Mitig Adapt Strateg Glob Change (2014) 19:969–996
DOI 10.1007/s11027-013-9455-1

ORIGINAL ARTICLE

From federal to city mitigation and adaptation: climate change policy in Mexico City

Fabiola S. Sosa-Rodriguez

Received: 18 October 2012 / Accepted: 1 March 2013 / Published online: 7 May 2013

Abstract Climate change is projected to affect Latin America and the Caribbean as a result of increased temperatures and changed rainfall patterns. The impacts of climate change are expected to be unevenly distributed throughout the region, due to differences in geographic location, demographic pressures, levels of poverty, and natural resource dependence. To date, few studies have explored these impacts and the governmental responses to cope with them at a city scale. This article examines the challenges faced by the Mexico City government as it translates the federal climate change policy into successful mitigation and adaptation. It analyzes climate change impacts on Mexico and Mexico City (also known as the Federal District), the federal and city's mitigation and adaptation responses, and advances and contradictions in the implementation of these strategies at the national and city levels. Similar problems have limited the effectiveness of these actions at both the federal and city levels, including the overexploitation of natural resources, a lack of climate information and monitoring systems, and the subordination of climate change strategies to the objectives of economic growth and poverty reduction. These problems have resulted in poor coordination and collaboration among various levels of government to cope with climate change, in addition to avoiding local capacity building, particularly in regard to forest conservation.

Keywords Adaptation · Advances · Challenges · Climate change policy · Climate scenarios · Federal and city scale · Mexico · Mexico City · Mitigation

1 Introduction

Global mean temperature is projected to rise by 1.1 to 6.4 °C by 2050 if the current rate of increase of greenhouse gas (GHG) emissions is not slowed. Even if emissions stabilize, the global temperature is projected to rise by 0.9 °C by 2100, with severe impacts worldwide

F. S. Sosa-Rodriguez (✉)
Economic Growth and Environment Group, Department of Economics, Universidad Autonoma Metropolitana (UAM)-Azcapotzalco, Av. San Pablo Xalpa # 180. Reynosa Tamaulipas, Azcapotzalco, Mexico City 02200, Mexico
e-mail: fssosa@gmail.com

(Solomon et al. 2007). Latin America and the Caribbean (LAC) are likely to be affected by increased temperatures and changed rainfall patterns (Magrin et al. 2007; Boulanger et al. 2006a, b; Aguilar et al. 2005), which could have a range of negative consequences. These include biodiversity loss and the extinction of fragile species, reductions in crop productivity with negative consequences for food security, sea level rises and intensification of hydro-meteorological events, glacier receding and disappearance, and decreases in water availability (BID 2012; Magrin et al. 2007; Nagy et al. 2006; Conde et al. 2006; Eakin 2005; Magrin et al. 2005; Brown et al. 2000).

The impacts of climate change are expected to be unevenly distributed throughout LAC due to differences in geographic location, demographic pressures, economic specializations, levels of poverty, and natural resource dependence (EuropeAid 2009). Small islands in the Caribbean are considered to be the most vulnerable areas because they are more susceptible to sea level rises (Tompkins 2005). Most LAC countries have made efforts to reduce GHG emissions and adapt by protecting their forests and ecosystems, setting up early warning systems, implementing strategies to deal with droughts and floods, and building infrastructure in their coastal areas to avoid the adverse consequences of rising sea levels (Magrin et al. 2007; Conde et al. 2006; Chandler et al. 2002). In Bolivia and Peru, for example, local vegetation types that are able to adapt to new microclimates have been identified, and have been used in place of some crops. In Brazil, the federal government has reduced deforestation in the Amazon by implementing land-use enforcement mechanisms that sanction private companies that extract raw materials from illegally deforested areas (EuropeAid 2009). In Mexico, efforts have been made to reduce energy consumption through the use of sustainable household thermal insulation, high efficiency air conditioning, and fluorescent rather than incandescent bulbs.

Despite these advances, LAC nations share common problems that limit effective mitigation and adaptation (M&A), including the overexploitation of natural resources, a lack of climate information and monitoring systems, and the subordination of climate change strategies to the objectives of economic growth and poverty reduction. Moreover, although the majority of countries in this region (e.g., Mexico, Chile, Brazil, Argentina, Uruguay, Venezuela, El Salvador, Costa Rica, and Colombia) have produced national climate action plans and at least one emissions inventory, these instruments have been used exclusively for reporting purposes, and have not been translated into specific planning or monitoring actions (EuropeAid 2009).

More research is required to improve our current understanding of the impacts of climate change at the city and local levels in developing countries, since by 2030 these nations will account for two-thirds of the world's population. Developing nations are more exposed to the impacts of climate change because of their reduced capacity—both financial and technological—to cope with its effects and their strong dependence on natural resource exploitation (Eakin and Lemos 2006). However, climate change is only one factor among many that must be considered by governments of developing countries; hence, policy makers need to adjust their actions such that they support M&A while not hindering development (Lim et al. 2004).

To date, few studies have explored the impacts of climate change on LAC at the city and local scale. Thus, this article seeks to analyze the impacts of climate change on Mexico and Mexico City (also known as the Federal District), in particular the efforts of the federal and city governments to mitigate and adapt to climate change, and the degree to which the city government's actions fit the federal climate change policy. This analysis provides a useful example of the challenges faced by city governments in the developing world as they endeavor to translate federal policy into successful actions. Finally, this research examines advances and contradictions of climate change responses at the national and city levels, in addition to pointing out present and future challenges.

2 Background: impacts of climate change on Mexico and Mexico City

2.1 Impacts on Mexico

Climate change is expected to modify the temperature and precipitation in Mexico. The mean temperature is projected to rise by 2 to 4 °C in the period 2020–2080, and precipitation levels to fall by up to 15 % in winter and up to 5 % in summer (INE 2006; Magaña et al. 2004). The surface temperatures of the Caribbean Sea, Gulf of Mexico and the Mexican Pacific are expected to increase by 1 to 1.5 °C, a situation that favors the occurrence of more frequent and intense hurricanes (IPCC 2007; Gallegos García 2004).

