-sensitive cities: challenges and opportunities in urban governance

Chapter 3

Water quality risks associated with climate change: three Mexico City case studies

Blanca Jimenez Cisneros
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Raquel Montes

Introduction

Water quality is affected by climate change. However, studies on the detection of such impacts are still very scarce in the literature (IPCC, 2014). This limits the opportunities for governments to reduce the vulnerability of their population through the implementation of effective actions to address the risks. An example of this is the Action Plan on Climate Change for Mexico City 2014-2020 (Velasco *et al.*, 2014). The objectives set in this programme to address the impacts of climate change on water are: (a) the control of water leaks in the water network; (b) the promotion of water conservation in public administration buildings; and, (c) the development of infrastructure to conserve water in urban protected areas. The action plan highlights the fact that the city is highly vulnerable to several types of impact on water resulting from climate change. Escolero *et al* (2009) and Soto *et al* (2009), among others, have noted this, suggesting that the scope of the climate change plan should be expanded to include water quality.

Climate change impacts on water availability are complex and vary significantly at the local level. For this reason, it is important to study their effects under specific conditions.

Mexico City has suffered from water scarcity for many decades (CONACYT, 2014). If no action is taken to mitigate the associated risks, this situation will worsen in the future. The purpose of this chapter is to, firstly, use quantitative data to illustrate the current risks to water availability because of the impairment of its quality. It also draws attention to the need to have proper information and methodologies to assess these risks. To achieve this, the present chapter presents three case studies:

a) The impact of extreme rain events on the quality of the aquifer of Xochimilco, which is the main source for municipal supply.
b) The effect of temperature increases on the depollution capacity of the Magdalena River.
c) The assessment of population vulnerability to waterborne diseases associated with climate change and its links to water quality and acute diarrhoeal diseases.

The first case study was selected to illustrate that Mexico City's water supply may be additionally challenged by the pollution of groundwater –the main source of water supply– resulting from extreme rain events. The purpose of the second case study was to assess if, as suggested in the current literature, one impact of climate change will be to decrease the depollution capacity of urban rivers (IPCC, 2014). The third case study was developed to investigate the relationship between water quality changes resulting from climate change and the incidence of diarrhoeal diseases. However, the latter was found to be unfeasible due to the lack of suitable information. Thus, the vulnerability of the population to acute diarrhoea was investigated, after linking climate to water quality and diarrhoeal diseases separately. The overall aim of the chapter is to increase understanding of how cities will be affected by climate change through changes in the quality of water.

The Metropolitan area of Mexico City

This region has nearly 22.4 million inhabitants distributed throughout Mexico City (8.8 million people) and 40 different municipalities. The metropolitan area represents 20% of Mexico's population but only 1% of the country's surface area. The city produces 18% of the gross national product (GNP) (INEGI, 2011), but 28.7% of the population live in conditions of poverty and only 63.8% have access to health services. The metropolitan area uses an annual mean of con 62 m^3/s of water, mostly for municipal purposes (household uses and public services). Groundwater is the main source of water, and represents nearly two thirds of the supply. The recharge area is located in the western and southern parts of the city. The aquifer is highly overexploited, to the point that the city experiences soil subsidence in some areas at the rate of around 30 cm/year. Overexploitation is causing, among other negative effects, damage to buildings due to the differential sinking of the soil, the deterioration of groundwater quality, and a large number of water leaks (leading to losses of more than 35% of the water supplied). Mexico City has the best water services and data collection within the metropolitan area. These data show that, despite the fact that 327 L/inhab/d of water enter the distribution network, the population receives much less because of significant leakage. The actual supply rate varies considerably: while rich areas receive up to 1000L/inhab/d, in shantytowns supply is limited to 28 L/inhab/d, a value below the minimum set by Mexico City law as a human right (GDF, 2010). Moreover, water does not continuously circulate through the network. As a result, around 81.5% of the population receive water for some hours per day, 2.6% for four days per week, 6.5% for three days per week, 2.5% for two days per week and 1.6 % for only one day per week (GDF, 2010). Prior to its distribution, the water is treated to comply with the drinking water standard for 94.3% of households but, because of the intermittent operation of the system, most of the water reaching consumers is not necessarily potable.

According to climate change projections, by the end of the century Mexico City will experience a temperature increase of between 1.3 and 1.9° C, while pluvial precipitation is expected to be between 0 and 11% higher during the summer with more frequent and intense extreme rain events. It is expected to decrease between 12% and 23% during the dry season (Escolero *et al.*, 2009). To overcome the shortage of water and the lower reliability of its supply, an investment of $7,500 million dollars is required over the next 10 years (SACM, 2012), of which 49% is necessary for infrastructure improvement. Studies performed by Escolero *et al* (2009) and Soto *et al* (2009) highlighted that water challenges due to climate change will not only be associated with water quantity but also its quality. However, little information is available in this regard. Lastly, according to the Mexico City Climate Change Action Programme 2008-2012 (GDF, 2008), its citizens are vulnerable to climate change largely because internal water resources are managed unsustainably, and there will be a high future dependency on external water sources; population density is very high, and efficiency in water use is low.

Case study 1. Impact of extreme rain events on the quality of an aquifer

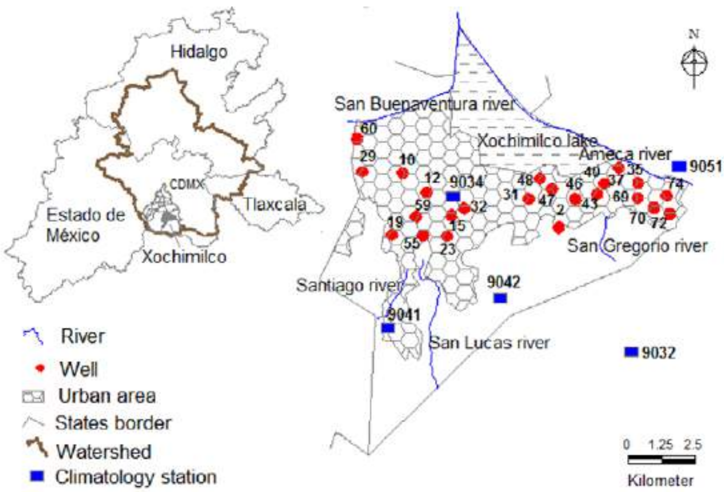
Extreme rain events are linked to increased pollution of groundwater (Rozemeijer *et al.*, 2009). These events are exacerbated in cities by both climate change and the "heat island" effect (the increase in urban atmospheric temperature due to urbanization) (Jauregui, 2001; IPCC, 2014). Since groundwater is an important source of water for cities, this study quantitatively assessed the impacts of extreme rain events under climate change conditions on the quality of an aquifer used as a source of drinking water.

Study site description

The Xochimilco aquifer provides 7% of the water used in the Metropolitan area of Mexico City. The aquifer is located in the southeast of Mexico City, in the recharge area. It has a surface area of 125 km^2, 30% of which is urban and

70% rural (figure 1). The urban area, to the north, harbors 400,000 inhabitants and includes several industries, commercial shops and services. In the rural area, most of the 100,000 inhabitants use septic tanks for sanitation. The mean annual rainfall in Xochimilco has decreased by 17% relative to measurements for 1951-1980, to a value of 681 mm. However, the number of extreme rain events (> 45 mm of pluvial precipitation) has significantly increased over the past 30 years, rising from 5-7 events per year to 20-28 (Jauregui, 2005).

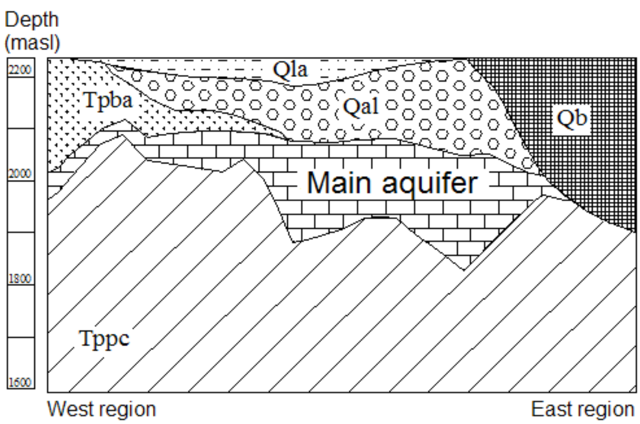
Figure 1. Site Study for the Xochimilco aquifer



The groundwater system comprises an upper aquitard, a main aquifer and a deep aquifer (figure 2). The upper aquitard has a mean depth of 20 m, occurs in quaternary lacustrine deposits, and has a hydraulic conductivity of 0.0864-0.000864 m/d. The main aquifer occurs at a depth of 400 m and is a free semi-confined aquifer with rapid flow judging from the high volumes of water extracted from it. Its piezometric level is below the aquitard. Over-extraction is at least 15% above the natural recharge rate and the hydraulic conductivity is very variable (0.0001296 to 30.24 m/d). Recharge occurs in the south, where the soil and the aquitard are highly permeable (Lesser, 2003). The deep aquifer, composed of volcanic stratified and highly compressed fractured rock layers, occurs at a depth of 200 m and has low permeability and a hydraulic coefficient of 31.97 m/d (Ruvalcaba, 2009).

Figure 2. Lithographic profile and hydrogeological units of the Xochimilco aquifer (Ruvalcaba 2009)

Qla: Quaternary lacustrine deposits, k=0.000864-0.0864; Qal: Quaternary alluvial deposits, k= 0.3542-30.24; Qb: Quaternary volcanic rocks, k=1.4688-2505.6; Tpba: Basaltic-andesitic volcanic rocks from the Superior Pliocene, k= 1.1232-596.16; Tppc: Pyroclastic volcanic sequence and Pliocene clasting, k=0.1036- 31.10



Methodology

Data collected

Pluvial precipitation data was collected from five climatological stations reported in the CLICOM metadatabase (DGCOH, 2007). For water quality, the information from 79 sites for the1980-2007 period (SACM, 2008-A) was analysed. It was concluded that, of all the reported parameters, only conductivity and total dissolved solids (TDS) data from 23 wells would be used for the study because of the amount of available information, its precision and significance in reflecting changes in the quality of water. Of the wells selected, thirteen were located in the eastern part and ten in the western area. Limited data on the occurrence of faecal coliforms, a parameter used to represent water pollution, were available and thus a correlation between its content and the above-mentioned parameters was made.

Groundwater Vulnerability

Several methods have been developed to quantitatively assess vulnerability. One of these is the GOD method (Groundwater Hydraulic Confinement -Overlaying strata- Depth to Groundwater), which is useful in estimating the degree of hydraulic confinement, the type of soil above an aquifer, the piezometric level and the characteristics of the recharge zone. These properties, combined with human activities with the potential to pollute, give the vulnerability of an aquifer, which is expressed as: (a) Negligible, when there are natural or artificial barriers to pollutants; (b) Low, when effects are long term and only apply to a few pollutants that are continuously and widely discharged or leached; (c) Moderate, when the aquifer is vulnerable to some pollutants that are continuously discharged or leached; (d) High, if the aquifer is affected under different scenarios but only by pollutants that are not strongly absorbed or transformed; and, (e) Extreme, if most pollutants reach the aquifer under different scenarios. More detail on the procedure for the calculations can be found in Foster *et al* (2002).

The delay time (tc), which is the time for pollutants to move from the recharge site to the site in which water is extracted for use, was determined under normal recharge conditions and extreme rain event conditions. Equation (1) was used for this calculation (Alley *et al.*, 2002; Nolan and Hitt, 2006).

$$t_c = S\,L^2 / k \qquad \text{(Equation 1)}$$

where, tc is given in days; S is the storage coefficient, equal to 0.2/m; L is the layer depth in m; and k is the hydraulic conductivity (figure 2).

To link water quality to extreme rain event data, the pluvial precipitation was first characterized by calculating the mean and maximum values and frequency. Subsequently, the monthly rainfall, conductivity and TDS data were fitted using a Gumbel univariate model, estimating the location (α) and scale (ν) parameters with the maximum verisimilitude method. Relationships between conductivity and TDS with extreme rain conditions for the 1980-2007 period were established, using a simple linear regression analysis, and different delay times (to) –from one to twelve months– and applied to find which one resulted in a better fit. Results for the presence or absence of faecal coliforms under conditions of extreme rain events were extrapolated from the relationship obtained between these and conductivity and TDS.

Climate change scenario

Baseline scenarios were set for rainfall, conductivity and TDS using information for the 1980-2007 period. The A2 climate change scenario was used to calculate the anomalies for pluvial precipitation for the 2011-2030 and 2031-2050 periods with data provided by the SIECCRe model (INE, 2011) at a 50 x 50 km2 scale. The periodic autoregressive time series model of order two PAR(2) was used to couple the monthly anomalies for pluvial precipitation with the baseline scenario (Equation 2).

$$PAR(p)\colon z_{v,t} = \varphi_1 z_{v,t-1} + \cdots + \varphi_n z_{v,t-p} + \varepsilon_t \qquad \text{(Equation 2)}$$

where, φi is the autocorrelation coefficient, zt is a standard normalized value, and εt is the aleatory or residual component of the model. Correlations for precipitation/conductivity, precipitation/TDS, and conductivity/TDS were performed with a 95% confidence interval for all scenarios using a Gumbel mixed function (Yue *et al.*, 1999). For this purpose, α1, α2, ν1, ν2 parameters for the univariate Gumbel function were used, adding a parameter m for the bivariate association. To perform such an estimation in a mixed manner, a Newton-Raphson iterative process was used with an initial value of *m* =1. Once the parameters were determined, the joint *F(y,x)*, conditional *F(y|x)* and marginal *F(x)* probability functions were estimated using equations 3, and 4 for each one of the variables (Navarrete *et al.*, 2013). The r^2 correlation coefficients were estimated for each of the functions to select the one that best fitted the data.

$$F(y,x) = exp\left\{-\left[e^{-m\left(\frac{x-v_1}{\alpha_1}\right)} + e^{-m\left(\frac{y-v_2}{\alpha_2}\right)}\right]^{1/m}\right\} \qquad \text{(Equation 3)}$$

$$F(x) = \frac{F(y,x)}{\mathrm{F}_{(y|x)}} \qquad \text{(Equation 4)}$$

Finally, considering climate change scenarios, the values for conductivity and TDS were estimated using the probability function and the determined delay period and the Gumbel mixed function (Equation 5).

$$x = v_1 - \frac{\alpha_1}{m} ln\left\{[-\ln y)]^m + e^{-m\frac{hp-v_2}{\alpha_2}}\right\} \qquad \text{(Equation 5)}$$

Where, x and y are the conditional, joint or marginal functions, according to the relationship selected, and hp is the monthly accumulated rainfall (mm).

Results

Groundwater characteristics

The aquifer was found to have very different vulnerability between its eastern and western parts; therefore, analysis of results was performed separately for each. In the eastern part, vulnerability was high because the aquifer there is unconfined, there is a high rate of extraction of water inducing infiltration from the aquitard, the piezometric level is high and the soil layer is thin (less than 1m). In contrast, in the western part, vulnerability is low as the aquifer is semi-confined, is covered by consolidated layers and has a piezometric level of 20 m.

In the eastern part the mean conductivity was 568 µS/cm, TDS concentration was 425 mg/L and 10% of the samples contained faecal coliforms. In contrast, in the western part, mean conductivity was 533 µS/cm, TDS concentration 399 mg/L and less than 4% of the samples contained faecal coliforms. The probability of finding faecal coliforms in the eastern part was 3% for conductivity values above 400 µS/m, 18% for values between 400 µS/m and 700 µS/m, and up to 19% for values higher than 700 µS/m. In the western part, no faecal coliforms occurred for conductivity values below 400 µS/m, 7% for values between 400 µS/m and 700 µS/m, and 14% for values above 700 µS/m.

Impact of extreme rain events on water quality

Mean daily precipitation for the 1980-2007 period ranged between 7 and 10 mm, with 14-16 rainy days per month. During this period, no significant increases in conductivity or TDS were observed for accumulated extreme rain events below or equal to 45 mm for the eastern or the western parts with a 95% confidence level. However, the probability of water quality deteriorating increased for the ninth decile (>180 mm), corresponding to four consecutive days of extreme rainfall. This probability varied from 7 to 16% in the eastern part with return periods of 7-15 months, and from 3 to 7 % in the western one with return periods of 14-36 months. When the monthly rainfall was above 180 mm (which occurred only during the rainy season and using a delay time (to) of four months as the value providing the best correlation coefficient) the conductivity and TDS values were 60% higher than the mean historical value. The values for the quality of water with a delay time of four months are shown in table 1.

Table 1. Extreme precipitation and maximum values observed for conductivity and TDS for a delay time of 4 months

	East					West				
Year	Extreme monthly precipitation (mm)	Monthly max. Conductivity (ms/cm)	% increase compared to the mean value	Monthly max. TDS (mg/L)	% Increase compared to the mean value	Extreme monthly precipitation (mm)	Monthly max. Conductivity (ms/cm)	% increase compared to the mean value	Monthly max. TDS (mg/L)	% Increase compared to the mean value
1982	213	987	161%	865	216%					
1984	170	980	159%	800	192%	146	1150	258%	992	291%
1992	160	1100	191%	1700	520%	140	950	196%	902	255%
1994	162	1600	323%	976	256%	141	1007	214%	656	158%
1997	204	1151	204%	808	195%	183	942	193%	780	207%
1998						182	868	170%	650	156%
2001	244	968	156%	780	185%					
2002	204	1250	231%	712	160%					
2003										

2004	257	905	139%	540	97%	202	1200	274%	780	207%
2005	254	1100	191%	750	174%					
Historical mean value	114	378		274		97	321		254	

For the 2011-2030 period, mean annual rainfall showed a slight increase in the eastern part, of only 1.4%. However, the monthly variations were much more significant, increasing by +16% and +30% for the months of May and June, respectively. Similarly, for the 2031-2050 period, despite the fact that a slight decrease in the annual precipitation was observed, the months of May and June experienced an increase in monthly rainfall of +12% to +16%, respectively. Considering these anomalies, the joint and conditional relationships for conductivity and TDS were obtained on a monthly basis as a function of precipitation for the baseline scenario (1980-2007), and the 2011-2030 and 2031-2050 scenarios. The results for the monthly accumulated pluvial precipitation, shown in table 2, indicate that in the eastern part, conductivity values above 800 µS/cm and TDS of 500 mg/L are observed for rainfall above 170 mm, with a probability of occurrence of 25% for the baseline scenario, 27% for the 2011-2030 scenario, and 28% for 2031-2050. The same values for conductivity and TDS are observed for the western part but for an accumulated rainfall of 200 mm, and with a lower probability of occurrence of 16% for the baseline scenario, 19% for the 2011-2030 scenario and 21% for the 2030-2050. The higher values of conductivity and TDS are associated with a higher occurrence of faecal coliforms in water.

Case study conclusions

Groundwater quality is affected by extreme rain events, but the impacts depend on the local vulnerability of the aquifer. Impacts are not observed immediately, but after a delay time, which depends on local conditions. For the Xochimilco aquifer, the eastern part is much more vulnerable to pollution than the western one. This information could be used in the planning of human settlements and activities in the area.

When within a month there are repeated extreme rain events, conductivity and TDS values increase by up to 60%. These higher values are associated with a higher probability of the occurrence of faecal coliforms in water. These conditions are observed in the eastern part of the aquifer for an accumulated rainfall of 170 mm, while in the western region this applies for rainfall above 200 mm. Under climate change scenarios, the probability of deterioration in the quality of water in the eastern part is increased by 27% and 28%, compared to the baseline scenario, for 2030 and 2050, respectively; while in the western part the increases may be up to 19% and 21%, respectively.

The pollutants investigated in this case study may be controlled with conventional treatment where infrastructure is available. However, operating conditions for drinking water plants have to be adjusted and the monitoring schedule reinforced during the rainy period to ensure that the drinking water standards continue to be met.

Table 2. Conductivity and TDS values as a function of pluvial precipitation

Eastern part												
Monthly accumulated rainfall/mm)	Conductivity (µS/cm)						TDS (mg/L)					
	Baseline		2011-2030		2031-2050		Baseline		2011-2030		2031-2050	
	value	probability	value	probability	value	probability	value	probability	value	probability	value	probability
120	614	34%	560	37%	456	42%	349	42%	409	36%	359	40%
150	781	25%	691	29%	619	32%	439	34%	500	29%	461	32%
170	808	24%	804	24%	858	28%	473	32%	523	28%	501	29%
200	958	18%	844	23%	904	21%	561	26%	604	23%	601	23%
220	1029	16%	905	20%	969	18%	616	23%	645	21%	662	20%
230	1102	14%	955	18%	1034	16%	650	21%	681	19%	702	18%
240	1110	14%	970	18%	1081	14%	674	20%	690	18%	729	17%
250	1147	13%	999	17%	1136	13%	703	18%	710	18%	762	15%
260	1189	12%	1031	16%	1194	12%	734	17%	732	17%	796	14%
Tolerance (±)	16%		18%		18%		28%		26%		26%	

Western part												
Monthly accumulated rainfall/mm)	Conductivity (µS/cm)						TDS (mg/L)					
	Baseline		2011-2030		Scenario 2031-2050		Baseline		2011-2030		Scenario 2031-2050	
	value	probability	value	probability	value	probability	value	probability	value	probability	value	probability
120	525	33%	499	34%	497	34%	268	45%	253	48%	243	49%
150	656	26%	627	27%	622	28%	373	35%	360	38%	353	39%
170	715	23%	686	27%	680	27%	426	31%	417	33%	414	34%
200	831	18%	801	19%	793	21%	538	23%	532	25%	532	26%
220	896	15%	867	16%	858	17%	611	19%	608	21%	612	22%
230	941	14%	911	12%	901	13%	653	17%	651	19%	656	19%
240	961	13%	932	12%	923	13%	689	16%	688	17%	696	18%
250	988	13%	961	11%	952	12%	729	14%	729	15%	738	16%
260	1015	12%	990	11%	981	11%	769	12%	771	14%	782	14%
Tolerance (±)	17%		18%		18%		25%		28%		29%	

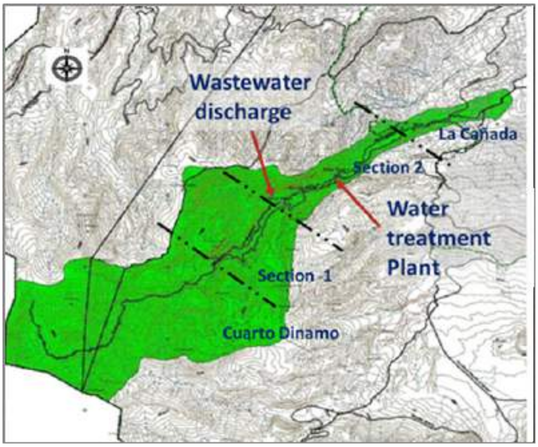
Case study 2. Impact of climate change on the self-purification capacity of an urban river

A decrease in the self-purification capacity of rivers, notably in mountainous areas is one of the impacts on water quality envisaged as a result of climate change (IPCC, 2014). This is caused by a decrease in the concentration of dissolved oxygen in warmer water. Microorganisms use dissolved oxygen to decompose biodegradable pollutants, and, since solubility decreases at higher temperatures, less oxygen is available for this process. In Mexico City, the warm season coincides with the wet one, leading to larger amounts of pollutants in rivers that are carried by runoff, and therefore demanding a higher depollution capacity in rivers. The following case study was performed in order to explore the impact of climate change on the self-purification capacity of a mountain-urban river in Mexico City.

Study site description

The Magdalena River Basin is located to the southwest of Mexico City in a 30 km^2 mountain basin (figure 3). At the basin's highest altitude, the weather is wet semi-cold while at the lowest it is temperate sub-wet. Rainfall ranges from 964 to 1,257 mm/year and temperature varies between 9 °C and 15 °C. The river begins at 3,850 MASL and ends at 2,470 MASL, from whence the river is channelled into a sewer, which passes through the city. The river is 21.6 km in length, of which the first 13 km flows through a protected forested area. In this area, the quality of the water is very good but, soon after, the river receives uncontrolled wastewater discharges. These are initially from a recreational area, followed by the disposal of domestic waste.

Figure 3. Section of the Magdalena River used in this case study



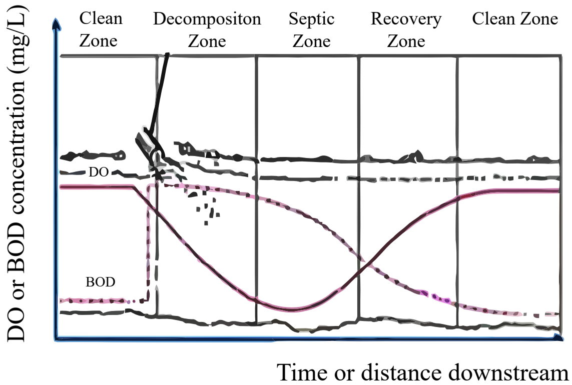
At the highest altitude, the maximum concentration of dissolved oxygen in the river is 7.6 mg/L at 9 °C. The mean river flow is 1 m^3/s, but it may increase up to 200 m^3/s during the rainy season, which lasts from June to September. During the last 2 km of free flow of the river, up to 210 L/s are extracted to supply 5,600 inhabitants. Prior to the distribution of the water it is treated through coagulation-flocculation and chlorination. The river section examined in this study is located between the Cuarto Dinamo and La Cañada, i.e., between kms 7 and 13, and includes the wastewater discharges from the recreational area and the intake to the water treatment plant.

Methodology

Depollution properties

For the study, the self-purification theory was considered (figure 4). According to this the oxygen dissolved in the water is consumed along the river by microorganisms to biodegrade organic pollution through the process of respiration.

Figure 4. Dissolved oxygen (DO) sag curve. Adapted from Montgomery (2008).



This phenomenon was mathematically described by Streeter and Phelps in 1925 (Loucks *et al.*, 2005), and since then other elements of the model have been added to include the degradation of nitrogenous matter, the uptake of oxygen by river sediments, and re-oxygenation of water. A commonly used expression for plug flow conditions is Equation 6.

$$D = D_o e^{-k\,ax/u} + \frac{k_d L_o}{k_a - k_d}\left(e^{-k_d x/u} - e^{-k_a x/u}\right) + \frac{k_n N_o}{k_a - k_n}\left(e^{-k_n x/u} - e^{-k_a x/u}\right) + \frac{S}{k_a H}\left(1 - e^{-k_a x/u}\right) + \frac{R-P}{k_a}\left(1 - e^{-k_a x/u}\right) + \frac{k_d L_b}{k_a}$$

(Equation 6)

where,

D: dissolved oxygen deficit or current content of dissolved oxygen in a river for a control volume, under steady and plug flow conditions, mg/L
D_o: initial dissolved oxygen saturation deficit in the water, mg/L
L_o: initial carbonaceous content measured as BOD, mg/L
L_b: initial BOD coming from non-point sources for pollution, mg/L
N_o: initial nitrogenous BOD or nitrogen oxidation demand, mg/L
S: sediment oxygen demand, mg/L
P: photosynthetic oxygen production, mg/s
R: sinks and sources of oxygen due to respiration and photosynthesis of

aquatic plants [macrophytes, phytoplankton (algae) and attached benthic algae] (Lin, 2001), mg/s
k_a*: re-aeration rate,* s^{-1}
k_b*: non-point source pollution BOD removal rate,* s^{-1}
k_d*: re-aeration rate* BOD_c*,* s^{-1}
k_n*: BOD removal rate* BOD_n*,* s^{-1}
u: mean flow velocity, m/s
x: distance, m

From the data gathered during the site inspection, Equation 6 was simplified by eliminating the terms representing nitrogen oxidation (as nitrogen content was low), the sediment respiration (due to the rocky river bed) and the biodegradation of pollution contained in non-point sources (as there were very few in the section of river selected). The additional provision of oxygen by aquatic plants was also ignored, as plants were very scarce in the river and photosynthetic data was not available. This resulted in Equation 7. In addition, to meet the plug flow conditions of the model, the river was divided into two sections (figure 1).

$$D = D_o e^{-k_a x/u} + \frac{k_d L_o}{k_a - k_d}\left(e^{-k_d x/u} - e^{-k_a x/u}\right) \quad \text{(Equation 7)}$$

where, the biodegradation (kd) and re-aeration (ka) rates at 20 °C for the first section were 225 d-1 and 1.5 d-1, and 0.671 d-1 and 0.69 d-1 for the second, respectively (Peavy *et al*., 1985). To adjust these values to the different temperature conditions the Arrhenius equation (Metcalf & Eddy, 2003) was used considering correction factors of θd= 1.056 and θa=1.024 (Schnoor, 1996) for kd and ka, respectively. The river velocity was estimated from the river flow, the transverse area section, and the river depth from measurements taken during the monitoring campaigns.

In total four monitoring campaigns were undertaken during 2010 and 2011 covering the dry and wet seasons and considering nine sampling sites. These data were used to calibrate the model. For this purpose, the dissolved oxygen content (DO), the biochemical oxygen demand (BOD), the total nitrogen (TN) and the ammoniacal nitrogen (N-NH3+) contents were analysed using the AWWA, APHA, WEF (2012) methods; a HACH Sension 156 detector was used for DO measurement, and a 10031 HACH monitor for nitrogen. All analyses were performed in duplicate but BOD analyses were performed in triplicate. In addition, the atmospheric and water temperatures were taken along the path of the river as a function of altitude. In general, a 6.5 °C increase was observed for each kilometre of decrease in height (Figueruelo and Davila, 2004).

Baseline scenario

A reference scenario with no climate change (baseline) was constructed for 2020 and 2050 using historical and experimental data. A 30-year period of data (1967-2007) for both atmospheric temperature and rainfall obtained from the climatological station (No. 9020) was used. The maximum monthly historic atmospheric temperature data were correlated with the monthly water temperature to obtain the equation used to make maximum water temperature projections (Tmax-r). Water temperature was inferred from the air temperature using a linear relationship established from historic 1968-2007 data. Water temperature was roughly 1.5 times that of the environment.

Using data series analysis, rainfall was projected and the results were used to estimate the river flow (Q), the mean water depth (Y) and the mean velocity (v) in the river using the Manning equation. Relationships between different water quality parameters (BOD and DO) with the temperature and the flow were estimated using information provided by the National Water Commission for the Cuarto Dinamo sampling station for the 2000-2008 period.

The organic pollution load emanating from the recreational area was estimated as a function of the total number of visitors per year (13,000 persons per month, PUEC-UNAM, 2008), the annual tourist growth rate of 2.4% (Banco Mundial-SECTUR, 2005), and the volume of water supplied which was equal to 40 L per person per day (Walski *et al*., 2003). This resulted in a total wastewater discharge flow for 2020 of 0.8 L/s and of 1.1 L/s for 2050. The organic matter content in the discharge was set at 30 mg/L of BOD, as this is the maximum value established by the Mexican standard for wastewater discharge, under the conditions of the study (NOM-001-SEMARNAT-1996).

Climate change scenarios

The A1B, B1 and A2 climate scenarios were used with the ECHAM and HADCM circulation models, as they are considered appropriate for Mexican conditions. The values for the temperature and precipitation anomalies for 2020 and 2050 (expressed as a mean monthly percentage for 2011-2040, and 2041-2070, respectively) were obtained from the Pacific Climate Impact Consortium (platform PCIC) (www.pacificclimate.org/tools/select), using the regions and downscaling method proposed by Douglas for Mexico (Conde and Gay, 2008). To detect the conditions under which the river's self-purification would change, the DO and BOD content in the river and the total amount of organic matter removed were estimated for each one of the different scenarios.

Results

The quality of water and the flow conditions –flow (Q), velocity, (v) and depth (Y) –as measured during the monitoring campaign for the Magdalena River– are shown in table 3; these were the data used to calibrate the model. It was observed, that during the rainy season the flow increased by more than three times the mean flow.

Table 3. Mean characteristics of the Magdalena River during the 2010-2011 monitoring campaigns

River segment	Season	T_{water} °C	BOD mg/L	DO mg/L	Q m^3/s	v m/s	Y M
1 (3072 masl)	Dry	13.7	9.9	4.6	0.2	0.25	0.13
	Rainy	12.0	4.7	8.1	0.7	0.41	0.28
2 (2568 masl)	Dry	16.8	8.9	3.6	0.3	0.29	0.16
	Rainy	12.0	2.6	8.0	1.3	0.51	0.40

Using the Streeter and Phelps model, it was found that the river was able to remove 54% and 76% of BOD in the dry season in 2010 and 2011, respectively. During the rainy season (July to September) efficiencies were negative, -18 and -12 %, for the same years respectively. The lower efficiency is due to storm runoff increasing both the flow of the river and its organic matter pollutant content. Indeed, during the dry season the river only received 19-49 kg BOD/d, while in the wet season the load increased to 98-164 kg/d. In any case, all these values are below the tolerable load of 345 kg BOD/d corresponding to a BOD of 30 mg/L set in the national regulations. As a result of the seasonal variations, the organic matter load entering the drinking water plant also varied between 27 and 74 kg/d during the dry seasons of 2010 and 2011, respectively, to 195 and 316 kg/d in the rainy seasons.

For the three 2020 climate change scenarios studied, the atmospheric temperature increased between 0.2 and 2.4 °C and with it water temperature between 0.4 and 2.7 °C. Pluvial precipitation, together with water velocity in the river, are also modified, with a tendency for both to increase during the wet season. Figure 5 shows that the initial concentration of dissolved oxygen in the river varies throughout the year, for all climate change scenarios and the baseline. However, it is during the dry season, when temperature is lower, that it is more common for the river to be at or below the DO limit of 4 mg/L. Similar results were obtained for the two models used, the ECHAM and the HADCM (results not shown).

Figure 5. Projections with the ECHAM model on the initial dissolved oxygen in the river in mg/L, indicating 4 mg/L as an acceptable value

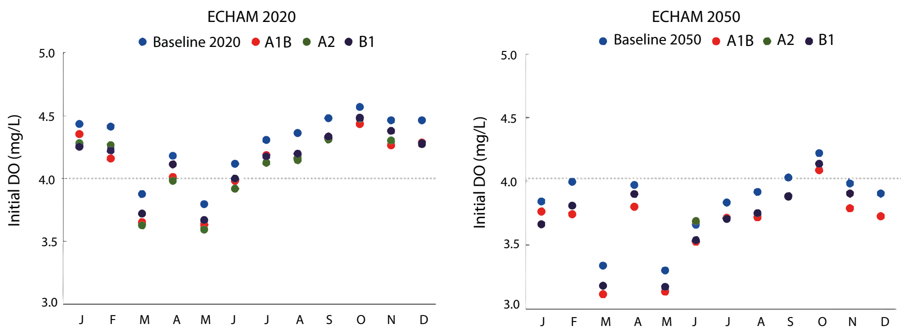


Table 4 shows that, under mean annual conditions, the initial mean DO concentrations were 4.3, 4.1, 4.1 and 4.2 mg/L for the 2020 baseline, A1B, A2 and B1, ECHAM scenarios, respectively.

Table 4. Initial dissolved oxygen content in the river in mg/L for 2020 ECHAM model

Month	Baseline 2020	A1B	A2	B1
1	4.4	4.4	4.3	4.3
2	4.4	4.2	4.3	4.2
3	3.9	3.7	3.6	3.7
4	4.2	4.0	4.0	4.1
5	3.8	3.6	3.6	3.7
6	4.1	4.0	3.9	4.0
7	4.3	4.2	4.1	4.2
8	4.4	4.2	4.2	4.2
9	4.5	4.3	4.3	4.3
10	4.6	4.4	4.5	4.5
11	4.5	4.3	4.3	4.4
12	4.5	4.3	4.3	4.3
Mean	4.3	4.1	4.1	4.2

The 2020 and 2050 projections for the organic matter removal efficiency, shown in table 5, illustrate that the values are similar for all scenarios. However, there are monthly variations, with negative efficiencies occurring during the rainy season. The lower flow and river velocity explain the higher BOD removal efficiency for the dry season as they allow a higher retention time, increasing biological degradation in the Magdalena River. In contrast, storm runoff increases both the river flow and organic matter content that reach the river. The residence time is therefore lower and subsequently the BOD removal decreases.

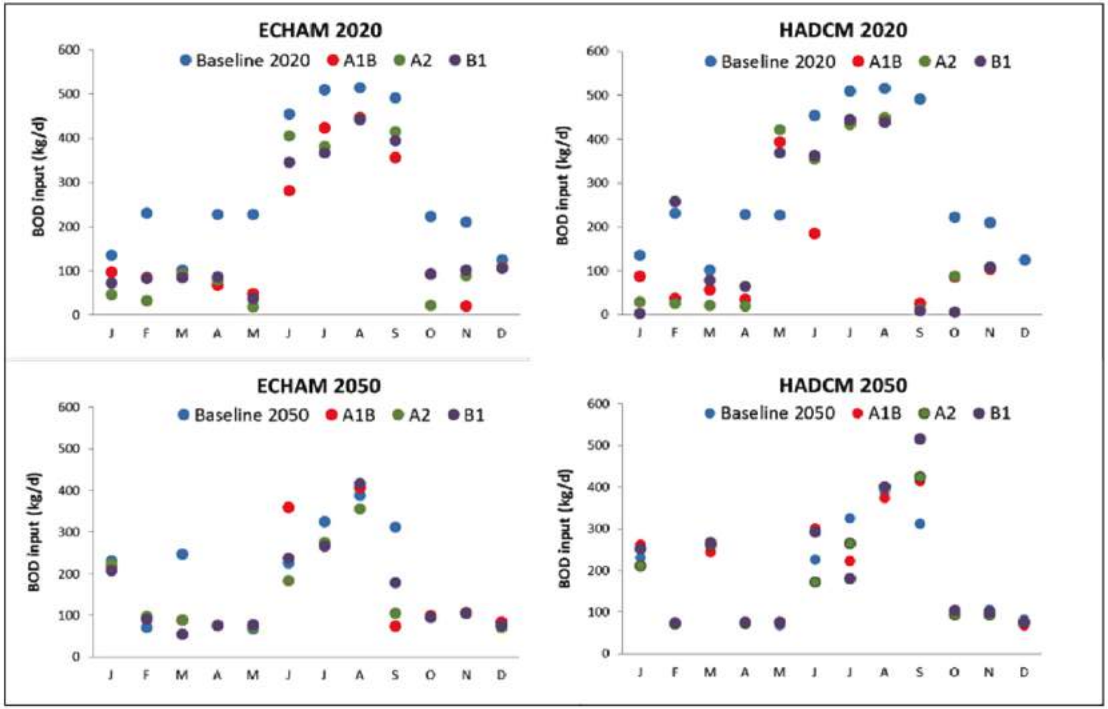
Table 5. Monthly BOD removal (as a percentage) for different climate change scenarios and models

	2020							2050						
Month	BS	ECHAM			HADCM			BS	ECHAM 2050			HADCM 2050		
		A1B	A2	B1	A1B	A2	B1		A1B	A2	B1	A1B	A2	B1
1	23	13	-29	61	26	29	21	12	14	13	61	39	17	21
2	-30	64	83	52	52	85	75	61	36	31	52	24	61	75
3	22	-17	43	32	22	21	20	10	44	40	32	63	9	20
4	73	37	57	53	70	89	70	58	58	59	53	7	61	70
5	69	42	90	80	81	90	66	63	60	62	80	60	59	66
6	-57	-59	-54	-44	-55	-52	-57	-60	-54	-59	-44	12	-59	-57
7	-42	-43	-35	-33	-34	-31	-32	-25	-15	-15	-33	62	-12	-32
8	-57	-51	-51	-54	-47	-45	-50	-56	-53	-23	-54	60	-36	-50
9	-61	-61	-58	-60	-53	-51	-56	-60	-68	-66	-60	-55	-42	-56
10	96	75	88	43	86	94	95	32	29	35	43	-3	37	95
11	44	84	47	30	50	49	96	10	-11	1	30	-31	33	96
12	-8	74	-10	-6	17	5	7	53	51	62	-6	-47	59	7
Mean	6	13	14	13	18	24	21	8	8	12	13	16	16	21

Negative values are in red while positive ones are in black
BS: Baseline scenario

Finally, figure 6 shows that for all climate change conditions, the overall mean organic matter entering the drinking water plant during the dry season was always below the threshold value of 345 kg BOD/d (BOD of 30 mg/L). The results for the projections for dry and rainy seasons under climate change scenarios are consistent with the measurements recorded during the monitoring campaigns of 2010 and 2011. A mean organic load of 48 kg BOD/d was observed for the dry season, representing better operating conditions for the water treatment plant when compared to the values observed for the wet season, amounting to 227 kg BOD/d on average. For the 2020 and 2050 scenarios mean loads of 89 and 110 kg BOD/d, respectively, were estimated for the dry season representing a 1.8 and 2.3% increase, respectively, in comparison to the baseline. For the rainy months, the mean load was estimated at 394 and 296 kg BOD/d, respectively, corresponding to 1.7 and 1.3% increases above the average measured value of BOD of 227 kg/d. Moreover, for 2050, when pluvial precipitation is even higher, the mean organic matter load entering the drinking plant is notably lower than that for 2020.

Figure 6. Monthly organic matter load as BOD entering the drinking water plant using the ECHAM and HADCM models for 2020 and 2050 estimations



Use of the methodology developed for the Coatzacoalcos River

Montes *et al* (2013) applied this same methodology to a much larger river discharging into the ocean in a tropical area for comparison. The Coatzacoalcos River is 315 km in length and has a flow rate of 415 m^3/s. It is located in the southern part of the state of Veracruz in a tropical area. The river will be affected by climate changes not only because of variations in temperature and rainfall but also as a result of sea level rise. In addition, one of the last segments of the river has been characterized as one of the most polluted in Mexico.

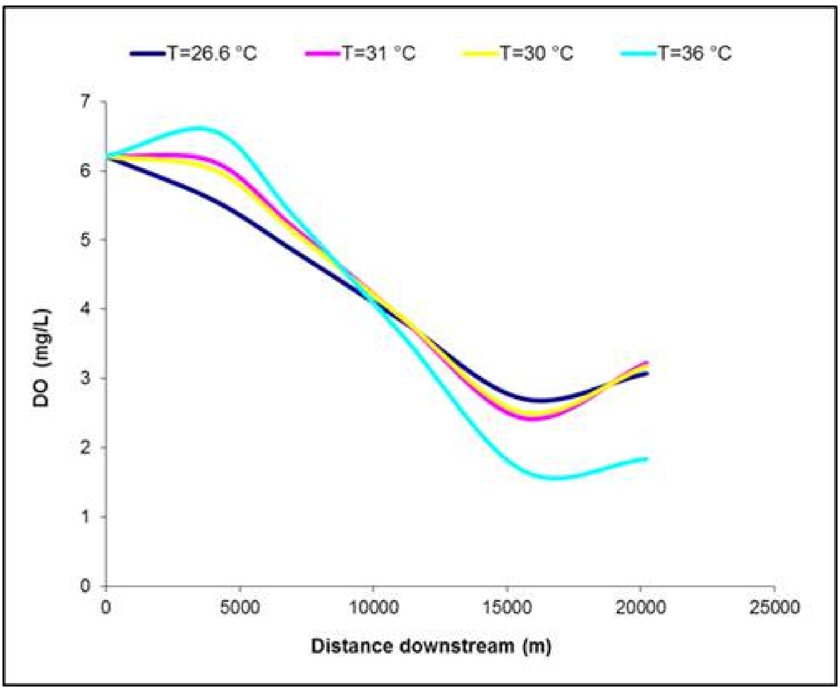
To perform the analysis, historical data for the 1997-2007 period were used for DO, BOD, nitrogen (nitrates, nitrites and ammoniacal nitrogen). The model was applied to the last 20 km of the river, where three monitoring stations are located, prior the discharge of the river into the Gulf of Mexico. Rainfall and temperature data recorded since 1945 from three climatological stations were used. The availability of data is presented in table 6. As expected, more information was available on climate than on water quality. Furthermore, the frequency of sampling of water quality was not regular, making it difficult to combine and compare data.

Table 6. Number of data points used for the Coatzacoalcos River for the 1997-2007 period

BOD	DO	COD	Nitrogen	Temperature	Precipitation
50	48	42	25	7,260	7,295

The Streeter and Phelps model was applied considering the typical characteristics of the river, i.e., a water velocity of 0.1 to 1 m/s, a mean flow of 465 m^3/s, a water depth of 5 m, an initial concentration of DO of 6.2 mg/L and wastewater discharges to the river with a BOD content of 300 mg/L. It was found that when the mean temperature of the river of 26.6°C was increased by 5°C the amount of dissolved oxygen in the river was reduced to only 2 mg/L, a value well below the critical concentration for aquatic life of 4 mg/L (figure 7). It was observed that at higher water temperatures not only was the initial DO reduced but the rate of DO consumption was increased, rendering it even more difficult for the river to recover from pollution. This illustrates that for larger rivers in tropical areas, temperature increase may be a limiting factor in the self-purification processes, since the velocity of water and the river depth play a significant role in the re-aeration of a river.

Figure 7. Effect of the changes on water temperature on the dissolved oxygen content in the Coatzacoalcos River



Case study conclusions

As stated in the literature, the maximum amount of oxygen dissolved in a river depends on water temperature: a higher water temperature corresponds to a lower dissolved oxygen content. However, oxygen is constantly dissolved into water depending on the velocity of water, the depth of the river and its turbulence, which are all functions of river flow. Ultimately this is a contribution of pluvial precipitation. Given the small size and characteristics of the Magdalena River, the re-aeration conditions were predominant in the overall self-purification of the river, compared to the effects of higher temperature. However, for the Coatzacoalcos River, which is a larger and deeper river, located in a warmer environment, pluvial precipitation had no positive effects on the re-aeration of the river and the higher water temperature affected its self-purification capacity. Thus, these examples show that the impacts of climate change on the self-purification conditions of a river depend on its individual characteristics and location.

Case study 3. Waterborne diseases and drinking water quality

The extent to which waterborne diseases affect populations depends on both water pollution and population vulnerability. As waterborne diseases are expected to increase under climate change scenarios, this research attempted first to assess the relationship between acute diarrhoeal diseases and changes in the quality of drinking water with climate change. Since it became clear that this was not feasible, the focus was altered to assess the vulnerability of the population of six different districts of Mexico City to waterborne disease under climate change scenarios (Osnaya, 2013).

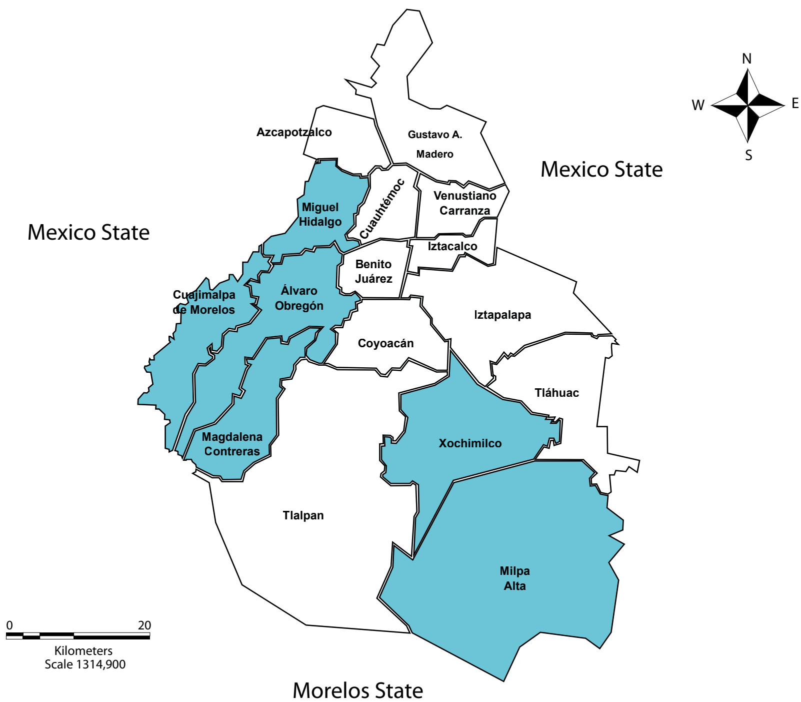
Background

In Mexico City, acute diarrhoeas are the sixth most common cause of disease among children. In fact, children, as well as adults over 65 years of age, are the most affected. Diarrhoeas are linked to lack of water services but also to poverty. Diarrhoeas have a seasonal pattern, as they most commonly occur during the hot, rainy season, as storm runoff conveys turbidity and parasites into water sources (Hammond and Pryce, 2007). In Mexico City, acute diarrhoeal diseases (ADD) increase by 15% during the hot season (GDF, 2009). ADD cause economic losses, as working days are lost, productivity of workers is decreased, and there are costs to cover medical expenses and hospitalisations. Further economic losses occur due to a lower income in the food industry, restaurants and tourist areas. Moreover, for the poor, the cost is even higher as a non-working day results in a complete loss of income. Medical and hospitalisation costs, alone, amount to $35 USD/disease (Chacon & Leal, 2006). The population is not affected equitably, as this depends on vulnerability. Vulnerability is a systemic condition that is multi-factorial, multi-sectorial, multi-temporal and multi-scale (IPCC, 2007 & 2012).

Site description

Mexico City comprises 16 districts, six of which were part of this study (Alvaro Obregon, Cuajimalpa, Magdalena Contreras, Miguel Hidalgo, Milpa Alta and Xochimilco) (figure 8). These areas were selected because of the opportunity to contrast vulnerability as they have different social and economic conditions (table 7), together with the availability of water quality and acute diarrhoeal disease data.

Figure 8. Mexico City and its 16 districts
(Those which are part of this study are shaded)



Climate and water supply characteristics for the six districts are shown in table 7 and 8. The figures on water supply and sanitation coverage for the entire city is 86.7% and 94. %, respectively. As is the case for the rest of the country, all the districts of Mexico City receive water intermittently.

Methodology

Most of the data on water quality were provided by the Mexico City Water Utility (SACM, 2008-B) while the health data came from the Ministry of Health. Water quality databases contained 15 different parameters; of these, seven (pH, TDS-total dissolved solids, TH-total hardness, TC-total coliforms, FC-faecal coliforms, turbidity, and Cl-free chlorine) were selected because of their relevance to the study. This information came from 202 wells. Health databases covered only the 1995-2008 period and hence only the data on water quality for this same period was used. Ten diseases catalogued according to the 10th International Classification of Diseases (CVE-CIE10, WHO) were selected. They were regrouped into six categories: (a) typhoid fever (A01.0); (b) giardiasis (A07.1); (c) acute hepatitis A (B15); (d) intestinal infections and diseases caused by other or non-identified organisms (A04, A08, A09); (e) paratyphoid and salmonellosis (A01.1, A01.4, A02); and (f) shigellosis (A03).

Table 7. Main Characteristics of the six districts studied

		Population					***Households***	
Delegation	***Surface km²***	***Total population***	***% Living with food insecurity***	***% With no access to health services***	***% Economically active***	***% Literacy in those above 15 years of age***	***% Connected to the to the water network***	***% With sewerage connection***
A. Obregon	96,2	727,034	8.5	30	58.9	97.2	96.2	97.2
Cuajimalpa	74,6	186,391	8.1	31	47.2	97.0	93.4	95.7
M.Contreras	74,6	239,086	9.2	33.1	47.2	97	93.4	95.7
M. Hidalgo	47,0	372,889	3.0	23.8	52.8	96.9	94.1	94.1
Milpa Alta	228,4	130,582	12.5	46.3	69.7	98.4	82.6	96.3
Xochimilco	122,0	415,007	9.6	43.2	47.6	96.5	87.1	96.1

Source: INEGI, 2011

Table 8. Relevant figures on climate and drinking water supply for the six districts studied in Mexico City, with information from GDF (2010) and SSDF (2008).

District	Mean Temperature, ^{0}C		Mean Rainfall, mm	Water supplied	Frequency of supply*		Intestinal infections
Data period	Mean	Min-Max (MAX)	Mean (MAX)	L/ inhab/d	Daily	3 days per week	Ranking **
A. Obregon 1976 -2007	12.0	9.6-24.1 (30.5)	2.4 (13.0)	391	90.3	2.6	7th / 20th
Cuajimalpa 1965 -2009	8.5	4.6-15.4 (27.8)	3.5 (31.5)	525	90.3	2.6	-/13th
M. Contreras 1967-2009	10.7	8.1-22.9 (31.6)	2.8 (15.5)	414	78.7	5.6	-/19th
M. Hidalgo 1977 -2008	11.5	9.3-24.6 (30.8)	2.5 (11.3)	478	94.0	1.7	--
Milpa Alta 1929 -2009	11.6	9.0-21.7 (32.5)	2.1 (13.6)	231	70.0	12.5	--
Xochimilco 1965- 2008	11.6	8.3-25.3 (36.7)	1.5 (7.3)	214	70.0	12.5	6th/--
Mexico City				**327**	N.D.	N.D.	--/19th

* Does not include the population with 5, 4, 2, or 1 day per week water supply, ND: No data, MAX: Absolute monthly maximum
** Ranking for infant/Ranking for total population mortality

The methodology used consisted of three steps: (a) climate, water quality and disease data analysis for each one of the districts; (b) estimation of correlates between climate, water quality and ADD cases; and (c) estimation of the population vulnerability index for each region for the years 1995, 2000, 2005 and 2010.

Faecal coliform data was transformed from positive and negative values into numerical values (1 and 0). Correlations were established using the statistical program StatWizard, 4th version. The vulnerability index was calculated using the ICRISAT (2009) method with the following indicators:

- For exposure: faecal coliforms, total coliforms, turbidity, maximum monthly temperature and pluvial precipitation.
- For sensitivity: total population, population living under conditions of food insecurity, population with no access to health services, and total cases of waterborne diseases reported.
- For adaptation capacity: literate population, economically active population, households with water connection, and population with sewerage connection.

The information for the sensitivity and adaptation capacity indicators was obtained from the last national census (INEGI, 2011). The values estimated for each indicator were standardized between 0 and 1 using MS-Excel and it was assumed that all indicators but the one for the adaptation capacity related positively to vulnerability. For positive relationships, the indicator was standardized with Equation 8:

$$x_{ij} = \frac{X_{ij} - Min_i\{X_{ij}\}}{Max_i\{X_{ij}\} - Min_i\{X_{ij}\}} \qquad \text{Equation 8}$$

where xij is the indicator standardized between 0 ≤ xij ≤ 1; with 1 as maximum and 0 as the minimum; it is the j indicator for the i region.

For negative functional relationships, the indicator was standardized with Equation 9:

$$x_{ij} = \frac{Max_i\{X_{ij}\} - X_{ij}}{Max_i\{X_{ij}\} - Min_i\{X_{ij}\}} \qquad \text{Equation 9}$$

The weighting wj for each j indicator was estimated using Equation 10, as suggested by Iyengar & Sudarshan (1982), where i = 1,…,6 represents the district, k is the indicators' assessment (j = 1,…,k), and vari(Xij) is the variance of the set of Xij values for the j standardized indicators in each of the regions.

$$w_j = \frac{c}{\sqrt{var_i(X_{ij})}}$$ Equation 10

It was assumed that the sum of all the weighting values assigned fulfil Equation 11, with c as a parameter of standardization estimated with Equation 12.

$$\sum_{j=1}^{k} w_j = 1$$ Equation 11

$$c = \left[\sum_{j=1}^{k} \frac{1}{\sqrt{var_i(X_{ij})}}\right]^{-1}$$ Equation 12

Finally, the vulnerability index for the region i (IVi) was estimated as the sum of all weighting values (wj) multiplied by the standardised indicator (Xij) for all the j indicators assessed, as follows:

$$IV_i = \sum_{j=1}^{k} w_j X_{ij}$$ Equation 13

The vulnerability index value (IVi) was then classified as: (a) very low (0 ≤ IVi < 20th percentile); (b) low (20 ≤ IVi < 40th percentile); (c) moderate (40 ≤ IVi < 60th percentile); (d) high (60 ≤ IVi < 80th percentile); and e) very high (80 ≤ IVi < 100th percentile). Each category was estimated using a beta probabilistic distribution function for the vulnerability index estimated.

Results

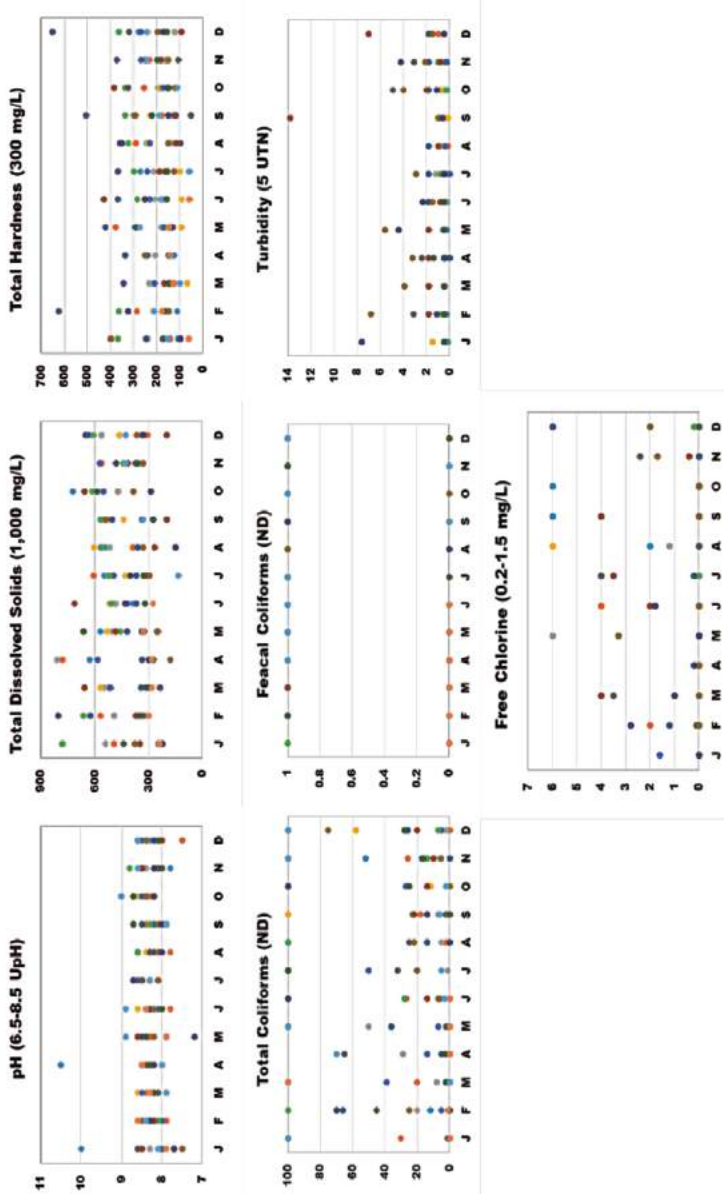
Climate Variables, Water Quality and Disease cases

Table 8 shows the daily mean values obtained for the atmospheric temperature and rainfall for each district. Figure 9 shows, as an example, the maximum values obtained for seven water quality parameters for Xochimilco for the

1995-2008 period. Values in brackets refer to those set by the national drinking water standards for comparison.

For the six districts, the most frequent non-compliance to the drinking water standards was due to turbidity and faecal coliforms during the rainy season. The latter occurred even when water contained residual chlorine, which meant that pollution was recent and the contact time between the chlorine and the bacteria for disinfection was insufficient. Only in Xochimilco were faecal coliforms also found to be present during the dry season. This region is located in the groundwater recharge area, where sewerage coverage is enforced by law and septic tanks are commonly used for sanitation. Cifuentes *et al* (2002) and Torres (1999) assessed the presence of enteric diseases transmitted through water by pathogens resistant to chlorine in the Xochimilco area.

Figure 9. Xochimilco, maximum monthly values for water quality parameters, 1995-2008



Water quality and climate parameters

Water quality parameters showed a weak relationship with mean daily maximum temperature and precipitation at a 95% confidence level (table 9, shows results for precipitation alone). The only clear positive relationship was found between total coliforms (TC) and precipitation. For the remaining parameters, the relationship was negative although only slightly. Turbidity increased with precipitation in only three (Alvaro Obregon, Milpa Alta and Xochimilco) of the six districts.

Intestinal infections were positively correlated with both temperature and rainfall. Giardiasis was associated only with temperature while paratyphoid and salmonellosis were linked to pluvial precipitation (results not shown). However, in terms of water quality, these relationships were weak. Acute hepatitis A had a negative relationship with precipitation for the six regions. Waterborne diseases are manifested after an incubation period, which ranges from 3 hours to 10 days, thus further analysis is needed to draw proper conclusions. However, the information needed for such analysis is not available.

Relationship between ADD and water quality parameters.

In general, both positive and negative relationships between the diseases and water quality parameters were weak in all cases, and under all conditions; no statistically significant correlations were found at the 95% confidence level (table 10). One of the main reasons for this is the lack of data concerning water quality. In most of the cases less than 25 data points were available for the entire period of the study. However, the correlations between AD and total and faecal coliforms with turbidity were linear and positive, and highly variable between the different districts. Weak relationships were found between total coliforms and typhoid fever, giardiasis, and acute hepatitis A. Faecal coliforms had a positive relationship with typhoid fever and giardiasis diseases for some districts; while in some cases an association was found between turbidity and paratyphoid-salmonellosis, acute hepatitis A, and intestinal infection.

Table 9. Parameters for the linear relationship estimated for water quality and mean daily rainfall values, 1995-2008.

District	Ph	TDS	TH	TC	FC	Turbidity	Cl
A.Obregon	**0.0448 (0.526)**	**0.0934 (0.206)**	**0.0577 (0.413)**	**0.1607 (0.051)**	**0.1728 (0.098)**	**0.3579 (0.079)**	sr
Cuajimalpa	**0.0194 (0.848)**	**0.0480 (0.664)**	**0.1922 (0.059)**	-0.0579 (0.719)	**0.1230 (0.510)**	-0.3322 (0.141)	sr
M.Contreras	**0.2710 (0.011)**	**0.1494 (0.198)**	**0.0783 (0.476)**	**0.0963 (0.576)**	**0.2029 (0.353)**	-0.2196 (0.493)	**0.5655 (0.055)**
M.Hidalgo	-.0.0376 (0.652)	**0.0501 (0.597)**	-0.0018 (0.984)	**0.0195 (0.844)**	-0.0275 (0.808)	-0.1226 (0.587)	-0.3814 (0.080)
Milpa Alta	-0.0297 (0.791)	-0.1836 (0.128)	¿	**0.1339 (0.296)**	-0.0035 (0.981)	**0.1156 (0.659)**	**0.0831 (0.751)**
Xochimilco	-0.0678 (0.472)	-0.3081 (0.001)	-0.1297 (0.171)	**0.1065 (0.294)**	-0.0353 (0.730)	**0.0501 (0.630)**	**0.01235 (0.233)**

Table 10. Parameters for a linear relationship between ADD and water quality

District	pH	TDS	TH	TC	FC	Turbidity	Cl
Typhoid Fever							
A. Obregon	-.0038 (0.9671)		-0.0472 (0.6140)	-0.0616 (0.5616)	-0.0617 (0.6367)	-0.0748 (0.6508)	-0.0424 (0.8033)
Cuajimalpa	**0.1513 (0.3098)**	-0.0802 (0.6521)	-0.0840 (0.5875)	**0.1118 (0.5100)**	-0.0229 (0.9007)	-0.0817 (0.7111)	Sr
M. Contreras	-0.0247 (0.8634)	-0.1039 (0.4922)	**0.1152 (0.4305)**	**0.4156 (0.0486)**	**0.5749 (0.0315)**	Sr	Sr
M. Hidalgo	-0.1476 (0.1492)	**(0)**	-0.1418 (0.1753)	**0.1752 (0.1177)**	-0.0853 (0.5602)	-0.0733 (0.7218)	-0.2356 (0.2677)

District	pH	TDS	TH	TC	FC	Turbidity	C1
Milpa Alta	0.1244 (0.5203)	-0.2601 (0.2549)	0.0595 (0.7775)	-0.0859 (0.6699)	0.2055 (0.3588)	-0.1227 (0.4124)	-0.1078 (0.6804)
Xochimilco	0.0782 (0.4739)	-0.0635 (0.5685)	-0.0693 (0.5263)	0.0102 (0.9283)	(0)	0.3721 (0.0007)	-0.1316 (0.2506)
Giardiasis							
A. Obregon	0.3576 (0.0001)	0.4173 (0.0000)	(0)	0.0097 (0.9275)	-0.1287 (0.3230)	-0.1696 (0.3020)	-0.2632 (0.1156)
Cuajimalpa	-0.3559 (0.0036)	0.1536 (0.2868)	-0.2229 (0.0816)	0.1109 (0.5074)	-0.1629 (0.3729)	0.0027 (0.9901)	Sr
M. Contreras	-0.2069 (0.0981)	-0.2369 (0.0845)	-0.1779 (0.1630)	0.2944 (0.1079)	0.3268 (0.1482)	-0.2099 (0.5125)	-0.2524 (0.4286)
M. Hidalgo	-0.0581 (0.5716)	-0.0379 (0.7258)	-0.0023 (0.9826)	-0.0176 (0.8763)	0.4076 (0.0036)	-0.1074 (0.6015)	-0.1763 (0.4099)
Milpa Alta	-0.1565 (0.2449)	0.0511 (0.7300)	-0.1158 (0.4091)	0.2370 (0.1408)	0.0172 (0.9321)	-0.1609 (0.5374)	-0.3923 (0.1194)
Xochimilco	0.1444 (0.1672)	0.0787 (0.4607)	-0.1071 (0.3068)	-0.2007 (0.0608)	-0.0664 (0.5415)	-0.1309 (0.2294)	-0.0965 (0.3704)
Acute Hepatitis A							
A. Obregon	-0.0542 (0.5633)	-0.0952 (0.3178)	-0.0931 (0.3225)	-0.0874 (0.4102)	-0.0368 (0.7782)	-0.2243 (0.1698)	-0.0072 (0.9661)
Cuajimalpa	-0.1214 (0.3394)	-0.0987 (0.4952)	-0.0989 (0.4484)	-0.2327 (0.1658)	-0.1999 (0.2809)	0.1033 (0.6473)	Sr
M. Contreras	0.1783 (0.1552)		0.1968 (0.1222)	0.1100 (0.5557)	-0.0574 (0.8047)	-0.0536 (0.8686)	0.2447 (0.4434)
M. Hidalgo	0.1783 (0.1552)	0.2532 (0.0648)	0.1968 (0.1222)	0.1100 (0.5557)	-0.0574 (0.8047)	-0.0536 (0.8686)	0.2447 (0.4434)
Milpa Alta	0.0515 (0.7036)	0.1457 (0.3231)	-0.2128 (0.1261)	-0.0927 (0.5695)	-0.1419 (0.4802)	0.1856 (0.4758)	-0.2954 (0.2497)
Xochimilco	-0.0754 (0.4724)	-0.2446 (0.0202)	-0.1035 (0.3236)	0.0033 (0.9755)	0.0326 (0.7647)	0.1700 (0.1176)	-0.0471 (0.6685)
Intestinal infection and other poorly defined diseases							
A. Obregon	0.0248 (0.7916)	0.0675 (0.4792)	-0.0378 (0.6884)	-0.0432 (0.6844)	-0.3764 (0.0028)	-0.0992 (0.5477)	0.1118 (0.5101)
Cuajimalpa	0.1339 (0.2873)	-0.1111 (0.4420)	0.0232 (0.8577)	-0.0829 (0.6203)	0.1231 (0.5020)	0.3460 (0.1058)	Sr
M. Contreras	0.2411 (0.0531)	0.2816 (0.0391)	0.1729 (0.1753)	-0.2428 (0.1882)	-0.7298 (0.0002)	0.0317 (0.9200)	-0.2056 (0.5215)
M. Hidalgo	-0.0461 (0.6537)	-0.2200 (0.0394)	0.1835 (0.0783)	-0.1456 (0.1948)	-0.4607 (0.0009)	-0.2847 (0.1586)	-0.1847 (0.3876)

District	pH	TDS	TH	TC	FC	Turbidity	C1
Milpa Alta	-0.1204 (0.3722)	0.1011 (0.4943)	-0.2423 (0.0805)	-0.2826 (0.0773)	-0.2087 (0.2961)	-0.1155 (0.6589)	**0.4657 (0.0596)**
Xochimilco	**0.1843 (0.0770)**	-0.0088 (0.9347)	-0.1354 (0.1957)	-0.2299 (0.0311)	-0.0351 (0.7465)	-0.2060 (0.0570)	-0.1011 (0.3572)
Paratyphoid-salmonellosis							
A. Obregon		-0.0570 (0.5502)	**0.0393 (0.6766)**	**0.0513 (0.6293)**	-0.2212 (0.0866)	-0.0553 (0.7382)	**0.2568 (0.1249)**
Cuajimalpa	**0.0354 (0.7794)**	-0.1098 (0.4480)	-0.1481 (0.2507)	-0.1683 (0.3126)	-0.0232 (0.8994)	**0.4042 (0.0558)**	Sr
M. Contreras	**0.0026 (0.9838)**	**0.2319 (0.0915)**	**0.1923 (0.1311)**	**0.3459 (0.0566)**	-0.1150 (0.6196)	**0.0345 (0.9153)**	**0.7817 (0.0027)**
M. Hidalgo	-0.0011 (0.9916)	-0.1367 (0.2041)	0.1111 (0.2892)	-0.0717 (0.5247)	-0.0853 (0.5420)	**0.0031 (0.9881)**	-0.1537 (0.4732)
Milpa Alta	-0.0544 (0.6880)	-0.3119 (0.0309)	-0.2882 (0.0364)	-0.2745 (0.0865)	-0.2361 (0.2357)	-0.1734 (0.5058)	-0.0815 (0.7558)
Xochimilco	**0.0078 (0.9408)**	**0.1620 (0.1271)**	**0.0646 (0.5382)**	-0.0129 (0.9047)	**0.2144 (0.0462)**	-0.1011 (0.3544)	-0.1014 (0.3558)
Shigellosis							
A. Obregon	**0.0439 (0.6393)**	**0.1367 (0.1505)**	**0.1195 (0.2034)**	**0.1774 (0.0924)**	**0.0635 (0.6268)**	-0.0287 (0.8622)	**0.3894 (0.0172)**
Cuajimalpa	**0.0412 (0.7524)**	-0.0877 (0.5446)	-0.0023 (0.9862)	-0.1338 (0.4507)	-0.1667 (0.3966)	-0.1265 (0.6059)	**Sr**
M. Contreras	**0.0535 (0.6745)**	**0.0846 (0.5469)**	**0.1258 (0.3300)**	-0.0174 (0.9275)	-0.1784 (0.4516)	-0.2552 (0.4235)	**0.8058 (0.0016)**
M. Hidalgo	-.0.0298 (0.7723)	-0.1379 (0.2000)	**0.0511 (0.6267)**	-0.1244 (0.2685)	-0.1893 (0.1927)	-0.0212 (0.9181)	-0.0307 (0.8867)
Milpa Alta	**0.0098 (0.9492)**	**0.0871 (0.6082)**	-0.2585 (0.1027)	-0.1699 (0.3523)	-0.1438 (0.5233)	-0.0882 (0.7364)	-0.1144 (0.6618)
Xochimilco	-0.2394 (0.0460)	-0.1105 (0.3732)	-0.1154 (0.3413)	-0.1885 (0.1296)	-0.1764 (0.1565)	-0.0692 (0.5838)	-0.0579 (0.6490)

Negative correlations are in red, positives in black.

Information and Data

To perform the study, sufficient information was available for pluvial precipitation and temperature, but not for water quality or waterborne diseases. For water quality, the monitoring frequency was very poor and the monitoring period insufficient; for pH, data was available for the 1955-2008 period but for the other parameters the period covered was 2000-2010. The main source of uncertainty for this study was therefore lack of information. The lack of data cannot be excused, as the economic level of the city is high, water is a key resource and the local government has a proper institutional and human resource capacity. In the best-case scenario, the monitoring frequency was 3 data points per year for an entire district. In addition, for critical parameters such as residual chlorine, which is key to protect human health, the maximum amount of data available was 5 samples per 100,000 inhabitants. These are values that fulfil the Mexican monitoring standard (NOM-179-SSA1-1998), citing one sample per year for 50,000 people for physico-chemical parameters and one for every 250,000 inhabitants for microbial parameters. Finally, it was observed that most of the data was gathered during the rainy season, and there were some erratic figures. Moreover, to assess the effects of climate change on water quality and health, notably during heat waves, it is important to have information for both seasons to coordinate the monitoring regimes within the health and water sectors.

A further challenge was that information on diarrhoeal diseases was spread throughout different reports, which used different classifications for diseases. Additionally, having information on diseases only for the 1995-2008 period was troublesome as it is simply insufficient to allow climate change studies.

Vulnerability

As expected, the vulnerability indices (IVi) (table 11) depend on the weighting assigned to the different indicators. In the present study, exposure contributed 24.4%, sensitivity 37.8% and adaptation 37.9%. This means that to reduce vulnerability, decreasing exposure and increasing the capacity to adaptation are highly relevant. It was also observed that the exposure indicator increased from 1995 to 2005, and decreased after 2010. Throughout these same years it was observed that the sensitivity indicator constantly decreased while for the reverse was observed for adaptation, for which values increased over time (results not shown). The indicators associated with the population (food insecurity, lack of access to health services, sensitivity and illiteracy, capacity for adaptation) were the most important in determining vulnerability. For climate, only rainfall proved to be highly significant, particularly at the beginning of the period under analysis.

The region with the highest levels of poverty and lowest incomes was found to be the most vulnerable. This is due to the higher sensitivity and lower capacity for adaptation of the population. It is evident that it is not sufficient to merely improve the quality of water services to protect the population. It is also necessary to reinforce its capacity for adaptation. The increase in temperature was seen to be the component of the vulnerability index that contributed most to exposure in almost all cases.

Table 11. Vulnerability indices (IVi) for each district in 1995, 2000, 2005 and 2010

1995		2000		2005		2010	
	IV_i		IV_i		IV_i		IV_i
Milpa Alta	64.7	Milpa Alta	66.4	Xochimilco	63.7	Milpa Alta	60.7
A.Obregon	57.5	Xochimilco	63.6	Milpa Alta	57.5	Xochimilco	59.9
Xochimilco	50.7	A. Obregon	47.5	A.Obregon	52.7	A.Obregon	55.7
Cuajimalpa	40.9	M. Contreras	39.3	M. Hidalgo	43.7	M. Contreras	40.9
M. Hidalgo	32.4	Cuajimalpa	23.3	M.Contreras	35.1	M. Hidalgo	39.6
M.Contreras	22.6	M. Hidalgo	20.6	Cuajimalpa	27.6	Cuajimalpa	37.2

Note: Very low: dark green; low: light green; moderate: yellow; high: orange; and very high: red

The vulnerability indicator developed, showed that:

a) Vulnerability proved to be a dynamic process; thus, it is important not only to assess it for different conditions and periods of time but also

to use different combinations of indicators.
b) It can be used to follow up the impact of adaptation in public policies.

Adaptation measures

Based on the results it was recommended to pursue the following adaptation measures:

Outside the water sector:
- Increase access to health services for the entire population
- Put measures in place to fight illiteracy

For the Mexico City Water Utility:
- Implement a monitoring programme following the Mexican standards but also gathering information to assess the impacts of climate change and to ensure the safety of drinking water
- Increase effective access to safe water for the entire population
- Protect surface water and groundwater sources from pollution
- Repair leaks and operate the water network system continuously and under positive pressure

For local and national governments:
- Apply an open access policy to water quality and health information

Case conclusions

Obtaining water quality data is an expensive, though valuable, undertaking. However, available data is always limited, even in developed countries. Thus, it is important to reflect on the amount and type of data required but at the same time it is important to develop methodologies to assess climate change impacts using less water quality data.

The current monitoring frequency of the water quality and the type of parameters assessed for Mexico City is insufficient and inappropriate to set policies to address the possible impacts of climate change. This is a concern, since even if the government decided today to start a proper monitoring programme, thirty years' worth of data is required; delays in decision-making will further hinder this process.

The use of other methods, such as the estimation of the vulnerability of the population, was valuable. Although limited, it allows the measurement of the risk to the population of diarrhoeic diseases associated with climate change to guide policy decisions.

This study is relevant because, despite Mexico City being the region with the highest income and data availability in the country, it was evident that serious limitations due to lack of information hamper proper preparation to adapt to climate change impacts.

Lessons learned from the three case studies and overall conclusions

From the three case studies the first thing to note is the lack of sufficient and proper information concerning water quality to perform climate change studies, using the currently available methodologies. Nevertheless, the impacts of climate change on the quality of water in Mexico City are evident, particularly because:

a) The city is already suffering severe problems in water quantity and quality related to climate change. These problems are expected to be exacerbated in the future.
b) The main source of water for Mexico City is groundwater, and its quality is affected. However, its protection has not been considered in governmental plans for adaptation.
c) The IPCC highlights that temperature increase will limit the self-purification capacity of rivers. This was not observed for a small river in Mexico City but was evident for a larger river in a tropical area. This showed the relevance of studying the impacts of climate change at the local level.
d) It was difficult to identify links between climate change, water quality

and diarrhoeal diseases using the currently available methodologies. However, alternative methods, such as the estimation of the vulnerability of the population, can be used to define options to improve adaptation and reduce this vulnerability.

Mexico City is currently experiencing, and will continue to experience, serious risks because of climate change impacts on water quality. To better adapt to future conditions, it is important for the different government agencies involved in the metropolitan area to be more aware of the risks and to understand the potential impacts. Some of these have been identified in this study and its results can be used to define the next Climate Change Action Plan.

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Chapter 4

Water management and adaptation to climate change in urban settings: between dominant paradigms and local dynamics

Celia Ruiz de Oña Plaza

Introduction. Adaptation to climate change through water management in urban environments: an expanding area of politics

"If mitigation of climate change is about gases, adaptation to climate change is primarily about water" (de Fraiture, 2005, in: Rockström *et al*., 2014: 253). This phrase synthesizes the present chapter's premise: that water management will be central to humankind's efforts to adapt to the Anthropocene's[1], accelerating, intensifying climate change, which will become manifest principally in the alteration of hydrologic cycles. The immediate effects of that alteration will be felt especially on the local scale, the privileged scene of adaptation (Stucker and Lopez-Gunn, 2015).

The questions raised here are, "By what concept of adaptation will those efforts be informed and guided, and what types of water management will be practiced?"

The objective of this chapter is to examine, critically, the dominant depoliticized and naturalized visions of adaptation to climate change and

1 The term "Anthropocene" was coined in the year 2000 by Dutch chemist and Nobel Laureate Paul Crutzen, and his colleague Eugene Stoermer. They posited the emergence of a new geological era, the Anthropocene, in which human civilization has become a geological force that is modifying the biosphere on a global scale, and is in fact the key driver of climatic and geological dynamics (Moore, 2016: 3).

urban water-management, noting that those visions evade the conflictive nature of both subjects. This chapter is conceived of as a "concept paper"; that is, "a work whose objective is to show the analytic connections, still not fully developed, within an area of research which is being rapidly constructed" (Lampis, 2011: 41), as is the case for the adaptation of cities to climate change, and to their interaction with urban water management. The concept-paper framework makes possible a deep and wide-ranging discussion of adaptation to climate change and its multiple conceptualizations.

In the words of Lampis, discussion of adaptation, at present, "is characterized by the emergence of a few, dominant discourses and postures that simplify the problem and limit it to a finite number of dimensions" (Lampis, 2013: 44). This chapter begins by examining those dominant perspectives. We present first the principal characteristics of the dominant vision of adaptation, together with subsequent criticisms. Then, the tenets of neoliberalism are discussed, along with some history of its effects upon water management. Key axes of the dominant hydric paradigm will also be examined, along with that paradigm's evolution in Mexican and international political contexts.

Finally, we will turn to the hydric scenario of Chiapas, where some neighborhoods have seriously insufficient access to water even though Chiapas has abundant natural water resources. Our aim is to illustrate how the socio-political conflicts in Chiapas' main cities regarding water –although they share common features with other Mexican cities because of the effects of neoliberal policies– have historical and cultural particularities that must be taken into account by future adaptation strategies.

Adapting to climate change in urban settings: building a critical perspective

Urban planning can be conceived of as a potential political arena for public action regarding urban adaptation to climate change. In particular, the related discipline of land-use planning has pioneered the study of synergies between development patterns that configure urban form and function, and the scope for adaptation that those patterns make possible. That same discipline makes important contributions to analysis of the effects of urban resource use upon urban metabolism and carbon emissions (Pizarro, 2009). Thus, urban development plans can be designed to take effects of future climate change into consideration, from a point of view of prevention.

However, cities' plans for adaptation to climate change are often equated with (and reduced to) management of extreme hydro-meteorological events (Lampis, 2013). Although those distinct lines of policy-making need to be integrated without excluding either (Caravani, 2015), the bulk of funding for adaptation is dedicated to reducing risks from disasters (Caravani, 2015).

If cities' emphasis upon risk-reduction rather than adaptation is in need of critical examination, so, too, is the cities' tendency to select extreme events as the category of risks for which to prepare. A degree of uncertainty surrounds the nature and geographical location of the impacts of future climate change, as well as the rate at which those effects will become apparent. Climatic variability brought on by climate change may not be restricted to large, frequent, extreme impacts: some variation may be incremental, like the gradual reduction in the availability of water, which can be associated equally with unusual climatic variability as with deficient water management that does not match projected future climate changes. Management of availability of water, as well as of sanitary services, is an example of such a deficiency.

The means that cities choose for adapting to climatic risks also need review. Water services and urban sanitation are two principal axes of adaptation strategies in the recent document Climate Change Adaptation Plans (see: Delgado *et al.*, 2015). Nevertheless, excessive weight has been given to construction of gray infrastructure as the principal axis of adaptation for reducing "natural" risks (Lampis, 2013: 38), especially with reference to flood control. This emphasis upon the technocratic is reflected in the fact that 40% of resources allotted to adaptation are spent upon infrastructure projects (Caravani, 2015).