Extreme hydrometeorological events and sea level rises are likely to damage transportation and energy-production infrastructure in Mexico. Droughts may also affect hydro-power generation due to reductions in water flows and dam levels (IPCC 2007). To date, however, the planning and operation of such infrastructure have been conducted without considering the effects of climate change, making the transport and energy sectors more vulnerable, particularly in coastal areas. In the Gulf of Mexico, for example, hydrometeorological events could potentially cause 160 oil platforms to suspend operations, leading to high economic losses (Semarnat 2009).

Natural ecosystems may be endangered by a changing climate, and some species may become extinct if regional and local temperatures increase at a rate that exceeds their capacity to adapt. For instance, coniferous, cloud and oak forests are the types of vegetation that will be most affected by temperature and precipitation changes in Mexico. The extent of these ecosystems and the number of species living in them are expected to decrease in the next few decades (Villers-Ruiz and Trejo-Vazquez 1997). Among the species at risk of extinction is the Horned Guan (Oreophasis derbianus), which is found only in the cloud forests of Mexico and Guatemala (Arriaga and Gomez 2004). In addition to the impacts of climate change, forests have been heavily damaged by deforestation. This problem, exacerbated by intense droughts, urbanization, and irregular settlement growth, has resulted in more frequent forest fires and a reduction in the environmental services provided by these ecosystems (e.g., carbon sequestration) (Villers-Ruiz and Trejo-Vazquez 1997). Indeed, a lack of research on the impacts of climate change on fragile ecosystems in Mexico intensifies the vulnerability of such ecosystems to shifts in climatic conditions and limits the capacity of authorities to encourage conservation.

Changes in temperature and precipitation may destroy agronomic crops (especially rain-fed ones) and endanger food supply and the economic stability of farmers (Appendini and Liverman 1994; Liverman and O'Brien 1991). In Mexico, current agricultural practices cannot deal with extreme weather events because of a lack of infrastructure, financial support, and climate information for planning. Moreover, irrigation systems are inefficient and many areas are still irrigated by gravity due to low water costs. Consequently, in several regions, rainfed corn crops are no longer sustainable and have been replaced by sorghum, which requires less water and serves as livestock feed (Semarnat 2009; INE 2006). Water availability may also be reduced by climate change, potentially leading to (or intensifying) conflicts among sectors as they compete to ensure access to this resource. Presently, water and sewage service demands cannot be met by existing infrastructure and natural water availability. Thus, water is transferred from distant watersheds and untreated sewage is disposed of into rivers. In this context, the rapid population and urban growth occurring in Mexico further increase the country's vulnerability to climate change.

The impacts of climate change are likely to be unevenly distributed throughout Mexico due to its variety of climates, natural resources and infrastructure allocation, as well as demographic and economic development. In the north, based on the GFDL-R30 (created by the Geophysical Fluid Dynamics Laboratory (GFDL), USA) and CCCM (created by the Canadian Centre for Climate Modelling and Analysis (CCCMa), Canada) models, the temperature is projected to rise by up to

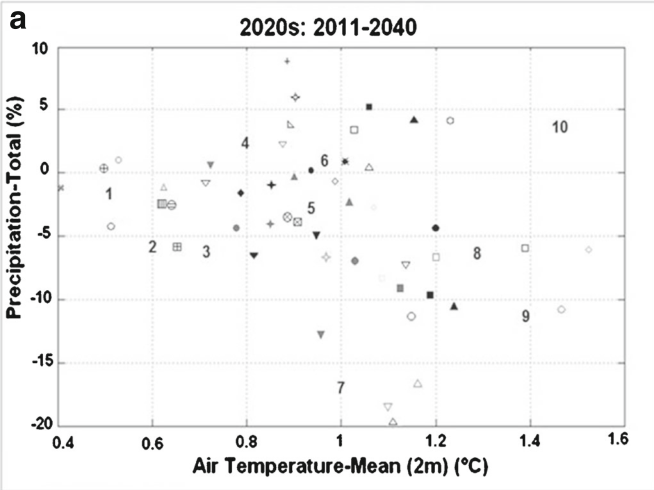
6 °C by 2080, thus increasing the frequency and severity of droughts and heat waves (Hernández and Valdez 2004; Magaña et al. 2004). These events may affect hydro-power generation, and hence may impact numerous industrial activities requiring energy and water (Semarnat 2009). In the central region, the mean annual temperature is likely to increase by up to 2.8 °C and the annual precipitation to decrease by 10.4 % from the 2020s to 2070s. These changes in temperature and precipitation may magnify pre-existing vulnerabilities arising from unmet water, energy and food demands, high demographic and economic activity, deforestation, and dependence on distant water sources (Delgado 2012; Romero Lankao 2011, Romero Lankao 2007; Sosa Rodriguez 2010b). Similar to the north, this region is very likely to be affected by prolonged droughts (Hernández and Valdez 2004). In the south, precipitation is projected to remain almost the same (1,500 mm per year on average) (Conagua 2011a, b), but temperature may rise by up to 2 °C, which will increase the frequency of vector-borne disease outbreaks (Semarnat 2009; Hernández and Valdez 2004; INE 2006). More extreme and intense hydrometeorological events are expected to occur, causing significant economic losses for the tourism, energy, agriculture, and forestry sectors. The Caribbean Sea, Gulf of Mexico and the Mexican Pacific will be particularly affected and likely to be damaged by an estimated 1 to 1.5 m rise in sea level (Overpeck and Weiss 2009; Weiss et al. 2011).