All three of the trends criticized above may be caused, in part, by documents such as the initial reports from the Intergovernmental Panel on Climate Change (IPCC). Those reports have prioritized technical scientific knowledge in the area of natural sciences, presenting a concept of climate change as, principally, an environmental problem (Bjurström and Polk, 2011: 18). That priority is reflected in the political sphere as well. Thus, the initial framework for adaptation was conceived, above all, from the perspective of climate science (Lampis, 2013), without considering how social processes might affect adaptation, and limiting the potential of adaptation as a process of social learning (Morchain, 2016).

Arguments for an alternative vision

Increasingly, the critical literature on urban adaptation emphasizes (and provides evidence for) the social and political processes behind dynamics of risk generation (Eaking *et al.*, 2017). According to Eaking *et al* (2017: 5), "…making the social and political processes that undergird urban risk dynamics tractable and transparent is a political act as much as a research challenge, and one that may not be welcome in all spheres of decision making". For their part, Eriksen *et al* (2015) point out the importance of understanding the role played by power dynamics, with the objective of constructing an adaptation framework that is more representative and relevant for populations excluded from decision-making processes.

From the field of political ecology, Marcus Taylor (2014) notes that suppression of historical details and oversimplification of local socio-political dynamics are root causes of ineffectiveness of adaptation actions (Taylor, 2014: 54). Here, again, we see the importance of conceiving adaption to climate change as a sociopolitical process that reflects social inequalities and non-sustainable values, rather than a merely technical and economic matter, if we are to aspire to an adaptation that entails transformation of the forms of development that have generated climate crisis (Pelling, 2010: 15).

From that point of view, adaptation actions guided by criteria of social equality and environmental sustainability (and not so much by economic maximization) might be more effective in the long term, in combination with the establishment of physical (and green) infrastructure barriers which, in addition, open spaces for public recreational use. This observation is consistent with the more general assertion that urban adaptation increases its scope of effectiveness if the population's cultural particularities and subjectivities are integrated into actions of adaptation (O'Brien and Wolf, 2010), along with recognition of the political nature of the management of water and climate (Swyngedouw, 2013).

In short, and in the words of Lampis (2013: 44):

> Seeing adaptation as a process of natural and human systems adjusting to climatic stimulations and the effects thereof, and seeing adaptation as a means of integrating climate change in a perspective of social and human development, are not the same thing (…) Different perspectives will determine different types of policies.

We would argue that the above-described criticisms of adaptation efforts that are guided by urban-planning perspectives can actually strengthen them –rather than downplaying their usefulness– by nuancing the technocratic and managerial character that tends to pervade them.

The dominant concept of adaptation coincides with the basic pillars of the dominant paradigm for urban water management, where technological modernism is also predominant (Adams, 2009 in Lampis, 2013: 38). In this way, continuity is given to a political viewpoint[2] that does not raise the subject of the deep roots of vulnerability to climate change entrenched in social and political inequality. Instead, it contributes to "environmentalizing" that vulnerability and to naturalizing it, promoting the notion of climate change as a matter of natural and environmental character, rather than as a result of an unsustainable model of development, aligning itself with the dominant policies for climate change and environmental management (Newell and Paterson, 2010). The next section presents an overview of the main features of the neoliberal model of development in relation to urban water management.

Neoliberalism and the political construction of shortage as the dominant paradigm in urban water management

Since the 1970s, the hydrosphere's deterioration and the unsustainability of water have been topics of discussion in international politics, adopting a global character. Initially, the problem of water was presented, fundamentally, as a question of resource scarcity, formulated as an environmental deficiency (Kaika, 2003; Trottier, 2008), in combination with limited institutional capacity, and with inefficiency resulting from obsolete technology. Upon these three pillars was constructed the dominant hydraulic paradigm: a global project of technocratic, capitalistic development, with strong emphasis upon large-scale infrastructure. The debate over human causes of the shortage (Curl, Neri, and Scott, 2015) was thereby sidelined.

2 With respect to the neoliberal character of adaptation proposals put forward in the United Kingdom, Felli and Castree (2012: 2) argue that "Neoliberal thinking has penetrated so deeply into all aspects of social life…-and into much social science discourse too (often surreptitiously) —that it would be surprising *not* to find neoliberal ideas animating a policy document sponsored by any U.K. government department" [emphasis in the original].

In international political arenas, political strategies are designed for remedying water shortage, which is explained, mainly, as a result of population growth and an increasingly urban world's demand for goods and services (Malvares Miguez, 2013; Rockström *et al*., 2014; Trottier, 2008). Any alternative explanation based upon lack of political and social equality is relegated (Peña Garcia, 2007; Lampis, 2013), and reduced to a mere appendix to the predominant discourse about good water governance (Dominguez, 2012).

Under the predominant neoliberal ideology, the 1980s saw the implementation –worldwide, but especially in Latin America– of policies for liberalizing, deregulating, and privatizing goods and natural resources (Zurbriggen, 2014-A; Castro, Kloster, and Torregrosa, 2004). Neoliberalism's political and ideological framework had profound effects upon water management, water services, and water treatment, favoring the actions of large, private water monopolies both national and international (Castro, 2005). The role of the State as the center of governmental action was redefined, basing it upon free-market principles (Pena Garcia, 2007). Accompanying that redefinition of the State's role was a transformation of water's status, from a public asset and universal social right to a private commodity (Castro, 2005; Malvares Miguez, 2013; Zurbriggen, 2014-B), subject to the laws of supply and demand in a supposedly neutral and apolitical market (Zurbriggen, 2014-A). That market was in turn presented according to neoclassical economic theory as an entity that would regulate itself without any need for intervention by public management.

Starting in the 1990s, this mercantile reification grew in strength. Market principles were prioritized over the principles of a substantive democracy (Zurbriggen, 2014-B), generating and imposing an idealized vision of processes of governance that was not exclusive to the water sector, but which found in that sector a remarkable expression. Within that vision, processes of water governance are represented as "an idealized system of symmetric power relations among central actors, the State, the market, and civil society" (Castro, 2005), thereby hiding asymmetric relations of power and dominance on the part of those actors who are capable of manipulating the market for their own purposes and interests.

In Latin America, water management to a great extent aligns itself with and adapts itself to neoliberal policies, which are summarized in the following table:

Table 1. Principles of neoliberal policy in the water sector.
a) Uses of water resources should be assigned via capitalistic market mechanisms; private, freely commercializable water rights must be created and assigned, replacing pre-existing collective and public water rights.
b) Water resources, along with water and sanitation services, must be considered an economic commodity, in the sense of being a private asset that must be purchased under market conditions. Once these services are considered private goods, it will be possible to exclude parties that don't pay for using them. The notion that these services constitute a public asset must be abandoned.
c) Control of water sources, as well as provision of water and sanitation services, must be the exclusive purview of private operators, who are inherently more efficient than public operators. Public regulation should be reduced to a minimum, in favor of self-regulation via market mechanisms.
d) The majority of water management operations can be open to market competition, with the sole possible exception of some central activities, although the introduction of mechanisms of competition can find itself obstructed by high transaction costs. In those cases, a private monopoly is preferable to a public monopoly, and to the degree possible must be an unregulated one.
e) Users of water and sanitation services must be converted into consumers, and rights-holders into clients.
Source: Castro (2005)

Castro notes that the privatization model in Latin America not only leaves unresolved the majority of the water-sector problems that justified its adoption (e.g., insufficient coverage, poor quality of service, inefficient systems, and corruption), but actually exacerbates them, along with existing conditions of inequality and social polarization (Castro, 2007; Nieto, 2011).

Against that backdrop of the failure of neoliberal governance of water, Latin America faces the new millennium with a reevaluation of the role of the State and of community water management systems, although it does so by dragging along the negative consequences of privatization efforts: the lack of public support for community systems, and the historic weakness of democratic governments.

Mexico: Between the neoliberal water paradigm and state control

Although the dominant water paradigm doesn't always go hand-in-hand with policies of liberalization and deregulation (Curl *et al*., 2015), the combination of both has been the underpinning of Mexico's water-management reforms during the last three decades. Those reforms were attempts to adjust to the demands of globalization, opening the door to privatization of water management and use of market mechanisms to allocate the resource (Funes, 2012).

The Federal government provided impetus for privatizing water and sanitation services at the local level by ceding, to municipalities, the responsibility for providing these services (Pena Garcia, 2007). However, this decentralization did not bring about greater efficiency or transparency, much less more democratic control. Corruption, lack of managerial capacity, insufficient financing, and the culture of patronage overlay the reforms of the Mexican water-management model through which, at the end of the 1980s, and with the creation of the National Water Commission (Comision Nacional del Agua, CONAGUA, by its Spanish acronym), Mexico attempted to foster social participation in water management (Castro *et al*., 2004), in a political context in which public participation had been scarce.

Without denying the importance of the institutional dimension of water management –and, by extension, of climate management– an understanding of that dimension must be complemented with an understanding of the political dimension, which is characterized by economic and socio-environmental inequality (Göbel, Gongora-Mera, and Ulloa, 2014; Castro *et al*., 2004). A good example of the interplay of those two dimensions in the city of Villahermosa, Mexico, is provided by Anja Nygren (2016), who presents evidence for the key role of those inequalities in shaping the implementation of strategies for reducing vulnerability to flooding. Nygren's work indicated that funding for high-technology flood-control measures went to benefit affluent districts of Villahermosa, to the detriment of poor neighborhoods with little infrastructure or public support.

This case also highlights the dominant water paradigm's limitations when dealing with Mexico´s urban realities in the context of climate change. On the one hand, the dominant vision of water management is centered upon the notions of stability and predictability of drinking-water supply, despite increasing evidence that water systems are difficult to predict and control (Pahl-Wostl, Jeffrey, Isendahl, and Brugnach, 2011). On the other hand, the dominant vision is obsessed with optimization and efficiency, instead of promoting equitable access to water (Dominguez, 2012; Pena Garcia, 2007).

What lessons might be inferred from this brief review of Mexico's experience with neoliberalism and the dominant paradigms of water and adaptation? Studies such as Nygren (2016) call into question the unilateral vision of the crises of urban water management and adaptation as a matter of governance; that is, as a question of coordination of actors to arrive at a political consensus in a negotiation setting (Murillo Licea, 2012; Felli and Castree, 2012). The neoliberal approach to governance ignores the social unrest deriving from conflicts over water, as well as from the helplessness of citizens before parties that include the State; the water suppliers (public as well as private); and those actors who have the power to control access and distribution of water for their own convenience (Castro *et al*., 2004; Nieto, 2011). All three of those parties can coordinate their efforts quite effectively. When structural and historical factors carry more weight than institutional mechanisms for governance, those mechanisms become permeated by the historical and structural factors, with the result that they frequently become a sham in which democratic process is merely another front in the dominant sectors' battle to preserve their privileges. Conceptualizing this political scene in terms of governance does not allow us to explain the local dynamics and histories that have brought about the present functioning of a given local political system.

In summary, arguments that treat shortage as a principal factor to be managed have functioned as a justification for legitimizing both the privatization of water and the construction of large water projects (Kallis, 2010; Otero, Kallis, Aguilar, and Ruiz, 2011; Pena Garcia, 2007; Castro, 2002). Moreover, those arguments have led to a naturalization of the water problem, distracting attention from unequal access to water and from socially differentiated water management, both of which are important matters in southern countries. The dominant vision of adaptation to climate change has incorporated these same features in its incipient endeavors, by emphasizing the technocratic vision of adaptation and its environmental dimension.

Castro (2015) stresses that the principal focus of urban water management must be the highlighting of linkages between injustices and inequalities in access to water and sanitation services, and the processes of democratization and public participation. The same might be said of the interaction between adaptation and urban water management.

Water shortage in the midst of abundance: the social production of water scarcity in Chiapas

The following section seeks to offer an example of how neglecting historical and sociopolitical realities contributes to failure of water and climate policies in Tuxtla Gutierrez, the capital city of Chiapas State, and San Cristobal de Las Casas, a renowned historical town and tourist attraction. The aim is to highlight current processes that emerge out of neoliberal management trends and contribute to erode the natural availability of water. We first present a brief overview of water and sanitation services in Chiapas.

A brief, descriptive panorama of water and sanitation services in Chiapas

In Chiapas, we witness neoliberal tendencies in urban water management combined with the historical and cultural peculiarities of an urbanization process that was late in arriving and is still incomplete[3] (Rus and Morquecho Escamilla, 2015; Viqueira, 2009). This combination occurred –and continues to occur– in a territory characterized by an abundance of water. Chiapas lies

3 Among Latin American cities, Chiapas's are peculiar in that their population began to increase rapidly only in the 1970s, much later than in other parts of Latin America. That late start enables us to observe the recent effects of an accelerated process of urbanization, which had already reached its limit of expansion elsewhere. Chiapas continues to be an eminently rural state, even though official statistics from the *National Institute of Statistics and Geography* show that 50% of the population is urban, and 50% is rural. However, historian Juan Pedro Viqueira (2009) speaks of the "ruralized cities" in Chiapas, many of whose inhabitants moved there after being ejected from their rural homes by land conflicts, and now lack options for attaining a decent standard of living. The most notable trait of those cities is the enormous disparity in the distribution of goods, services, and incomes, accompanied by intensification of social and environmental conflicts.

in the heart of southeast Mexico, which receives half of the country's total rainfall (49.6%). The water region of the Southern Border, of which Chiapas forms the greater part, has Mexico's greatest natural abundance of water: an average of more than 24,000 m^3 per person. Note, too, that this same region comprises 3.74% of Mexico's territory, and holds 4.4 % of its population (CONAGUA, 2016).

Nonetheless, it is thought that in Chiapas climate change may affect both the availability and the quality of water. An increase in frequency of intense climate-related events is expected. Chiapas's mountainous topography will add to the intensity of those events and make flooding more common, with grave consequences for cities (Ramos Hernandez, 2010: 28, 30). Although we do not have specific scenarios for rural zones, climatic variability predicted for the region as a whole, combined with impacts of urban development, constitute a panorama of high vulnerability. In the Chiapas Highlands, temperatures have increased by 1 to 1.8°C, and annual precipitation has decreased by up to 2000 mm, while precipitation has increased slightly in the central region of the state (Ramos Hernandez, 2010: 13). In general, it is expected that by 2020, with an increase of 1°C for a scenario with a moderate use of fossil fuels, precipitation will decrease by 2%, causing a critically insufficient water supply (Ramos Hernandez, 2010: 69).

With respect to coverage by water and sanitation services, the 2015 Intercensal Survey conducted by Mexico's National Institute of Statistics and Geography (INEGI by its acronym in Spanish) shows that between 2012 and 2015, the number of private Chiapas dwellings with water service inside the home increased by 8%, reaching 49.9%. An additional 40% of homes had access to piped water outside the home. Coverage by sewer services was similar: 53.3% of homes are connected to public systems (INEGI, 2015).

However, additional data from *The Water Advisory Council*, an independent citizens' group, offer a more complex picture of access to water and sanitation services in Chiapas cities. The group's 2011 report notes that provision of these services in the South and Southeast is the worst and least-efficient in all of Mexico (*Consejo Consultivo del Agua*, 2011). In Tuxtla Gutierrez, the capital city, lack of the necessary water distribution infrastructure forces some districts to obtain water via tank trucks, and only 43.2% of the population receive water every day (SMAPA, 2011, cited in *Consejo Consultivo del Agua*, undated).

In Chiapas, the most important limiting factor in access to water and sanitation services is social inequality. It is no coincidence that Chiapas is the state with the least-equitable distribution of income: the richest 30% of households earn 63.5% of the income, while the other 70% of households earn only 36.5% (CONEVAL, 2012: 28).

These three features of Chiapas's water situation –hydric abundance, combined with a relatively small population and inefficient access to water and sanitation services– make clear that neither hydric abundance nor population size, by themselves, determine availability of drinking water to the public (Bunge, 2012). Instead, it can be argued that by not taking into consideration the history, etc. of Chiapas, authorities not only have failed to produce a situation with a promising outlook for adaptation, but have generated a socially constructed scarcity of water in the middle of a natural hydric abundance.

The situation in Tuxtla Gutierrez

The most obvious effects of the social fragmentation described above are a socially differentiated access to water and sanitation services, and poor quality of water service. Tuxtla Gutierrez, with 593,710 inhabitants (INEGI, 2015), and located within the Rio Grijalva basin, exemplifies the contradiction presented by deficient water management in a context of natural hydric abundance, where scarcity and squandering occur simultaneously.

Tuxtla has the dubious distinction of having the leakiest water-distribution network among all Mexican cities: as much as 70% of its drinking water is lost to leaks, according to a recent report by the Organization for Economic Cooperation and Development (OECD, 2016). Similarly, 60 of its 500 *colonias* (neighborhoods) have no access to drinking water (Observatorio Ciudadano del Agua, 2016).

Moreover, Tuxtla's deficient water management made it the target of an attempt to privatize water and sanitation services in mid-2013.[4] That attempt triggered the formation of an active civic movement against privatization, and in support of the right to water: *Chiapanec@s en Defensa del Agua* (Chiapas people in defense of water), composed of students, community organizations, and various NGOs. The movement not only stopped the privatization attempt, but put together a proposal called the Citizen's Proposal for the Improvement of the Municipal Water and Sewage System (*Propuesta Ciudadana para la Mejora del Sistema Municipal de Agua Potable y Alcantarillado —SMAPA*) (CEPAZDH A.C. & Chiapanec@s en Defensa del Agua, 2014).

Citizens' movements against privatization continue to this day, with the recent formation of a Citizens' Observatory of the Potable Water and Sewer System in Tuxtla Gutierrez, and the creation of the Chiapas Front in Defense of Water, Land, and Life. Nevertheless, attempts to privatize water services continue. The door remains open for the multinational company

4 In June of 2013, the *Governing Board of the Municipal Water and Sewage System* approved a draft call for tenders for a 25-year, public-private partnership that would provide sewer service as well as production, purification, distribution, and sale of drinking water. SMAPA, with a debt of 130 million pesos, declared itself bankrupt, pleading insufficient resources while being accused of fraudulent management. http://aguaparatodos.org.mx/observatorio-ciudadano-aguas-smapa-con-el-agua-en-tuxtla/(http://aguaparatodos.org.mx/observatorio-ciudadano-aguas-smapa-con-el-agua-en-tuxtla/).

Proactiva-Veolia (*Comite Promotor del Observatorio Ciudadano & CEPAZDH A.C.*, 2016).

The situation in San Cristobal de Las Casas

San Cristobal, for its part, is experiencing rapid urban growth on its periphery, based upon an intense historical social breach between San Cristobal's indigenous population –many of whom were expelled from their rural communities of birth by violent conflicts over land, political power, and religion– and its *ladino* (mixed progeny) inhabitants[5]. San Cristobal (elevation 2,350 m) is located in an endorheic valley, meaning that it has no surface outlet for water flow. The city is ringed by a semicircle of hills up to 3,000 m high, where descendants of pre-hispanic peoples lived (and still live). Against the backdrop of this this natural heritage, well into the 20th Century, a rapid and chaotic centrifugal urban expansion occurred, product of a demographic growth that has seen the city's population double every 20 years since 1940. During the last 50 years, San Cristobal's population has grown by 579% (Paniagua, 2010), reaching 209,591 at present (INEGI, 2015). Ever since its foundation in 1528, the city has had a pronounced dual character, divided by racial, religious, and economic considerations.

Those divisions have important consequences now in San Cristobal's urban water management; for example, in control of water sources and in unequal

5 Historically, the city was a mosaic of neighborhoods (*barrios*) separated from each other and from the center by expanses of open land. The neighborhoods displayed a marked duality: Spaniards controlled the center, while mestizos and indigenous people lived on the periphery. The region beyond the city's outskirts was strictly indigenous. In the beginning, the city comprised barely 12 streets and 18 blocks. The barrios grew centripetally from the 16th to the 19th Century, connecting among themselves and with the center. For 450 years, San Cristobal maintained this atypical, *intramural* pattern of urban growth, without expanding its urban footprint (Audry, 2008: 62; Paniagua, 2010), thereby conserving extensive natural areas and green belts.

access to water. Table 2 summarizes the principle problems with water supply and purification, as observed by the author during field work conducted from 2014 to 2015.

Table 2. Basic characterization of water management problems in San Cristobal de Las Casas.

Area of concern	Characterization	Description
Water infrastructure	The distribution network is obsolete, and poorly maintained.	• None of the water distributed by SAPAM is safe to drink. Throughout the city, residents buy water from bottlers of drinking water, some of which have been accused of not complying with minimum standards for quality. • Sewers are unhealthy and in poor condition. • SAPAM has difficulty supplying water to peripheral neighborhoods. • The "*tunel del sumidero*"—a hydraulic engineering work that bored a tunnel beneath the surrounding hills in the 1970s to drain the valley and stop recurrent flooding—now shows structural damage, including significant fissures.
Water management	Deficient management by SAPAM: presence of neighborhood systems for providing water (e.g., *Sistema Chupaltic*) that are independent from municipal management.	• Insufficient field staff prevents SAPAM from attending to the wastage and leaks present at many points in the distribution network. • 60% of legal users do not pay their water bills • There are large numbers of illegal users, especially in parts of the city whose residents invaded vacant land. • Shortage of personnel, and lack of financial autonomy. (SAPAM has a debt of 148 million Mexican pesos due to non-payment of the electricity bill) • Internal problems related to trust, corruption, abuse of authority, and self-management.

Area of concern	Characterization	Description
Governability	Wars over water, and use of water as an instrument of pressure in political conflicts[6] Generation of social conflicts because of water shortages during the dry season.	• Water, and access to it, are used increasingly as weapons of political pressure, especially in conflicts between political parties in indigenous neighborhoods and communities near San Cristobal. • Invaders' control of use and access to wells in lands that they occupied illegally has become a form of obtaining rights to the invaded land. • Confrontations among neighbors over water are becoming more violent as supplies fail more frequently during the dry season. • Selectivity and corruption in water distribution, depending upon electoral issues. • Manipulation of authorizations for changes in land use. • Unsafe settlements in high risk areas.

6 See, for example: Martin, 2014. Another recent case is related to the assassination of seven persons, including the mayor of nearby San Juan Chamula, on 23 July 2016. As a means of pressuring authorities to release the accused assassins, communities in the indigenous municipality that contains the wells that supply the San Cristóbal neighborhoods of La Garita and Cuxtitali threatened to cut the ducts that supply those neighborhoods via a distribution system independent of SAPAM (interview with Rafael Miranda, resident of La Garita, during the community assembly of the Sistema de Agua Potable del Barrio de La Garita. October 2nd, 2016).

Area of concern	Characterization	Description
Quality of water and the environment	Pollution of bodies of surface water Absence of drinking water Increased risk of flooding	• Citizens use watercourses as dumps for the disposal of all types of waste. • Illegal disposal of industrial materials in river courses (see the documentary *La Pradera*, January, 2015). • Over-exploitation of aquifers, and of the 10 wells that supply San Cristobal de Las Casas. • Illegal invasion of water-catchment areas in protected zones • Arbitrary changes in land use, allowing urbanization of land that had been set aside for soil conservation in water-catchment areas. • SAPAM has reported numerous dead rats, and large quantities of meat waste and other garbage. • Recent construction of houses in inundation areas has made soils impermeable. • Deforestation of rivers and streams. • Lack of an integrated management of the hydric cycle.

Prepared by the author from an interview with an official of the *Potable Water and Sewerage System–SAPAM*, and from neighborhood meetings on community management of the *Chupaltic* water system, during field work conducted from 2014 and 2015. Other information used in preparation is summarized from the Chiapas newspapers *Diario Mirada Sur* and *Cuarto Poder*, published during the January-December, 2015 period.

Conflicts regarding water in San Cristobal have not been confined to drinking water; they have arisen over wastewater management as well. San Cristobal's new treatment plant, which began to be constructed [7] in the city's

7 Construction work on the plant provoked protests by residents of nearby neighborhoods, who alleged that they had not been consulted; that the permits required by law for the plant had not been obtained; and that siting the plant in the Rio Amarillo's floodplain could jeopardize residents' lives and property. On September 30th, 2015, PROFEPA Chiapas issued a Conclusion due to incompetence (#0457/15), as a result of which the work on the plant, for the time being,

lowlands in 2015, is a paradigmatic example of the risks incurred when urban water management infrastructure is installed piecemeal, without a sufficient operating budget and without the necessary functional integration with (for example) zoning, solid waste management, and environmental protection (Servicios de Ingenieria Aplicada, S.A. DE C.V., undated: 14).

On the one hand, constructing a water-treatment plant without improving environmental and sanitary conditions all along San Cristobal's watercourses condemns residents to continue suffering water-borne illnesses, especially in the zones that are most marginalized, and which have the poorest services. On the other hand, constructing the plant without an adequate maintenance budget, and without improving the obsolete (and in some areas, fractured) sewer network raises serious doubts about the plant's future operating capacity [8].

Moreover, disputes have arisen over the siting of the plant, which is near the valley's natural drainage sinks —the so-called *sumideros*, which are a natural system of caves that carries water underground and away from San Cristobal's endorheic valley. Residents of adjacent neighborhoods disagree over whether the plant should be built, and members of environmental organizations allege that the plant will damage the environment without restoring the *sumideros* (which have effectively become garbage dumps) to their natural condition (interview with Jovita Patricia Cruz, representative of "La Pradera" neighborhood, January 2015). The fact that 108 of Chiapas's water-treatment plants are inoperative, according to Alfredo Araujo, president

is suspended (Hernandez Nuñez, 2015).

8 The cost-benefit analysis for the plan recommends "an integral construction, including completion of collectors and outlets, which will allow complete capture of wastewater, and achieve cleanup of the rivers" (Servicios de Ingenieria Aplicada, S.A. DE C.V., n.d.: 11). Similarly, the authors recommend "restructuring of the billing system (so that the operator, whether that be SAPAM or some other designated party, may have the necessary resources for operating and maintaining the Treatment Plant)" (Ibid: 10; emphasis added).

of the Grijalva-Usumacinta Basin Council (*Consejo de Cuenca Grijalva-Usumacinta*) (Pineda, 2015), is indicative of a limited capacity to manage a water infrastructure that requires reliable financing in order to function.

Further observations upon urban water management and climate adaptation in Chiapas

Far from increasing efficiency as promised, the effects of the dominant water-management paradigm in Chiapas, including the attempts at privatization and emphasis upon "hard infrastructure", have instead exacerbated some of the endemic evils of the state's political culture. The result is that an inefficient and corrupt urban water management, in combination with a historical context of political and social conflict, accelerates environmental degradation, feeds socio-environmental conflicts over water use and access, and calls into question the supposed efficiency of the neoliberal paradigm of water management (Millan Malo, 2012). Moreover, the effects of that paradigm increase social and environmental vulnerability to climate change.

How can sustainable urban planning and adaptation to climate change be carried out in such a political setting?

In Chiapas cities, vulnerability –in combination with management of risks associated with extreme climatic events– has begun to be mentioned in two specific areas of urban water management: canalization of rivers to control flooding, and improvement of water quality. As an example of the former, Tuxtla's Plan de Desarrollo Urbano (Urban Development Plan), 2007, calls for changes in the operation of existing water-treatment plants, as well as in the planning of new plants and improvements to distribution networks. On page 33, the Plan emphasizes that operation and planning must "make use of new technologies (not academic proposals)" (emphasis added), and (Ibid: 34) that planners and operators must "formulate and conclude the necessary hydraulic studies, including a real solution (not academic proposals)" (emphasis added).

Nevertheless, the forms in which both recommendations are being carried out have generated new problems, exacerbating social conflict and diminishing the capacity for adaptation to climate change. See, for example, complaint number PFPA/14.7/2C.28.4.1/100040-15, submitted to the Federal Attorney for Environmental Protection by Jovita Patricia Gomez Cruz, 30 September 2015.

Due to increasing frequency and intensity of extreme hydro-meteorological events (such as those suffered by the city of Tapachula, also in Chiapas, because of Hurricane Stan in 2005, as well as the recurrent flooding in Tuxtla Gutierrez), Chiapas is witnessing a new wave of urban water-infrastructure construction.

Many urban rivers are being transformed into rectilinear canals by covering their banks –which are already seriously degraded and pollute– with concrete. Some of the new infrastructure is destroying what little remains of river-bank ecosystems, which are still important urban repositories of flora and fauna. At the same time, the canalization of rivers and destruction of riparian ecosystems increases the rivers' velocity, thereby making them more dangerous and transferring risk of flooding to lands downstream.[9] Such construction converts a river into an open duct, desiccating adjacent banks and concentrating pollution. As if that were not enough, the quality and durability of the constructions are quite deficient (Razo Velazquez, 2015).

In Chiapas, predominance of the technological approach has sidelined the possibility of restoring ecosystems as a means of adapting to climate change

9 Based upon observations made by the author in Tapachula, Tuxtla Gutierrez, and San Cristobal de Las Casas during field work conducted in 2013-2015 on the "Sistemas de Gobernanza Ambiental" project, undertaken by PROIMMSE-IIA-UNAM.

and designing sustainable cities. An approach based on restoring the functions of the ecosystem could be not only much more cost-efficient, but also more adequate to absorb the impacts of extreme climatic events. Restoration of ecosystems would also expand public spaces for ecology and recreation, while impeding construction of dwellings in areas exposed to flooding and landslides.

The brief panorama presented above clearly reveals the situation of conflict (even violence) in Chiapas, in which struggles over water, along with government incapacity and lack of transparency, will be factors that must be dealt with when implementing measures for adapting to climate change and managing urban water.

Conclusion: Toward an effective integration of climate change adaptation and water management

An adaptation to climate change that integrates the political dimension and places equity considerations as a central tenet in its workings, requires deep familiarity with the political field of action. It also requires involvement of key actors in negotiations, as well as in the design of strategies directed toward neighborhoods with historical and cultural particularities. An adaptation of this sort must balance "hard" and "soft" technologies, so as not to overlook environmental, social, cultural, and political conditions that might become obstacles to implementation. Of course, that adaptation strategy must be informed by and coordinated with a water-management plan that is designed to handle oncoming climate change, and that combines technological measures with restoration and preservation of ecosystemic functions.

This chapter provides examples of the kinds of historically rooted local dynamics that can exist, and that may need to be elicited and dealt with in a specific context. Those examples support the conclusion that the decision-making process for adapting to climate change is unlikely to be effective unless it includes those actors who tend to be systematically ignored, and who operate under a neighborhood and community logic very different from that followed by professional planners of adaptation.

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Chapter 5

Green infrastructure in walkable neighborhoods: A climate change adaptation strategy for cities in drylands

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Introduction

In this chapter, I explore the challenges for cities in drylands, particularly regarding water security under climate change conditions. One of the impacts of climate change that affects cities is severe storm events and subsequent flooding, which are projected to increase in intensity and frequency. Because floods can damage urban infrastructure and private property, some cities have invested in grey infrastructure which, combined with an increase in impervious surfaces, has resulted in degraded ecosystems, health hazards, and ironically, an increase in floods. I introduce green infrastructure as a stormwater management alternative to grey infrastructure that reduces the damage to social and ecological systems. Green infrastructure can also be considered a climate change adaptation strategy that has the potential to increase water security in cities in drylands. However, the human use of greenspace plays a major role in maximizing the coupling of social and ecological systems that can result in better chances of conservation and sustainability. Walkable neighborhoods have the potential to enhance the human use of greenspace. As a conclusion, designing walkable neighborhoods that include green infrastructure and provide access to greenspace has the potential to enhance human use and increase water security and resilience in the face of climate change.

Challenges for cities in drylands

A considerable amount of land area in the world is some type of dryland that includes hyper-arid, arid, semi-arid, and subhumid (Maestre *et al*., 2012). Drylands comprise 41% of the land area in the world and their main characteristic is water scarcity, and consequently, limited resources (Reynolds *et al*., 2007).

Cities are growing rapidly around the world and even more so in drylands. Since 2008, and for the first time in history, cities are the home of most people in the world, and this trend is projected to continue in the future (Grimm *et al*., 2008). Urban growth is more pronounced in drylands. Safriel and Adeel (2005) found that, as the land gets drier, the fraction of the population living in cities increases. The main challenge for cities in drylands is to accommodate an increasing urban population, mainly because there are limited resources (Grimm *et al.*, 2008). More people demand more food and water, more materials for shelter, and generate more waste and pollution. This increased demand for natural resources and ecosystem services impacts the ecological systems, modifying the biogeochemical cycles within and beyond cities (Ibid).

The impacts of climate change in drylands aggravate the situation. For drylands, an increase in temperatures, more prolonged drought, and more frequent severe storm events are projected to happen in the near future as a consequence of climate change (Maestre *et al*., 2012). For coastal cities, climate change projections also include rising sea levels (Ibid). In California and other places, prolonged drought and other climate change impacts are already evident (http://drought.ca.gov).

An increase in temperatures in cities located in hot climates poses a serious health risk to urban populations (Jenerette *et al*., 2016). Cities commonly experience an adverse effect of urbanization known as the urban heat island effect –an increase in temperatures in cities compared to the surrounding natural landscapes. This increase in temperatures in urban areas is caused by altering the energy balance of the earth's land surface when land cover is changed from pervious surfaces with vegetation cover to concrete and asphalt surfaces that store heat (Lee and Ho, 2010). An increase in temperatures as a consequence of climate change exacerbates the urban heat island effect, and this negatively affects the health of urban populations (Jenerette *et al*., 2016).

More prolonged drought in cities in drylands threatens water security. Water security is defined as "the sustainable availability of adequate quantities and qualities of water for resilient societies and ecosystems in the face of uncertain global change" (Scott *et al*., 2013). In drylands, as surface water is over-allocated, depleted, or degraded, cities are relying more on groundwater as their main water source (Varady, 2015). Groundwater has brought important benefits to millions of people worldwide in terms of livelihoods and food production; but over-exploitation of groundwater resources is a significant long-term consequence (Mukherji and Shah, 2005). More prolonged drought as a consequence of climate change aggravates the situation adding more pressure to the aquifers. Coastal cities in drylands face the additional risk of seawater intrusion into the aquifers when groundwater levels decline, particularly under conditions of increased temperatures (Bouderbala *et al*., 2016). Seawater intrusion makes groundwater unsuitable for human consumption and other water uses, threatening water security.

Another impact of climate change is more frequent severe storm events (Maestre *et al*., 2012) and this also threatens water security. For cities, more frequent severe storm events result in an increased frequency and intensity of floods. Furthermore, urban expansion and its associated land use and land cover change that include impervious surfaces (e.g., concrete and asphalt) have altered the hydrological cycle in cities (Xu *et al*., 2016) and have decreased water quality. Stormwater runoff that is not infiltrated in situ (in its place of origin) decreases water quality by contributing nonpoint source pollutants –or pollution that comes from different sources (Ibid). As water flows across paved streets, it picks up oil left by motor vehicles and other chemicals and nutrients, resulting in polluted runoff that contaminates water bodies.

Stormwater management in cities in drylands

Cities in advanced economies usually have a piped stormwater drainage system also referred to as grey infrastructure. Grey infrastructure was built to convey storm water runoff away from the city as rapidly as possible to prevent flooding (Pennino *et al*., 2016). Grey infrastructure includes storm drains, sewers, and combined sewer systems (CSS), which consist of a single pipe that collects both stormwater runoff and municipal and industrial wastewater (Levy *et al*., 2014; Pennino *et al*., 2016; Subramanian, 2017). Cities in developed countries are often required by law to treat water from CSS before it reaches the rivers, creeks, or lakes (Levy *et al*., 2014).

The City of Los Angeles provides an interesting example. Los Angeles suffered a severe flood in 1914 with extensive property damage. As a result, the authorities of the state of California implemented grey infrastructure; they lined the Los Angeles River with concrete and constructed a drainage system. This complex system was engineered to remove stormwater rapidly from the city and reduce flooding; and it has done so successfully, but has created other problems (Subramanian, 2017). Grey infrastructure combined with impervious surfaces have been found to cause erosion of waterways, degradation of ecosystems, water pollution, and more flooding (Pennino *et al*., 2016). CSS often overflow during severe storm events, resulting in wastewater combined with stormwater pouring into streets and water bodies and posing a serious health hazard (Subramanian, 2017). In 2008, the Natural Resources Research Council and Santa Monica Baykeeper sued Los Angeles County

Flood Control District for discharging polluted water into the river (Ibid).

Some cities in arid lands in developing countries do not have stormwater infrastructure in place. Because of the low frequency of rainfall in drylands, cities in poor countries rarely invest in grey infrastructure because many times this infrastructure is not cost-effective. Therefore, when it rains, it floods; causing significant damage to the urban infrastructure and increasing the costs of maintenance and repairs. The City of Hermosillo, Mexico is an example. This city receives very little rainfall, which ranges from 0.1 inches during the dry season to 3.5 inches during the wet season.[1] However, during the rainy season (June 29 to September 17), Hermosillo often experiences severe storms and floods.[2] Flooding in cities without stormwater infrastructure is slowly removed by evaporation, which can take up to several days, leaving stagnant water exposed and negatively affecting human health (Khan *et al*., 2014).

Green infrastructure

It is well-recognized that green infrastructure can be used to manage storm water effectively in cities (Xu *et al*., 2016). Green infrastructure is defined as "an array of products, technologies, and practices that use natural systems –or engineered systems that mimic natural processes– to enhance overall environmental quality and provide utility services" (Levy *et al*., 2014: 2393). Green infrastructure is also known as low impact development, source-control stormwater management, environmental site design, distributed stormwater management (Bhaskar *et al*., 2016), sustainable urban drainage system, water

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1 Average weather in Hermosillo, Mexico. Online: www.weatherspark.com/y/2821/Average-Weather-in-Hermosillo-Mexico#Sections-Precipitation

2 Deja lluvia inundaciones y caos vial (Rain causes flooding and traffic chaos). Online: www.uniensenada.com/noticias/hermosillo/455528/deja-lluvia-inundaciones-y-caos-vial.html

sensitive urban design (Dhakal and Chevalier, 2016), urban forest (Kim *et al*., 2015), and stormwater green infrastructure (Pennino *et al*., 2016). In larger scales, it is also known as best management practices, including retention ponds and wetland basins that are used at the outlet of drainage systems (Liu *et al*., 2016).

Green infrastructure, and greenspace in general, are crucial for the functioning of ecological systems in cities, especially if they are interconnected (Xu *et al*., 2016). We define greenspace as “public outdoor space, dominated by vegetation that allows physical activity and social interaction in cities” (Zuniga Teran, 2015: 15). Examples include parks, sports fields, golf courses, greenways, etc. The difference between greenspace and green infrastructure is that the latter is especially designed to capture, slow down, and infiltrate stormwater into the aquifers. It minimizes impervious surfaces, reduces soil compaction, and allows stormwater infiltration through bio-retention basins (Bhaskar *et al*., 2016), rain barrels, rain gardens, porous materials (Bhaskar *et al*., 2016; Baptise *et al*., 2015), green roofs, vegetated swales, planter boxes (Dhakal and Chavalier, 2016), and constructed wetlands (Levy *et al*., 2014).

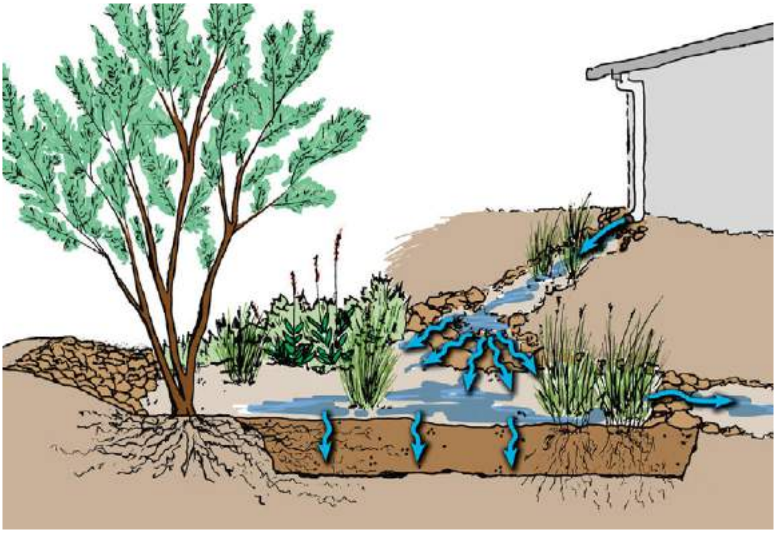
In the case of green infrastructure, concrete inflow structures with the necessary slope direct storm water runoff into basin-shaped spaces. Directing water flow through slope is combined with curb cuts strategically located along water flow paths and swales that allow stormwater to flow as directly as possible to porous green areas. The immediate direction of stormwater into infiltration basins in-situ is important because it avoids pollution by nonpoint source pollutants, which increases water quality (Xu *et al*., 2016).

Green infrastructure usually includes detention and retention areas, where stormwater is slowed down and infiltrated into the aquifers (e.g., curb cuts and swales that allow stormwater infiltration along sidewalks or storm water collection on building roofs directed through swales into small basins for infiltration; see figures 1 and 2). It is not necessary to have a large space, infiltration in-situ can be done in small spaces along sidewalks and boulevards along the streets.