Analysis of the impacts of climate change across Mexico indicates that Mexico City will likely experience the greatest effects due to its environmental and urban problems as a result of its high population density and susceptibility to climate events (Semarnat 2009). Even in the period between its foundation in pre-Columbian times and industrialization, Mexico City has been subject to catastrophic floods and long droughts (Sosa Rodriguez 2010a). Since the early 20th century, the city's mean temperature has risen by almost 4 °C due to the heat-island effect and global climate change (León Diez 2007). Consequently, it is a useful example to analyze whether the federal climate change policy has been translated into successful local actions (Semarnat 2009). The next section explores the impacts of climate change in Mexico City.

2.2 Impacts of climate change on Mexico City

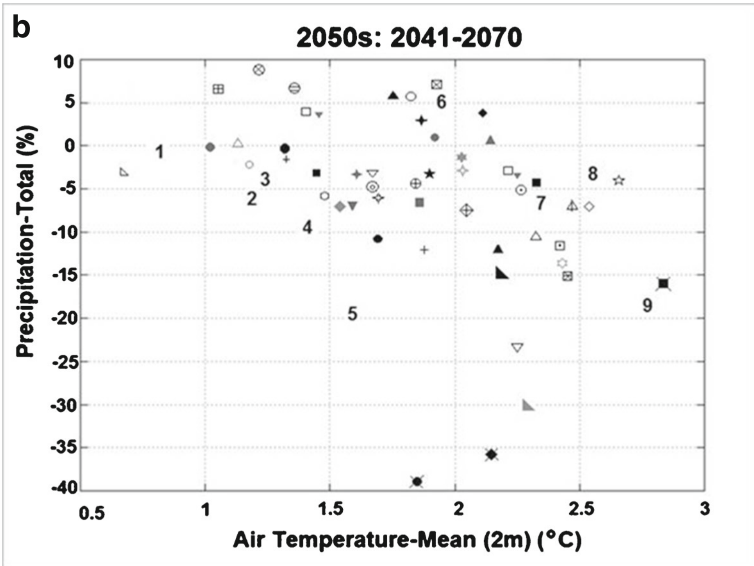
Overall, in Mexico City, mean, maximum and minimum temperatures have risen over the last decades. The warmest year occurred in 2005, with daily maximum temperatures exceeding 30 °C for 80 days. The greatest changes have been recorded in the maximum temperatures, which have increased by up to 7.0 °C since the early 1950s. Minimum temperatures have also risen in the same period by up to 3.0 °C. Therefore, in recent years, temperatures below 0 °C have been rarely recorded, and the number of cold days has been reduced (Conagua 2011a). A warmer atmosphere has reduced precipitation but increased the number of extreme rain events during the last decade. For instance, in 2004, there were 107 days with heavy rain exceeding 10 mm, and in 2006, 98 days (Conagua 2011a). Because the city's drainage infrastructure was not built to cope with these extreme events, flooding is common. Additionally, the city's hydrogeological characteristics—a naturally closed basin once formed by six interconnected lakes—make it highly vulnerable to such events (Sosa Rodriguez 2010a, b).

To assess climate change impacts on Mexico City's temperature and precipitation, General Circulation Models (GCMs) and three emission scenarios (SRES A2, A1B, and B2) were analyzed. From 67 models, 13 GCMs were chosen with the percentile method (PM), using mean annual temperature (°C) and precipitation (%) as change fields (Fig. 1). These models project that the average annual temperature in Mexico City will increase by 0.9 °C in the 2020s, by 1.8 °C in the 2050s, and by 2.8 °C in the 2070s—from 16.5 to 19.3 °C, on average. In warmer years between the 2020s and 2050s, temperature is expected to rise by more than 2 °C, and by the end of this century, by up to 4.2 °C—over the 2 °C increase forecast as the tipping point for irreversible global climate



ID	2020s GCM model	Mean Air Temperature (°C)	Total Precipitation (%)
1	GISS-AOM(M)-SR-B1	0.5090	-1.5432
2	MRI CGCM2.3.2a(M)-SR-B1	0.6026	-5.6877
3	FGOALS-g1.0(M)-SR-B1	0.7164	-6.1614
4	CSIROMk3.0(R1)-SR-A2	0.8016	2.3760
5	CNRMCM3(R1)-SR-B1	0.9291	-2.6822
6	HADGEM1(R1)-SR-A2	0.9678	0.5686
7	IPSLCM4(R1)-SR-B1	0.9984	-16.9368
8	NCARCCSM3(M)-SR-A1B	1.2927	-5.9638
9	MIROC3.2 medres(M)-SR-A2	1.3964	-11.2315
10	MIROC3.2 hires(R1)-SR-A1B	1.4451	4.7447
	Average	0.9659	-4.2517