Figure 1. Through curb cuts, stormwater is directed to raingardens and away from the street

Source: Watershed Management Group - https://watershedmg.org

Figure 2. Stormwater is directed from the roof to a rain garden for infiltration



Source: Watershed Management Group - https://watershedmg.org/

Green infrastructure in cities located in hot and arid climates

Green infrastructure can function as stormwater infrastructure anywhere, but in cities in drylands it can be used as a climate change adaptation strategy. As mentioned above, climate change projections for drylands include increased temperatures, more prolonged drought, and more frequent severe storm events.

In terms of increased temperatures –aggravated by the urban heat island effect in cities– green infrastructure in general, and trees in particular, reduce temperature in cities (Shashua-Bar *et al.*, 2011), alleviating the urban heat island effect (Ernstson *et al.*, 2010). A decrease in temperatures and evapotranspiration from vegetation enhances thermal comfort in hot and arid climates and provides outdoor spaces that can be enjoyed by urban populations (Yin *et al*., 2012).

Concerning more prolonged drought, greenspace allows the recharge of aquifers and reduces runoff (Ernstson *et al*., 2010). Because infiltration is done in-situ, water quality is enhanced by reducing contact of rain flow with nonpoint source pollutants (Xu *et al*., 2016). By recharging aquifers and avoiding pollution, water security is enhanced in cities in drylands, particularly those that use groundwater as their main water source.

As mentioned above, green infrastructure reduces flooding risk in cities (Xu *et al*., 2016; Ernstson *et al*., 2010), preventing damage to urban infrastructure while decreasing repair and maintenance costs. Less floods also translate into less stagnant water on the streets and better health (Khan *et al*., 2014).

The City of Los Angeles has understood the important benefits of green infrastructure and is conducting important efforts to transition toward this stormwater management approach. After enduring a severe drought and relying on imported water, city officials have realized that stormwater is a wasted resource (Subramanian, 2017). Los Angeles (LA) is shifting from grey infrastructure to a watershed planning process that includes green infrastructure (Ibid). The LA's Watershed Protection Program incentivizes the implementation of this type of infrastructure throughout the city in order to have (i) cleaner rivers, creeks, lakes, and beaches, (ii) recharged groundwater supplies, (iii) increased vegetation that cools communities, and (iv) improved aesthetics.[3] Part of this initiative includes a green alley program intended to mitigate stormwater runoff and reduce air temperatures (Tayouga and Gagne, 2016).

Scottsdale Arizona is also turning toward green infrastructure for storm water management. Their 45 year history of urban water management includes the construction of linear piped infrastructure (1955-1980), then the

3 Green Infrastructure. LA Storm water – LA's Watershed Protection Program. Online: www.lastormwater.org/green-la/green-infrastructure/

implementation of open engineered channels (1975-2000), followed by green infrastructure via natural washes (1980s onward), and retention basins (1970-1995) (Parr *et al*., 2016).

This trend from grey to green is also evident at a regional scale. The U.S.-Mexico border region is collaborating on green infrastructure projects along the border. The Border Environment Cooperation Commission (BECC) –a binational institution operating under a side agreement to the North American Free Trade Agreement (NAFTA)– is supporting the dissemination of research findings and the implementation of green infrastructure, by building capacities of the different actors in border cities.[4]

The human use of greenspace

Green infrastructure has the potential to function as a climate change adaptation strategy in cities in drylands, but there are additional health benefits. Green infrastructure and greenspace, in general, enhance human wellbeing because they improve physical, mental and social health, providing opportunities for recreational activities (e.g. walking, hiking, running, biking) with the potential to improve physical health (Herrick, 2009). The presence of vegetation improves air quality and reduces the risk of respiratory diseases (Nowak *et al*., 2014) and stress factors like noise and the perception of overcrowding –all consequences of urbanization (Chu *et al*., 2004). The increased presence of trees has been found to correlate with less use of antidepressant medication (Taylor *et al*., 2015). Conceivably, greater opportunities for social interaction in cities enhance a sense of community, and this could be one explanation

4 Border Green Infrastructure Forum III Materials. Arteaga, Coahuila, September 21 and 22, 2016. Border Environmental Cooperation Commission. Online: www.becc.org/page/border-green-infrastructure-forum-iii-materials

of the aforementioned observation (Francis *et al*., 2012). Last but not least, thermal comfort in cities in hot and arid lands could be related to better mood (Yin *et al*., 2012) and, consequently, less crime (Fazel *et al*., 2014).

The human use of greenspace is very important, not only for wellbeing but also to maximize the coupling of social and ecological systems, which is more pronounced in drylands. Nobel Prize winner, Elinor Ostrom, developed a framework to analyze the interactions between social and ecological systems (Ostrom, 2009). She describes the coupling of social and ecological systems and identifies four subsystems: (i) resource units, (ii) resource systems (for the ecological systems), (iii) governance systems, and (iv) users (for the social systems). If we consider greenspace as the resource unit on this framework, then the users are an essential component of the coupling. The higher the number of users, the higher the likelihood that it will be preserved and managed sustainably (Ibid). When many people use greenspace, the possibility of collaborative ecosystem management is higher (Ernstson *et al*., 2010).[5]

Walkability and neighborhood design

One way to enhance the human - green interaction in cities is through neighborhood design (Zuniga Teran, 2015). Because the provision and access to greenspace depends on neighborhood design, providing walkable environs in close proximity with green common spaces (five-minute walk) has been found to enhance the use of such places while promoting better physical and social health (Ibid).

What elements comprise a walkable neighborhood? Walkability in a

5 The human use of greenspace in cities also increases contact with nature in urban populations, and this is related to a higher level of support for the conservation of biodiversity within and beyond cities (Bryant, 2006; Zuniga Teran, 2015).

neighborhood can be assessed through a conceptual framework that contains nine categories: 1) connectivity, 2) density, 3) land-use, 4) traffic-safety, 5) surveillance, 6) parking, 7) experience, 8) greenspace, and 9) community. Connectivity refers to the directness and shortness of routes (e.g., grid street network). Density alludes to the number of dwelling units per unit of area, where higher density is related to higher walkability. Land-use denotes the proximity of different land uses that provide destinations for walking (shops and restaurants close to dwelling units). Traffic-safety refers to the pedestrian and cyclist infrastructure that prevents injuries to people walking and biking and reaching transit systems (e.g., sidewalks buffered from the road by a strip of vegetation or on-street parking, bike lanes, traffic calming treatments). Surveillance relates to the sense of people watching the street from inside the buildings (e.g., clear glass windows close to the street, outdoor cafes, front porches), which is perceived as safer from crime. Parking alludes to the availability of parking: where there is less parking, the district is more walkable. Experience refers to the sensorial experience while walking (e.g., thermal comfort, aesthetics, fumes, noise, way-finding). Greenspace denotes its proximity and access, and community refers to spaces and conditions that allow community interaction.

Walkable neighborhoods also have the potential to mitigate climate change and reduce some of the negative effects of urbanization, including sedentary societies that depend on the use of the automobile, and subsequent traffic, noise, and pollution. If more people choose to walk or bike as their method of transportation, besides improving wellbeing of urban residents, less cars will be on the streets.

Conclusion

Designing walkable neighborhoods with access to greenspace has the potential to enhance the human use of public space. Consequently, more users maximize the coupling of social and ecological systems, which may result in the preservation of greenspace and related wellbeing benefits. When greenspace is designed as green infrastructure to manage stormwater runoff in-situ, the negative impact of urbanization on water systems is reduced. Green infrastructure enhances water security because it decreases flooding risk, increases the recharge of aquifers, and improves water quality. Therefore, designing walkable neighborhoods that provide access to greenspace and include green infrastructure has the potential to increase water security in cities in drylands and promote resilience in the face of a changing climate.

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III. Water, energy, land use, urban nexuses and synergies in climate change sensitive cities

Chapter 6

Water-energy Nexus in semiarid regions and coastal cities of California and Baja California

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Introduction

The complexity of the environmental problems we face nowadays has been addressed by compartmentalizing issues into isolated systems to operationalize, characterize, and evaluate them and then propose solutions. Somehow, in the middle of such abstraction, assembling issues back again to resemble how they are encountered in real life with some of their entangled complexity is commonly forgotten; in doing so, crucial information is lost at the underestimated links; this is the case for the nexus between water and energy, their individual importance as engines for life and development is widely recognized but their areas of overlap have been disregarded.

And those neglected relationships have a latent social, economic, environmental, political and physical relevance. For example, the water-energy link is crucial for urban development; it has been reported that between 30 to 40% of energy demanded by local governments is to operate water and wastewater treatment plants; this demand is likely to increase in 20% for the next 15 years due to population growth and potential drought conditions (Coppeland, 2013). Energy investment could be higher if the transference of water in aqueducts is taken into account. Furthermore, the fuel mix to generate electricity consumed to move and treat water and wastewater will have an impact on air quality and the generation of Greenhouse Gases emission alike. Moreover, underestimating the link between water and energy could be costly in financial terms and has implications in planning.

Yet, the link between water and energy is not restricted to metropolitan environments; irrigation plays a key role in the production of food, given that agriculture consumes more than 70% of water withdrawals; that is accompanied by energy investment, which will increase with the use of fuel and electricity for harvesting, packing, transportation and commercialization. There is not only a water footprint but a long chain of energy investment that goes along with it, together with air quality impacts, greenhouse gases emissions, land use degradation and loss of biodiversity; to name but a few other implications.

This line of thinking is aligned with Peter Gleick's work from over 20 years ago when he stated that water and energy were related in many complex ways, too deeply interconnected to continue approaching energy policy and water policy as independent (Gleick, 1994). However, a decade went by before the water-energy nexus received any widespread attention; and when it did, the implications of water scarcity for meeting energy needs to sustain population and economic growth tended to drive the analysis (Glassman *et al*., 2011; Allouche *et al.,* 2015).

In the U.S. much of the water-energy nexus research has focused on the energy embedded in the water and wastewater sectors; these studies were developed by academic, nonprofit and state agency researchers and policy analysts (Water in the West, 2013). Although there are studies from various locations around the U.S. (Stillwell *et al*., 2010), most were concentrated in the Southwestern region (Glassman *et al*., 2013), in particular, California (Blanco, 2012; Bennett *et al*., 2010-A and 2010-B; CEC, 2005; Cooley *et al*., 2008; Cooley and Wilkinson, 2012; Climate Registry, 2015; Wilkinson, 2000, Wilkinson, 2007).

In Europe, the Netherlands and the United Kingdom are examples of leading countries that have adopted circular economy principles and implemented its associated technologies to reduce water-energy and water-food nexus pressures (Brears, 2015). There are additional efforts to harmonize energy and water systems elsewhere. For example, in Spain, a study on the estimation of energy consumption for urban water treatment and seawater desalination and the role that new technologies and policies may play in reducing energy consumption was sponsored by the Spanish Institute for Diversification and Energy Conservation (IDEA) (OPTI-IDAE, 2010); as well as research on the role of consumption-production on the water-energy nexus (Velazquez *et al*., 2011). The Stockholm Environment Institute (SEI) report 'The Water, Energy and Food Security Nexus: Solutions for the Green Economy' provides an additional example of the increasing prevalence of research on this concept.

In the Middle East and North Africa region (MENA), the work by Siddiqi and Diaz (2011) was seminal to present a systematic, quantitative evaluation of energy consumption in water systems and water consumption in energy systems at a country level in the MENA region; and to inspect the broader issues of water supply and its energy implications, plus environmental considerations for future planning.

In Asia, the water-energy-food nexus was explored by using two case studies, namely Central Asia and the Mekong Basin; findings showed that within existing policy frameworks, energy and water policies are developed largely in isolation from one another (UNESCAP, 2013). Additionally, in China the water energy nexus has been related to the generation of GHG emissions from groundwater pumping for irrigation (Wang *et al*., 2012).

In Australia, Barry Newell, Deborah Marsh, and Deepak Sharma (2011) took the principles and concepts of systems thinking and applied them to an analysis of the resilience of the Australian National Electricity Market (NEM) to characterize the water energy nexus as a result of severe water shortages in 2007 that saw generation capacity curtailed and a threefold increase in the wholesale price for electricity.

Concerns regarding the water energy nexus are not limited to countries; world organizations have reported on the issues in publications such as the World Bank's 'Thirsty Energy', The United Nations (UN) 'World Water Development Report (WWDR) 2014', The International Energy Agency's (IEA) 'World Energy Outlook 2012', The 'Water Security: The Water-Food-Energy-Climate Nexus' book, launched in 2011 by the World Economic Forum (WEF); this last work links the nexus to development and conceptualizes the nexus as a technical-managerial fix for resource scarcity, an approach that has been critiqued for neglecting underlying issues of equity and distribution (Allouche *et al*., 2015).

Studies listed above carried out characterizations, identified problems, and, in some cases, provided public policy recommendations. A constant, however, is that water as well as energy sources are considered to be resources that are managed at multiple scales. That is, resources at local level are managed by utilities and city or municipal governments; however, the very same resources at a regional scale are administered by several and diverse local domains each of them at an identifiable location and with jurisdiction over a specific "piece" of resource. To complicate and fragment this issue further the management of resources, service regions, infrastructure, and physical resources can also cross State boundaries; these at regional and political levels are not necessarily coterminous. This fact has complicated consequences, but is not necessarily problematic. It has been posited by policy and management experts that for resources management purposes, administrative boundaries are more relevant than the physical boundaries (Scott *et al*., 2011), and may be more appropriate for problem solving (Blomquist and Schlager, 2008).

This chapter evaluates how energy and water, as interdependent and shared resources, could be characterized in the coastal US-Mexico border region, in particular California and Baja California; this characterization is achieved through a comparison of official statistics. To achieve this objective this paper is divided into eight sections; the first reviews the current status of the nexus between water and energy in Mexico; the second, third and fourth parts describe the water and energy sectors and their regulations in both Baja California, Mexico and California, U.S. The fifth and sixth sections summarize energy and water sectors' impacts; and influencing factors on future water and energy demand and supplies for the region. The seventh section provides energy and water policy options, in particular for Baja California. Conclusions are given in the last section.

The water-energy nexus in Mexico and the U.S.

The nexus between water and energy in Mexico as well as in the U.S. is very much focused on the role of water for energy generation. To a lesser extent, the importance of energy is recognized for the operation of wastewater treatment facilities and water pumping. Within California, because of its elaborate water conveyance system, there is also significant attention paid to energy embedded in water delivery.[1]

In the U.S., the thermoelectric generating industry is the largest withdrawal user of water. According to the USGS, 349 billion gallons (1.32 billion cubic

1 Reports by the Baja California Water Commission suggests that the highest energy use for water in Baja California is for conveyance at the Colorado River-Tijuana aqueduct, without accounting for informal water delivery methods like water tankers. However, a full discussion of the embedded energy in Baja California is beyond the scope of this chapter.

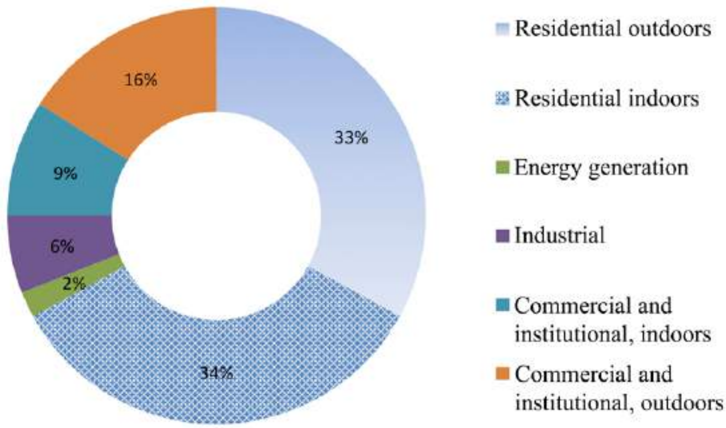
meters) of freshwater were withdrawn per day in the U.S. in 2005. This amount accounted for 41% of freshwater withdrawn. However, freshwater consumption for thermoelectric purposes is low (only 3%) when compared to other use categories such as irrigation, which was responsible for 81% of water consumed. Conversely, American water and wastewater systems account for approximately 3%-4% of energy use in the U.S. Furthermore, water and wastewater treatment plants are typically the largest energy consumers of municipal governments, accounting for 30%-40% of total energy consumed, and this is expected to increase 20% in the next 15 years due to population growth and tightening drinking water regulations.

In California about 50% of the available fresh water is used for environmental purposes (e.g., maintaining and restoring of aquatic and riparian ecosystems, instream flows, managed wetlands). The rest, known as "consumptive use," is used for agricultural operations and for urban use. Of this "consumptive" use, agriculture uses about 80% of the total while "urban" consumption is disaggregated as shown in figure 1. The sticking message of figure 1 is that landscaping (outdoor use in the residential and commercial sectors) account for roughly half of the total urban water use (PPIC, 2015).

In Mexico, the thermoelectric power plants are the third withdrawal users of water. By 2014, 11.37 million cubic meters/day (3.0 billion gallons/day) were consumed by this sector; however, this amount —of which 89% was from freshwater origin— represented only 4.9% of consumptive use in the country; as in the American case, this amount is low when compared to irrigation, which was responsible for 76.7% of water consumed. The second most important water user with 14 % (29 million cubic m^3/day or 3.18 billion gallons/day) of consumption was the public sector that includes domestic and urban public users (Conagua, 2015). Urban water uses in Mexico are distributed as follows; 71% is for residential users, 12% is for Industry, 15%

is for commercial customers and 2% is destined for public services (IMTA, 2002).

Figure 1. Urban Water Use in California



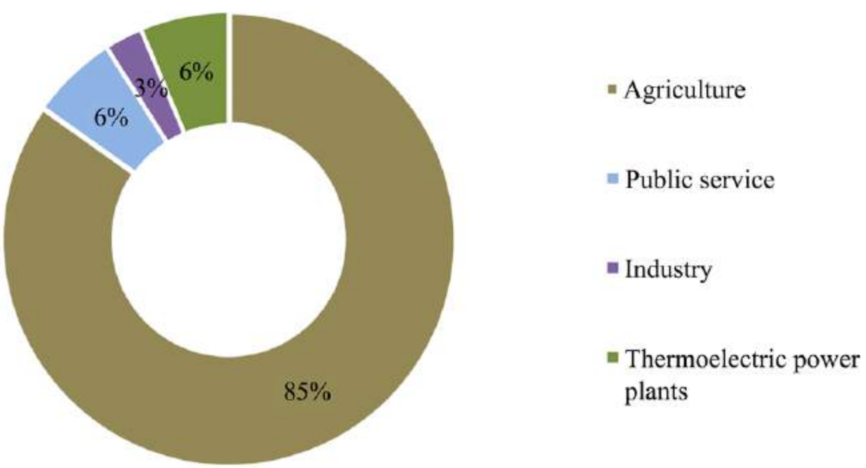
Source: Modified from PPIC, 2015. Data from the California Department of Water Resources.

In Baja California, of the 3048.4 million cubic meters (Mm^3) assigned to consumptive usage during 2014, 2.586 billion cubic meters were destined to Agriculture (59% of these were surface water withdrawals), 192 Mm^3 were consumed by thermoelectric plants (all from groundwater origins), 188 Mm^3 were for public supply, and 83 Mm^3 were used in Industry (without considering power plants) (CONAGUA, 2015) (figure 2).

There are no records of urban water uses for Baja California; however, they are expected to follow the national trend, and be mainly allocated to residential consumers, and considering prevailing household characteristics in Mexico; it is likely that urban water use could be concentrated in residential indoor utilization.

The average water consumption per capita in the State is 215 liters/day. Coastal towns currently host 77% of the State population—and are estimated to grow at a rapid pace for the following 30 years— and so far, their water supply has been secured through the Colorado River-Tijuana aqueduct. Tijuana depends on such water transfers for nearly 90 % of its supply.

Figure 2. Water Uses in Baja California



Source: CONAGUA, 2015

Energy sector characteristics

Mexico and the U.S. have 18 interconnection points to transport Natural Gas for importation to Mexico (SENER, 2016). There are two Liquefied Natural Gas (LNG) terminals in Mexico, both in the border region; one is at the Altamira port in Tamaulipas, the other is the Costa Azul terminal near Ensenada in Baja California.

Mexico and the U.S. also have nine electricity interconnections with varying capacities and voltages. Five operate for backup purposes in the event of supply distortions and system blackouts on both sides of the border. The transfer of electric energy between the U.S. and Mexico is controlled by the Mexican Electricity System (Sistema Eléctrico Mexicano–SEM) and two regional councils in the U.S. —the Western Electricity Coordinating Council (WECC) and the Electric Reliability Council of Texas (ERCO) (SENER 2008-A, SENER, 2008-B). Under the energy bill that was passed at the end of 2013 and the regulatory measures that were enacted during the first half of 2014, private investment on the Mexican energy sector is now possible; this could bring changes to the border region (http://cdn.reformaenergetica.gob.mx/explicacion.pdf).

A. Energy sector of Baja California

I. Electricity

Baja California is a State with one of the highest-demands for electricity in Mexico. This is for two main reasons, the first is climate conditions, in particular extremely high temperatures during summer; and the second reason is increasing electricity consumption by economic activities, especially exporting industrial activities, such as “maquiladoras” including car assembly plants. In 2016, the overall annual electricity demand in Baja California was 13,122 GWh (gigawatt-hours), with a peak-demand of 2,374 MWh (megawatthours) driven by air conditioners' use during summer (PRODESEN, 2016).

The current electricity infrastructure in Baja California consists of four main power generating plants, several small plants, and a system of transmission lines, concentrated in two zones denominated the Valley (Mexicali) and the Coast (Tecate-Tijuana-Rosarito and Ensenada). The grid is not connected to the National Electricity Grid; instead it is connected to San Diego, California, in the U.S., by way of three 230 kW lines. One of these lines is located in Tijuana, and the other two are located in Mexicali. The transmission lines belong to the U.S. companies of Sempra, InterGen, and San Diego Gas & Electric. Thus, the Baja California electricity grid provides public and export services.

Energy sources to generate electricity have drastically changed over the last fifteen years. Before 2000, up to 70% of electricity generation was from geothermal sources (see figure 3) followed by about 25% from fuel oil and in a minor degree from diesel. In 2001, natural gas to generate power was introduced in the region to generate power; and only five years later natural gas became the most important source to produce power, due to the establishment of two privately-owned power plants in Mexicali. At present, power generation in Baja California is dominated by power plants burning natural gas (see figure 4). The participation of renewable sources —in particular solar and wind— is still incipient.

By 2014, the total effective generation capacity in Baja California was 3,929 MW, with 2,693 MW of interconnection capacity and an annual gross generation of 19,482 GWh. The public suppliers provided 1,800 MW; of these 1,300 MW were operated by the Mexican Federal Electricity Commission (Comision Federal de Electricidad – CFE), with the geothermal plant of Cerro Prieto as the most important power plant in the Valley region, and the natural gas combined cycle (NGCC) station "Presidente Juarez" as the principal electricity provider for the coastal cities. The remaining 500 MW —for public supply— come from the power plant owned by InterGen “La Rosita” (with an installed capacity of 1,100 MW), located in Mexicali. Electricity exportation to California reached 1,200 MW, of which half was provided by the NGCC “La Rosita” station, and half from the Sempra Energy Power central (also located in Mexicali).

Figure 3. Geothermal Electricity Generation Stations in Baja California, Mexico and Southern California, U.S.

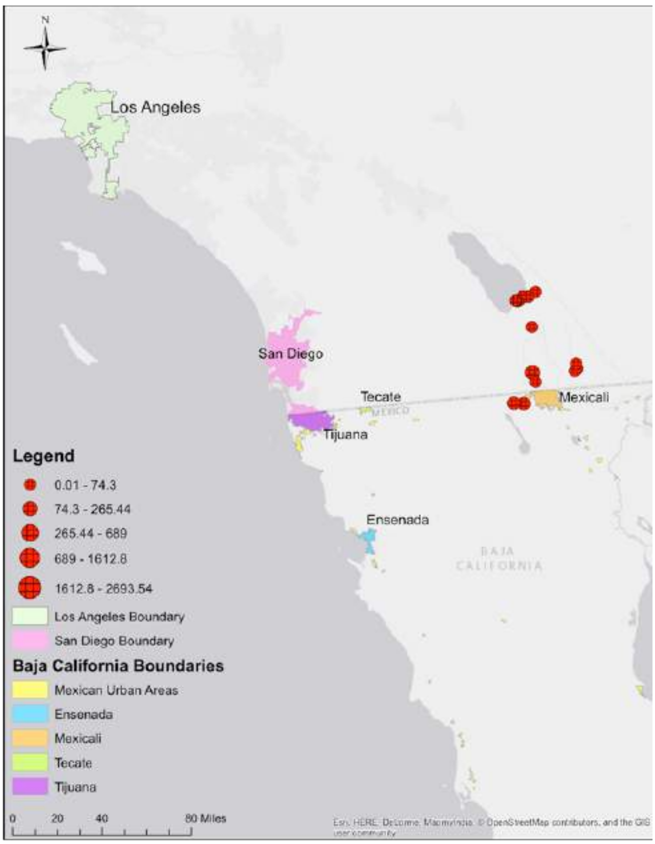
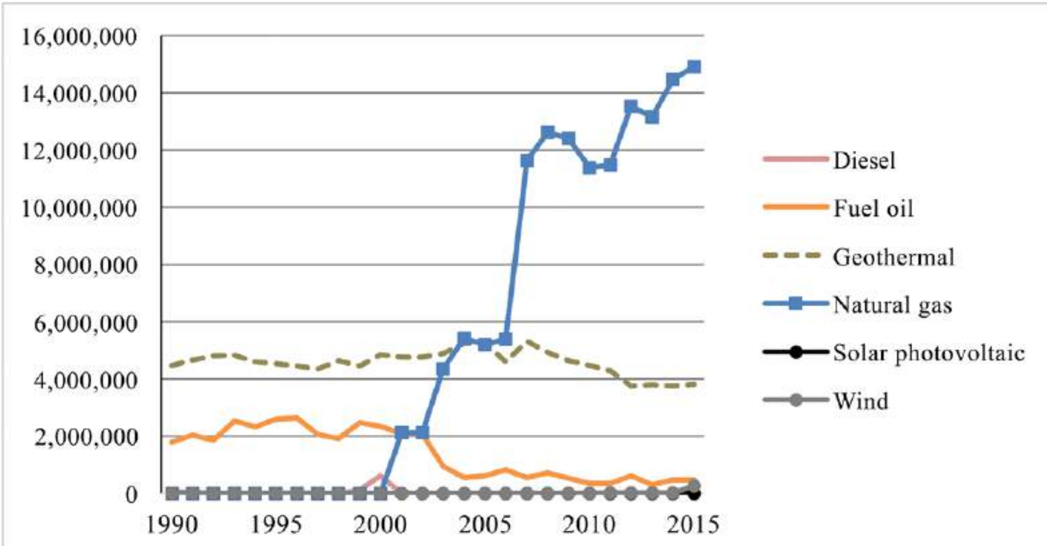


Figure 4. Energy sources of Electricity Generation in Baja California 1990-2015, units are expressed in MWh



Sources: prepared by the authors using data from INEGI, 1991 to 2014; PRODESEN, 2016 and CEC, 2015-A

II. Natural gas

There is no Natural Gas (NG) production in Baja California. However, over the past decade the consumption of natural gas has increased considerably. Demand for natural gas rose from 13.9 million cubic feet per day in 2000 to 256.4 million in 2009 —an increment of 38% annually. NG consumption is up 300% since 2010, and is set to double again by 2019 (Lobet, 2017).

All of the natural gas used in Baja California is imported from the U.S., as the State is not connected to the national pipeline network in Mexico. SEMPRA operates the 180 miles Natural Gas pipeline for imports to Baja California. This NG pipeline interconnects with El Paso Natural Gas Co. near Ehrenberg, Arizona, traverses southeastern California, crosses the border and heads west across Baja California, Mexico near "Los Algodones" town, ending at an interconnection with the Transportadora de Gas Natural (TGN) Pipeline, which runs from an interconnect with SDG&E at the US/Mexico border south of San Diego to the Presidente Juarez Power plant in Rosarito, Baja California. Gasoducto Rosarito includes a lateral that connects to the Costa Azul LNG terminal (www.northbajapipeline.com/company_info/) and since 2016 also connects the new NG CC "La Jovita" power plant in Ensenada, property of Iberdrola, under construction at the moment, but scheduled to start operations late in 2017. By 2015, 333.8 million cubic feet per day were imported through "Los Algodones" interconnection point (SENER, 2016).

As seen, the main end-user of NG is the electricity sector. In 2009 the sector used 93% of the total NG consumed in Baja California. One potential reason for such an enormous share of natural gas could be because in 1999 the electricity generation in the Coastal region transitioned from fuel oil to natural gas. Meanwhile, in the Valley, the use of natural gas displaced geothermal vapor (Campbell *et al.*, 2006).

III. Petroleum

No oil-based fuels are processed in Baja California; thus there is no oil refinement infrastructure. However, oil-based products are highly consumed goods, and the State has a well-connected distribution network. Transport is the main end-user of gasoline in Baja California; its demand reached 75% of the total amount supplied to the whole of Baja California. The coastal towns of Tijuana, Rosarito and Ensenada consumed nearly 60% of the total gasoline and diesel provided to the State.

In 2017, Petroleos Mexicanos (PEMEX) ceased to be the only oil-based fuel provider in Mexico as a result of the Energy Reform implementation, from now on there will be new providers of fuels, in particular gasoline and diesel.

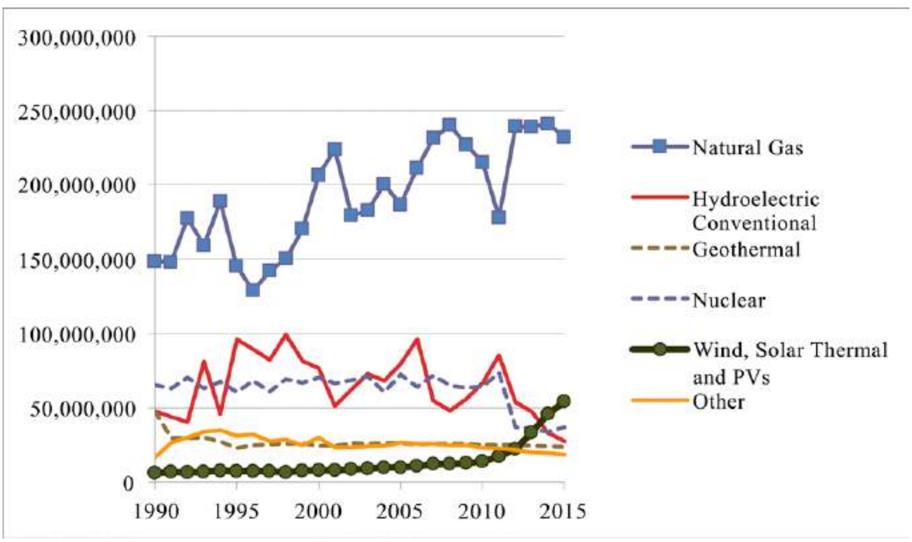
B. Energy sector in California

The energy sector of California is extensive and very well integrated. The coastal cities in Southern California are very well connected with the overall energy system in California; and, for this reason, we provide an overall view of the energy sector in the state of California and emphasize certain peculiarities of Southern California.

I. Electricity (Including natural gas based electricity generation)

The overall annual electricity demand in California is about 280,000 GWh and the peak demand can be more than 60,000 MW (CEC, 2015-A). The hours of peak demand occur during the hot summer hours during weekdays driven by the demand from air conditioning units. Electricity generation in California is dominated by power plants burning natural gas. But power generation is highly diversified with substantial amounts of renewable sources of energy-dominated by geothermal and hydropower generation (See figure 5). The penetration of wind and solar resources is increasing at a rapid rate, driven by laws mandating that 33% of the electricity provided to customers must come from renewable sources of energy by 2020, which must be increased to 50% by 2030 (CEC, 2015-B). However, the legal definition of renewable excludes "large" hydropower units (capacity larger than 30 MW) and on-site generation (generation after the utility meters). Since hydropower is an important source of electricity in California and the on-site use of PV units is becoming more prevalent, the legal definition of renewables means, in practice, that the electricity consumed in California in 2020 and 2030 will have a much higher content of "renewables" than 33% and 50%, respectively.

Figure 5. Energy sources of Electricity Generation in California 1990-2015 -units are given in MWh-



Source: prepared by the authors using U.S. EIA, 2016 data

California also imports large quantities of electricity from the Pacific Northwest and the Southwest and it is part of the Western Energy Coordinating Council (WECC). As noted above, the northern part of BC is also part of WECC and not physically connected to others part of Mexico. California imports most of its hydropower from the Pacific Northwest. Its fossil based electricity mostly comes from the Southwest, U.S. By law, the import of "coal by wire" is vanishing with the mandate to eliminate all the long-term contracts from out-of-state coal burning power plants (CEC, 2015-B). However, keeping track of the sources of electricity sending power to California is challenging and an almost impossible technical task given the strong interconnections in the WECC and the fact that the actual flow of electrons in a network follows the laws of nature ignoring "mandates" from contracts and human laws.

Some argue that a mandate for clean electricity from out-of-state power plants could encourage an apparent reduction of carbon dioxide emissions from consumption in California accompanied by an increase in emissions in other parts of the WECC (Bushnell *et al.*, 2014). The contribution of coal to electricity generation in the overall WECC has decreased. But, this may be mostly due to the retirement of old coal burning power plants that were replaced with natural gas power plants. The change came in response to the availability of low cost natural gas and the increased efficiency of natural gas burning power plants using combined cycle. The California mandate should have also had an effect on this transition but the real magnitude of the impact remains unclear.

At the same time, due to the relatively unexpected high methane emission rates from the natural gas system, the climate benefits of natural gas are diminished in relation to other fossil fuels (Alvarez *et al.*, 2012). The magnitude of these emissions has been a matter of scientific dispute but recent comprehensive studies demonstrate that counting the emissions from "super-emitters" brings the estimated emissions close to the range estimated using aircrafts, instrumented towers and other so called "top-down" methods. These methods are characterized by their ability to detect overall methane emissions from natural gas fields, the distribution network, and other parts of the natural gas system, but are unable to identify and quantify individual sources (e.g., an individual natural gas well) for the most part (Lyon *et al.*, 2016). It is unclear at this time how successful, and at what costs, efforts to reduce methane emissions from the natural gas system will be. The identification of super-emitters may be difficult, hampering emission reduction efforts. At the same time, if their identification is found to be straightforward, controlling them, because they represent a small fraction of the potential sources of emissions, may lower compliance costs. That said, any methane leaks will reduce the comparative advantage of natural gas over other fossil fuels and may compromise its perceived role as a bridge fuel for the next decades.

In Southern California, while generation is dominated by natural gas, it also relies in part on a coastal nuclear power plant and large recent additions of solar and wind farms in the Mojave desert.

II. Natural gas

The production of natural gas in California is dominated by "associated wells", which are wells that produce both crude oil and natural gas. Natural gas production in California has declined. In more recent years California imports from other parts of the U.S. about 90% of its consumption. Southern California is served by a network of transmission pipelines bringing natural gas from producing basins in New Mexico, Texas, Utah, Colorado and Wyoming. There is also an interstate transmission line bringing natural gas from the western part of Canada. An intrastate transmission line connects Southern California with this supply source from the north.[2]

Natural gas is, by far, the dominant fossil fuel consumed in California in all sectors excluding transportation, which is dominated by petroleum based products such as gasoline. The transition to natural gas in the residential, industrial, and commercial sectors has been due to multiple factors including air quality considerations. Emissions of nitrogen oxide, particulate matter, sulfur oxides, and carbon monoxide tend to be much lower in units burning natural gas in comparison with other fossil fuel based fuels.

III. Petroleum

Fuels derived from crude oil dominate the transportation sector mainly due to their high energy content per unit of volume. Several oil refineries are located in Southern California serving its natural market but also exporting products to other parts of western U.S. As with natural gas, most of the crude oil that is processed in California refineries is imported from other regions. For example, in 2015, the imports came in descending order of amount supplied from Saudi Arabia, Ecuador, Colombia, Kuwait, Iraq, Brazil, Angola, Canada, and other regions.[3]

Water sector characteristics

Mexico and the U.S. use in common three watersheds: Bravo, Colorado and Tijuana; of these, the last two are shared between California and Baja California, being the Colorado River the most important one, as it provides nearly 60%

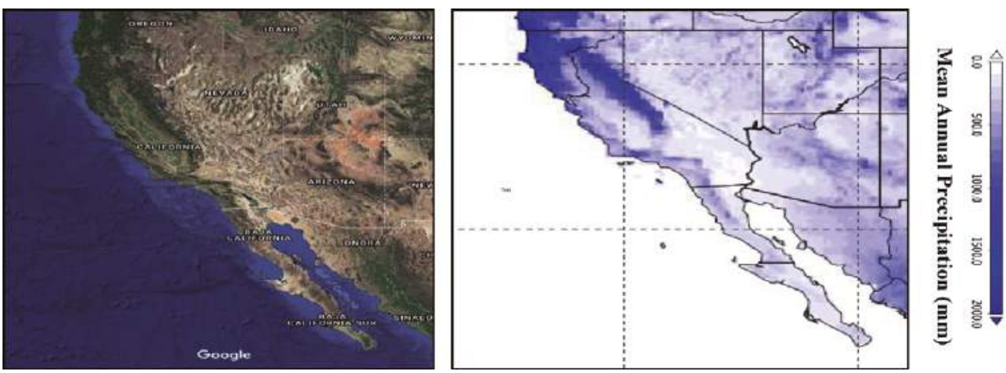
2 See: www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/ngpipelines_map.html

3 See: www.energy.ca.gov/almanac/petroleum_data/statistics/2015_foreign_crude_sources.html

of water to Baja California; given its importance, a brief explanation about the bi-national management is provided. The 1944 Water Treaty entails that the U.S. provides Mexico with 1.5 million acre-feet of Colorado River water per year, which represents about 10% of the river's average flow. Under the Treaty, bi-national disputes over water quantity, quality, and conservation can be resolved through amendments, called "minutes." For example, the last amendment: Minute 319, agreed to in 2012, provides for a bilateral basin water management, storage, and environmental enhancement effort (Carter *et al.*, 2015).

Figure 6 shows the topographic features of California and Baja California, but more importantly, clearly presents the semiarid characteristics of the southern part of California and the entire Baja California, where water scarcity is a frequent event.

Figure 6. Topography and Average Precipitation in California and Baja California



Sources: Google Earth and adaptation from Livneh *et al.,* 2015.

A. Water sector in Baja California

The water resources available in Baja California are 3,250 Mm^3 per year, of these 2,950 Mm^3 are concentrated in the Mexicali Valley, where 1,850 Mm^3 come from surface waters (57% from the Colorado River) and 1,100 Mm^3 are withdrawn from underground sources. The remaining 300 Mm^3 come from aquifers on the coast. Baja California has an average rainfall rate of 68 mm per year in most of its territory; due to this the "renewable water" contribution is considered negligible, and the infiltration of water to underground aquifers is slow (GobBC, 2015). When it does rain, it could be copious and continuous, and in the past has caused flooding of coastal cities. Baja California does not have the infrastructure to collect and store rain water, and this generally drains into the sea.

Given the situation described above, it is appropriate to enquire about the status of local watersheds in a water-stress location. By December 2010 seven aquifers were considered to be overexploited, three of them with saline intrusion. The region is considered to be very dry and with a tendency towards drought.

Regarding water end-users, of the 3004.4 Mm^3 of freshwater allocated in 2012; 2556.6 Mm^3 were destined to Agriculture, 170.3 Mm^3 were for public supply, and 82.3 Mm^3 were used in Industry (without considering power plants) (CONAGUA, 2013-A). As seen, agriculture is the most important end-user. However, water losses in that sector could reach up to 500 million cubic meters per year (Department of Agriculture Statistics of the National Water Commission-Irrigation district 014-Colorado River). This is a factor for the increasing degree of pressure on the water resources (the proportion of water available that could be extracted); this indicator is classified as "strong" (< 40%) for Baja California. As well, it should be noted that the average water consumption per capita in the State is 215 liters/day.

To face water scarcity, Baja California has opted for developing infrastructure; in relation to water infrastructure, the storage capacity provided by dams is 127.40 Mm^3. Additionally, there are 12 aqueducts; of these the “Colorado River-Tijuana” is the most important because it provides the most populated city (Tijuana) in BC with above 80% of its water supply. The aqueduct is 135.3 km long and has a transport capacity of 5,333 liters per second.

On the other hand, and in relation to additional sources of water, in Baja California the use of treated wastewater reached 30% at state level, although there are important regional differences. The use of recycled water is near 80% in the Mexicali Valley; in contrast, the coastal cities of Ensenada, Tijuana and Rosarito do not use more than 10% of treated wastewater (GobBC, 2016). Finally, desalination of seawater is still incipient; the construction of a 4.4 m^3/s desalination plant started in Rosarito in 2016.

B. Water Resources in California

Precipitation in coastal California is highly variable from year to year. Paleo records, including analysis of tree rings, dating back 1,200 years indicate that the region is prone to multidecadal droughts linked with warmer temperatures (Woodhouse *et al*., 2009). But the aridity of the region is also punctuated by wet years and flooding associated with storms from atmospheric rivers[4] (Dettinger, 2011).