Fig. 1 GCM outputs for Mexico City. Source: GCMs, Canadian Climate Change Scenarios Network (2012). *GISS-AOM(M)-SR-B1* Geophysical Fluid Dynamics Laboratory (GFDL), USA, *MRI-CGCM2.3.2a(M)-SR-B1* Meteorological Research Institute (MRI) and Meteorological Agency, Japan, *FGOALS-g1.0(M)-SR-B1* Center for Climate System Research, University of Tokyo, Japan, *CSIROMk3.0(R1)-SR-A2* Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, *CNRMCM3(R1)-SR-B1* Centre National de Recherches Meteorologiques (CNRM), France, *HADGEM1(R1)-SR-A2* Hadley Centre for Climate Prediction and Research (HCCPR), UK, *IPSLCM4(R1)-SR-B1* Institut Pierre Simon Laplace (IPSL), France, *NCARCCSM3(M)-SR-A1B* National Center for Atmospheric Research (NCAR), USA, *MIROC3.2 medres(M)-SR-A2* National Institute for Environmental Studies, Japan, *MIROC3.2 hires(R1)-SR-A1B*, *CSIROMk3.0(R1)-SR-B1* Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, *MRI CGCM2.3.2a(M)-SR-B1* Meteorological Research Institute (MRI) and Meteorological Agency, Japan, *BCM2.0(R1)-SR-B1* Bjerknes Centre for Climate (BCM), Norway, *FGOALS-g1.0(M)-SR-B1* Center for Climate System Research, University of Tokyo, Japan, *CGCM3T63(R1)-SR-B1* Canadian Centre for Climate Modelling and Analysis (CCCma), Canada, *ECHO-G(M)-SR-A2* Meteorological Institute of the University of Bonn and Meteorological Research Institute of KMA, Germany, *CNRMCM3(R1)-SR-A1B* Centre National de Recherches Meteorologiques (CNRM), France, *HADCM3(R1)-SR-A2* Hadley Centre for Climate Prediction and Research (HCCPR), UK, *MIROC3.2 medres(M)-SR-A2* National Institute for Environmental Studies, Japan, *GISS-AOM(M)- SR-B1* Geophysical Fluid Dynamics Laboratory (GFDL), USA, *NCARCCSM3(M)-SR-B1* National Center for Atmospheric Research (NCAR), USA, *NCARPCM(M)- SR-A2* National Center for Atmospheric Research (NCAR), USA, *CGCM3T63(R1)- SR-B1* Canadian Centre for Climate Modelling and Analysis (CCCma), Canada, *MRI CGCM2.3.2a(M)- SR-A2* Meteorological Research Institute (MRI) and Meteorological Agency, Japan, *BCM2.0(R1)-SR-A2* Bjerknes Centre for Climate, Norway, *GFDLCM2.1(R1)-SR-A2* Geophysical Fluid Dynamics Laboratory (GFDL), USA, *CGCM3T47(M)-SR-A2* Canadian Centre for Climate Modelling and Analysis (CCCma), Canada, *ECHAM5OM(M)-SR-A1B* Max Planck Institute für Meteorologie, Denmark

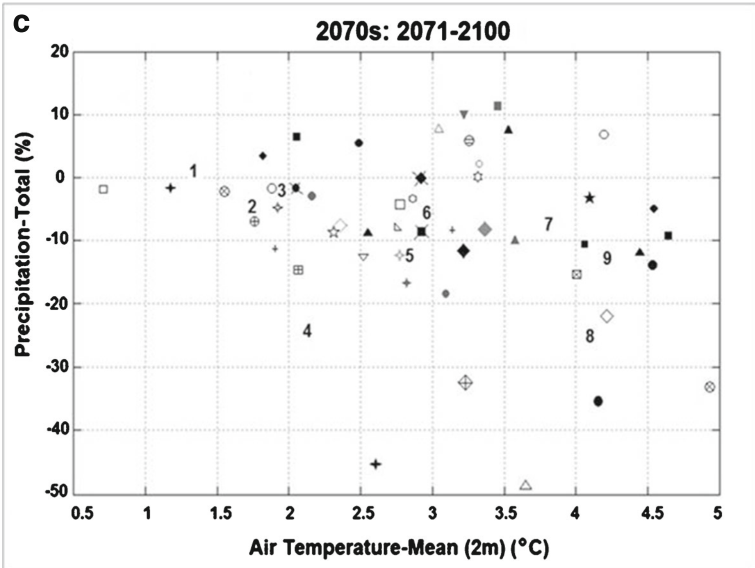


ID	2050s GCM model	Mean Air Temperature (°C)	Total Precipitation (%)
1	CSIROMk3.0(R1)-SR-B1	0.8179	-0.1660
2	MRI CGCM2.3.2a(M)-SR-B1	1.1861	-5.8098
3	BCM2.0(R1)-SR-B1	1.2362	-4.5691
4	FGOALS-g1.0(M)-SR-B1	1.4169	-9.8576
5	CGCM3T63(R1)-SR-B1	1.5763	-19.6242
6	ECHO-G(M)-SR-A2	1.9532	5.0576
7	CNRMCM3(R1)-SR-A1B	2.3402	-6.4529
8	HADCM3(R1)-SR-A2	2.5470	-3.6100
9	MIROC3.2 medres(M)-SR-A2	2.7594	-18.3204
	Average	1.7592	-7.0392

Fig. 1 (continued)

change (Solomon et al. 2007). Although the frequency of heavy rain events is expected to increase in the same period, annual precipitation is likely to decline on average by 5.8 % in the 2020s, by 7.0 % in the 2050s, and by 10.4 % in the 2070s. However, two GCMs (IPSLCM4-SR-A1B (created by the Institut Pierre Simon Laplace (IPSL), France) and A2) projected a decrease in precipitation of up to 50 %, between 2020s and 2070s. A decrease of this magnitude is very unlikely; however, if it were to occur, Mexico City would not have sufficient water to fulfill basic needs and the requirements of economic activities. Figure 1 shows Mexico City's GCM outputs in terms of changes in the mean annual temperature and percent of precipitation for the 2020s, 2050s and 2070s.

Projected changes in temperature and precipitation may increase the frequency of water shortages and droughts and cause emergencies such as the one faced by the city in 2009. During this event, the dam levels in the Cutzamala System, which provides 28.7 % of the total water supply to the city, were reduced to less than 38.9 % as a result of drought. In particular, such water shortages would likely affect the inhabitants of the south and east of the city, who have already experienced scarce or poor quality water for decades. Some people from these areas use less than 20 l/day (Sosa Rodriguez 2010b), which is insufficient to meet the minimum



ID	2070s GCM model	Mean Air Temperature (°C)	Total Precipitation (%)
1	GISS-AOM(M)-SR-B1	1.3514	0.5004
2	NCARCCSM3(M)-SR-B1	1.7648	-6.6137
3	NCARPCM(M)-SR-A2	1.9341	-1.0416
4	CGCM3T63(R1)-SR-B1	2.1436	-24.2392
5	MRI CGCM2.3.2a(M)-SR-A2	2.7743	-12.0397
6	BCM2.0(R1)-SR-A2	2.9791	-5.6598
7	GFDLCM2.1(R1)-SR-A2	3.7875	-7.2252
8	CGCM3T47(M)-SR-A2	4.0807	-24.9554
9	ECHAM5OM(M)-SR-A1B	4.1984	-12.2303
	Average	2.7793	-10.3894

Fig. 1 (continued)

requirements. Longer and more intense droughts may increase Mexico City's dependency on external sources since, for safety reasons, the volume of the water extracted from the aquifer Valley of Mexico must be reduced. To date, this water source provides 43.5 % of the total supply to the city; however, the amount of water extracted (507.36 hm^3/year) almost doubles the natural recharge capacity (279.1 hm^3/year) (Semarnat 2008; Sosa Rodriguez 2010b).