Strong inter-annual and decadal variability does not mean that coastal

4 Atmospheric Rivers (ARs) are relatively narrow regions in the atmosphere that are responsible for most of the horizontal transport of water vapor outside of the tropics. While ARs come in many shapes and sizes, those that contain the largest amounts of water vapor, the strongest winds, and stall over watersheds vulnerable to flooding, can create extreme rainfall and floods. These events can disrupt travel, induce mud slides, and cause catastrophic damage to life and property.

cities have necessarily lacked reliable freshwater resources. Over the last century, powerful and populous coastal cities in California have developed water supplies that reach beyond the physical limits of the water resources within the city boundaries. San Francisco, Los Angeles, and San Diego for example have dammed and redirected water from the snow covered mountains and other water rich areas (Reisner 1993; Worster 1985). With the advent of new groundwater pumping technologies in the mid 20th century, agricultural lands and cities were able to exploit underground aquifers, frequently at unsustainable rates (c.f. Ostrom, 1990). And finally, “new” sources of water are provided through water recycling and desalination.

When it does rain, about 2/3rds of precipitation falls in Northern California, but about 2/3rds of the population lives in Southern California (Hanak *et al.,* 2011). This geographic mismatch is managed by a complex system of dams, canals, and pumping stations that divert surface water from major rivers near the Sacramento-San Joaquin Delta —pumping the water to an elevation of nearly 2,000 feet and along 700 miles of the California aqueduct (DWR, 2008). Surface water is further connected to groundwater, and recycled or desalinized water through local and state-level conjunctive management projects. Recycled water, for example is injected underground in San Diego to help form a barrier against saltwater intruding into freshwater aquifers. Surface water is used to recharge overdrawn aquifers, and groundwater is used to augment dwindling surface water supplies (Sugg *et al.,* 2016; DWR, 2015).

Coastal California uses approximately 29.9 million acre feet annually (MAF/yr) for human purposes—in other words, excluding ecosystem management and maintenance of instream flows in rivers (Hanak *et al.,* 2011). The region has about 9.1 million acre feet of surface storage and another 197.6 million acre feet of groundwater storage (Hanak *et al.,* 2011).

The largest share of water in California has gone to agriculture, which consumes approximately 80% (PPIC, 2014); most of this consumption takes place in land in the state's central valley. Urban consumption though is dominated by coastal cities in California. For the past two decades, even though population has increased, urban water use has held steady. And per capita use has declined from over 200 gallons of water per day in 1990 to 178 gallons per day in 2010 (PPIC, 2014). Landscape irrigation though remains the single largest residential use of water (Ibid).

Water-energy regulations at federal and State level in California and Baja California

A review on laws governing the nexus between water and energy at the Mexico-U.S. border region revealed that by 2014 in the U.S. only nine states —Arizona, California, Colorado, Connecticut, Nevada, South Dakota, Washington, West Virginia and Wisconsin— have statutes that recognize the nexus between water and energy. Arizona, California, and Nevada have laws considering the water use for generating electricity (NCSL, 2015). On the other hand, in Mexico since 2015, the Water Act (DOF, 2016) considers the water-energy link in its section six, chapter III. Water for Electricity generation. In addition, there are Mexican regulations (Normas Oficiales Mexicanas-NOM) that take into account the nexus between water and energy; for example, those related to energy efficiency standards for washing machines and to increase pump proficiency. The latter is particularly relevant given that the electricity consumption of water pumping (water, wastewater and agricultural irrigation) reached 13,000 GWh/year or 6.5% of the total electricity consumed in the country (Conuee, 2013). These numbers indicate that there are several other water-energy linkages in Mexico, although they tend to be examined in a piecemeal way.

In these American and Mexican laws, allocation of water volumes for electricity generation and priorities of end-users under scarcity conditions are considered. Although at the federal-level, there is no comprehensive management of the water-energy-climate nexus, within California management has been more involved. The state has programs aimed at improving combined water and energy efficiency such as water appliance standards to save both water and energy (www.energy.ca.gov/releases/2015_releases/2015-04-08_water_appliance_standards_nr.html), and has encouraged the use of dry cooling for power plants for the last decades, and has three climate adaptation bills. For example, Senate Bill 246 (Wickski, Climate Change Adaptation) mandates the creation of a Climate Adaptation and Resilience Program in the Governor's Office of Planning and Research to coordinate adaptation efforts at the local, regional, and state level. Governor Brown signed these Bills into law late in 2015. Their implementation will facilitate the consideration of the interlinkages between water and energy systems within California.

Water and energy sectors' impact on air quality and greenhouse gas generation

I. Energy sector

Environmental impacts of the electricity sector in Baja California are primordially associated with atmospheric emissions due to fossil fuel combustion. Other environmental impacts are: 1) the use of water, 2) waste generation, and 3) heat, noise, and subsidence at geothermal fields.

In relation to Greenhouse Gases emissions from Power Plants, it was estimated that in 1990 CO_2 emissions reached 1.8 million tonnes; of these 78% were generated at the Rosarito Power Plant (based on fuel oil) located at the Baja California Coast. The switch to Natural Gas in 1991, had a positive effect during the first years, however higher electricity demand ended up increasing the CO_2 emissions; for 2010, 3.7 million tonnes were released, however, the contribution of power plants at the Coastal region decreased by 57% (Muñoz *et al.*, 2012-A).

Regarding air quality; in 1990 about 19,000 tonnes of SO_2 were produced at Power Plants, of that 94% came from the fuel oil combustion at the Coastal region. Since 2001, sulfur dioxide decreased due to substitution of fuel oil for natural gas; thus in 2004 SO_2 emission were 8,300 tons. On the other hand, NOx emissions had increased from 2,500 tonnes in 1990 to 6,000 tons in 2010; 63% of such emissions were originated at the Coastal region (Muñoz *et al.*, 2012-A), this was a side effect of the transition from fuel oil to natural gas, and specially the exponential growth of consumption of the latter (see figure 4). Natural gas is the cleanest of all fossil fuels but by all means is not emission free. The combustion of natural gas, releases very small amounts of sulfur dioxide and nitrogen oxides, virtually no ash or particulate matter, and lower levels of carbon dioxide, carbon monoxide, and other reactive hydrocarbons (http://naturalgas.org/environment/naturalgas/).

The energy sector is the dominant source of GHG emissions in California contributing more than 80% of the in-state emissions. Here we use the IPCC definition of the energy sector that encompasses all sources of energy services such as mobility, illumination, space heating, and industrial process heat. By law GHG emissions from California must be at or below what the state emitted in 1990 by 2020 (AB 32). The official GHG inventory of California, maintained by the California Air Resources Board, includes estimates of emissions of electric power plants serving California. In terms of energy consumption natural gas dominates the energy consumed from fossil fuels in California. However, in terms of GHG emissions, natural gas and gasoline have very similar contributions. This reduced contribution of natural gas to overall GHG emissions is due mainly to three factors: 1) the lower carbon content of natural gas per unit of heat released during combustion; 2) an incomplete understanding of the methane emissions associated with the natural gas system; and, 3) the fact that methane emissions outside California are not counted in the official ARB inventory. Since California imports about 90% of the natural gas that it consumes, not counting methane emissions outside California represents a serious shortcoming from an environmental perspective. However, there are other programs such as the Clean Fuels Standard that by law must take into account GHG emissions from a full fuel cycle perspective, but this program only covers transportation fuels (AB 32, EO S-01-07; also see Yeh *et al.,* 2015).

It is interesting to compare the main sources of carbon dioxide and NOx in-state emissions normalized to total emissions. Statewide emissions from different sources as a fraction of their contributions to total emissions. NOx emissions from power plants contribute less than 1% of the NOx emissions in California but they are a major source of carbon dioxide. Surprisingly, as NOx emissions have gone down in California, automobiles are no longer the main source of NOx, which is a successful outcome from years of efforts aimed at reducing their emissions. Nowadays heavy duty and off-road equipment are the main sources of NOx pollution in California (CEC, 2015-B).

II. Water sector

According to the National Inventory of Municipal Plants for Water and Wastewater Treatment in Operation (CONAGUA, 2011); there are 31 water treatment plants in operation, most of them utilize direct filtration treatment. By 2012, the coverage of potable water in Baja California was of 95.6% (3,069,818 inhabitants) (CONAGUA, 2013-B). On the other hand, there are 36 wastewater treatment plants; most of them use activated sludge treatment (CONAGUA, 2011). Sewage service coverage is 83% at State level; however, this percentage changes by regions. In the coastal region, Ensenada has a coverage of 58%, while in Tijuana and Rosarito, sewage services were provided for 89% of the population. By mid-2016, 83,783,483 m^3 of wastewater were generated in Baja California, 58% came from coastal towns.

The GHG emissions generated from wastewater treatment plants and their sludge are primarily methane; it is reported that such emissions increased in 43% from 2.7 Gg in 1990 to 4.7 Gg in 2005. By 2014, 5.3 Gg methane were released, the amount represented a 49% increment from the 1990 levels. In terms of CO_2 equivalent, the volume generated went from 57.2 Gg in 1990 to 112.0 Gg in 2010 (Muñoz and Vazquez, 2012).

Methane emissions from the water system are complicated to calculate because about 12% of the total energy consumed in California is associated with the use of water. About 19% of the electricity consumed in California is used to transport clean, and disposed water. In this section, we do not discuss the GHG embedded emissions associated with the use of energy in the water sector and, as done for the section above covering Mexico, we discuss here GHG emissions from waste water treatment plants.

Methane emissions from wastewater treatment plants are reported to have gone from 2.47 in 2000 to 2.41 million teragrams of CO_2 equivalent in 2013 (ARB, 2015). This very modest decline should have the result of programs designed to reduce methane emissions using multiple options such as the use of digesters to produce methane and to use the methane to generated electricity and/or process heat.

Factors influencing future water and energy demand and supply

Biophysical Aspects

I. Climate

Baja California is highly vulnerable to climate changes; according to IPCC climate scenarios, the entire Northwestern region of Mexico will have a reduction of annual rainfall rate between 10% to 20%, while the mean temperature per year will increase between 1.5 and 2.5 °C in the next 50 years. This increment will change additional climate variables that together will impact augmenting the hydrologic cycle and possible phenomena such as El Niño, La Niña and tropical rains (Knutson and Tuleya, 2004). The El Niño effect on Baja California will result in winter flooding, meanwhile in summer la Niña could cause drought, heat waves (Meehl and Tebaldi, 2003) and fires (Westerling *et al*., 2006). The increment of climate phenomena variability has already caused disasters such as flooding, mudslides and economic losses in coastal areas, canyons and lowlands during 1993 and 1997-1998 El Niño events in California and Baja California (Cavazos and Rivas, 2004).

Studies have been developed to assess climate change impacts in Baja California; results have indicated that impacts could highly affect human and natural systems alike. It has been reported that power plants at the Baja California Coast are very vulnerable to climate change impacts (Sanchez and Martinez, 2004). It has been also recognized that the water infrastructure in Baja California is rapidly reaching its capacity limit, this together with population growth and a decrease of the Colorado River flows, could compromise water supplies to the region in a near future; and may force the restructuring of water assignments from agricultural activities to urban uses (PEACCBC, 2012).

California has experienced an increase in temperature of above 1°C since 1895[5] and the statewide average annual temperature is expected to increase from 1°C to 3°C by 2050. These temperatures are estimated to increase by 2 °C to 5 °C by the end of this century depending on the global emissions path that will materialize in the rest of this century (Franco *et al*., 2011). Precipitation has not changed much in the last 150 years but the warming fingerprint is present

5 See: www.wrcc.dri.edu/monitor/cal-mon/frames_version.html

in multiple factors such as the tendency for the snowpack in the Sierra Nevada to melt earlier than before and more and more of the precipitation falling as rain instead of snow in the Sierra Nevada. Additionally, higher temperatures have meant that effects of drought are exacerbated through the mechanism of evapotranspiration (Diffenbaugh *et al*., 2015). The use of multiple statistical and dynamic regional climate models applied to California using as a starting point AR4 (the *Fourth Assessment Report*), suggest a higher probability of more precipitation in the northern part of the state and the opposite for the southern part (Pierce *et al*., 2013).

There are multiple studies covering California concluding that the impacts of climate change can be severe (e.g., Moser, Enkstrom, and Franco, 2012) and differentiated by regions and sectors. However, efforts to adapt and to reduce the vulnerability to a changing climate can substantially reduce the economic costs to human-made systems such as the electricity and water sectors (Franco *et al*., 2011). The same cannot be said about natural ecosystems that will suffer the combined effect of an increased demand for services from an increased human population and a changing climate.

II. Water availability

Water availability for 2020 in Baja California will be lower than 1,000 m^3/inhabitant/year (a figure close to water scarcity); in addition, the Colorado River runoffs are likely to decrease in 20% by 2050 (Milly *et al.,* 2008). This scenario complicates further when considering the degree of variability in rainfall and temperature, placing Baja California in a critical situation in relation to pressure on water resources going from the current strong to severe, particularly in drylands where water stress will increase by 30%.

The snowpack in the Sierra Nevada is the dominant surface natural water reservoir in California supplying on average over 60% of the fresh water consumed in the state. Increased temperatures and the possibility of dry manifestations of climate change in this region are expected to result in drastic reductions of the snowpack that would be available at the end of the winter. Some researchers have reported reductions of up to 80% of April 1st snowpack levels by the end of this century. What would be the net effect on water supply in California? This is unknown at this time because it depends on multiple factors including supply management, for example how the large water reservoirs in California are managed and the potential use of groundwater aquifers in the Central Valley (Langridge *et al.*, 2012), as well as changes in demand. Large water reservoirs are currently managed using old flood management rules that dictate the maximum amount of water that can be stored during winter flood months. These "rule curves" were formulated with only a small set of historical data, and have not been updated in decades (Willis *et al.*, 2011). It has been shown that the use of probabilistic hydrologic forecasts and a modern computer-aided holistic management system could substantially improve the availability of water for consumption and for environmental purposes and increase hydropower generation under current and potential hydrological conditions. However, legal and institutional barriers have, so far, hampered its implementation for large reservoirs. Underground aquifers have about ten times the storage capacity of human made surface reservoirs, have the added benefit of not losing water to evaporation, and could be recharged in wet years or in the winter time and provide water in dry or in the dry periods of the year. A recent law requiring the sustainable management of groundwater may facilitate the implementation of this option (Sugg *et al.,* 2016).

III. Energy availability including renewables

The current fuel mix for electricity generation in Baja California is shared by 79% of fossil (of which 77% are provided by natural gas) and 21% of renewable sources [geothermal (20%), solar and wind]. Renewable penetration in the State started in late 2009, with the opening of the 10 MW wind farm "La Rumorosa", this facility is owned by the Mexicali municipality and provides power for public service. By June 2015, the 155 MW wind farm "Energía Sierra Juarez", increased the renewables installed capacity in Baja California; although the electricity generated is solely and exclusively destined for exportation to California.

The electricity system in California is changing very rapidly as explained before. Electricity generation from renewables is increasing at a very fast rate as shown in figure 5. In addition, because the California market is so big, this is affecting the mix of generation outside California with the purpose of serving the lucrative energy market in California. Planning is also on-going for transmission lines that could tap into large sources of wind energy in the Midwest and other parts in the WECC region with large sources of potential for renewable sources of energy.

IV. Air quality

California and Baja California share airsheds, and the San Diego-Tijuana metropolitan area, alone, accounts for nearly 40% of the overall population of the border region, with over 4.5 million people. Air quality monitoring in the shared region though is not coordinated. This has posed difficulties in forecasting air quality. Thus, as an indicator of the border region, air quality forecasts to the year 2020 were based on the California Almanac of Emissions and Air Quality (Cox *et al*., 2009). According to this, PM10 and PM2.5 emissions are forecasted to increase between 2010 and 2020. Furthermore, the increase for PM10 will amount to nearly 85% and PM2.5 will increase 67% over the ten-year period. The main particulate source, however, continues to be area sources. In forecasting ozone, this is expected to decrease as a consequence of the reduction of its principal precursors, NOx and VOCs by 2020. However, one must keep in mind that ozone can also be transported over long distances and, thus, bi-national airsheds could be quite relevant (as well, perhaps, as intercontinental transport from East Asia).

It is unknown so far, if air quality in Baja California will behave as in California; however, it seems that in the future, as currently, many residents of the U.S.-Mexican border region will be exposed to health-threatening levels of air pollution, especially ozone (O_3), particulate matter (PM), and carbon dioxide (CO2) (Muñoz *et al*., 2012-B); these atmospheric emissions are associated mostly to the Mexican energy sector.

Air quality in California and in Southern California, in particular, has substantially improved with time since the 1950s. However, Southern California and the San Joaquin Valley (the southern portion of the Central Valley) are out-of-compliance with federal air quality standards for ozone and particulate matter (PM). Electricity generation contributes less than 1% of the NOx budget in California. This together with the realization that a deep reduction of GHG emissions would require the electrification of as many energy services as possible (CARB, 2012), suggest that electrification can also be used to drastically reduce NOx emissions.

Population growth and economic development

Population projections for Baja California indicate that the 3,252,690 inhabitants in 2010 will increase to 5,425,676 inhabitants in 2035, this growth rate for the next 15 years will oscillate around 2% and from then to 2050 will fall to 1.35% (CONAPO, 2010).

According to the Energy Secretary (SENER, 2010) the electricity consumption for Baja California will increase at a median growth rate of 3.7 per year going from 12,280 GW in 2010 to 21,649 GW in 2025. Power demand is expected to be higher in the Valley Region (Mexicali). In contrast, the demand of water is expected to be higher at Coastal Baja California (Tecate, Tijuana, Rosarito and Ensenada) because this region has 77.3% of the total population statewide and it is likely to continue. The current water supply in coastal cities depends 54.4% on the Colorado River–Tijuana aqueduct; and 45.6% on regional aquifers, that are currently overexploited or at equilibrium. For Tijuana, in particular, the Colorado River aqueduct provides 87.3 % of its water supply; the remaining 12.7 % comes from local aquifers.

Population growth with increasing energy demands in a water scarce area could increase the vulnerability of Coastal Baja California. However, the region is likely to continue attracting people as it is considered a land of opportunities. The perceived prosperity in the Mexican border region was based largely on industrial development, which increased even more with the implementation of the North American Free Trade Agreement (NAFTA) beginning in 1994. In Mexico, the border region has had the lowest unemployment rate and the highest salaries. Economic growth clearly has generated jobs, but such growth has not been accompanied by a corresponding increase in infrastructure (such as water-related facilities and roads) and pollution control.

The California Department of Finance projects that the population of California will grow from 38.8 million to 49.7 million by 2050 (Schwarm *et al*., 2014). In the Southern California counties of Los Angeles and San Diego, the state population projections envisage an increase of 15.4% by 2050 from the current level of 13.4 million inhabitants (Schwarm *et al.*, 2014).

Electricity consumption in California was 227.575 GWh in 1990 which increased by 22% in 2013 and it is expected to increase 40% from the 1990 level of consumption in 2025 (Kavalec, 2015). This rapid rate of consumption is driven mostly by population growth and the expanded growth of economic activity. Water demand for the agricultural sector and for urban use have stabilized since the 1980s and the 1990s, respectively. The demand for agriculture could decrease by 2.0 to 5.9 MAF/yr by 2050 while urban demand could increase by 1.0 to 6.7 MAF/yr (DWR, 2013). The net effect would be a relatively small change in overall fresh water demand in California.

Energy and water policy options

As observed in this document, water and energy policies have developed very much in isolation one from another, even for regions that share water and energy resources such as California/Baja California; furthermore, this region also shares climate vulnerability although this is differentiated. Thus, water policy and energy policy should be amended to incorporate integral, feasible solutions in the short, medium and long term. Prior to looking for critical points of harmonization, however, there are longstanding problems that must be attended to, in particular in Baja California; this Mexican State urgently needs to improve conservation and efficiency in both energy and water sectors; other reasonable solutions include widening the portfolio of alternatives for both water and energy supply –including renewables.

In Baja California, with its water infrastructure working at limit capacity, water supply can be increased without the need of further sources in the short term if water losses in irrigation are controlled; as detailed above, agricultural activities in the Mexicali Valley produce water losses due to obsolete practices, such as flooding irrigation. The water saving could be of the order of 11,258 liters/sec, equivalent to 355 million cubic meters per year; such an amount could be distributed to coastal cities, that also have to attend to their leaks in distribution pipelines –of the order of 20%. In the medium and long term, the portfolio of water alternatives should increase and consider reuse of grey waters and compel coastal cities to reach the percentage of use of treated waste water that Mexicali has already achieved. Desalination has been considered for a long time as a solution to provide clean and reliable water; however potential environmental aspects must be taken into account, in particular two: GHG emissions –as long as renewable sources of energy are not used– and brine disposal (Nava, 2009); an especially sensitive issue, when some desalination plants are programed to be installed near tourist coastal towns such as Ensenada and Rosarito. It has been speculated that desalination in Mexico could provide water for a bi-national market (http://otaywater.gov/about-otay/water-information/desalination/rosarito-desalination/). It must be added that there are no trade experiences of this kind in Mexico, and that currently there are no national regulations on desalination.

Concerning energy intensity, it is recommendable to design energy saving programs with specific, achievable and legal-binding targets for end-users; for example, given the energy consumption of the domestic, commercial and services and industrial sectors, it is possible to reduce energy demand in two phases: first a reduction of 15% in the short term and then a reduction of 30% in the medium term, by incrementing efficiency in water pumping, street lighting and maintenance.

Conclusions

Although in different countries, CA and BC share water resources under pressure, a situation that is likely to be exacerbated under climate change conditions. In addition, rapid development in the region includes activities that are energy and water intensive. Also, both countries share energy infrastructure and trade, although small at the moment; these could increase under the 2013 Mexican Energy Reform and Energy Transition Law; and the California Renewables Portfolio Standard (RPS). Moreover, despite being independently created, both countries have regulations on climate change: the *Global Warming Solutions Act*, or AB 32 for California (CARB 2012) and the

Climate Change Act for BC (PEACCBC, 2012).

The advances in energy efficiency and water supply diversification in California in recent years presents a model that Baja California would do well to study, and collaboration with U.S. agencies would also be of great benefit.

It should be acknowledged, however, that national and state law and regulations for each country stop at the fence. Given the history of sharing of water resources and energy at the border region, as well as the many examples of cooperation on these topics –particularly between California and Baja California– a binational collaborative initiative addressing the link between water and energy should be something to contemplate developing.

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Chapter 7

Transforming urban water infrastructure for a changing climate context in Los Angeles and Mexico City.

Gian Carlo Delgado-Ramos
Hilda Blanco

Introduction

Cities are greatly dependent on neighboring basins, either for fresh water provision or wastewater discharge. This modern socio-hydrological cycle (Linton and Budds, 2014)[1] is a well-established pattern among a wide set of urban settlements worldwide, a process for the most part not free of contradictions and controversy.

At the beginning, urban water infrastructure expansion was focused on channeling water flows, mainly for sanitary reasons. With the expansion of the built environment and growing populations, particularly since the second half of the XX Century, such an approach has resulted in local water sources loss and depletion and consequently water provision has become even more important and energy intensive, as sources are located further or deeper and water pollution builds up (increasing treatment requirements). In addition, socio-ecological costs and conflicts associated with current dominant

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1 Following Linton and Budds (2014), the hydrosocial cycle deliberately focuses on water's social and political nature, meaning a socio-natural process by which water and society make and remake each other over space and time. In other words, "…it attends to the social nature of water flows as well as the agential role played by water, while highlighting the dialectical and relational processes through which water and society interrelate" (Ibid: 170).

management practices and consumption patterns have intensified, just as the financial costs of building and maintaining ever more extensive infrastructures for water provision, purification, discharge and treatment have grown. The increasing costs of water supply and sanitation, as well as the depletion and uneven appropriation of water sources, already leave hundreds of millions of people across the world with inadequate water supply and billions without adequate sanitation. This situation, not free of social challenges and conflicts[2], prompted the United Nations General Assembly to pass Resolution 64/292 in 2010 which "explicitly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the achievement of all human rights."[3] In 2015, the UN passed a resolution adopting 17 Sustainable Goals; the 6th goal focuses on attaining universal access to drinking water and sanitation (UNDP 2017). In this context of human needs, rights, and global commitment, local and regional effects of climate change on the water cycle and hydro-meteorological extreme events promise to make the so-called urban water governance even more challenging and complex.

Climate change can decrease urban water availability and change demand by increasing water stress conditions, flooding risk vulnerability, or both, as occurred in 2017 in California when after a severe drought, a flooding threat followed (Oroville's dam breach (Vartabedian, 2017)). Yet, water and sanitation infrastructure constraints and challenges currently respond to a

2 From 1950 to the present, 313 water conflicts have taken place worldwide, of which 71% happened during the XXI Century (culled from the data base of the Pacific Institute: www2.worldwater.org/conflict/list/).

3 The resolution noted that approximately 884 million people lacked access to safe drinking water, and that more than 2.6 billion did not have access to basic sanitation at that time. See: www.un.org/es/comun/docs/?symbol=A/RES/64/292&lang=E

combination of other factors, including aging and insufficient maintenance and, above all, land use practices and patterns within and beyond the urban hinterland. Addressing urban water security in a climate change context, therefore, requires considering local hydro-climate variables and the existing interactions within coupled human-water systems (Jaramillo and Nazemi, 2017), which encompass concrete biophysical and socioeconomic changing features, technological and technical existing capacities, sociocultural practices, and the capability of institutions and stakeholders through which water is governed, an issue which, in turn, involves not only multi-layered decision making structures and existing power relationships, but also local capacity building, social involvement and participation, and long-term financing and planning. All those components, among other features, shape urban water governance.

Urban water governance: a brief framework

The UN Water Conference of 1977 in Mar del Plata recognized the limitations of conventional water infrastructure management, and the need for fundamental integration necessary to confront the increasing complexity that characterizes the sector, particularly in today's context of growing population and ecological erosion. Following, in 1992, the economic and ecological values of water were recognized at the International Conference on Water and the Environment in Dublin, and the Earth Summit in Rio, respectively. After that, the Millennium Summit (New York, 2000) called for recognizing the social value of water, which resulted in the acknowledgment of the human right to water in the context of the 2002 International Covenant on Economic, Social and Cultural Rights. Entities such as United Nations and the Global Water Partnership (GWP) have pointed out the need to improve 'water governance' and policy integration. In this respect, Rogers and Hall (2003: 7), of the GWP, define water governance as follows: "…the range of political, social, economic and administrative systems in place to develop and manage water resources, and deliver water services, at different societal levels".

From academia, numerous reflections and critiques have been made regarding the concept of governance (Swyngedouw, 2005; Ioris, 2014), and thus of its translation to water governance (Schulz *et al.*, 2017), as well as other issues, such as the lack of coordination between efforts to integrate water governance and land use planning, which is a key issue as water unavoidably is a territorialized resource (Neto, 2016). This involves different paradigms of the production of space. As a result, the urban factor gains center stage since, today, the production of space, independently of its paradigm, tends to occur from and for the urban.

It, therefore, seems appropriate to talk about an urban water governance that departs from an integral management, socio-spatially localized, that transcends the mere coordination and planning of stakeholders' actions (Neto, 2016). The idea is to manage water from a holistic approach that considers multiple and changing aspects and needs at diverse spatial and temporal scales. In that context, an anthropocentric perspective not only is undesirable but unfeasible in the face of an increasing transgression of planetary boundaries (Steffen *et al.*, 2015). The multiple functions of water are to be recognized; on the one hand, indeed, the vital and human health functions, as well as those for food and energy production, and on the other, its ecosystemic functions, meaning the recognition of water that supports habitats and water as a carrier of nutrients and therefore as an agent for dissolving degraded matter (Neto, 2016).

As a reflexive notion, in practice, water governance departs from a diversity of values and takes shape in different ways (Schulz *et al.*, 2017): from those that have been termed in the literature as *normative,* or those approaches that do not entirely transcend the notions of free market economy and of a hierarchical interaction among the State, ‘experts’, and society; to those of *analytical* nature that, instead, seek to build capacities and better conditions for plural, deliberative and participative processes in relation to a common good.

In this chapter, we argue from an analytical standpoint; in other words, from the standpoint of a water governance that is socio-politically situated, but not ideologized; a governance that recognizes biophysical, technological, technical, ecological, legal, economic-administrative, and sociocultural aspects (including gender), as well as the power relations that shape the imaginaries of (un)desired future scenarios. Indeed, it is relevant to notice that power relations and interests "…reinforce existing system configurations; [the] political power across scales [e.g. institutional, spatial]; the agency of actors initiating transformations; and [the] participation and deliberation within transformation processes" (Olsson *et al.*, 2014, cited in Patterson *et al.*, 2016).

With that in mind, our understanding of governance is closer to that of Patterson *et al* (2016), who describe it as an intentional process of transformation, unavoidably political, "…that implies fundamental changes in structural, functional, relational and cognitive aspects to enable new patterns of interactions and outcomes" (Ibid: 2). Therefore, they add, governance "…refers to the structures, processes, rules and traditions that determine how people in societies make decisions and share power, exercise responsibility and ensure accountability" (Ibid: 3). Those transformation processes, indeed, imply an encounter, or clash, of different visions, languages of valuation, interests, and ways of perceiving processes, challenges and solutions. In that sense, consensus building becomes the basis of governance practice, despite that, in principle, it cannot maximize all factors in play. Any deviation towards fragmented, vertical, exclusive, antidemocratic or opaque scenarios, contributes to a 'weak' and even 'bad' (in a sense of undesirable) governance; the same is true when changing biophysical features –which have resulted in increasing ecological erosion and climate change (the focus of this work)– are excluded.

We consider that an assessment of specific case studies and comparative analyses contributes to shed light on how to move forward a climate-ready, efficient and inclusive urban water governance, with all its potential gaps, contradictions, synergies, solutions and co-benefits. To that end, this paper focuses on two similar but contrasting cases: Los Angeles and Mexico City.

As briefly described below, both cases experience similar challenges such as water scarcity in a climate change context and vulnerable and old infrastructure –yet each case involves different territorialities as well as management, sociocultural, political and financial realities and practices.

In the following section, we briefly contextualize both case studies to later present some of the main historical processes that led to the current water infrastructure deployment. We include current water inflows and outflows, using an urban water metabolic analysis approach. Later, we describe current and expected challenges in both case studies for achieving Sustainable Development Goal #6 which, as stated, seeks to "ensure availability and sustainable management of water and sanitation for all". We then draw attention to the condition of infrastructures as well as to climate change local and regional impacts and sustainability requirements and opportunities by focusing on key aspects of the urban water nexuses. We finally focus on financial needs and constraints, and conclude with some recommendations for improving urban water governance. The recommendations are an outcome of a literature review and cross-fertilization exercise based on our comparative analysis of the two case studies.

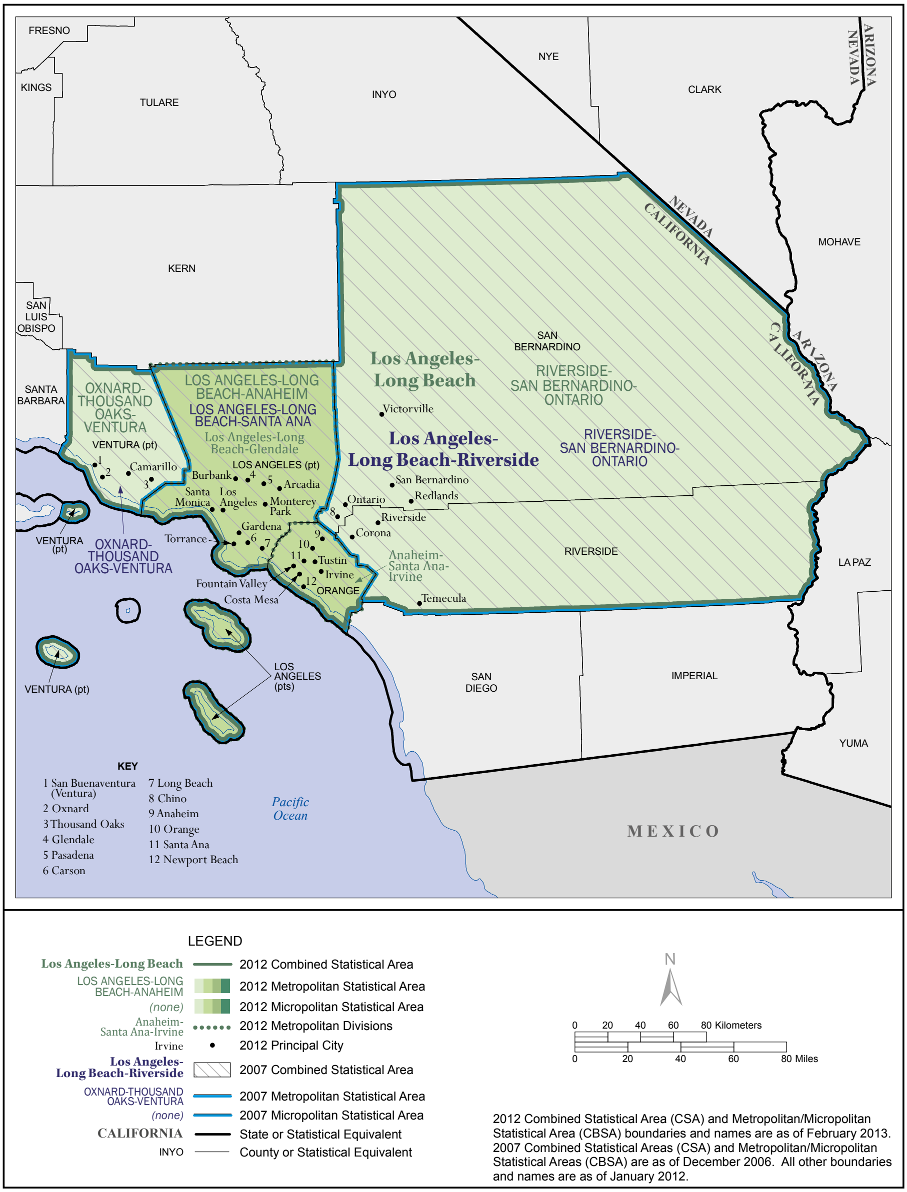
Contextualizing both case studies

General aspects

A. Los Angeles

With continuing urbanization, urban areas throughout the world have been exceeding their traditional municipal boundaries. The case of Los Angeles illustrates this phenomenon of metropolitanization and mega-city regions. Los Angeles can refer to the municipality, to Los Angeles County in which the municipality is located, to the Los Angeles-Long Beach-Anaheim, CA Metropolitan Statistical Area (MSA) recognized by the U.S. Census, which includes Los Angeles and Orange Counties and finally to the Greater Los Angeles area, which includes all of Los Angeles County, Ventura County, Orange County and the two counties of the Inland Empire, making up the Los Angeles-Long Beach, CA Combined Statistical Area. The Greater Los Angeles combined metropolitan area is the largest urban settlement in California with about 18.7 million inhabitants as of 2016 (US Census 2017) and more than 4.5 million housing units. The statistical area of Los Angeles-Long Beach-Anaheim stretches along 12,562 km^2 and the Greater Los Angeles Area up to 87,945 km^2. See figure 1.

Figure 1. Los Angeles-Long Beach, CA Combined Statistical Area



Source: US Department of Commerce, 2012.
https://www2.census.gov/geo/maps/econ/ec2012/csa/EC2012_330M200US348M.pdf

The Los Angeles metropolitan area economy is dominated by services and industry, including port related services in Los Angeles and Long Beach. It has the largest container port in the US and the ninth largest container port complex in the world. The metro area's GDP reached 930.8 billion dollars in 2015, ranking second place among all metropolitan areas in the US (with the New York-Newark-Jersey City metropolitan area ranking first). Projections for Los Angeles and Orange counties suggest that population will grow from 13.3 million inhabitants in 2015 to 14.97 inhabitants by 2040; total personal income will increase from 375 billion to more than a trillion; households will increase to 4.8 million units; and the vehicle fleet from 10.5 million to 12.5 million during this period (Caltrans, 2015). As of January 2017, the City of Los Angeles, the largest municipality in California, had a population of 4,041,707 inhabitants (San Diego is the next largest city in California with a population of 1.4 million) (California Dept. of Finance, 2017).

In 2015, 15% of the metropolitan inhabitants lived below the poverty level of 24,250 dollars of yearly income, but the figure goes up to 25.6% –the highest poverty rate in California– when the California Poverty Measure is considered; Latinos and African Americans, as well as the less educated had the higher poverty rates (www.ppic.org/main/publication_show.asp?i=261).

Los Angeles' sustainability is affected by thermal inversion that the city suffers most of the year due to the surrounding mountains in the north and east and the cool marine air, a phenomenon that contributes to the trapping of air pollutants and represents a challenge for attaining good air quality. In addition, the low-lying areas of Los Angeles are subject to flooding due to hydro-meteorological extreme events. The flood of 1938 is an example of this type of vulnerability which climate change will likely intensify in the future.

B. Mexico City

Mexico City's metropolitan area is the largest urban settlement in Mexico and among the top ten worldwide in terms of population. Its expansion has been very dynamic, starting in the 1950s in the central city, and progressively moving towards the periphery. Mexico City has grown, from a population of 3 million inhabitants and an urban land cover of 229.89 km^2 in 1950, to 8.8 million inhabitants and 612.06 km^2 in 2010 (Delgado, De Luca, Vazquez, 2015). The metropolitan area (including Mexico City's sixteen municipalities as well as 59 municipalities of the State of Mexico and 21 of the State of Hidalgo) accounted for 21 million inhabitants and 1,460.32 km^2 of urbanized land in 2010 (SEDESOL, 2012). The complexity of this settlement is due not only to its size –density and extension of the built environment– but also to the fact that it covers three states in central Mexico, so its actual management, planning and assessment pose great political and coordination challenges.

Mexico City's metropolitan area concentrates 17% of the national population, produces 27.2% of national GDP, and generates 18% of total employment. Mexico City accounts for 7%, 16.5% and 8% respectively. By 2030, the metropolitan population may grow 13% while its contribution to the national GDP may be similar, between 25% and 27%. Nowadays there are 5.7 million housing units and about 5.3 million vehicles (a third with an average age of 21 years); the latter figure may double by 2030.

Despite being the most relevant economic hub in Mexico, almost 34.7% of Mexico City's population is poor and 4.8% extremely poor, mostly located in the periphery; 23.4% of its population lacks access to health services; 52.5% of the population lacks social security; and 13% of the population have insufficient access to food (CONEVAL, 2012).

Mexico City's sustainability is constrained by its biophysical features: the city is in a valley surrounded by mountains, which restrains the evacuation of polluting particles and causes challenges to local air quality. In addition, the valley is part of an endorheic basin, which does not flow to the sea and is prone to flooding.

Water in-flows and out-flows

A. Los Angeles

This section profiles the complex water management and resource characteristics important to understand the urban water metabolism of the City of Los Angeles in the broader context of Southern California.

Southern California is dependent on several sources of water: its own groundwater and surface water sources, and external sources which are captured through dams, stored in reservoirs, and transported through aqueducts over hundreds of kilometers. Surface water, primarily imported, provides about 70% of water demand; but during drought years this amount can drop to about 40%. Particularly, the City of Los Angeles imports huge volumes of water (see below). On average, over the 2010-2015 period, about 12% of total water supplies came from groundwater sources. The City has important groundwater sources, but contamination of these sources has made it difficult to fully use them. To change this situation, the City of Los Angeles is currently investing in extensive groundwater treatment facilities to increase this source of water supply.

The Metropolitan Water District of Southern California (MWD) plays a unique role in water supply and management in Southern California. It was established in 1928 by vote in 13 California cities, with the mandate to develop, store and distribute water to residents of Southern California. It currently includes 26 member agencies (14 cities, 11 municipal water districts, and 1 county water authority) in portions of Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura counties, serving 85% of the population of these counties.

The Colorado River Aqueduct (CRA) was the first MWD project. This aqueduct conveys water from the Colorado River, and began delivering this water to its member cities in 1941. To meet the growing demands in Southern California, in 1960, MWD contracted with the State of California to obtain new supplies from the State Water Project (SWP) via the California Aqueduct, which was owned and operated by the California State Department of Water Resources. Deliveries of imported water from Northern California began in 1972. Thus, MWD has two major sources of imported water, Colorado River water through the CRA, and the SWP water from Northern California via the California Aqueduct.

From 2006-2015, MWD provided between 50-60% of municipal, industrial and agricultural water used in its service area (MWDSC, 2016). The rest of the water supply in its service area came from groundwater, local surface water and recycling, and the City of Los Angeles' aqueducts from Owens Valley/Mono Basin east of the Sierra Nevada and several other sources. In total, Los Angeles metropolitan area consumes about 634 thousand acre-feet yearly (or 782 million m^3/yearly).

Of the 26 water agencies that make up the Metropolitan Water District, 14 cities and one municipal water district are water retailers that buy directly from MWD and sell it to households and businesses; 12 Municipal Water Districts – typically special districts focused on water supply– and one County Authority are wholesalers that buy from MWD and sell to retailers. Retailers own water pipe networks for distribution, water rights over groundwater, wells, pumps, meters, et cetera. In the MWD service area, there are a total of 215 retailers: 85 cities, such as the City of Los Angeles; 57 special districts, such as Cucamonga Valley Special District, 33 divisions of investor owned utilities (IOUs), 32 mutual companies, and 4 other institutions such as Camp Pendleton Marine Base.