Less frequent, but more intense precipitation events may further exacerbate the city's susceptibility to rain and wastewater flooding, landslides, and soil erosion from increased runoff. Heavy rain may cause landslides in settled gullies in the city's west; runoff may damage impoverished housing in the south and east; and floods due to differential soil subsidence and poor drainage may affect the north and center. Floods will not only affect urban and rural areas, but also roads and the transportation of goods and people. The program Storm Unit, managed by the Ministry of the Interior (Segob), has identified 376 sites and more than 3 million residents at risk due to heavy rainfall (SPCDF 2010). Nevertheless, heavy rainfall also represents an opportunity to capture rainwater if adaptation strategies are implemented; such practices can increase water availability for the city.

Higher temperatures and lower precipitation may also negatively affect the city's air quality by reducing pollutant dispersion in the atmosphere due to changes in wind speed and increases in solar radiation. The decrease in air quality may be greater than expected because of the mountain system with elevations above 5,400 m in the southwest of the city, which hinders the free movement of wind and the dispersion of pollutants. Furthermore, increasing maximum temperatures may affect the entire population, because most homes are not equipped with air conditioning systems. Poor areas could be particularly impacted since houses in those areas are generally built with materials that cannot withstand extreme weather. In addition, existing green areas—which serve as carbon sinks—already face greater pressures due to illegal construction and conversion of green areas to agricultural land. The rapid loss of the city's green areas is a serious problem that will promote more radical climate change and negatively affect biodiversity. Indeed, the number of forest fires in the city has increases with temperature (Fig. 2). As a result of several programs implemented to enhance forest conservation, the area damaged by forest fires has been reduced in the last 20 years, but forest degradation and deforestation continue decreasing the environmental services provided by this ecosystem (e.g., carbon capture). Figure 2 shows the number of forest fires in the city between 1970 and 2010, as well as the affected surface area in hectares (ha).

There is evidence that temperature and precipitation are changing both in Mexico and in Mexico City. Since these changes are likely to affect several groups and economic sectors, the federal government, and subsequently the city government, have implemented diverse M&A actions, whose strategies at the national and city scale are explored in the next section.

3 Mitigation and adaptation responses at the federal and city levels: methodology and findings

Since M&A actions occur across different sectors, the methodology followed to analyze federal and city responses involved analysis of the literature on actions implemented, including those aimed at coping with climate change and those established to solve other problems (e.g.,

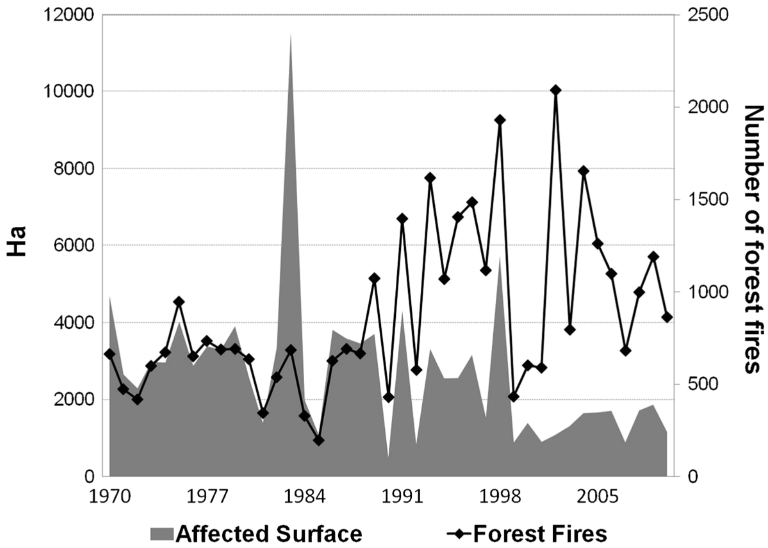


Fig. 2 Number of forest fires and affected surface area in Mexico City, 1970–2010. Source: Conafor 2010b

reducing vulnerability and poverty) but contributing to this end. The documents studied at the national level are the National Development Plan (NDP), the National Strategy on Climate Change (ENACC), the Special Climate Change Program (SCCP), the National Communications to the UN Framework Convention on Climate Change (UNFCCC), the Emissions Inventories, and a number of sectoral (e.g., water, agriculture, forest, transport, and energy) programs. The documents studied at the city level are the Local Climate Action Strategy (ELAC), the General Program of Development, the Green Plan, the Climate Change Mitigation and Adaptation Law (LMACC), the GHG Emissions Inventory for the Metropolitan Area of Mexico City, and diverse sectoral programs (such as the Housing Improvement Program and the Support Program for Highly Vulnerable Groups during the Winter Season). The analysis includes only the ongoing strategies, whose advances can be evaluated. Strategies were identified and classified depending on whether they contribute to mitigation, adaptation, or both. Likewise, commonalities and differences among these strategies were considered for their classification. Federal and city responses to climate change are explored next.

3.1 Federal mitigation and adaptation responses

Mexico joined the Framework Convention on Climate Change (UNFCCC) in 1992. However, during the 1990s, M&A were not public issues in Mexico and were not given priority by the Mexican government. It was only at the beginning of the 21st century that the federal government announced that reducing Mexico's emissions by 50.7 $MtCO_2e$ by 2050 was to be an important goal for the country. To meet this objective in the National Development Plan (NDP) (2007–2012), actions to deal with climate change were made a national development priority for the first time. As a consequence, several actions to reduce GHG emissions and support adaptation have been implemented, including legal, institutional and planning adjustments, emission inventories by source and sink, emission and climate scenarios, and sectoral climate change vulnerability studies. To date, most of the actions have been oriented towards reducing emissions because Mexico has adopted the international trend set by developing countries of prioritizing mitigation while hoping that technological advances will be sufficient to avoid the negative effects of a changing climate. Recently, with the recognition that some impacts are unavoidable (IPCC 2007), reducing sectoral, regional and local vulnerability has become a main objective internationally, and also for Mexico.

To support collaboration among federal and regional agencies, minimize conflicts among sectors, and maximize the benefits of synergies for the integration of a climate change policy, the Interministerial Commission on Climate Change (CICC) was created in 2005. This commission is responsible for the formulation of cross-cutting strategies for climate response, and with this mandate, coordinated the formulation of the National Strategy on Climate Change (ENACC) in 2007 and the Special Climate Change Program (SCCP) in 2009. The latter program represents a governmental effort to integrate strategies with existing programs, and so develop sectoral and regional M&A capacity. Although most actions were not originally created to reduce or cope with climate change impacts, they contribute to this end (Table 1). For instance, to promote forest conservation and the benefits forests provide in terms of environmental services (e.g., carbon sequestration), the SCCP integrates the strategies of 1996's Natural Protected Areas Program (ANPs); 1997's Forest Development Program (PRODEFOR), Forest Commercial Plantations Program (PRODEPLAN), and Forest Conservation and Restoration Program (PROCOREF); and 2007's ProArbol. Presently, ProArbol oversees 2003's Hydrological Environmental Services Program (PSAH) and 2004's Carbon Sequestration and Agroforestry Program (PSA-CABSA) (Conabio 1998; INE 2005; Semarnat 2009; Arriaga et al. 2009; CONAFOR 2010a, c). Other objectives of these programs

Table 1 Mexico's Special Climate Change Programme (SCCP)

<table>
<tr><th>Sector</th><th>Mitigation strategies</th><th>Adaptation strategies</th></tr>
<tr><td>Water</td><td>•Promote efficient water use in all sectors by implementing water-and-energy saving devices—particularly for water pumping, transportation and distribution</td><td>•Adjust water management and policies (e.g., water prices and fines for polluters)</td></tr>
<tr><td></td><td>•Encourage sustainable water consumption habits</td><td>•Include climate information in water management
•Improve water conservation (e.g., recover aquifers and clean water bodies)
•Promote society's participation in water management</td></tr>
<tr><td></td><td colspan="2">Finance infrastructure and technology for efficient wastewater treatment and irrigation</td></tr>
<tr><td>Agriculture</td><td>•Maintain vegetation cover to enhance carbon sequestration</td><td>•Promote soil remediation programs and crop insurance</td></tr>
<tr><td></td><td>•Reduce machine hours used for farming and rehabilitate pumping systems to decrease fuel consumption</td><td>•Use climate information systems</td></tr>
<tr><td></td><td>•Promote renewable energy use</td><td>•Change the temporal range of crops and select crops resistant to droughts
•Diversify the activities of farmers</td></tr>
<tr><td></td><td colspan="2">• Conserve biodiversity and soil by building live fences and windbreaks in intensive farming areas and reducing livestock sprawl
• Capture rainwater and extend the drip irrigation infrastructure</td></tr>
<tr><td>Forest</td><td>•Improve land-use regulation effectiveness to prevent forest cover loss</td><td>•Encourage sustainable forestry programs that incorporate weather information</td></tr>
<tr><td></td><td>•Implement reforestation practices using native species and reducing deforestation</td><td></td></tr>
<tr><td></td><td colspan="2">•Promote pay for environmental services (e.g., carbon capture and water sources conservation)
•Support agroforestry practices, and forest and soil conservation</td></tr>
<tr><td>Biodiversity</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2">•Create Clean Development Mechanisms (CDMs) for ecosystem conservation/restoration
•Integrate species conservation programs with those focused on agriculture and infrastructure development
•Reduce environmental degradation and deforestation by fostering local communities' participation in environmental conservation</td></tr>
<tr><td></td><td></td><td>•Assess climate change effects on biodiversity</td></tr>
<tr><td>Transport</td><td>•Reduce GHG emission through the No Driving Day program</td><td>•Incorporate climate information in transportation planning and infrastructure building</td></tr>
<tr><td></td><td>•Assess vehicle emissions
•Foster clean transportation and alternative technology development
•Promote energy efficiency research
•Build and maintain transportation infrastructure for more efficient use</td><td>•Allocate funds to assist natural disaster reconstruction and recovery of transportation infrastructure damaged</td></tr>
</table>

Table 1 (continued)

Sector	Mitigation strategies	Adaptation strategies
Energy	•Develop alternative sources of energy (e.g., wind, solar or biofuels) •Design and implement energy-saving devices in all sectors (e.g., for water pumping, street lighting, and traffic lights) •Optimize production processes and promote rational energy consumption •Promote carbon capture projects and implement a market for carbon credits	•Use climate information for operation and planning decisions in the energy sector •Relocate energy production infrastructure to low risk areas when possible.
Health		•Prevent and treat climate-related diseases by distributing oral serum and through organizing vaccination campaigns •Improve diagnosis, treatment and prevention of gastrointestinal diseases by raising people's awareness about symptoms, treatments and preventive actions •Implement early warning systems to avoid disease spread •Protect the most vulnerable people during extreme heat/cold periods •Improve water quality and its monitoring
Tourism		•Improve early warning systems and promote climate information and insurance use •Build infrastructure in the coastal areas to face extreme natural hazards •Advance building regulations for tourist facilities to withstand extreme weather events •Diversify economic activities in tourist areas to reduce dependence on a single activity •Foster sectors' coordination during emergencies in touristic areas •Guarantee the operation and access of highways, roads, airports and ports during emergencies
Socio-economic		•Inform decision-makers and society about climate change impacts and their prevention •Develop atlas of climate risks to identify the most vulnerable groups and sectors •Build infrastructure in areas at risk and install early warning systems
	•Promote local communities' participation in the conservation of their natural resources	

Semarnat 2009; Semarnat-INE 2009; INE-II-UNAM 2008; INE-Semarnat 2006, 2005; and INE-Semarnat 1990 include reducing the number of forest fires, diversifying forest uses, advancing agroforestry, and developing the Mexican market for carbon sequestration.