General aspects of the Water Supply System in the City of Los Angeles

Given the complexity of water resources management in Southern California, for the purposes of this analysis, we will focus on the City of Los Angeles (about 4 million inhabitants within a land surface of 1,214 km^2), which will be compared with the case of Mexico City.

The water supply for the City of Los Angeles is managed by a city department, the Los Angeles Department of Water and Power, which was established in 1925. It is the largest municipal utility in the nation, with over 675,000 active connections.

There are four sources of water supply for the City (see figure 2):

Figure 2. Major Sources of Water Supply for the City of Los Angeles

Source: LADWP (2016), p. ES-3

- Los Angeles Aqueduct. This aqueduct was constructed by the City of Los Angeles in 1913. It conveys water from the Owens Valley and the Mono Basin areas in the eastern Sierra Nevada to Los Angeles. In 1970, a second Los Angeles Aqueduct was constructed with 75% more capacity than the first. The aqueduct supplied much of the city's water demand until the mid-1980s. Following a long litigation with the local communities of Owens Valley, the city agreed to a number of environmental mitigation projects that have reduced the availability of water that can be transferred to Los Angeles. Consequently, in the past 5 years, the City's reliance on this source of water supply has dropped significantly.
- Imported water from MWD. The city also purchases water from the Metropolitan Water District (MWD), which imports water from the Colorado River, and from the San Joaquin and the Sacramento River Delta to Southern California.
- Groundwater sources. The City has water rights over several groundwater basins in the City, the San Fernando, Sylmar, and Central and West Coast basins. These basins combined could produce up to 110,000 acre-feet/year of groundwater (more than 135.6 million m^3 yearly). But contamination of these basins, as well as rates of depletion, have restricted the City's use of this resource.
- Recycling. Several wastewater treatment plants in the City recycle water, which is primarily used to irrigate parks, golf courses, and other city grounds.

The latest data available on the City's annual water consumption by source is for the 2010-2015 period (see Table 1). This five-year period included the worst drought recorded in California's history, making the annual totals lower than historical averages.

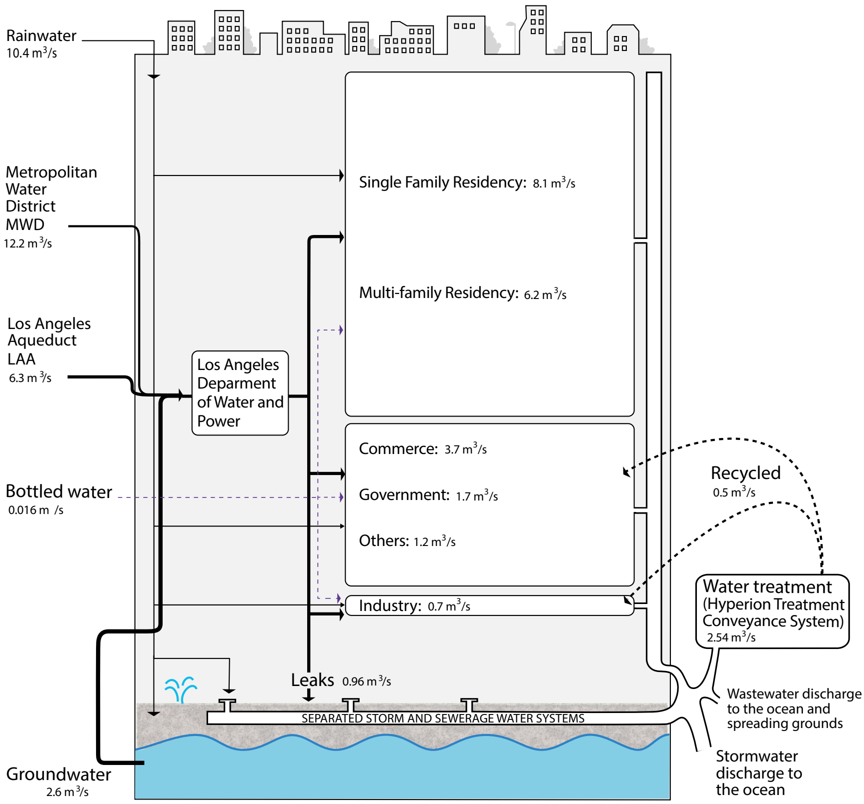
Table 1. LADWP Average Water Supply (2010/2011-2014/2015) by Source		
Source	*Acre-Feet-Year*[4]	*Percent*
MWD	313,574	57%
LAA	159,538	29%
Groundwater	66,016	12%
Recycled water	11,002	2%
Total	550,130	100%
		Source: LADWP, 2016: ES-21.

In March 2013, the city of Los Angeles reported a per capita water use of 77G/C/D (or 291.5 liters/c/d). This amount dropped to 63 gallons per capita per day (or 238.5 liters/c/d) by March 2016, about a year after Governor Brown called for a 25% mandatory reduction in urban water use during the historic drought (the mandatory reduction mandate went into effect on April 1, 2015) (CA State Water Resources Control Board, 2016).

The residential sector is the largest user of water in the City, followed by the commercial sector (see figure 3). Note that non-revenue use of water, which includes unbilled authorized consumption, such as for firefighting, and water losses are at a low level (5.6%), compared to other cities.

4 One acre-foot equals 1,233.48 m^3. Average water supply in million m^3 per year, was: 386.7; 196.7; 81.4; and 13.5, respectively.

Figure 3. Water inflows and outflows of the City of Los Angeles



Source: Authors own elaboration. **Graphic Design:** Angeles Alegre Schettino.

Outdoor water use is very significant in the city, especially in the residential sector; it accounted for 46% of the single family residential sector, and 32% of the multi-family sector during 2011-2014. Overall, outdoor water use amounted to 39% of the City's water use during this period.

Water leakages are reported to be of about 4% of the total water supply, an amount considered by experts quite low when compared to the best international rates of 10%. However, even such a rate of water leakage is calculated to lose about 8 billion gallons a year (30.2 million m^3) for the City of Los Angeles, enough to supply 50 thousand households a year (Poston, 2015).[5] In relation to wastewater, the City relies on the Hyperion Treatment Conveyance System which has a capacity to treat up to 580 million gallon/day (mgd) or almost 2.2 million m^3/day. It consists of 4 plants, the Hyperion Treatment Plant, which provides secondary treatment with a capacity of 450 mgd (1.7 million m^3/day), with 3 ocean outfalls, and which processes 363-420 mgd (1.37 – 1.59 million m^3/day); the Tillman Water Recycling Plant is a tertiary treatment plant with a capacity of 80 mgd (302,832 m^3/day); the LA-Glendale Water Reclamation plant provides tertiary treatment, with a capacity of 20-30 mgd (75,708 –113,562 m^3/day); and the Terminal Island Water Reclamation Plant, treats 15 mgd (56,781 m^3/day). The reclaimed water is used for irrigating parks, golf courses, for industrial purposes, as well as for groundwater replenishment.

The City has separate storm and sewage water systems. Storm water is untreated and flows into the ocean. Much of the precipitation that falls in the City is either carried out to the ocean through storm water pipes and the Los Angeles River and little of it replenishes the groundwater basins due to the extensive impervious surfaces in the city.

A recent article in the *LA Times* indicates that during a 2-week rainstorm in January 2017, about 77,000 acre-feet (94.9 million m^3) drained into the ocean from the LA River watershed. LADWP estimated that the City retained about ⅙ of this runoff (Boxall, 2017). To enhance percolation of storm water

5 The figure includes leakages as well as water used for firefighting, and lost to evaporation, theft and other unaccounted losses (Poston, 2015).

into aquifers, spreading grounds (areas above or connected to aquifers that are prepared and monitored to enhance percolation) are often needed. The City's Tujunga Spreading Grounds is a 60.7 hectares site which catches an average of 6,600 acre feet per year (8.1 million m^3/year). By 2018, the City's improvements to the spreading grounds will double this capacity.

B. Mexico City

The Mexico City metropolitan area, as in the case of the Greater Los Angeles (and in fact as in all Southern California), is highly dependent on other basins for its water provision as well as wastewater discharge. The *hydropolitan region* (Perlo and Gonzalez, 2009) of the metropolitan area interconnects four basins that are not otherwise linked: The Valley of Mexico, Alto Lerma, Cutzamala and Tula basins. See figure 4. To achieve that, a massive infrastructure has been built, first, to drain the lake that was in The Valley of Mexico and on top of which the pre-Columbian city was erected, and later by subsequent interventions, from the construction of the Huehuetoca Royal Channel (1607) and the Nochistongo Tajo (1789) to the first (1905) and second (1954) Tequixquiac tunnels, the deep drainage system (1975) and the recent Emisor Poniente deep Tunnel (2010).

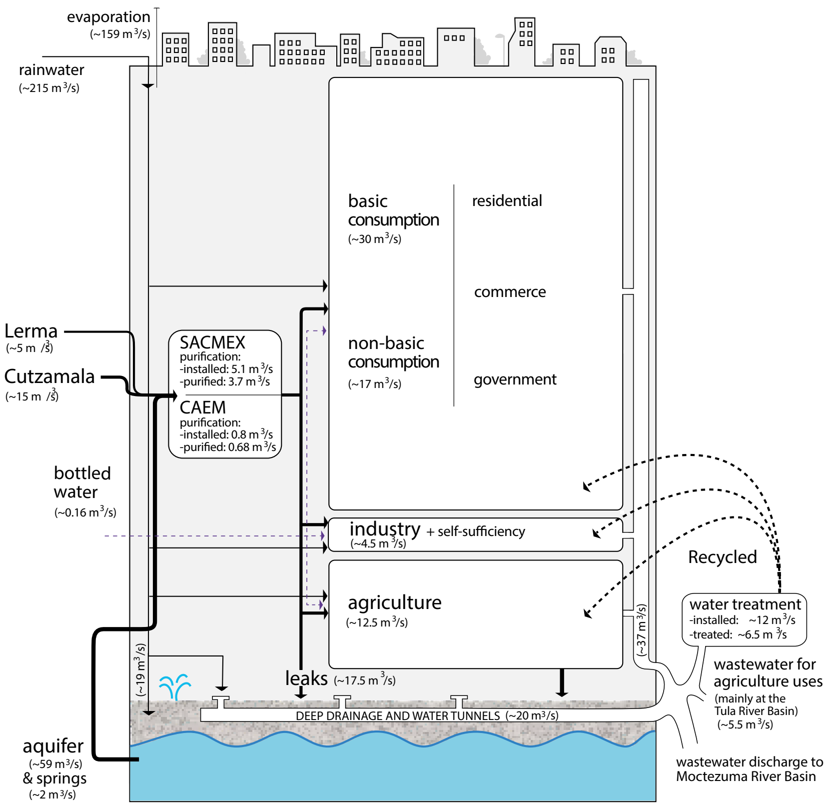
Figure 4. Interconnected water basins in the Metropolitan Area of Mexico City

Source: SACMEX, 2012. Adjusted (designed by Angeles Schettino)

Today, as figure 5 shows, more than 600 wells extract water from the Mexico Valley aquifer (not counting illegal wells), providing about 75% of all water inflows into the Metropolitan Area which are estimated at 81 m^3/s or 2,554.4

hm^3/year. The remaining water inflows are imported from the Lerma and Cutzamala basins (15 m^3/s and 5 m^3/s, respectively). The main source of water, the Mexico Valley aquifer, is overexploited already, causing a 1 meter drop per year in the static water level with a deficit of 28 m^3/s (Delgado, 2015). Due to questionable water quality, inhabitants of Mexico City import 2.07 hm^3/year of bottled water, which is used by 76.9% of the population that do not receive, or believe they do not receive water of sufficient quality.

Figure 5. Water inflows and outflows of the Mexico City Metropolitan Area.



Source: Delgado, 2015. **Graphic Design:** Angeles Alegre Schettino.

The frequency and quality of the service is uneven, as are water consumption patterns. Average consumption is 318 liters per capita/daily (Ibid). Yet, municipalities with the highest incomes have an average consumption of water of around 400 to 525 liters daily (e.g., Cuajimalpa municipality), while the lowest consumption is of 177 liters daily (e.g., Tlahuac municipality) (Ibid). Water outflows represent 57 m^3/s, most of which are not treated (Mexico City's installed capacity is of just 6.7 m^3/s and that of the metropolitan area is 5.1m^3/s) (Ibid). Most of the wastewater and storm water streams are channeled to the Tula Basin (Tula-Moctezuma-Panuco River) via the deep drainage system, the Grand Canal (which operates at only 30% of capacity due to subsidence of soil), and the currently under construction Emisor Oriente Deep Tunnel. Up to 60% of such outflows may be treated by the Atotonilco treatment plant once it is operative. With a treatment capacity of 35 m^3/s, it is expected to be fully operative in the second half of 2018 when the construction of the Emisor Oriente Deep Tunnel is expected to be concluded. Most of the year the treatment plant will receive 23 m^3/s, except during the rainy season when it will receive an expected additional flow of 12 m^3/s.

Current and expected climate and infrastructural related challenges for attaining Sustainable Development Goal #6

Climate projections and infrastructure conditions for the US and California

According to the 2014 U.S. National Climate Assessment (Melillo, Richmond, and Yohe, eds., 2014), average annual rainfall is projected to increase across the northern part of the country, and to decrease in the Southern part, especially in the Southwest. Very heavy precipitation events, and the number and magnitude of heaviest precipitation are projected to increase throughout the country. Increased risk of flooding is projected for many regions, even in areas where the total precipitation is expected to decline. Short-term droughts are also projected to increase in most regions. Long-term droughts could intensify in the Southwest and the Southern Great Plains and the Southeast. In California, by 2070-2099, annual mean temperatures are projected to increase throughout the State by 5.8˚F (3.2˚C) compared with 1990 annual mean temperatures (Cal-Adapt 2017).

Focusing on water resources, the national assessment (Georgakakos, in: Melillo, Richmond, and Yohe, eds., 2014) makes clear that in several major regions of the country, where rainfall is projected to decline, but where flooding will intensify, water resources, both surface and groundwater, will diminish, and flooding will pose an increased hazard to water and other urban infrastructure. Increasing air and water temperatures, more intense precipitation and runoff, and intensifying droughts may as well decrease river and lake water quality (e.g. increases in sediment, nitrogen and other pollutants) (Ibid).

At the state level, California is already experiencing higher temperatures, the rising of sea levels and a decrease of the Sierra snowpack (between 32% to 79%), which in turn directly reduces natural water storage, alters winter spring runoff patterns, and threatens coastal water supply infrastructure. As a result, droughts and wet weather will be more extreme, which, in turn, will have profound effects on biodiversity and human settlements (in terms of water availability and wildfires during the hot season and, on flooding during the rainy season). In fact, over 7 million inhabitants and 580 billion in assets are exposed to flood hazards (Government of the State of California, 2016).

Climate change will consequently affect Los Angeles and its metropolitan area. Temperature may rise 4°F to 5°F (2.2°C – 2.8°C) by mid-century and consequently, heat waves and their related health threats may increase by 2 to 6 times (resulting in dehydration, exhaustion, aggravation of existing medical conditions, etcetera) (Smith and Gallon, 2015). Mountains in the Los Angeles area could lose at a minimum 31% of snowfall and the duration of snowpack will shorten, ending 16 days earlier than usual on average (Ibid). This is of special concern as snowpack is an essential source of fresh water to the region where water stress is already substantial and disputes for water are frequent among regions and users (as described earlier, Los Angeles gets a considerable amount of water from the north of the State). Groundwater extractions may increase during drought periods, a measure which directly relates to higher energy consumption levels and thus of greenhouse gases (GHG) emissions.

Risk of flood and wildfires, as well as sea level rise (of 7 to 19 inches by 2050 and up to 55 inches by the end of the century) are also among the expected impacts from climate change that threaten Los Angeles. Heavy rains may overload the capacity of sewer systems and treatment plants. Sea level rise may increase the salinity of coastal aquifers, and pose a potential threat to coastal treatment facilities.

Thus, it is not a minor issue that currently water infrastructure in the US is in poor condition and underfunded. The American Society of Civil Engineers (ASCE) has been assessing the condition of the nation's infrastructure and providing a report card since 1998. It evaluates infrastructure conditions according to 8 criteria: capacity, condition, funding, future need, operation and maintenance, public safety, resilience, and innovation. Its latest report card (2017) gives the overall grade of D^+ (poor, at risk) to the nation's infrastructure, and identifies \$4.59 trillion dollars needed for investment between 2016 and 2025 to bring these infrastructure systems into good condition (ASCE, 2017). Failing to close such an investment gap may imply \$3.9 trillion dollars in losses to national GDP; 7 trillion dollars in lost business sales and 2.5 million lost jobs by 2025 (Ibid).

The assessment of water-related infrastructure is even more negative, with dams, inland waterways and levees, and drinking water infrastructure receiving D's; and wastewater infrastructure D+.

The average age of the more than 90 thousand dams in the U.S. is 56 years; in 2016 about 15,500 dams were considered high-hazard potential dams while 2,170 were deficient high-hazard potential dams. A similar age is estimated for inland waterways infrastructure, and about 75-100 years-lifespan of the one million miles (or 1.6 million km) of pipes that cover the country. Notice that in this context, 240,000 annual water main breaks waste about 2 trillion gallons (7.5 billion m^3) of drinkable water, according to the ASCE report (Ibid). The challenge of replacing these systems is huge as the average pipe replacement rate is 0.5% yearly, which means that 200 years would be needed to entirely replace the system, a time that doubles the useful life of the pipes (Ibid). In addition to the replacement rate, infrastructure replacement should also incorporate ecological criteria, be efficient, well planned, climate ready and resilient. This applies to all water related infrastructure but particularly to drinking water and wastewater infrastructure, the latter of great importance to prevent the spill of untreated sewage in the context of hydro-meteorological extreme events. In addition to maintaining the 800 thousand miles (1.28 million km) of public sewers and the 500 thousand miles of private lateral sewers that connect private property to public sewers lines, there will be the new infrastructure demand from new users that are expected to connect to centralized systems in the following two decades: projected to be about 56 million additional users (Ibid).

From ASCE's perspective, water and wastewater infrastructure will demand an investment of 150 billion dollars by 2025, dams will require 45 billion, and levees 80 billion, but even such an investment will not mean that the systems will be fully updated. To do that, just the drinking water system would demand a total investment of at least 1 trillion dollars while the wastewater system will require an additional 271 billion dollars over the next 25 years (Ibid).

Projections of climate change impacts on water resources combined with the poor condition of water infrastructures and the financing needed to bring such infrastructure up to scratch makes clear the challenges that many urban areas in the US will increasingly face in ensuring a safe and adequate water supply for urban populations.

Climate projections and infrastructure conditions in Mexico

Like the projected impacts in the US, adverse effects of climate change in Mexico may impact 15% of its territory, 68% of the population and 71% of its GDP (DOF, 2013).

In addition to the rise in the average surface temperature of almost 2°C between 1901 and 2009, a further increase of 2°C to 4°C in the average surface temperature is expected by the end of the XXI Century (Delgado, De Luca and Vazquez, 2015). Accordingly, wet and hot seasons already are and will be affected. In the latest decades, average precipitation has slightly increased but its actual distribution has been geographically uneven. Therefore, even when some regional and global climate change models differ in their projections of the local climate change water-related effects, due to population growth and the expansion of the built environment, the country will still be under a water stress condition. In fact, droughts could potentially affect up to 70% of the national territory (Ibid). As part of that scenario, other issues are of concern as well, from the increase of hazards and disasters of hydro-meteorological origin, the rise of wildfires, and the propagation of infectious diseases, to the rising sea levels (Ibid).

As discussed above, among other issues, it is estimated that from a total of

2,457 municipalities, 824 jurisdictions with 61 million inhabitants are actually exposed to floods; 283 municipalities with 4 million inhabitants to landslides; 1,202 municipalities with 54 million inhabitants to agricultural droughts; 584 municipalities with 29 million inhabitants to a decrease in rainfall; 545 municipalities with 27 million inhabitants to a decline in food productivity associated to temperature changes; 1,020 municipalities with 43 million inhabitants to heat waves; and 475 municipalities with 15 million inhabitants to epidemics, particularly of tropical diseases (DOF, 2013).

It is important to highlight that, even though climate change policy design and implementation has been relatively dynamic at the Federal level, this has not been the case at the municipal or local level. In the case of the urban built environment, improvements are notoriously uneven. While no more than 10% of the cities with less than 500 thousand inhabitants had some type of climate change action plan elaborated by the beginning of 2015, 40% of cities with a population between 500 thousand and a million and 30% of cities with a population between 1 million and 5 million inhabitants had one (Delgado, De Luca and Vazquez, 2015). Mexico City, the only city in the country with more that 5 million inhabitants, is the pioneer in elaborating and implementing a climate change action plan. Yet, only 16% of the municipalities included in its metropolitan area had some type of specific climate change planning (Ibid). In fact, of the 33 major cities with a climate change action plan, only 10 of these included some specific adaptation action on water provision, 11 on river overflow control, 14 on sewer maintenance, 4 on water-energy efficiency, 14 on water leakage reduction, 16 on sewage treatment and sludge management and 13 on rainwater capture (Ibid).

Three major challenges can be identified: lack of infrastructure, aged infrastructure or infrastructure without proper maintenance. In fact, as an answer to that situation, the National Infrastructure Program 2014 – 2018, has committed 7.7 trillion pesos (or 416 billion dollars; 70 billion per year) for renovating and expanding national infrastructure, including water infrastructure (Gobierno Federal, 2014). The *Global Competitiveness Report 2015 – 2016* places the country in the 57th position with a score on infrastructure of 4.2 which places the country in the 59th position overall among 140 countries (it was in the 64th position on infrastructure in 2013). In contrast, the US rank 3rd with a score on infrastructure of 5.9 which places that country in the 11th position overall. Given the deficits in infrastructure maintenance in the US discussed above, the relatively high position of the country (11th/140) is a good indication of the precariousness of infrastructure conditions around the world.

In Mexico, water infrastructure in 2016 comprised five thousand dams and levees with a total storage capacity of 150 thousand hm^3, more than 3 thousand km of aqueducts with a total capacity of 112 m^3/s, 874 water treatment plants with a total capacity of 97.9 m^3/s, 2,477 municipal wastewater treatment plants that treat 120.9 m^3/s or 57% of total collected wastewater, and 2,832 industrial wastewater plants that treat 70.5 m^3/s (CONAGUA, 2016). Water availability was around four thousand m^3 per capita yearly; 4.5 times less than in 1950. Even though 92.5% of the national population has access to water and 91.4% to sanitation services, access and quality are unevenly distributed among urban and rural populations, and within urban populations as well (Ibid).

In response to this situation, which is largely linked to the current state and degree of infrastructure maintenance, but also to population growth and climate change, the investment needs have undoubtedly increased. Water infrastructure investments for 2014-2018 are projected to be 417.7 billion pesos: 292.2 billion for new infrastructure for water supply, sanitation and treatment; 94.1 billion for water related infrastructure in the agriculture sector (mostly irrigation); and 31.3 billion for flood prevention and management (Gobierno Federal, 2014). Nonetheless, most of the investment is being captured by a handful of mega-projects, mostly serving Mexico Valley, such as water and sanitation infrastructure for the new Mexico City airport, the Emisor Oriente deep tunnel and the Atotonilco treatment plant (which has increased its budgeted cost to 4 times its original estimate).[6] This situation reinforces the existing spatial asymmetries.

Thus, it is not accidental that Mexico City has the best infrastructure in the country, followed by Monterrey, Nuevo Leon. In the case of Mexico City, 98% of its population has access to water service and 94% to sewerage. The total population served within Mexico City (excluding its metropolitan area) comprise 8.8 million inhabitants and 4.2 million floating population. The challenges of renovation and expansion for water and wastewater services are striking. In a business-as-usual (BAU) scenario, by 2025 more than 55%

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6 Total investment in water infrastructure for 2014 and 2015 recorded 35.1 billion pesos yearly (CONAGUA, 2016); two-thirds was federal investment. In 2017, PROAGUA's budget for water supply infrastructure was authorized at 9 billion pesos (or about 486 million dollars) while, in 2016, the combined PROAGUA-PROTAR budget, the latest program related to wastewater treatment, was 12.45 billion pesos. Notice, most of the Federal water infrastructure investment has been captured by a handful of mega-projects such as the deployment of the new Mexico City airport water infrastructure that added up to a 6,350 million pesos budget in 2016 and 2017 (the airport won't be operative until the end of 2020, in the best of the cases). Another mega-project that has devoured a substantial part of the Federal water infrastructure budget in the last years is the Emisor Oriente deep tunnel in Mexico City with a current final cost of 40 billion dollars, four times the original estimated cost. The Atotonilco treatment plant and the third "tier" of the Cutzamala System are to be added as well with a cost of 9,564 million pesos and 5,209 million pesos, respectively. Besides other Federal investment water infrastructure projects currently under study, mostly intending to increase water availability in the Mexico Valley (Río de la Compañía Tunnel II; Macrocircuit; Western Aqueduct; Tula-Mezquital water wells; Tecolutla-Necaxa water wells; and the 4th extension of the Cutzamala System); other mega-projects are under construction at present, such as the El Zapotillo and El Purgatorio water dams, both in the state of Jalisco (see: www.gob.mx/cms/uploads/attachment/file/229161/Estrat_gicos_-_Junio_-_2017.pdf).

of the water is expected to be imported while the water quality of the local aquifer will decrease due to an even greater overexploitation. Climate change will only intensify and accelerate such challenges and their implications.

Mexico City's average annual temperature is 15°C, varying 8°C between summer and winter. Because of climate change, temperatures are expected to rise in the short term between 0.5°C and 1.5°C and up to 2.25°C in the long term (SEDEMA, 2014). Rainfall reductions may be between 5% and 10% in the rainiest months (June and July) and even more during December, the driest month of the year. Such reductions, along with population growth and the expansion of the built environment which reduces the aquifer recharge capacity[7], could intensify water service disruption that is already experienced in certain parts of the city and the metropolitan area. The official BAU forecast suggests that water supply may decrease. Currently a third of users –1.6 million inhabitants– receive water only some hours daily or some days of the week (the so-called '*tandeo*' scheme). By 2025, this percentage may increase to 55% while only 28% of users may have an acceptable service (SACMEX-UNAM, 2013).

In addition, water leakage is a great problem: already more than a third (35% to 40%) of total supply is lost along the system due to soil subsidence and obsolescence of infrastructure (the City's accumulated soil subsidence from 1930 to 2007 is estimated up to 9 meters in certain areas). Because of all these projections, the central city alone will require an investment of 4,500 million pesos within the next 60 years. Such investment will need to include the replacement of 3.1 thousand kilometers of water pipelines by 2020 (AGU,

7 It has been estimated that every m^2 of new urbanization reduces 205 liters of annual recharge; 200 ha of conservation areas (suelo de conservacion) are lost every year (SACMEX-UNAM, 2013).

2014).

Despite reductions in average precipitation volume, heavy rain is already a phenomenon that causes flooding in both disadvantaged and affluent communities; yet, in the last 30 years most of the 180 flooding events have affected disadvantaged communities. The number of inhabitants vulnerable to flooding and other meteorological extreme events has been estimated to be 5.6 million (SEDEMA, 2014). This means that most of Mexico City's population is vulnerable.

Financing water infrastructure in a new management context

For both case studies, the challenge to integrate water management and planning is formidable. In Mexico City, complexity relates to the diversity of political parties in charge of local and state governments, in addition to the multiplication of stakeholders involved because of the importation of water and due to a decentralization and privatization process promoted in the last decades. In Los Angeles, the high dependency of Southern California on imported water from the Northern part of the state also translates into the complexity of actors involved, including local and regional governments that manage and invest in water/wastewater infrastructure. In that sense, ensuring water security is a priority in both cases, a goal that may be eventually achieved only through multiple simultaneous measures, such as: water conservation, better alignment of land use planning and ecosystem restoration and preservation (particularly in those areas where most of the water infiltration or snowpack formation occurs), water recycling and reuse, capture and treatment of storm water for groundwater recharge (a particular challenge since both cities have historically deployed systems to discharge rainwater, one to the ocean and the other outside the valley), and the promotion of further efficiencies in water management through the deployment or development of better technology for water conservation, the introduction of novel practices, or by advancing on the water urban nexuses analyses to establish realistic goals at different levels of operation, maintenance and final uses (Blanco *et al.*, 2012; Blanco and Maggioni, 2016; Delgado, 2015).

Water urban nexus may particularly influence energy efficiency, either by seeking efficiencies in pumping, treatment and distribution, or by generating (bio)energy with water treatment of biosolid disposals. As it is well known, such biosolid disposal can be linked to nutrient recovery for "closing" nutrient cycles by using residues as fertilizers or through its pelletization and incineration at high pressure and temperature for energy production (Rulkens, 2008; Joo *et al.*, 2015; Cano *et al.*, 2017; Kollmann *et al.*, 2017; Seiple, Coleman and Skaggs, 2017).

In both Mexico City and the City of Los Angeles, there is room for increasing efficiencies and reducing undesirable costs such as those related to the emission of GHG (see below for some possible actions). In the case of energy efficiency, the water-energy nexus is intensive for both cases. While in California nearly 20% of total electricity is used by the water sector, a context in which Southern California uses 50 times more electricity than Northern California, mainly due to its high volumes of water imports from Northern California, the Sacramento Delta and the Colorado River Aqueduct, as well as to the greater reliance on groundwater during drought years (CEC, 2005), Mexico City's water system uses about 570 million kWh, primarily to pump water from the Lerma-Cutzamala system (Delgado, 2015).

In the City of Los Angeles, the carbon footprint has been estimated at 0.88 tCO_2e per acre-feet for water imported from the California State Water Project, and at O.87 tCO2e per acre-feet for local recycled water (0.713 gr and 0.705gr per liter, respectively) (Fang, Newell and Cousins, 2016; Blanco *et al.*, 2012); this is more than double the water-inflow carbon footprint for

Mexico City which has been estimated between 0.298 and 0.349 grams per liter, giving an annual total emission of 332,000 to 284,000 tCO_2e (Delgado, 2015). Mexico City's metropolitan area water-inflow carbon footprint adds up to between 830,000 to 710,000 tCO_2e, for a total carbon footprint for water-inflow of 1,16 million to 0.99 million tCO_2e for the whole metropolitan area (Ibid). Methane emissions of water outflows for Mexico City metropolitan area add another 1.5 million tCO_2e (Ibid). End-user emissions, among which residential buildings play the greatest role, are associated with water heating which represents at least 13% of the total amount of energy consumed by this sector (Ibid). Total energy consumption for heating water in Mexico City metropolitan area is of about 31.2 Pj per year (Ibid). Future potential savings are possible in both water and energy consumption (and thus GHG emissions can be mitigated), but that will depend on the type and efficacy of implemented measures and certainly on funding availability. Attention can be paid to a diversity of measures, from reducing leakages and the improvement of energy use by renovating old pumps and aging machinery, to increasing rainwater capture, promoting green infrastructure or generating energy from wastewater; among other actions.

In addition to the above, in the case of material efficiency, an innovative approach to the future replacement of failing water infrastructure may be "mining" the physical water infrastructure as such, meaning the recycling and reuse of materials and demolition wastes from water infrastructure renovation. In Mexico City, as indicated, the replacement of 3.1 thousand kilometers of water pipelines represents a great opportunity to recover recyclable materials while removing toxic ones, such as asbestos and lead that, in some degree, still make up the network. Yet, as far as it is publicly known, such urban mining strategy has not been developed, nor has it been properly integrated into investment plans (Delgado and Guibrunet, 2017).

This set of actions, among others (see below), will require moving from traditional managing and funding schemes, towards an integrated, efficient, multi-criteria and multi-temporal planning and funding practice which derives from novel and more holistic approaches to urban sustainability and resilience (Delgado and Guibrunet, 2017).

In this context, while important levels of funding will be needed in the short and medium term, in the long-term, funding could be expected to decrease as efficiencies achieved through the new investments become a reality. Such a transition towards a more sustainable, climate ready and resilient water infrastructure is not an option any more, but an imperative since replacement of failing infrastructures in many cases is already overdue. Climate change will certainly accelerate current and future challenges. 'Planning by doing', as apparently has been the practice for quite some time in Mexico City, would have to change and become more strategic and sustainable for the long-term, with more creative incentives and financing and even insurance schemes, instead of just choosing traditional debt arrangements and subsidies.

One central difference between our case studies is that while in the Los Angeles metropolitan area and in the City of Los Angeles most of the revenue is collected through water rates (in addition to a relatively smaller proportion of state and federal grants), in Mexico City funds partially come from water rates (60%) while the shortfalls are made up by state allocations and grants from the federal government.

Current collection of water rates in Mexico is insufficient because, on one hand, the collection includes only 88% of the real users, of which only 65% had water meters installed by 2013, and, secondly, because actual collection includes, at best, only two thirds of the billed water. Therefore, water revenues alone cannot cover the expenses for operation, maintenance, and the necessary renovation/expansion of the system. The investment required just in Mexico

City (excluding its metropolitan area) is of at least 7,500 million pesos yearly for the next 25 years (about 400 million dollars yearly) (Ibid). In this context, it is to be noticed that the entity in charge of water management in Mexico City (excluding its metropolitan area), SACMEX –*Sistema de Agua de la Ciudad de México*, does not have collection powers. It is only an auxiliary "deconcentrated" organism of Mexico City's Ministry of Finance and, in fact, does not operate any infrastructure directly, as water retailing has been "concessioned" to private companies.[8] Therefore, SACMEX has no incentive to make collection more efficient and optimize expenditures.

Even if there is some room for improvement, it is important to note that urban poverty is a major limitation: 75% of residential water users, which are either poor or extremely poor, only represent a third of the total collection of water rates in Mexico City. An increase in water tariffs is in real terms limited since those for high and mid income households are already within the parameters of other Latin-American cities.

Localities in Southern California, with such fragmented water management systems, also face problems financing both the maintenance of existing infrastructure and investment in new infrastructure. Hampered by the tax limitation movement since the 1970s, increases in property tax (the major source of revenue for local governments) and other local fees have been restricted in California.[9] As a result, a significant portion of the costs of

8 Water service has been partially privatized since 1993. Tariffs and collection of revenues are still carried out by local authorities (bills are issued by the "concessioned" companies). The system is operated by four utility companies: Proactiva Media Ambiente, S.A. de C.V. (ICA/Veolia-FCC); Industria del Agua de la Ciudad de México, S.A. de C.V. (Peñoles/Suez); Tecnología y Servicios del Agua (Peñoles/Suez); and Agua de México, S.A. de C.V.

9 Proposition 13 (1978), a popular initiative amendment to California's Constitution, restricted property tax to 1% of the cash value of real estate property. Proposition 218 (1996) requires a majority voter approval for all new taxes, fees (including water rates), and increases

new infrastructure and repairs to existing systems has had to rely on periodic statewide water bond issues. The passage of statewide water bond issues, however, is politically contentious, given the varying water resources in the North and Southern parts of the State. The political climate can delay the passage of such acts and reduce the amount. The last two bond issues were passed in 2006 and at the end of 2014. But the 2014 bond issue for $7.545 billion dollars was originally proposed for $11 billion dollars and delayed for 5 years. State funding for water infrastructure in California is vital for financing water infrastructure in Southern California but it is not sufficient for maintaining existing infrastructure and investing in the future. The State Water Bond program only meets a fraction of the needed investment, since investment in infrastructure for drinking water needs in California is estimated to be $44.5 billion dollars (ASCE, 2017). As described above, this is a challenge shared with Mexico City.

The challenge of a fragmented government and 'governance', is a major problem in the U.S. and in Mexico. As we discussed, there are over 200 water supply agencies in the MWD or Southern California area. This does not include the many other agencies involved in wastewater treatment or storm water management. And yet, it is evident that financing and climate change challenges to the water supply will require a more integrated and better managed water system. In addition to investment in maintaining needed water infrastructure, substantial new investment in treating and recycling wastewater for potable use, and capturing and treating storm water will be necessary to meet population increases and a warmer climate. In this paper,

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at the local level. Proposition 218 also stipulates that fees charged to property owners may not exceed the cost of providing the service (CA Legislative Analyst's Office, 1996). Tiered water rates are being legally challenged under Proposition 218 (Cadelago, 2015).

we have focused on water services and the need for greater integration in their planning and management. In addition, the connection between water services and land use planning is also essential, since the uses of land, and their densities determine water (and sewerage) demand.

A recent study by Gober *et al* (2013), which analyzed the barriers between planning and water management in Portland, Oregon and Phoenix, Arizona, concluded, however, that conflicting perspectives and interests make collaboration between water and planning professionals very problematic; that inadequate staff and resources are important obstacles, especially in small communities, and that fragmented responsibilities in water management hinder integrated planning. To address this issue, the American Planning Association (the association of professional planners in the US) recently recognized water "as a central and essential organizing element in a healthy urban environment" and the need for a close connection between water and land use planning (Cesanek and Wordlaw, 2015). Despite this, even in the state of California, where water is such a crucial issue for land development, the connections between land use planning and water services planning remain weak (Blanco and Maggioni, 2016).

The recognition of the need for greater integration among water services is being spearheaded in the US and in California by the City of Los Angeles' One Water Initiative (City of Los Angeles Bureau of Sanitation, 2017), which is being led by the City's Bureau of Sanitation and which aims at strengthening the collaboration between City departments, other agencies, and stakeholders to develop joint planning and "guiding principles for coordinated water management and Citywide facilities planning". The broader One Water approach, of which the Los Angeles program is a pioneering effort, is a movement led by the U.S Water Alliance and National Association of Clean Water Agencies in the US. This new movement argues that the separation among water supply, wastewater treatment, and storm water catchment is counterproductive and calls for greater integration of water services (U.S. Water Alliance, 2016). One Water planning and eventually One Water utilities, aim to reduce the transaction costs and other institutional fragmentation costs generated by multiple institutions.

In addition, the approach emphasizes the connections with urban planning, recognizes institutional barriers, the lack of incentives (including economic and financial) to develop new paradigms for water management, appreciates the value of collaboration with stakeholders and communities, and advocates changes in federal legislation and programs to achieve a more integrated approach (Mukheibir, Howe, Gallet 2015). This approach is also supported by the United Nations Development Program in its report that calls for mainstreaming environmental issues into urban planning (Dodman, McGranahan, and Dalal-Clayton, 2013).

This is a lesson which indeed would be useful to Mexico City's water decision-makers and, in a broader sense, for all stakeholders interested in improving water governance and coordinated land use and water planning.

A more modest and interim approach to address the multiplicity and fragmentation of water services in the U.S. is the use of joint powers authorities. The state of California enables several local governments to establish agreements for adopting or implementing water management programs by establishing joint powers authorities (Blanco and Maggioni, 2016). Through this mechanism local governments are enabled to increase efficiencies, promote synergies and tap into opportunities that coordination and partnership efforts may offer for recycling projects, storm water capture, treatment facilities, conveyance, etc., without curtailing their current powers or interfering with the current organization of the agencies. In the case of Mexico City one may think of different governmental agencies at the metropolitan and even megalopolitan level. Such efforts may include arrangements or collaborations among the state agencies but also between them and local communities and market actors. For example, there may be no appropriate land for a large treatment facility in a water basin given the extent of urbanization of both regions, but a nearby agency may have suitable land or access to financing. Joint powers authorities can provide a viable instrument for more integrated water projects, since the formation of Joint Powers Authorities is relatively straightforward. This type of organization would facilitate the type of infrastructure projects that could ensure the sustainability of water resources (for the case of California, mainly groundwater resources). In addition, joint powers authorities may help to explore other types of solutions that are not exclusively related to water and wastewater infrastructure management, renovation and expansion, such as those for adaptation and risk prevention.

Mexico City may have some experience on such joint powers managing schemes, for example by means of the Executive Commission of Metropolitan Coordination which since 2008 includes a Metropolitan Commission on Water and Sewerage. This is, however, a recent practice, and therefore concrete water and sewerage management still is relatively fragmented and dependent on local political cycles.

Participatory or bottom-up governance may accompany this process recently put into practice, either through the active integration of social actors within the planning processes, or by means of social mobilization and pressure, or both. In Mexico, the *Water for All. Water for Life* movement has been promoting in the last few years a proposal for reforming the National Water Law. The initiative, the outcome of a broad public consultation, includes a well-informed evaluation of the current water crisis in Mexico, as well as concrete measures and actions. The movement has found several allies, particularly in the face of more water related conflicts, which, in the urban context include: lack or poor service, high tariffs, water expropriation, infrastructure deployment, and wastewater discharges. It is worth noting that a review carried out nationwide between 1990 and 2002 of some 5,000 newspaper articles on water conflicts, found that 49% of such conflicts took place in Mexico Valley (Jimenez *et al.*, 2011). Social mobilizations included public demonstrations and facility takeovers. About 56% were due to lack of water and 24% to hikes in prices. In the metropolitan area of Mexico City, the districts that experienced most social unrest were precisely those with less access to water due to a lack of sufficient infrastructure, such as certain areas of the east of Mexico City and the conurbation (e.g. Cerro de la Estrella in Iztapalapa borough) (Ibid).

Mobilizing funds in such a scenario is complex but possible and unavoidable. Based on a survey of the literature on these topics, and our own past research, we identify goals and approaches for SACMEX, as well as other similar agencies in Mexico and California: a) increase agency efficiency and move towards a more integrated metropolitan planning (U.S. Water Alliance 2016); b) increase the revenues collection efficiency (including those from non-residential uses and, if viable, apply polluting fees) (OECD, 2013); c) reduce the city's reliance on distant and disputed water reserves (Government of the State of California, 2016; Perlo and Gonzalez, 2009; Jimenez *et al.*, 2011; Delgado, 2015); d) diversify the strategies for increasing recycled water, reducing leakages and inefficient uses (further embracing grassroots action programs such as the "female plumbers" program that since 2008 provides free training for women between the ages of 18 and 65 with up to 9 years of education); e) consider payments for ecosystem services that may preserve or increase water reserves (Caro-Borrero *et al.*, 2015; SEDEMA, 2013); f) use life cycle analyses and urban water metabolic analyses for an integral planning of water management at a metropolitan level, including water nexus approaches and their potential trade-offs (e.g. solutions for securing water provision and sanitation may exacerbate carbon emissions) (Kennedy *et al.*, 2014; Fang *et al.*, 2016; Delgado, 2015); g) use multiple criteria analyses for evaluating socio-ecological costs; h) consider emerging technologies, traditional technologies and non-technological solutions at different scales (this includes, for instance, decentralized storm water infrastructure closer to its source through green infrastructure or low impact development) (Johnstone *et al.*, 2012); i) create innovative incentives; j) seek subsidies from state and federal governments; and k) pursue a better understanding of the variety and types of funds and financing available nationally and internationally and their implications (including the carbon market, for example, by providing the capture of methane from wastewater for energy production); as well as other issues related to research and development, including education and public communication and engagement.

The strategies identified above are important, especially for Mexico City, where the mere increase of tariffs, or the price of water, in a developing country where officially 45.5% of the population is poor (this figure according to some analysts, may be as high as 80%), is highly questionable and costly in political terms. To a lesser degree, this applies, too, in Los Angeles, at least in the case of disadvantaged communities. Below, we discuss this issue further and its implications for guaranteeing water as a human right.

Water as a human right, and achievement of the Sustainable Development Goal #6

The pursuit of more coordinated and integrated water management (including related issues of land planning), the development and deployment of technologies and other types of alternative solutions, the great need for infrastructure investment and local capacity building, and a more efficient use of water resources to ensure that sustainable and climate ready urban water infrastructure meets current and future social needs, are essential objectives. These objectives need, fundamentally, to incorporate the human right to water and sanitation for all, starting with disadvantaged communities and individuals, while at the same time integrating the already mentioned ecosystem function of water.

California was the first state in the U.S. to recognize water as a human right (AB 685, 2012). During the height of the recent, historic drought in the state, hundreds, if not thousands of households, experienced water disruptions. The State recognizes that currently, over 300 drinking water systems in disadvantaged communities, serving approximately 200,000 people are not able to provide safe drinking water (California Water Boards, 2017). The drought amplified this problem. A recent study (Feinstein *et al.*, 2017: 22) on drought and its impact on disadvantaged communities in California, found that ⅔ of 149 public water systems (mostly in the Central Valley), affecting 480,000 people, that reported drought related impacts, served economically disadvantaged communities. Also, the 4,000 households not served by public water systems that reported shortages of water during the drought were disproportionately located in disadvantaged communities. In February 2016, the State Water Board passed a resolution declaring the human right to water as a top priority of the Board, calling for Regional Water Boards to consider the human right in any action involving drinking water, and to include communities in planning for changes involving water and in implementing solutions (CA State, 2016). While California spends over $2.5 billion dollars to provide subsidies for electricity, gas and telecommunication services to low-income residents, 56% of Californians have water service providers who do not offer rate assistance to low-income households. To implement the State's commitment to water as a human right, the State Water Resources Board is in the process of developing a plan, which will be completed in 2018, to extend assistance to low-income households throughout the State (California Water Board, 2017). Note, however, that LADWP, along with many other water utilities, already does provide assistance to low-income users, seniors and the disabled.

Similarly, following the federal reform of the Mexican Constitution on February 8, 2012 which recognizes in Article 4 the human right to water and sanitation, Mexico City's government included in Article 9.F of its new Constitution (from being a federal district, it just became a state in 2015) the right to water and sanitation in an adequate, safe, affordable, and accessible manner suited to dignity, life and health.

The right to water is not free of critiques and challenges as it is not understood as the right to free water *services*, which in turn raises questions of how to interpret and implement the right to water and sanitation, at least for disadvantaged communities. While in Mexico private utilities companies and the industry of bottled water and soft drinks are major stakeholders in the water business, in California, resistance to fully guarantee the human right to water comes mainly from the agricultural industry and water agencies. The road to implementation in both cases is still disputed, and is being developed, but hamstrung by lack of financing and enforcement. As discussed, in Mexico City, while officially it is recognized that 97.8% of households have access to water and 96.2% to sanitary services, the frequency of water availability, the consumption patterns, and water quality are geographically uneven (Delgado, 2015). In such a context, low income inhabitants benefit from two mechanisms: on the one hand, tariffs are established according to Area Income (popular, low, medium and high income blocks), consumption type (residential, or other), and level (water usage charges increase by blocks of consumption); except in those districts where, on the other hand, water service is provided only a few hours some days of the week (alternating shift service) in which fixed prices have been established (from 93 to 643 pesos –roughly, U$S 5,30 and U$S 36.75).[10]

The degree of success of an income-based approach to enable access to water provision in a developing country is questionable; the alternative, a free basic allotment of water to every household could be considered.[11] Whichever path is taken, any decision and concrete scheme of implementation must consider a multidimensional approach to poverty. In Mexico City metropolitan area, 69.3% of the population lacks access to at least one basic social need (CONEVAL, 2014). The implications of such figures within a climate change context must be clearly understood as the latter may be a "threat multiplier" (as it has been stated in a Congressional report of the Department of Defense in the U.S. [2015]). This is particularly true if urban adaptation measures are taken tentatively and slowly as it seems to be the case in Mexico City (Aragon and Delgado, 2016). In short, a great deal still needs to be done regarding adaptation strategies linked to the prevention and management of weather related risks, especially as it concerns water and sanitation issues where an inclusive and integrated approach and agenda are crucial (gender issues are again here to be considered; WEDO, 2003; GWA, 2006; Imaz *et al.,* 2014; http://genderandwater.org).

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10 For further data, see: www.sacmex.cdmx.gob.mx/storage/app/media/uploaded-files/6_tarifas172.pdf

11 For example, such a scheme has been implemented for the first 50 liters of household consumption, daily, in Soweto, South Africa, following paragraph 27 of the General Comment No. 15 of 2002 related to articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights of United Nations (www2.ohchr.org/english/issues/water/docs/CESCR_GC_15.pdf).

Conclusion

Water provision and sanitation in a climate change context, especially in mega-city regions such as Mexico City and Los Angeles, will increasingly require a hybrid governance, meaning one that achieves a genuine integration process of all *policy* or institutional aspects, *polity* or power relations in place, and *politics* or the mechanisms and instruments to achieve certain desirable outcomes (Schulz *et al.*, 2017). Such integration is a multidirectional process: top-down, bottom-up and horizontal; the latter referring to the integration of different planning and decision-making tools and mechanisms needed to confront the complexity of water issues.

The discussion above implies a shift away from traditional approaches to 'manage' the 'water sector', which additionally tends to dissociate land planning policy, politics and polity, to instead address water issues as a unity, in all their complexity, multidimensionality and multiple spatial and temporal scales. The goal is to move towards a paradigm shift that enables the coproduction of more consistent, robust and creative solutions, evaluating and monitoring tools, legal arrangements, administrative, funding and accountability schemes. Such hybrid water urban governance will require a capacity building progress and a broader consensus among different discourses, viewpoints, organizational structures, and power relations, in order to promote a profound and localized hydro-social transformation. Without addressing such diversity and conflicting processes in play, including the production of urban and non-urban space, a more resilient and socio-ecologically robust outcome may not be reached in the long term, while water security, which comprises the human right to water, may therefore be in peril as climate change accelerates and magnifies water-related vulnerabilities and challenges.

Our case studies allowed us to identify some of the complex technical, technological, ecological, sociocultural, political, institutional, and financial current and foreseeable challenges of two mega-city regions.

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IV. Cross-cutting issues in the urban transition agenda: finance, gender and education

Chapter 8

Green financing for cities: current options and future challenges

Antonina Ivanova

Introduction

The world in 2050 will be home to more than 9 billion people. Three quarters of the population will live in cities, and will need housing, education and employment. Water and energy will be very important to satisfy their basic needs. Other essential services for city life are transportation, communications and waste processing. The rate of urbanization in developing countries is expected to reach 50% in the next decade (Z/Yen Group Ltd and WWF, 2015).

This chapter explores funding sources that could be implemented with national support, local funding schemes, or private financial institutions. We also present the main options for financing the development of cities, analyzing the possibilities for their improvement. It is important to mention that not all existing problems can be solved through financial engineering, as there are many regulatory barriers and regional specificities that must be taken into account.

Cities and their problems: objectives and challenges

According to current estimates, the world population will grow from approximately USD$ 7 billion in 2012 to more than USD$ 9 billion by 2050, and virtually all the increase will be absorbed by urban areas in developing countries. With 70% of the population living in urban areas by 2050, it is also no surprise that, while cities will be centers of wealth and relative prosperity, the number of urban poor may well be higher than that of the poor rural population (EIB, 2013-A).

The number of megacities (with populations of more than 10 million people) is expected to increase from 19 today to 27 by 2025, when 10% of the world's urban population will reside in these cities. Of the projected 27 megacities, 21 will be in developing countries. By 2025, there will be 48 cities with populations of between 5 and 10 million, and three quarters of these will be in developing countries (City of London, 2014). Metropolitan areas generate more than a quarter of national GDP in industrialized countries (Ibid.). The same is true in developing countries, for example, 27% of GDP in Istanbul, and 52% in Buenos Aires (WB, 2013).

At the same time, there are significant costs to metropolitan growth, especially if poorly managed. Threat to life by air pollution in Beijing and Delhi, traffic congestion in Bangkok and Sao Paulo, the proliferation of urban slums, corruption and crime in many cities in developing countries attest to the challenges of metropolitan development (Bahl and Linn, 2013). The benefits and costs of metropolitan growth are not limited to the big cities themselves. The positive effects include the growth of industries in the metropolitan area and the generation of fiscal revenues that are redistributed to local governments in the rest of the country (Smoke 2013; WB, 2013).

Key drivers of strong and sustainable growth of metropolitan income and employment are: (1) an economic base that is competitive in national and global markets; (2) transport and strong ICT links within cities and with the rest of the world; (3) concentration of human capital skills; and (4) the quality of governance that supports metropolitan growth and takes advantage of generated opportunities (Agster, 2015).

The main objective for urban planners and managers is to create a competitive city that attracts modern investment and skilled workers. Particular goals are the creation of a smart, ecological, safe and fun city (ASU, 2014; EC, 2013). Intelligent means access to modern information and media as well as transportation technology that connects business, government and city dwellers with each other and with the rest of the world. Green refers to an efficient and sustainable use of energy, water and air. Safe means protection against crime and natural disasters, including the potential effects of climate change (Gouldson, 2015). Finally, being fun refers to the facilities of culture, cultural heritage, sport, and green spaces (EIB, 2013b). The five objectives interact with each other, so achieving one supports the success of others.

In pursuit of these five objectives, urban planners and managers have five main sets of tools at their disposal: public service provision, land use planning, business regulation, connectivity and financing.

As in the case of the objectives, there is a close interrelation between the instruments: effective public service delivery creates the basis for better connectivity and has to be related to land use planning, while business regulation can support or impede the efficient delivery of services, implementation of land use and effective connectivity.

Funding is essential for the effective delivery of public services and metropolitan regulation, and vice versa. The increasing demands of spending that the metropolises exert on the tax systems of their respective countries become an especially important question. Pressure on budgets to support services and infrastructure in cities will increase in the coming decades, although the severity of the problem will vary from city to city.

The demand for services will continue generating high costs, whose management will be problematic, especially in relation to poor neighborhoods. Factors that will drive increased public expenditures in urban areas include: (1) population growth; (2) per capita income growth; (3) corporate demands;

(4) improvement of infrastructure and public services needed to attract and retain a skilled workforce; (5) the need to address the negative externalities that come with urbanization, such as pollution (e.g., solid waste management) and transport congestion; and (6) the special needs of a large concentration of families in expanding poor neighborhoods that require large public investments from metropolitan governments.

An idea which is gaining increasing international acceptance is that collaboration between governments of cities and counties and the business sector turns out to more efficient in the promotion of development and social progress when compared with the action of federal governments.

It is very important the idea whose acceptance increases internationally that the collaboration between the governments of municipalities and cities with the business sector, turns out to be more efficient to foment the development and the social progress, in comparison with the actions of the federal governments.

Financing for green urban development

Background

Although different methodologies and estimates are applied, there is a consensus that very important needs exist for financing infrastructure works in cities. According to Standard & Poor's, by 2030 the requirements will amount to USD$ 57 billion (Standard & Poor's, 2014), while the OECD estimates about USD$ 82 billion (including energy generation and related infrastructure) for the 2009-2030 (EIB, 2013).

Historically, governments have been the main funders for infrastructure development. However, after the financial crisis, public financing of infrastructure and related services has declined. After the debt crisis in some European countries, the governments of the OECD member countries have also reduced their infrastructure financing to about 3% of their GDP, compared with 4% in the 1980s and 5% in the 1970s (EIB, 2013). In Europe, public infrastructure financing has fallen from about 5% in the 1970s to only 2.5% after 2000 (EIB, 2013).

Within the private sector, banks have traditionally provided long-term financing for infrastructure projects, which currently amounts to USD$ 300 billion a year (Standard & Poor's, 2014). However, their ability to provide financing has been affected by the crisis and by new regulations such as Basel III.

Therefore, considering future projections of GDP and infrastructure deficits, and assuming that government funding will maintain the same levels, Standard & Poor's (2014) estimates an annual gap of at least USD$ 500 billion in the requirements of infrastructure. This lack of resources becomes one of the major political concerns and requires a significant involvement of the private sector.

On the other hand, new agencies are emerging in the financial sector as providers of long-term financing, such as pension funds, insurance companies and sovereign wealth funds.

With over USD$ 70 billion of assets in OECD countries, institutional investors are often referred to as an alternative source of financing (Della Croce and Yermo, 2013). Over the past decade these institutions have diversified their investments into alternative options, such as real estate, and recently infrastructure, including "green infrastructure" (USS, 2014).

These investments are an area of opportunity for institutional investors because of their long-term assets and liabilities management needs, besides receiving higher yields than traditional investment options in government or corporate debt (Della Croce and Yermo, 2013).

However, the share of infrastructure financed by institutional investors is still very low: only 1% of pension funds are earmarked for infrastructure projects.

According to Standard & Poor's estimate, the level of investment by institutional investors could increase to 4%, about USD$ 200 billion a year in additional infrastructure funds (or USD$ 3.2 trillion by 2030). That represents a substantial increase of the current level (Standard & Poor's, 2014).

Securing financing for urban projects can be challenging, especially during the early stages of construction when the needs are greatest and the level of risk may be unacceptable to many potential investors and providers of funds.

Potential sources of funding and instruments are varied and multiple, but the right mix of funding sources will ultimately depend on the return period and the duration of the projects to be funded. The capacity and willingness of the competent entities to assume adequate levels of risk and acceptable forms of security are also very important (BLP, 2012).

Improving city resilience

Between 2000 and 2012, natural disasters, such as climate, health and seismic events, caused USD$ 1.1 trillion in damages worldwide, taking into account both the direct impacts on infrastructure, resources, communities, and the environmental and indirect impacts, such as decrease in business profitability and economic growth in the affected regions (Siemens, 2013).

Building resilience requires long-term coordination and cooperation between decision-makers, communities, companies and other stakeholders to reduce disaster risk, both through policies and investments to reduce specific risks, and by improving infrastructure and provision of services (Carraro *et al*., 2013, CCFLA, 2015).

Resilient infrastructure systems may require large-scale changes in planning, design, and management and maintenance modes. While technology is part of the solution, the ability to anticipate risks and plan long-term urban development is critical. Resilience should not only be included as a decision-making criterion for new infrastructure projects, but should also be systematically taken into account in evaluating projects to maintain and improve existing infrastructure (Siemens, 2013).

Resistance to climate change not only influences the ability to respond to extreme weather events, but also has implications for the safety of the inhabitants of the cities (Agster, 2015). Insurance against catastrophic events and other forms of risk transfer are essential for the maintenance of urban assets and for financing recovery from extreme events.

While governments have historically absorbed the gap between private insurance losses and total economic losses, their ability to continue to do so is limited by declining public finances.

On the other hand, the unpredictability of such events and the magnitude of the losses are undermining the insurability of urban infrastructure and assets (CCFLA, 2015). Decision-making cities and insurers have much to gain, working together to improve and strengthen city security through better resilience (ClimateWise, 2013).

Smart cities

The financing of smart cities requires solutions to ensure energy-efficient urban development. Power grids, energy-efficient buildings, energy supply systems, transport systems and citizens' attitudes will lead to considerable energy savings and reduced GHG emissions.

Strategic planning, integrated municipal departments and supply processes should be supported with financial innovation mechanisms to attract the necessary private investment for the large-scale transformation of energy use.

Over the next few decades, energy costs will continue to fluctuate and cities will face the challenge to raise their economic growth, while simultaneously reducing GHG emissions. In such conditions, the public sector is more likely to encourage investment in intelligent technologies, low carbon and environmentally friendly goods and services (LCEFGS). These include smart grids and broadband access, electric vehicle recharging systems, installation of heating systems, on-site power generation, and other adaptation and mitigation initiatives. This sector has a clear socio-economic impact and is based on a growing demand at global level.

The benefits of energy transformation are not only recognized in terms of economic returns, but also of socioeconomic and health benefits. The initial investment and the longer periods of recovery of investment are sometimes barriers to private investment. Other barriers are uncertainties about the prices of renewable energy and fossil energy prices. In this sense, it is important to have government incentives and encourage public-private investment.

To mobilize investments, governments and public governmental institutions need to promote innovative tools and solutions. Thus, it is very important to ensure that regulatory frameworks do not constitute barriers to innovation.

Main financing options: analysis and ways of improvement

Intergovernmental transfers

Presentation and analysis

The degree of dependence of metropolitan areas on transfers can vary widely between cities. On the one hand, central cities like Buenos Aires have the capacity to collect taxes and finance about 70% of their budget with their own revenues. A similar case is represented by large cities in South Africa.

However, in most cities reliance on inter-governmental transfers is very high (Boex, 2009). Although financial analysts favor self-financing, it is generally not supported by politicians in office, both for financial reasons and for political control issues. High-income cities are being controlled through transfer-versus-tax policies, with justification for more equitable distribution of resources or to finance central government expenditures (Ivanova, 2016).

These policies are sometimes supported by authorities at the subnational level, who do not wish to lose their popularity by establishing unpopular taxes. With the increase of the urban population, and more places in national and state congresses, local rulers prefer not to lose popular support (Boetti, Piacenza and Turati, 2010). On the other hand, cases exist when granting more power to establish taxes to subnational governments, has led to distortions in economic decision-making.

Sometimes, for reasons of equalitarian distribution, metropolitan areas and large cities are not favored. This has been observed, for example, in São Paulo and India (Peterson and Annez, 2007). In South Africa, special funding is provided to municipalities to improve services in poor neighborhoods (Paulais, 2012). Another approach is to divert a portion of intergovernmental transfers to debt repayment, as is done in Mexico.

Some countries have developed special agencies (municipal development funds) to support the development of government capacity to manage urban areas. These agencies have channeled financial funds (grants or loans) to local governments in support of construction and infrastructure (Ivanova, 2016). Grant funding usually sets the objectives of the project or contractual obligations of local authorities. National governments often resort to endorsements that can suspend financing in case of non-compliance.

There are successful cases of such financing in the Indian state of Tamil Nadu, in Senegal, and other regions of South Asia and sub-Saharan Africa (Peterson and Annez, 2008; Paulais, 2012; Streitferd, 2012).

Paths to improvement

It is not uncommon for developing countries to make efforts to restructure their intragovernmental transfer systems. But reforms rarely coincide with the development of a metropolitan public financing strategy. To do so, the strategy for the restructuring of transfer regimes for large cities should include three components of reform.

The first would focus on the gradual independence of local metropolitan governments from transfers, while ensuring that they have sufficient authority to tax users. A strong budget constraint for funding deficits from subsidies by the top-level government would be part of this strategy. Currently, financing of infrastructure investment has shifted from subsidies to debt. In this arrangement, the borrowing is supported by locally sourced income. Subsidies should never disappear altogether as a source of funding, since external factors will always have to be available, but in many metropolitan areas subsidies can be drastically reduced.

A second, complementary component of the strategy would be to redesign the transfer system so that the local governments of megacities may be treated under a different regime from other local governments. The vertical law quota of metropolitan area governments would be lower due to their greater tax capacity. The loss of revenue resulting from local metropolitan governments would be offset by increased tax authority. With a separate system, it would be possible for the central government to recognize differences between metropolitan governance structures (greater reliance on subsidies when the local government is more fragmented), provide incentives for more efficient regional taxes, and greater fiscal effort. The transfer formula for central (state) grants must include horizontal transfers from the richest to the poorest local governments within the metropolitan area, and specific subsidies, such as slum upgrading programs.

A third option is to link institutional capacity building, with the granting of funds through the creation of a municipal development fund. This would provide grants for infrastructure investment and also support the design and implementation of projects, the development of capacity for income mobilization, as well as improvements in the operation and maintenance of urban services. The municipal development fund will also address the strengthening of personnel and management capacity for urban planning, regulation and financial management. The type of financial support may be gradually shifted from subsidies to loans as the fiscal capacity of local governments improves, or could be structured asymmetrically, by providing subsidies to smaller municipalities, while providing loans to metropolitan governments with relatively strong income bases.

Loans

Presentation and analysis

The practice and success of using loans by local governments in metropolitan cities varies greatly between different cases. Local governments in South Africa use loans from government banks and private financial intermediaries, but without a guarantee from the central government (van Ryneveld, 2007). At the other extreme are the local Chinese governments. They could not borrow but instead created an alternative route for urban investment firms that borrowed on behalf of the municipal government. These were supported by a revenue base provided by the municipal government (Wong, 2013). Municipal bonds are used in Colombia, Mexico, Brazil, South Africa, India and the Philippines (IADB, 2012; Peterson and Annez, 2007). Over-indebtedness has occurred in several cities and has led to some kind of rescue in metropolitan cities such as Buenos Aires, Sao Paulo and Johannesburg, and more recently in China (UNEP and Gwangju City, 2012; Cao, Feng and Tao, 2008). Many countries try to control excessive borrowing with various forms of tax liability legislation, although these programs have reported varying degrees of success (Liu and Webb 2011).

Municipal development funds have been used in some middle-income countries to help develop the institutional conditions for local government loan services and to assist urban local governments in developing capacity to access loan financing, often with external assistance (Peterson and Annez, 2007; Kharas and Linn, 2013). One of the most successful cases is FINDETER in Colombia, which was created in early 1990 with the assistance of the World Bank and the Inter-American Development Bank, based on rediscounting of long-term commercial credits to municipalities. Over time, FINDETER became a well-functioning financial intermediary, supported by local credit rating institutions and better cadastral services. This led to higher local revenue collection and greater solvency, effective municipal access to long-term credit, and ultimately improved urban services (Kharas and Linn, 2013).

Pathways to Improvement

Governments could consider the following guidelines in shaping policies to strengthen the use of debt financing for the improvement of metropolitan infrastructure services:

- Provide local governments with greater autonomy on both sides: income and expenditure budgets. If infrastructure is to be maintained, and if debt obligations are to be achieved, local governments need to be able to control their level of budgetary resources. Even a well-structured debt framework cannot be a substitute for the local government's ability to pay.
- Debt financing limit for long-term capital projects. It must be ensured that any exchange risk is hedged; either through commercial hedges or that the central government assumes the risk of the exchange rate.
- Impose a strong budget constraint on borrowers, without the possibility

> of a "free" bailout by top-level governments if the underlying problem is that local government was reckless in incurring debt obligations. It is recommendable to create a regulatory framework for central debt, with clear rules for borrowing: how much, for what purpose, who, what instruments and what restrictions (Nixon, Cambers, Hadley and Hart, 2015). Compliance with the framework should be carefully monitored.

Public- Private Partnerships (PPP)

Presentation and analysis

PPP funding expanded rapidly in the 1990s and outpaced official external assistance almost tenfold. Most of the PPP infrastructure investment has been targeted at telecommunications, followed by energy. Together, these two sectors accounted for nearly four-fifths of total PPP investments from 1990 to 2008. Less than one-fifth went to transport and only 5 percent to water and sanitation. Carraro *et al* (2013) attributed these differences between the sectors mainly to the different capacity to charge commercially viable users in the first two sectors compared to the last two. However, with the exception of the telecommunications sector, PPP investments have generally bypassed low-income countries. It is therefore not surprising that PPPs have added relatively little to the financing of urban capital in developing countries over the past two decades (Bahl and Linn, 2013; Peterson and Annez, 2007). However, there have been cases where PPP investments have exceeded official external aid flows even for water and sanitation, and highly visible projects have been funded with PPPs in selected metropolitan areas of developing countries, including urban rail projects in Bangkok, Kuala Lumpur, and Manila (Liu and Waibel, 2010).

Inman (2005) and Liu and Waibel (2010) argue that the inherent risk of urban investment is the main obstacle to increasing the flow of private capital.

There is insufficient record of full cost recovery, since local governments are often unwilling to accept the types of tariffs and regulatory provisions needed to attract private investors, especially for long-term contracts. Pethe and Calvani (2006) describe that the lack of use of PPP schemes in Mumbai was due to a "confidence gap" between the private and public sectors. There is also weak institutional capacity to manage PPPs. For the public sector, a risk is present that the services provided may not be what the public wants. There is also a risk that the private partner will make a mistake and the public sector will have to assume the obligation in full. How successful such arrangements are, from the perspective of either party, depends heavily on the details of the contractual arrangements and how the risks are shared.

Pathways to Improvement

Although they have not provided the expected results, PPPs have made an important contribution to the financing of infrastructure in metropolitan areas, especially in middle-income countries. However, reform is needed in five areas to address the obstacles and constraints that prevail (Liu and Waibel, 2010):

- The legal framework in the country should be supportive and allow an arbitration process that puts public and private partners on an equal footing within a framework of transparency.
- Cities need to be supported in their efforts to build build the capacity to deal with PPP problems and to conduct complex investment design negotiations. This is an area where top-level authorities and external aid agencies can be useful, including their participation in municipal development funds.
- PPP projects need to be carefully planned and transparent standards and documents must be established for participants.
- Improvements in national and local business climates are critical, as they are important signals to potential PPP investors that they will be

treated fairly and predictably.

- PPP will be more difficult to organize and implement in an environment of fragmented, vertical and/or horizontal metropolitan governance. Therefore, it will be important to establish territorial management, negotiation and implementation of large PPP projects.

International Aid

Presentation and analysis

Many donors are involved in providing aid. The World Bank is the largest, followed by Japan, and then by the regional development banks. However, in the last few decades, the flow of aid to urban areas has stagnated and is inferior to that required for urban investment needs, despite frequent calls for increased support from urban experts in the aid agencies. Aid in urban areas has been limited to particular projects, such as roads or sanitation, without addressing more general, cross-cutting issues of management that could enhance the sustainability of existing interventions. Africa's urban investment needs, in particular, have been neglected by donors. More generally, the implementation of urban strategies by donors has fallen far short of the targets set.

This scarcity of specific urban aid came despite the fact that evaluations show that such investments on average tend to be more successful in terms of their impact on the development of other sectors. The situation has been worsened by the involvement of donors at the country and city levels in general; it has lacked a long-term strategic perspective and therefore has been fragmented and uncoordinated, instead of being systematic and continuous for successful interventions. A key constraint to the sustainability and expansion of donor-supported programs has been the lack of local funding capacity to sustain and build on the funded aid initiative, once donor support ceases. This can be attributed to the lack of attention on the part of donors to the fiscal capacity of urban governments or their lack of impact in improving local capacity for revenue collection.

In addition, donors generally do not focus on the question of how to rationalize intergovernmental transfers, which are a key part of local government resources. And although there have been some examples in which donors have systematically helped to strengthen borrowing capacity, institutional frameworks and policy for municipal governments in general, such interventions have had little impact.

Finally, donors have not paid sufficient attention to the special financing needs and capacities of metropolitan areas compared to other urban areas (Pethe, 2013). This is partly because many donors are required to work with national entities at the government level, and partly because metropolitan areas are often not formal levels of government, in contrast to state or municipal authorities.

Pathways to Improvement

A number of changes in donor strategies could benefit metropolitan and city funding in general. First, aid donors must go beyond broad strategy statements and focus more systematically on the funding needs and institutional capacity of urban governments.

Second, experience shows that donors can effectively channel at least some of their resources through municipal development funds (also known as urban investment funds), which are the national level agencies that provide funding and support to urban governments to meet their investment needs. But those funds and the financial and technical support that donors provide must be carefully tailored to country conditions (e.g., credits in middle-income countries and grants in low-income countries) (Peterson and Annez, 2007; Kharas and Linn, 2013).

Third, donors could also enhance partnerships and pool their resources for comprehensive and long-term support for urban and metropolitan investment, institution building and policy reform. To do so effectively would require a thorough analysis of local socio-economic conditions and investment needs, assessing the institutional capacities and interests of participants, and helping to create and implement longer-term metropolitan development strategies. In doing so, special attention should be paid to urban finance. Donors should support the development of local income mobilization and management capacity, intergovernmental transfer and debt management schemes.

A much stronger national and international effort in data collection is imperative. It is suggested to use caution when drawing homogeneous conclusions for different countries and cities, and to make recommendations based on “best practices”.

Conclusions

The prevailing theory of metropolitan governance and finance provides useful guidelines for public policy, but it does not provide many firm rules on how best to govern and manage finances. Rather, the frameworks of policy options are set in terms of a series of advantages and disadvantages that entail significant costs and benefits. Among these advantages and disadvantages are: centralization or vertical decentralization; consolidation or horizontal fragmentation; effectiveness of income, efficiency or equity in local income generation; central control through categorical subsidies or local control through generalized transfers; strict limits on local indebtedness or the freedom to access credit markets.

Nevertheless, some conclusions and general directions arise from the metropolitan management and finances in the last decades based on prevailing practice:

- Developing countries have different patterns from industrialized ones. Developing countries generally tend to be more centralized, their metropolitan areas tend to be more fragmented, and their cities are less self-financing and thus more dependent on subsidies. These countries tend to borrow less and have less PPPs. In addition, they rely more on external aid funding, especially the poorest countries. A significant shift away from these differences is not observed.

- There are few long-term success stories of metropolitan governance and finance in developing countries. Hong Kong and Singapore have been very successful in a sustained way, but they are special cases, due in part to their status as city-states. Bogota and Shanghai have also become successful cities in the last few decades, but they also demonstrate how success can be ephemeral, as both cities now face significant problems due to changes in city management (Bogota) or to the accumulation of inherited problems, including congestion and pollution (Shanghai).
- Very few central governments have clear strategies to support the development of cities and/or metropolitan areas in their countries. With few exceptions (e.g. cases of new capital development, such as Astana, Kazakhstan), national authorities do not focus on developing visions and strategies for their metropolitan areas; rather, they approach them in a non-differentiated manner from other local or regional jurisdictions. They are not coordinated through functional ministries that are involved in metropolitan area services, regulation and taxes, and they rarely see their role as a supporting one, designed to guide local authorities in their difficult task of complex management and challenging metropolitan-controlled dynamics.
- Political economy is at the heart of the problems of metropolitan finance, both in developing and industrialized countries (Eaton, Kaiser and Smoke, 2011). Barriers are reflected in vested interests preserving the status quo; short-term time horizons and misaligned incentives as a result of postponing difficult decisions are also hurdles to be dealt with. Likewise, corruption in government agencies undermines the provision of effective public service and sound management of funding. As a result, central governments do not want to give up control and create political competition at the local

level, metropolitan managers do not want to introduce unpopular but essential local income measures. Competition between sub-metropolitan jurisdictions prevents effective coordination, and local administrators are not responsible for the effective management of the limited functions they have.

- Innovative funding and management practices have emerged. These include the use of information and communication technology (ICT) and geographic information systems (GIS) in land use planning and property taxes; the capture of capital gains (Seto *et al.,* 2014); emissions of metropolitan bonds; municipal development funds for funding, channeling and loaning, along with capacity building assistance; as well as the PPPs in the financing of infrastructure and alliances in neighborhood improvement.

It is clear that there are no universal solutions for urban governance and financial reform. Each country and each city has to find its own way. However, some recommendations may guide national and local authorities as well as external donors and advisors:

- Create a long vision. Involve national, regional and local institutions instead of quick and simple solutions; look for fundamental and lasting changes that require perseverance and courage to make difficult political decisions.
- Understand the history, institutions and political economy of each country and city. While solutions to problems of governance and metropolitan finance can work in one country and/or city, they will not necessarily do so elsewhere, unless they are adapted to the specific characteristics of local history, institutions, and political interest.
- Develop a comprehensive vision of the governance and fiscal conditions of each country and city. Even if interventions ultimately remain relatively narrow and selective (e.g. reform of a tax or a grant instrument), it is essential that they be seen within the broader institutional context of the country. Without an understanding of the context, limitations or unexpected unwanted consequences, there is the risk of impairing the effectiveness of interventions.

- Pay attention to effective governance (function, finances and officials) and for the triad of autonomy, accountability and capacity, in the right sequence. Allocation of financial resources should follow the rule of functional accountability, which depends on the vertical and horizontal governance structure that is put in place. Effective and personal management should be performed by local authorities for it to function well. Officials must have sufficient autonomy to do their job well, but they also have to be held accountable for results and have the knowledge and institutional capacity to function effectively.
- Activate the right financial instruments. Again, there is no easy transfer of an instrument from one place to another. However, it is worth exploring some innovative tax institutions and agreements, including those mentioned above: property taxes in general and land value specifically, based on ICT and GIS; competitive, results-based subsidies; well-regulated loan financing for infrastructure capital investments; public and private multi-stakeholder partnerships and alliances; and municipal development funds.

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Chapter 9

Gender, Climate Change and Cities: A Case Study of Gendered Climate Policy in Mexico City

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Introduction

Climate change is an imminent threat with consequences that will, and have been, differentiated, having a disproportionate impact on developing countries and on the underprivileged, such as the poor, the indigenous population, and women. On a local level, the magnitude of inequality between the privileged and the poor is comparable to that between developed and developing countries. In an urban context, inequalities are linked to accessing economic resources, education, political participation, and paying jobs. Because of gender roles due to unequal power dynamics that mediate social relations, women find themselves at a disadvantage in comparison to men when it comes to accessing these resources. Gender and Environment literature confirms that women have been the least favored in the face of a changing climate (Neumayer and Plümper, 2007). Nevertheless, we note that climate change has not affected nor will affect all women equally. Other social axes of power such as age, class, race, and ethnicity are equally important in fully understanding the consequences of climate change on a society. Climate change policies must consider this complexity in their design and implementation so that vulnerable groups do not continue to be at a disadvantage.

Literature on gender and the environment has mainly focused on rural areas, and has found that in the face of climate change, given the sexual division of labor that keeps them in the domestic sphere, women will spend more time collecting increasingly limited resources for household consumption, such as water, food, and firewood, limiting their ability to participate in decisions that will affect them directly (Vaquez and Velazquez, 2004; Skinner, 2011; Denton, 2002). Significantly less research exists on the impacts of climate change in urban areas from a gender perspective, but the socioeconomic position of women in urban settings makes this an important issue to study since in urban settings, women's social vulnerability will increase, reinforcing already existing inequalities. Research concerning gender relations in urban spaces finds significantly different lived experiences in the city due to gender roles, the sexual division of labor and the spaces and activities that men and women are allowed to navigate and conduct in an urban setting. A particular fragmentation is observed which segregates and excludes women and other marginalized social groups from participating in the public sphere, often obstructing their mobility as well as their social, political, and economic participation – reflected in occupational roles, salaries and the gendered wage gap (Navarro *et al.*, 2014).

The aim of this work is to underscore the current state of public policies around gender and environment in Mexico City, through the Mujer de Huerto program[1]; we analyze the impact of a gender and climate change program in Mexico City. The remainder of this chapter is organized as follows. We first introduce our theoretical and methodological frameworks through three main concepts: gender, intersectionality and vulnerability. We then underscore the importance of a gender perspective when designing and implementing climate change policies. Mexico´s biophysical and socio-economic vulnerability to climate change via a gender perspective is discussed next, to then underscore

1 Women´s orchard Program

the ways gender perspectives are developed and the way in which they are implemented in Mexico City. We present our findings around the currently operating program Mujer de Huerto to contextualize efforts in favor of gender equality and the environment in Mexico City. Finally, we will outline some recommendations for the program and general considerations so that climate change actions do not further marginalize and reproduce the inequality of vulnerable groups, but rather create spaces that invite participation and transformation.

Theoretical and Methodical Considerations

This chapter examines environmental public policy in Mexico from a gender perspective; the way it has been contemplated in legislation; its different legal instruments; and the way in which it has been implemented in Mexico City, through a case study analyzing the Mujer de Huerto program. Quantitative tools of social science research were employed, which mainly included researching Mexico City government sites, newspaper publications, and a semi-structured interview with an official from Mexico City's Ministry of the Environment (*Secretaria de Medio Ambiente de la Ciudad de Mexico* or SEDEMA in Spanish). Our theoretical framework includes concepts from critical feminism: gender, intersectionality and social vulnerability, which are pivotal in adequately researching environmental programs aimed at women. A critical perspective of these concepts allows us to evaluate the way in which they have been applied or not, by government institutions, and the challenges faced in implementing them.

Gender, according to Fernandez (1998: 83), can be understood as a series of values and beliefs, norms and practices, symbols and representations controlling the way in which men and women behave. The values of the gender system configure social relationships (De Barbieri, 2013) embedded in inequality and social exclusions. A gender perspective distinguishes those instances where gender gaps are produced and reproduced, in detriment of women. To analyze how gender roles overlap with other systems of oppression, we use the concept of intersectionality, which differentiates the experiences of women in diverse spaces and cultures to avoid homogenizing women's experiences (Crenshaw, 1991). Intersectionality highlights that gendered bodies can also experience other forms of oppression along other social signifiers such as race, class, ethnicity, age, sexuality, disability, among others. These signifiers must be understood as part of historical processes perpetuating practices of political exclusion and domination (Ibid). An intersectional framework becomes essential to ensure that programs aimed at women recognize that some women may suffer multiple forms of oppression. This way we can identify programs that might seem progressive, since they incorporate a gender component, but in reality, are reproducing colonialist, classist, and sexist relations.

Thus, we use the concept of intersectionality to understand vulnerability in the context of climate change. Arora-Jonsson (2011) stresses that it is problematic to assign women an intrinsic vulnerability entailing certain disadvantages, instead of understanding their vulnerability as a series of socially constructed complex power relations. We steer clear from notions which assume that women are naturally vulnerable due to biological/anatomical reasons, but stress that gendered disadvantages are the result of historical processes of exclusion and marginalization. Vulnerability to climate change from a gender perspective should attend to the conditions of fragility that women and men experience due to certain abilities and capacities that they were, or were not able to develop, to confront an environmental impact and react to it (Munguia, 2012: 2). In other words, conditions of vulnerability emerge from the sexual division of labor, through which different roles and degrees of power are assigned to men, women, the poor, the indigenous, etc

(Imaz, 2014). Gender vulnerability depends on various physical as well as social situations of risk, such as the frequency of natural phenomena and the degree of exposure to these, but also from the ability to avoid dangerous situations reducing elements of vulnerability before a disaster occurs (Munguia, 2012; Vazquez *et al.*, 2015). According to Vazquez *et al* (2015), more information is needed to correctly diagnose social vulnerability in Mexico in the face of climate change (Gay *et al.*, 2015). In addition, the issue of vulnerability to climate change and gender in Mexico, but most strikingly in cities, has been insufficiently studied.