The SCCP also incorporates existing strategies to improve air quality in major metropolitan areas (e.g., Mexico City, Toluca, Puebla), in particular the actions undertaken by the Programs to Improve Air Quality to promote clean industry (e.g., substitution of fuel oil by natural gas) and vehicles (e.g., catalytic converters), transport efficiency (e.g., fuel injection), fossil fuel reduction (e.g., hybrid vehicles), fuel quality improvement (e.g., diesel with low sulfur content), public transportation use (e.g., expansion of Metro and Metrobus services), and relocation of industrial activities. The first air quality program, the Comprehensive Program Against Air Pollution (PICCA, 1990–1995), was implemented in 1990 when Mexico City's air pollution reached critical levels. This program was the basis for others in the largest cities in the country and incorporated existing actions such as 1989's 'No Driving Day' Program. In Mexico, efforts to improve air quality have typically been pioneered in Mexico City, which has subject to many actions to reduce emissions and monitor criteria pollutants (e.g., carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), ozone (O_3), particle matter (PM_{10})). These actions compose 1995's Program to Improve Air Quality in the Valley of Mexico (PROAIRE I, 1995–2000), 2002's PROAIRE II (2002–2010), and 2011's PROAIRE III (2011–2020) (GDF 2002; Semarnat 2002; SMA 2011). Unfortunately, the SCCP suggests no other strategies or actions to address air quality problems and reduce climate change impacts.

The federal government reported its GHG emissions related to the period 1990–2006 in its emissions inventories. To facilitate recording and inventory production, the Voluntary GHG Emissions Reporting Program (GHG Program-Mexico) was created in 2004 as part of the National Strategy on Climate Change (ENACC). This program represents a participatory response from industry to support mitigation. Indeed, Mexico was the first non-Annex I nation in which a large number of companies voluntarily adopted the protocol for accounting and reporting GHG emissions. Mexican companies have developed technical capabilities to estimate emissions, elaborate inventories and identify energy-saving and other technological opportunities to advance mitigation, and of course, increase their economic benefits. As of January 2012, 155 Mexican companies had registered in this program (Semarnat 2012). Another program underway is the Emission Limits and Exchange System (cap and trade). Petroleos Mexicanos (PEMEX) started this action in 1999; nevertheless, the cap and trade program has been used only by the petrochemical industry. It is intended to eventually promote emission-permits trading nationally and internationally once the system is registered as a Clean Development Mechanism (CDM) project of the UNFCCC. To date, only 25 subsidiaries of PEMEX have been able to participate. Subsidiaries compete with each other to reduce their emissions and trade their surplus (credits or emission rights) as bonds with other participants.

New programs were also created to complement the SCCP, chiefly in terms of mitigation. For example, to support the development and use of alternative energies, reduce energy consumption, and foster other sustainable energy initiatives (e.g., household thermal insulation, high efficiency air conditioning, and fluorescent lamp installation), the Energy Saving and Efficient Use Program (PRONASE) and the Renewable Energy Development Program (PAER) were created in 2009. These programs were realized with the financial support of, and knowledge exchange with, various international agencies, including the Global Environment Facility (GEF) and the World Bank (WB) (Semarnat-INE 2009).

In terms of adaptation, the SCCP promotes the use of climate information in planning and decision-making for purposes such as managing water, selecting crops resistant to drought, implementing sustainable forestry programs, assessing climate impacts on biodiversity, operating and building infrastructure, and preventing and treating climate-related diseases. Moreover, early warning systems have been improved and societal participation in natural resource and energy conservation has been promoted. Presently, local adaptation programs have been initiated nationwide. Table 1 summarizes the main federal M&A strategies already implemented by sector. Mitigation strategies are focused on promoting renewable and energy-efficient technology use and development, reducing GHG emissions in production processes, strengthening green area preservation, and regulating sustainable land-use management. Adaptation strategies are oriented to assess each sector's vulnerability to climate change and to strengthen sectoral and regional adaptive capacity. The diverse results of these sectoral measures implemented by the SCCP in Mexico to date are discussed further on.

3.2 Mitigation and adaptation responses in Mexico City

In addition to the federal government's actions, the authorities in Mexico City have also undertaken several actions to respond to a changing climate, which have been mainly oriented toward mitigation. Some of these actions match with the federal M&A strategies while others are unique to Mexico City, providing evidence of the city's efforts to reduce its vulnerability to climate change nationwide. Similar to the SCCP, Mexico City's climate change policy incorporates previous efforts to reduce the city's vulnerability. Although these measures were not originally aimed at addressing climate change, they may contribute to this end and strengthen the city's response capacity.

An initial effort was the approval of the Local Climate Action Strategy (ELAC) in 2004, which was a city government initiative that established the guidelines to be met by local governmental agencies, non-governmental organizations (NGOs), and private institutions for M&A purposes. In accordance with the federal priorities, these measures are focused on efficient and clean transportation, efficient energy use, fossil fuel substitution and green area conservation. Furthermore, in 2008, Mexico City was the first municipality in LAC to implement a Local Climate Action Program (2008–2012) [CAP], composed of 26 mitigation strategies for reducing emissions by 7 $MtCO_2e$ from 2008 to 2012, and 12 adaptation strategies aimed at identifying hydrometeorological hazards and developing response mechanisms. This program integrates strategies from the General Program of Development (2006–2012) and the Green Plan (2006–2012), although not created for such purposes, include specific actions that assist in M&A in response to climate change (Table 2). Contrary to the SCCP, whose strategies are divided by sector, the CAP actions are classified into five priority areas with specific quantitative goals for reducing emissions: energy, water, transport, waste, and communication/education. These thematic areas do not consider adaptation priorities centered on rural development, forest conservation, and health.