Mexico´s current biophysical and socio-economic context towards Climate Change

Mexico, given its geographical position and social and demographic situation, is a country that is highly vulnerable to climate change (Sanchez *et al.*, 2011; CENAPRED, 2014). The country is susceptible to cyclones, hurricanes, and seaquakes, and because of its latitude, to earthquakes and the adjustment of land and sea plates. The orographic conditions of Mexico increase the risk of extreme events. For example, there are high volcanoes, some still active such as the Popocatépetl, and the Sierras Madres mountain ranges (Gay and Estrada, 2007; Sanchez *et al.*, 2011; Conde *et al.*, 2011; COLMEX, 2010). Biophysical changes due to climate change are more severe for people in poverty, particularly for women living in precarious situations. The National Center for Disaster Prevention (*Centro Nacional de Prevención de Desastres*, or CENAPRED in Spanish) estimates that 36% of the national population is severely exposed to natural disasters, 22% are moderately exposed and 42% face low risk (CENAPRED, 2014). Mexico City is subject to the same biophysical risks as the rest of the country, but faces additional problems such as pollution and the Urban Heat Island effect (UHI). Its socioeconomic vulnerability differs from the rest of the country due to its large area, demographic density, and being the financial center of the country.

Very few empirical studies exist in Mexico on cities and climate change from a gender perspective, but there are several studies of social vulnerability towards climate change that inform our research questions. For example, Sanchez *et al* (2011) point out that atypical changes in the weather in urban settings like Mexico City will diminish the availability of water, increase the rate of migration, and reduce incomes, all of which have impacts on food security and health, while increasing the marginalization of poor communities (Ibid). These events will disproportionately impact poor communities because of their limited access to basic resources, such as potable water. Due to a high population density, these communities might suffer an increased rate of illness, largely correlated with climate irregularity, while their low and unstable wages will fail to provide viable alternatives to improve their quality of life.

Data from 2010 indicate that 77.8% of the Mexican population live in urban areas, and this process of urbanization is on the rise. In 2012, of the 53.3 million people living in poverty in Mexico, 68.6% or 36.6 million lived in urban areas (INEGI, 2010). Poverty in the city is related to low levels of education, larger households, and female headed households (Ibid). The most impoverished areas in Mexico City are also the most vulnerable to climate change since they do not have sufficient monetary resources, access to preventive information or the mobility necessary to avoid or cope with climate impacts. Women, due to their social and economic status, will be impacted most. This is why it is important to prioritize climate policies in the most vulnerable areas of the city.

Vulnerability to Climate Change in Mexico City: A Gender Perspective

Cities embody a paradox because, while they are centers of innovation, sources of employment, and providers of many services, they are also areas of exclusion, marginalization, and profound inequality. The impact of climate change in Mexico City will affect water supply, provision of energy, and industry which will damage the local economy and deprive the population of goods and services, making it difficult to earn a living, and increasing migration to other urban centers (Sanchez *et al*., 2011). These consequences of climate change in cities reinforce existing inequalities, disproportionately affecting those who live in poverty, experienced differently by men and women (UNEP, 2007). Due to political, cultural, and social reasons, women have roles that make them more vulnerable, resulting in lower wages, unpaid care work, and an increased workload, all of which diminish their ability to withstand and recover from events caused by climate change. The General Social Development Law (or Ley General de Desarrollo Social; DOF, 2016) sustains that the measurement of poverty that is carried out by the National Council for Social Development Policy Evaluation (*Consejo Nacional de Evaluación de la Política de Desarrollo Social*; CONEVAL, 2014) must at least consider income, educational lag, access to health services, access to social security, quality of living spaces, access to basic services, access to food, and some degree of social cohesion (Ibid). Because women are at a comparative disadvantage to men in accessing all of the latter, it seems prudent that they be prioritized in efforts aimed at reducing social vulnerability to climate change (CEPAL, 2016).

A gender perspective is particularly important in the city because the number of female-headed households has increased by four percent between 2010 and 2015, reaching 29% of all households (INEGI, 2015). At the same time, women have less access to the formal labor market (only 45% of women participate in economic activities in comparison to 79% of men); when women participate in the labor market, they are paid only 62.6% of what men earn. In addition, 50% of women depend entirely on their partner or family, since they do not have an income of their own (data for people older than 14). Furthermore, the proportion of women that work without pay is larger than that of men, as well as their participation in the informal sector. The latter reaches a rate of 30.4% of women, as opposed to a 26.4% of men (INEGI, 2012). Additionally, women experience limitations to their mobility due primarily to the high rate of gender violence that takes place in public transportation, as well as a lack of financial resources that restricts their access to it. The violence to which women are exposed in the public sphere limits their physical mobility, increasing their vulnerability to climate change. Promoting economic independence for women could address gender violence and should be a priority in all policies that aim to counter inequality.

According to the National Poll of the Dynamics of Household Relationships (Encuesta Nacional de la Dinamica de las Relaciones en los Hogares, INEGI, 2011) in Mexico City, gender violence in the public spectrum has a significantly higher percentage than the nationwide average (18% more). Regarding sexual abuse, Mexico City is the entity with the highest number of aggravated women, with 60 % suffering this type of violence. In addition, women also suffer from high rates of violence in the private sphere: 49% of married women (or living with their partner) of 15 years of age or older have been victims of an act of violence by their partner at some point in their relationship, a percentage that also surpasses the nationwide average (44.9%).

Female-headed households suffer from food insecurity, and lack of social security and access to health services (CONEVAL, 2014). Even though Mexico City ranks highly in terms of food-secure households nationally, 6 out of 10 households suffer from food insecurity, and at least one in ten households reported lacking food in the three months before the survey.

National Gender and Climate Change Outlook

Mexico plays an important role in global climate matters; having been present in high-profile international debates has allowed the country to be recognized for its role in the Conference of Parties (COP) as a leader in promoting gender equality and human rights. Negotiations dealing with international agreements on gender and the environment began since the Earth Summit in Rio de Janeiro in 1992 with the Political Declaration in Agenda 21, where women were recognized as a "major group" in sustainable development, having a considerable impact on national policies on gender and climate change. The incorporation of the equality focuses on public policy first took place in 1995 with the National Women's Program: An Alliance for Equality (Programa Nacional de la Mujer: Alianza para la Igualdad or PRONAM 1995-2000; Ruiz and López, 2003), which had an impact on the environmental sector.

Currently, the issue of gender and the environment, at least in the formal sphere, is incorporated into normativity at all levels of government. At a federal level, article 71 of the General Law of Climate Change (Ley General de Cambio Climático, or LGCC) establishes that "Programs in federal entities will be developed…always seeking gender equality and representation of the populations most vulnerable to climate change…" (DOF, 2012). This same legislation establishes that the National Climate Change Strategy (Estrategia Nacional de Cambio Climatico or ENCC in Spanish) is the directive instrument of national policy regarding climate change, and must consider "aspects of gender, ethnicity, disability, inequality, health status, and inequality concerning access to public services, and involve the various sectors of society in its implementation" (SEMARNAT, 2013). It also considers the design and inclusion of gender in strategies that reduce social vulnerability as well as in educational programs (Ibid).

Some Climate Change State Programs (Programas Estatales de Cambio

Climático or PEACC) have already incorporated gender into their climate change policies as well as Climate Change Municipal Programs. These have been analyzed by Delgado, De Luca and Vazquez (2015) and report on the examples of climate policies with a gender perspective that are currently under way, concluding that, while there has been significant progress in implementing gender perspective at the state level, policies do not address the particular way in which climate change will impact women, and they do not focus on the underlying causes of inequality between the sexes.

Mexico City and Climate Change: A Gender Perspective

Currently, in its transition towards becoming Mexico City, the former Distrito Federal (Federal District) is undergoing a process of transition from a territory under the sovereignty of a Federal State to an autonomous federal entity, with a new political Constitution. In this context, the demand of incorporating a gender perspective is being discussed in the city´s development project, which was addressed in a forum of UN Women (2016). This forum discussed the need to establish a gender perspective in the development project of Mexico City, within the framework of the Agenda 2030 of Sustainable Development. Monitoring this process is essential to ensure the proper implementation of future environmental policies with a gender perspective.

Mexico City appears to be at the forefront of public policy dealing with gender and climate change, at least at a discursive level (see: Delgado *et al*., 2015). In this research, our aim is to outline existing public policies concerning gender and climate change in Mexico City and present the effects of these policies through a case study of a plan to promote orchards and vegetable gardens, aimed at women in Mexico City.

Climate change projects that integrate a gender perspective exist but are difficult to find in Mexico. There is limited information in the institutional pages about these projects; it is hard to discern when they began, who was and/or still is involved, what their assigned budget was, what was their goal, etc. It is mandated that all environmental policies containing at least one component regarding climate change should be consolidated in the Mexico City Climate Action Program (*Plan de Accion Climatica de la Ciudad de Mexico*, or PACCM 2014-2020). However, there are many isolated policies regarding climate change that are not systemized within the PACCM. To find a gender and climate change project then, it was necessary to conduct an internet search including newspaper sources which ultimately led us to the program we selected –Mujer de Huerto—as our case study. Although it is not formally incorporated in the PACCM, we consider it to be a climate change adaptation effort by the government of Mexico City.

Case Study: Mujer de Huerto

According to SEDEMA, the main objective of the Mujer de Huerto program is to train participants, to create urban gardens in their homes, with the purpose of promoting better eating habits, and reducing household expenses through the production of their own fresh and seasonal produce (SEDEMA, 2016-A and 2016-B). It aims to empower women who are vulnerable, through increasing their food security. The idea is that through home gardens, they can access nutritious and natural foods, free of pesticides, gain the knowledge to cultivate medicinal plants, and acquire skills to potentially run a small business that could lead to their economic empowerment. It is directed towards elderly women, single mothers, disabled women, housewives, indigenous women, and businesswomen (SEDEMA, 2016-A).

Mujer de Huerto is within the Mexico City public policy framework, in the General Development Program (*Programa General de Desarrollo*). Mujer de huerto started in 2014, having conducted three rounds of workshops. The third occurred from the 8-11 of March in 2016, at the Center for Environmental Education Ecoguardas (Centro de Educacion Ambiental Ecoguardas), with 70 participants. The program included five talks imparted by specialized personnel from the National Institute of Ecology and Climate Change (Instituto Nacional de Ecologia y Cambio Climatico or INECC), the Chapingo Autonomous University, the Women's Institute (Instituto de las Mujeres or INMUJERES), the University Food Program (Programa Universitario de Alimentos or PUAL), and the Botanical Garden of UNAM.

According to our source, the Mexico City Human Rights Program Earmarked 70,000 pesos for a gender program to be run by SEDEMA. We were told that at first, there was little interest in SEDEMA to create a gender project; however, officials who believed in the issue decided to carry out the program, especially because it was aimed at vulnerable groups in the city.

Given that the main purpose was to have a project that gave elderly women and housewives the opportunity to carry out productive activities, this project addresses vulnerability, since it has given priority to elderly women, indigenous women, heads of households, and physically disabled women like the deaf (the next program aims to include women in wheelchairs). The official informed us that the objective of the program was not only to educate women to care for home gardens, but to strongly emphasize the social, health, economic and environmental benefits resulting from their participation in the program.

Our informant explained that, to fulfill the gender dimension of this project, INMUJERES was invited to give a lecture on general topics involving gender without necessarily linking them to the program or in what ways a gender perspective could be useful. After the gender workshop, there was no follow up to ensure that a gender perspective had been adequately incorporated. This superficial incorporation of gender in the program Mujer de Huerto, such a vital and complex topic that could ensure more equitable and just climate solutions, is most likely replicated in other similar programs. Although the program Mujer de Huerto had a follow up survey regarding what they had learnt specifically about home gardens, there was no follow up regarding what they had learnt about gender and human rights.

An environmental program with a gender perspective was not easy to sell, according to the official we interviewed; the program had to overcome many obstacles, such as convincing the authorities that the project was important, since they believed that a gender project was not politically attractive, nor was it attractive to serve only 100 people with the allocated money in cost-benefit terms. Nevertheless, our informant expressed that despite the lack of advertisement of the program, and then only through social media, there was a very high demand. In fact, the next generation of this project will be allocated around 1.5 million pesos, and will be expanded to serve over 700 women.

One of the program's strengths consists in guaranteeing food security, since current projections for 2030 demonstrate that expenses on food supplies will continue to rise, given the rising scarcity of water, soil and fuel, increasing food prices and generating higher levels of poverty (FAO, 2007; Sanchez *et al*., 2011). Additionally, the nutritional status of the inhabitants of Mexico City is in critical condition, both for men and women. In that sense, the program has been successful in addressing certain conditions of vulnerability, since we were told that those who have taken part in it have achieved the harvesting of medicinal plants, fruits, vegetables, and their own compost.

It is worth mentioning that, as stated in its name, the program is aimed at women. Taking this into consideration, we must point out that it adds to women's double workday, given that now they also have to take care of home gardens, as well as other consequential responsibilities such as the preparation of medicinal remedies for the sick, on top of their usual responsibilities around the workplace and the home. By incorporating men into the program's context, responsibilities could be distributed more equally and traditional gender roles could begin to be blurred.

A gender perspective underscores the danger of taking advantage of women's reproductive social role to subsidize what the state should be providing (Nagar *et al*., 2002). In this case basic food security. To focus solely on women, we limit the scope to the quintessential historical roles assigned to women as natural caregivers, being the ones solely responsible for ensuring their family's nutrition. By doing so, we hide other pressing visible problems and lose opportunities to make significant changes.

Conclusions and Recommendations

Below we provide a series of recommendations to enhance the transformative potential of incorporating a gender perspective into environmental programs such as Mujer de Huerto. Our recommendations enunciate in more general terms how a gender perspective can be beneficial if contemplated in Mexican normativity at all levels, to execute programs that can have a greater impact towards reducing women's social and biophysical vulnerability. It is worth mentioning that we discovered a strong willingness and enthusiasm by the SEDEMA personnel to further improve the program, as well as to increase awareness towards environmental issues and their implications for human health. While it is possible to improve the ways that gender was incorporated, thus increasing the benefits of the program, our informant expressed that it has had a positive impact on women who had the opportunity to participate because it allowed them to harvest nutritious foods and medicinal plants, and has served as occupational therapy for elder women, all of these having potential to help reduce the vulnerability of women while improving their quality of life.

We came to the realization through the Mujer de Huerto program (and surely this would be the case in other programs with gender perspective) that an increased and more active participation is required from INMUJERES or from the Secretariat of Women of the Federal District (*Secretaria de la Mujer del Distrito Federal*). Additionally, we believe that a proper implementation of a gender perspective necessitates inter-agency collaboration and the support of academia and civil society organizations. A gender perspective requires an exercise of reflexivity, in which gender becomes a category of analysis that allows re-designing environmental programs aimed at mitigating or adapting to climate change, in addition to struggling for sustainability, in ways which also promote the empowerment of women, eliminating the hierarchical structures that oppress them. To achieve this, we consider it essential to invite the women and men targeted for the project to be consulted about their needs and how they believe that resources can be used, right from the project design phase. We also consider that gender oriented projects must incorporate men so that traditional roles of women as caretakers can be disrupted in such a way care for home gardens and the responsibility for selecting and cooking food is shared with men. This would require incorporating a gender perspective at each stage of the program, that could be reflected later when participants are invited to demonstrate their acquired knowledge of the program; a critical focus that challenges gender as a series of social and cultural constructions which can be transformed and questioned for the benefit of women, but also men, is required at all times. Thus, a gender perspective must go beyond a simple incorporation of women into environmental programs risking adding extra burdens to their already full workdays; a gender perspective is required in the planning, design, implementation and control of the programs. This would require longer-term solutions, rather than short-sighted immediate environmental benefits, aimed at addressing socio-environmental problems from the root and understanding the ways in which women are made more vulnerable than men to the negative effects of climate change.

Taking full advantage of what exists already in the legislative framework will require allocating more resources to meet the needs of women in the face of climate change through programs that focus on the most vulnerable areas of the city, that incorporate both gender and environmental dimensions. Resources should also be used to monitor and ensure that those programs that incorporate a "gender perspective" are doing a good job. A gender perspective has become one of the guiding axes of the Mexico City's Climate Action Program; nonetheless, it is apparent that although many of the actions indicate the incorporation of gender perspective, future analysis is required to measure their scope and impacts. In addition, the lack of systematization is clear for all policies related to climate change with gender components that are dispersed rather than systematized. This is the case of actions related to gender and the environment, which are not necessarily all contemplated in the PACCM. Similarly, we are aware of the serious obstacles in accessing information about the programs that are currently operating, so more transparency is needed. A centralized system of gender and environmental projects would be useful, in which information on resources, how these are used, and who is responsible for each project can be found. Designing systems of evaluation that could measure the ways these programs are contributing to the situation of gender in the country would also be an important task. In addition, we found that disaggregated data is needed to better understand gendered vulnerability vis à vis climate change. Mexico needs indicators of social vulnerability that consider and incorporate class, age, gender, type of water supply, number of hours spent giving care to family members with illnesses related to climate change, number of hours spent recovering from and cleaning up after a disaster, home ownership, access to public transportation, security, the number of women who suffer directly from floods, heat waves, lack of water, etc. This index should also incorporate women's economic activities, their participation in decisions inside and outside the home, their level of education, their access to information and health services, if they have retirement insurance and whether they participate in government programs.

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Capítulo 10

Climate Change Education: an analysis of the Educational Measures in Climate Action Plans of Urban Municipalities in Mexico

Veronica Vazquez Zentella

Regarding the climate change issues that confront us, education is an essential component and a catalyst for responding to the challenge, since it contributes to the acquisition of competencies[1], concepts and instruments that lead to climate-resilient development in the face of the risks related to climate change, and encourages the participation and commitment of people in mitigation measures (UNESCO, 2016-A).

Educating for climate change entails the implementation of mitigation and adaptation measures[2] in response to this phenomenon. In this endeavor, such education helps individuals to make informed decisions as it fosters understanding about the causes and effects of climate change with which sustainable lifestyles[3] can be encouraged and the vulnerability of communities

1 Even though competency is often defined as the set of "knowledge, attitudes and skills necessary to perform a given task or activity" (Yaniz, 2008), in this work we coincide with Bernard Rey (1996): competency is the ability to generate applications or solutions adapted to each situation, mobilizing one's own resources and regulating the process to achieve the desired goal.

2 Climate change mitigation is geared towards reducing greenhouse gas emissions, as well as increasing carbon sinks or other forms of capture. Adapting to climate change implies understanding current and expected changes in order to reduce vulnerability to adverse weather impacts.

3 This includes waste reduction, efficient use of water and energy, better use of public transport, support for environmentally friendly policies, citizen participation and environmental

can be reduced in the face of an uncertain future. Thus, adaptation to climate change includes not only identifying vulnerabilities and risks, but also prioritizing certain areas worthy of attention in the short, medium and long term in an uncertain climate scenario[4] (UNITAR, 2013).

Correspondingly, the research conducted by Kawaga and Selby (2012) on climate adaptation points out that knowledge acquisition and skill development, which may be of a technical nature, such as learning drought or flood-resistant agricultural practices, becomes necessary to tackle climate impacts, while such actions help to maintain a vigilant mentality that encourages understanding and addresses climate change, which, while omnipresent, can also be stealthy and often invisible.

Similarly, studies conducted by Lutz, Muttarak, and Striessnig (2014) demonstrate that education contributes to vulnerability reduction and adaptive capacity enhancement in the pre-disaster phase and during disaster events and disaster aftermaths. It was also found that people with more formal education[5] coped better with income loss and the psychological impacts derived from the effects of natural disasters. Furthermore, Climate Change Education reduces disaster-related mortality, as the more educated tend to have greater risk awareness, which is initiated by perception of risk and followed by assessments of one's ability to respond to the threat, and understanding of the

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activism, among other actions (UNESCO-A, 2016).

4 Some actions aimed at adapting to climate change include collecting and storing rainwater so that it can be reused in crop irrigation and animal care; the use of natural barriers such as trees that help reduce the effects of wind and large flows, such as floods caused by heavy rains or overflowing rivers; eliminating agrochemicals use and the practice of burning the land in preparation for sowing; the promotion of food security and sovereignty, and the organization of modules in order to respond to natural disasters.

5 With this we refer to schooling in general.

consequences of their actions. Moreover, Climate Change Education brings community level co-benefits, such as lowering infant mortality as an evident effect of female education as it also opens opportunities of social interaction with more-educated members of the community.

Paradoxically, in urban contexts, it is often the most educated people that lead the most carbon intensive lifestyles as they generate the most waste and greenhouse gases (GHG) emissions (Vaughter, 2016).

However, as the inhabitants of urban settlements[6] are the main contributors to direct and indirect GHG emissions[7] and, therefore, the biggest generators of the climate issues, they are also key players in tackling them, while playing a strategic role in the solution process.

Therefore, it is necessary to emphasize that, even though the role of schooling[8] in the understanding of environmental issues is increasingly recognized to address the challenges of climate change, it is lifelong learning –that is, what is learned from everyday experience– which also promotes, without a doubt, the change of individual and collective behaviors (UNESCO, 2016-A).

6 In Mexico, as from the 2010 National Census, urban settlements are considered to be those with more than 15 thousand inhabitants; before that, 2,500 inhabitants qualified as an urban population (INEGI, 1996).

7 Urban settlements contribute with 67% to 76% of global emissions from energy consumption (Seto *et al.*, 2014).

8 The primary contemporary approach to addressing environmental challenges via education is through formal schooling. Schooling helps students understand a particular environmental problem, its consequences and the precise types of action required to address it. With improved environmental literacy, students are more inclined to change behaviors that affect environmental problems. Therefore, knowledge about the environment is increasingly being incorporated into the curricula of formal school education. Thus, the analysis of 78 national curricula in different countries shows that 55% of them use the term "ecology" and 47% the term "environmental education" (UNESCO, 2016-B).

In this sense, the General Law of Climate Change (DOF, 2012) establishes as one of its objectives to promote education and dissemination of culture in the field of climate change, which has been well received by the Municipal Climate Action Plans, while the category Education and Social Participation[9] appears in all the Climate Action Plans of the revised urban municipalities[10], concentrating 133 measures or actions, as detailed below in Table 1.

Table 1: Educational and social participation measures in Municipal Climate Action Plans

Municipality	*Area*	*Measure*
Benito Juarez, Mexico City	Water	1. Educational promotion of rainfall collection.
	Waste	2. Environmental workshops to reduce, reuse and recycle. 3. Encouragement of citizen's reports on clandestine dumps (accompanied by surveillance operations).
	Others	4. Awareness campaigns on climate change. 5. Educational talks. 6. Dissemination in streets and in neighborhood committees. 7. Promotion of citizen reporting and civic culture.

9 The categories addressed in the Municipal Climate Action Plans are: Health, Buildings, Energy, Water, Disaster Prevention, Transportation, Waste, Space Planning, Regulation and Research, Social Programs and Others.

10 The revised Climate Action Plans correspond to urban municipalities with populations greater than 500,000 inhabitants (Delgado, De Luca and Vazquez, 2015).

Municipality	*Area*	*Measure*
Tlalpan, Mexico City	Water	8. Training on water conservation.
	Waste	9. Social support for the promotion of a waste-management culture. 10. Workshops on waste management and composting.
	Others	11. "Ecotips" in social networks. 12. Campaigns to raise awareness of climate change. 13. Environmental education focused on mitigation. 14. Campaigns for communication and dissemination on climate change. 15. Mobility workshops, urban gardens, among others. 16. Cyclothon (promoting bicycle use). 17. 300 Ecologists for Climate Change program (voluntary registration of citizen actions in social networks).
Naucalpan, Mexico State	Water	18. Publishing the population's water consumption through their bills.
	Waste	19. Encouragement of the culture of recycling.
	Energy	20. Publishing the population's energy consumption through their bills.
	Reforestation / soil conservation	21. Opening of the "House of the Earth" (venue for events and environmental education).
	Others	22. Design of a non-formal environmental education program. 23. Road safety education and pedestrian education campaign.

Municipality	*Area*	*Measure*
Tlalnepantla de Baz, Mexico State	Disasters	24. Prevention campaigns in places vulnerable to the effects of climate change. 25. Increase in civil protection culture to prevent disasters and forest fires.
	Water	26. Dissemination of a water conservation culture.
	Energy	27. Dissemination of an energy saving culture.
	Waste	28. Dissemination of information on waste management (including information on waste management programs, batteries, etc.). 29. Program for biodiesel production from waste cooking oils (Biofuels of Mexico).
	Others	30. Environment Week. 31. Environmental education talks. 32. Ecological Inspectors Program in primary schools and guided visits to the landfill. 33. Organization of environmental events (environment week). 34. Promotion of home gardens. 35. Attention to environmental complaints.
Guadalajara, Jalisco	Water	36. Water conservation education.
	Health	37. Pest information to the population. 38. Disease prevention campaigns.
	Energy	39. Energy efficiency programs.
	Others	40. Promotion of culture, education and environmental training (for industry, schools and citizenship). 41. Website with information on climate change. 42. Promotion of the advantages of painting ceilings white. 43. Mandatory environmental education at basic levels.

Municipality	*Area*	*Measure*
Zapopan, Jalisco	Water	44. Environmental education in schools and community for water conservation.
	Health	45. Campaigns on the impacts of sun exposure (sunstroke).
	Energy	46. Environmental education in schools and communities on the efficient use of energy.
	Others	47. Creation of the Municipal Environmental Education Directory. 48. Network of social leaders who disseminate information on climate change. 49. Public awareness campaigns on climate change. 50. Environmental education for citizens. 51. Creation of working groups among society.
Puebla, Puebla	Reforestation / soil conservation	52. Promoting citizen participation in reforestation.
	Others	53. Awareness-raising campaigns on climate change and responsible consumption (emphasis on public and private dependencies). 54. Communication and dissemination workshops and campaigns. 55. “Ecotips”.
San Nicolas de los Garza, Nuevo Leon	Health	56. Preventive health culture to improve life quality.
	Disasters	57. Disaster prevention culture entailing risk reduction, first aid and emergency response training.
	Others	58. Promotion of environmental culture through talks in schools. 59. Informative brochures.

Municipality	*Area*	*Measure*
Toluca, Mexico State	Waste	60. Reduction in the use of packaging.
	Others	61. Dissemination of ecotechnologies. 62. Environmental education center. 63. Dissemination of measures such as safeguarding documents. 64. Informative brochures.
Aguascalientes, Aguascalientes	Water	65. Campaigns to raise awareness directed at the industrial sector on water conservation.
	Health	66. Information on the health consequences of climate change. 67. Training for disease prevention.
	Energy	68. Workshops on energy efficiency and renewable energy.
	Reforestation	69. Training on species affected by climate change.
	Waste	70. "Playing and learning to manage my waste" program.
	Others	71. Campaigns to raise awareness in the industrial sector about greenhouse gas emissions. 72. Workshop on urban gardens and sustainable agriculture. 73. Training on how to deal with natural disasters.
Benito Juarez, Quintana Roo	Waste	74. Solid waste recycling talks and information. 75. Local clean-up days to promote citizen awareness.
	Disasters	76. Identification and training of community leaders in disaster prevention. 77. Awareness-raising campaigns on potential risks and on actions to reduce them.
	Others	78. Awareness-raising campaigns on domestic wildlife catching and yard cleaning. 79. Distribution of brochures.

Municipality	*Area*	*Measure*
Celaya, Guanajuato	Health	80. Prevention campaigns on sunstroke and diarrheal diseases. 81. Campaigns to raise awareness on the health implications of climate change.
	Energy	82. Energy saving culture.
	Disasters	83. Dissemination of the Civil Protection Contingency Plan. 84. Promotion of the Prevention Culture Program. 85. Forest Fire Prevention Program.
	Others	86. Environmental and climate awareness campaigns, as well as road safety education. 87. Dissemination of adaptation measures to climate change.
Cuernavaca, Morelos	Waste	88. Campaigns to raise awareness through talks. 89. Workshops on waste sorting.
Jiutepec, Morelos	Waste	90. Waste education (separation, recycling and proper handling of batteries).
	Energy	91. Energy saving culture.
	Others	92. Courses and workshops on environmental issues and climate change.
Temixco, Morelos	Waste	93. Training on reuse and recycling.
	Energy	94. Good practice days for energy efficiency. 95. Awareness raising campaigns to reduce energy consumption through “ecotips”.
	Others	96. Public awareness campaigns on climate change and sustainable development, including employees from public institutions. 97. Promotion of green purchasing.

Municipality	*Area*	*Measure*
Xochitepec, Morelos	Waste	98. Citizen awareness and participation program on waste sorting (organization of community brigades).
	Water	99. Water conservation and its responsible consumption.
	Disasters	100. Campaigns for dissemination of actions in case of an environmental contingency.
	Others	101. Environmental Education Classes.
Culiacan, Sinaloa	Waste	102. Environmental waste education (reduction and reuse culture).
	Health	103. Prevention campaigns on sunstroke and diarrheal diseases. 104. Awareness of the health implications of climate change.
	Disasters	105. Dissemination of the contingency plan for civil protection. 106. Prevention culture.
	Others	107. Environmental education "A conscious school to improve the environment". 108. Climate change awareness campaigns. 109. Dissemination of the planned adaptation measures to climate change. 110. Promotion of regulations on the orderly growth of the city.
Oaxaca, Oaxaca	Waste	111. Information to raise population's awareness by informing on water reuse measures.
	Others	112. Awareness-raising and education program on climate change and its impacts. 113. Permanent workshop on environmental culture "de-growth by reduced consumption". 114. Information campaign on the importance of respecting natural water channels. 115. Identification of leaders in climate change.

Municipality	*Area*	*Measure*
Xalapa, Veracruz	Waste	116. Culture of waste sorting.
	Health	117. Information on the health effects of climate change (municipal surgeries, health days and visits by health supervisors).
	Disasters	118. Guidance to the migrant population on the danger of occupying high-risk areas.
	Others	119. Awareness-raising seminars for the implementation of urban recovery and environmental protection projects. 120. Promotion of cultural and artistic environmental activities. 121. Brochures.
Poza Rica, Veracruz	Waste	122. Environmental education on integral waste management.
	Water	123. Promotion of water conservation.
	Health	124. Information campaigns on preventing diseases associated with floods and heat stroke.
	Disasters	125. Campaigns to disseminate safety measures. 126. Media use for preventive campaigns.
	Others	127. Junk disposal campaigns in coastal communities. 128. Preventive campaigns to disseminate basic security measures.
Tuxtla Gutierrez, Chiapas	Waste	129. Information and education on waste management.
	Health	130. Information and awareness campaigns to prevent dehydration and other health problems.
	Disasters	131. Promotion of a culture of prevention.
	Others	132. Sustainability Education targeted on pedestrians. 133. Promotion of citizen's participation.

Source: author's elaboration with data from Delgado, De Luca and Vazquez, 2015.[11]

11 Annex 3 of the book Adaptacion y mitigacion urbana del cambio climatico en Mexico

While it is true that the incorporation of educational measures in all the revised Municipal Climate Action Plans represents a major effort by the municipal authorities, and an essential step to address current and future climate challenges, we can see the utilization of the educational sector as a strategic resource to mitigate and adapt to climate change. The bulk of educational measures are sensitive to improvements in at least two important aspects: (A) the implementation of the measures, that is, the methodology for their achievement, and (B) the thematic axes of these measures, that is to say, the categories that are targeted by these actions.

A. Implementation of educational measures

Even though *Education and Social Participation* is the only category that appears in all the Municipal Climate Action Plans in Mexico, it is not yet clear how its implementation can get the best possible results. To examine this, we classify the 133 educational measures presented in the 21 revised climate action plans (Delgado, De Luca and Vazquez, 2015) into three categories, according to the methodology they propose.

On the one hand, we see that, as established in article 9, section V, of the *General Law on Climate Change* (DOF, 2012), municipalities are responsible for conducting educational and information campaigns, in coordination with the State and Federal Governments, to sensitize the population on the adverse effects of climate change. As a result, most of the educational measures proposed in the Municipal Climate Action Plans follow a traditional approach and a linear process in which "informing" is presented as the most important educational objective. This group of measures could be denominated

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(Delgado, De Luca and Vazquez, 2015) presents all the adaptation and mitigation measures proposed in the 21st Municipal Climate Action Plans which are reviewed in this work.

"passive", since they are limited to inform without promoting any kind of participation or educational activities, such as analyzing and reflecting on their own values, attitudes and behaviors that, inscribed in the patterns of production and consumption, affect the environmental problem. The mere fact of informing on climate change cannot, by itself, achieve the modification of a current way of life. In this regard, research has shown that information alone is not enough for societies to change their behavior. It is crucial to emphasize the importance of competence for action.[12] Climate change education requires not only a commitment to inform, but a commitment to act (Vaughter, 2016). However, 40.6% of all proposed educational measures are geared towards giving information, either through leaflets, talks, "ecotips" or campaigns.

Regarding the latter, it is important to bear in mind that, if a campaign is to be carried out, for example, confronting a specific environmental problem, it must indicate its causes and how it is possible for people to solve it, given enough time, as was the case of the public awareness campaign launched by the Ethiopian government and its partners during two years to encourage the use of solar lighting products (UNESCO, 2016-A).

On the other hand, there are educational measures that could be classified as "active", which are characterized by the application of information; that is, educational measures that are oriented to action. Learning by doing offers an understanding of integrated concepts, knowledge and practical skills that can be applied. This is the case of the Cyclothon, and also of workshops on energy efficiency and renewable energies and workshops on waste sorting,

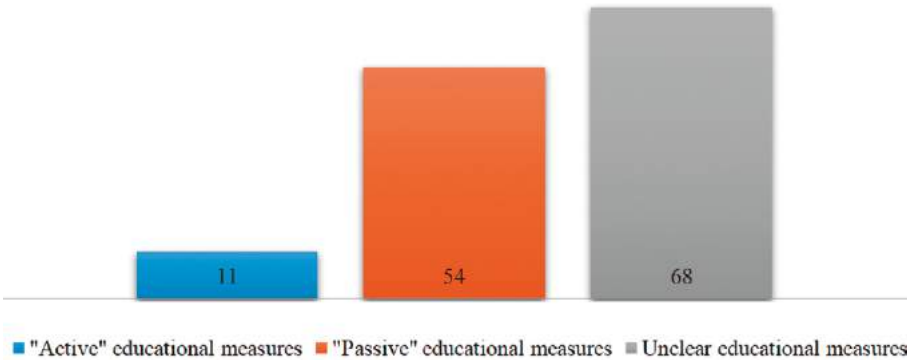
12 Experiential learning, outlined by John Dewey (1938/2010) in his work *Experience and Education*, is based on the assumption that knowledge is created through transformation brought by experience; that is, learning is based on the principle that people learn best when they come into direct contact with their own experiences. Thus, for this author, learning must be active in order to generate changes in the person and in his/her environment.

waste management and composting in which the participant plays an active role. Also, the workshops on urban gardens and sustainable agriculture stand out since they represent a situated experience through which values are learned, a connection with nature is created and environmental competences are developed with a sense of place (UNESCO, 2016-B). This is the most desirable type of implementation of measures and yet, the scarcest, with only 11 measures[13] in this group, that is, only 8.2% of the total.

Finally, there are a number of measures that are imprecise, given their ambiguity. These are the measures that use terms such as “programs” or “classes” and concepts such as “health culture”, “culture of prevention”, “environmental education” or “sustainability education”, which do not explain what is meant by that nor how it is intended to be implemented. It is noteworthy that out of the 133 measures analyzed, the largest group is the one of inaccurate or unclear educational measures, which includes 68 measures, or 51.12% of the total educational measures proposed in the Municipal Climate Action Plans, as can be seen in figure 1.

13 This is the case of measures 2, 10, 15, 16, 32, 52, 66, 70, 87, 90 and 111 that are presented in Table 1.

Figure 1. Number of educational measures by type of implementation



Source: author's elaboration with data from Delgado, De Luca and Vazquez, 2015.

B) Main themes of educational measures

It should be noted that education is interrelated with all other sectors, while health, nutrition, water and energy sources, among others, are essential for education.[14] Thus, in order to build a culture that strengthens Mexico in terms of climate and to promote the achievement of the mitigation and adaptation objectives that have been established in the national climate policy, an educational approach is needed in order to integrate all the concerted thematic axes. Thus, a holistic approach is indicated to address multidimensional challenges (UNESCO, 2016-A).

Nevertheless, the educational measures proposed in the Municipal Climate

14 For example, access to water and energy has a positive influence on education. In Ghana, reducing the time spent carrying water increased school attendance for girls and adolescent women, especially in rural areas. In rural Peru, the increase in the percentage of households with access to electricity led to an increase in children's study time (UNESCO-A, 2016).

Action Plans are oriented to a certain thematic axis, in which a particular predilection or preference for some issues is noticeable, as can be seen in Table 2, underlining a preference for certain items or categories and, in consequence, neglecting others.

Table 2. Thematic axes of the educational measures proposed in the Municipal Climate Action Plans		
Thematic axes	*Number of measures that address it*	*Percentage of measures that address it*
Reforestation and soil conservation	3	2.26 %
Energy	9	6.77 %
Water	10	7.52 %
Health	13	9.77 %
Disasters	15	11.28 %
Waste	20	15.03 %
Others	63	47.37 %
Source: author's elaboration with data from Delgado, De Luca and Vazquez, 2015.		

As can be seen in Table 2, the least addressed theme is Reforestation and Soil Conservation, which is noteworthy given that Mexico is among the countries with the greatest deforestation in the world; only in the 2005-2010 period, 155,000 hectares of forests and jungles were lost per year (Chavez Maya, 2014).

In the Energy category, the 9 measures proposed are aimed at energy saving and efficient use of energy. It is odd that, if education on climate change should promote the learning of new knowledge and skills that result in the mitigation and adaptation to climate change, we do not find in this category any workshops aimed at the production of heaters and solar panels, which, in addition, may mitigate GHG, and also increase the energy security of users, thereby enabling access to power which is independent from the grid, which becomes particularly important in the event of a disaster.

Similarly, our attention is drawn to the fact that Water is the subject of only 10 educational measures, 7.52% of the total, since in our country there are 90 million Mexicans living with water shortages (Sin Embargo, 2016), and that of these 10 measures, 9 concentrate on the efficient use of the precious liquid and only one is oriented to the educational diffusion of rainfall collection, which we consider to be of utmost importance since it allows us to reduce the energy consumption derived from the pumping from remote sources, while increasing water security.

Despite the fact that Mexico is highly vulnerable to climate change, as it is estimated that 80.86% of the 2,457 municipalities that comprise the country have high vulnerability and high risk of occurrence of climatic events (SEMARNAT, 2013), only 15 educational measures are aimed at Disasters. Note that one of the most important attributes of climate change education should be to prepare people to cope with the adverse effects of climate; that is, to develop and strengthen their adaptive capacity[15] by identifying priority areas of attention, potential risk reduction options and the effective participation of community actors (Gallardo Milanes, 2013).

On the other hand, one of the thematic axes that concentrates a greater number of educational measures is Waste. As an example of this, we should mention that in Mexico City and its metropolitan area, more than half of the environmental school projects are focused on waste, which are generally

15 Education can help communities prepare for climate-related disasters and adapt to their consequences. According to a study on Cuba, Haiti, and the Dominican Republic, lack of education and low literacy rates prevented people from understanding disaster warnings (UNESCO-A, 2016).

reduced to promoting the collection of solid waste for recycling purposes. It is important to point out that recycling entails an energy cost in itself and, consequently, an important environmental cost, so the best measure for waste management is to avoid its generation (Gonzalez Gaudiano, 2007).

Finally, in the Others category, all the measures that maintain a general orientation to the environmental theme are noted, without concentrating on a specific one, such as environmental education programs, sustainability education, environmental protection awareness days and climate change awareness, among others.

Conclusions

Climate change education requires the acquisition of new knowledge and skills in order to mobilize responsible actions and achieve significant behavioral changes in current patterns of production and consumption, as well as reducing the adverse effects of climate change and greenhouse gas emissions through more sustainable lifestyles.

We insist that, in order to achieve transformative effects, it is necessary to go beyond merely providing information on issues related to the environment and sustainability, and, instead, start fostering relational, integrative, empathic, anticipatory and systematic reflection. Therefore, to close the gap between knowledge and action, policymakers must move from educational measures that simply convey information to those that are most significant and genuinely committed to achieving long-term systemic change.

Educating to face climate change implies developing the necessary skills to deal with this phenomenon, by promoting the processes of social appropriation of knowledge in the new generations, concerning mitigation and adaptation to climate change, as well as to promote learning activities that are oriented to the development of capacities that allow individuals to cope with the present and future climatic challenges, promoting an improvement in the life quality of all human beings.

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Cities are, directly and indirectly, key responsible actors of current global environmental degradation, including the anthropogenic emission of greenhouse gases, which are the main cause of climate change. They are the places of residence of more than half of the global population, where most of the political power and wealth are concentrated, where a great deal of goods and services consumption takes place, and where most infrastructure is sited. Due to the current rate of urbanization, never seen before in human history, cities are now considered part of the solution, meaning that they offer an opportunity for change, and thus, for taking corrective and preventive measures, all within a time frame for action that is getting shorter every day.

Climate Change Sensitive Cities offers an interdisciplinary assessment of the increasing sensitivity of cities to the risks associated with a changing climate. It explores the opportunities for taking adaptation and mitigation measures while stimulating an integral and holistic approach for evaluating and managing cities, including those opportunities and synergies present in the so-called urban nexuses. It also takes into account key cross-cutting issues such as financing, gender, climate change education and social participation.

This compilation, authored by academics and decision makers from both Mexico and the U.S., seeks to enrich the reflection on the current state of affairs, as well as on the opportunities and challenges for urban transition and transformation towards more sustainable, resilient, just and inclusive urban settlements.