Examples of the city's mitigation strategies include the programs for energy efficiency, clean technology development, forest management and reforestation, air quality monitoring, and green transportation. Overall, these actions aim to reduce emissions by 4.4 $MtCO_2e$/year (14.78 % of the total annual emissions generated in the city, estimated to be 29.77 $MtCO_2e$) (SMA 2008a) (Table 3): the transport sector will account for 43.1 % of the total emissions to be reduced; the waste sector 35.4 %; the water sector 11.7 %; and the energy sector 9.7 %. The greatest emissions reduction will result from more sustainable waste management through the capture and use of biogas produced in garbage dumps and sanitary landfills (31.6 % of the total), and more efficient transport system by replacing old, low-capacity units with new, high-capacity ones (19.9 % of the total). Surprisingly, renewable energy and energy efficiency strategies will have only modest impacts on emissions reduction (0.45 % and 9.26 % of the total, respectively). This situation highlights the need to promote greater knowledge and technology transfer in order to enhance mitigation in production processes through the CDM.

Table 2 Mitigation and adaptation strategies implemented by sector in Mexico City

Sector	Mitigation	Adaptation
Water	•Maintain and build infrastructure to reduce energy consumption for water pumping and distribution	•Build infrastructure to prevent landslides and drainage silting
	•Modify building codes to enforce rainwater capture and reuse by gray water tanks	•Improve hydrometeorological forecasting and early warning systems, and implement preventive and emergency response programs to cope with these hazards
	•Build hydroelectric power generation plants to use existing waterfalls within Mexico City's water system	•Elaborate an Atlas of hydrometeorological and climate risks •Improve watershed management
	•Promote rational water consumption by price adjustments, measuring consumption and installing water-saving devices	
	•Reduce water losses by rehabilitating pipelines	
	•Reduce emissions from septic systems and wastewater treatment plants by building the East Emissor Drainage System and the Magdalena and Eslava Rivers Collectors	
Waste	•Build a system that capture, extract and burn the biogas generated in the Bordo Poniente (garbage dump)	
	•Build a plant for the production of compost that processes 700 t of organic waste daily	
	•Modernize and automate garbage transfer and selection stations and renew the waste collection vehicle fleet	
	•Increase wastewater reuse and treatment by building a treatment plant (that will treat 60 % of total wastewater)	
Agriculture	•Implement energy and water-saving irrigation technologies (e.g., drip irrigation)	•Rotate crops and remediate eroded and low productivity soil
	•Reduce extensive livestock grazing	•Improve farmers' living conditions by the Community Funds Program for Equitable and Sustainable Rural Development (FOCOMDES)
	•Promote organic agriculture to reduce pesticides and fertilizer demand and production	•Diversify rural activities by the Comprehensive Employment and Sustainable Production Program (PIEPS)
	•Support crop harvesting used in biofuels	
	•Capture rainwater for its reuse in irrigation	
Forest	•Reforest with native species and recover native herbs (particularly, native corn)	•Recover lacustrine areas
	•Implement Forest Management Programs (FMP) to prevent illegal logging	•Restore ecosystems in the ANPs and create biological corridors
	•Finance forest conservation program through the FACC •Monitor forest fires in real time	•Increase the number of Natural Protected Areas (ANPs) and soil conservation for the recharge of aquifers
	•Sanction and relocate irregular settlement in ANP	
	•Improve agroforestry and promote pay of environmental services provided by forest	
	•Implement a market for carbon credits	

Table 2 (continued)

Sector	Mitigation	Adaptation
Transport	• Reduce the number of vehicles by extending the *No-driving day* program (*Hoy no circula*) on Saturdays • Promote non-motorized mobility by building cycling infrastructure as part of the *Ecobici* and *Move by Bike* programs. • Replace 5 thousand old units of public transportation by less polluting units with higher capacity and replace 75,000 internal combustion vehicles that operate as taxis for electric vehicles • Build the *Ecobus* system to transport 150,000 passengers daily, as well as 9 Metrobus systems and the Line 12 of the Metro (subway) to transport 437,000 passengers/day • Expand the Atmospheric Monitoring System and update the Program to Improve the Air Quality (PROAIRE III) 2011–2020 • Improve roads to avoid traffic in conflicting areas and establish exclusive bus stops in the most important city's corridors • Implement the School Transportation Program (STP) to reduce traffic and emissions in areas close to schools	
Energy	• Replace regular streetlamps in parks and public spaces for solar luminaries • Promote renewable energy use, development and research (e.g., solar) • Reduce energy consumption in homes and buildings by installing water-and-energy saving devices • Increase the number of green roofs • Promote water heating with solar energy in hospitals and governmental buildings	
Health		•Prevent and treat climate-related diseases by organizing informative and vaccination campaigns, distributing oral serum, and monitoring epidemiological outbreaks •Provide social assistance to vulnerable groups by distributing free food and safe water, and establishing homeless shelters during heat and cold waves
Education	•Promote efficient use of resources among industry and population •Inform society about climate change impacts and their M&A responses •Educate people for an integrated waste and water management •Improve climate change risk communication	

SMA 2008a, b, c, 2009a, b, 2012

Adaptation actions are focused on strengthening early warning systems and response mechanisms. For instance, short-term adaptation efforts to improve early warning systems include hydrometeorological, epidemiological and forest fire monitoring and climate forecasting. Other initiatives are soil and water conservation, forest preservation, green roofing,

Table 3 Implemented actions for GHG emission reduction in Mexico City and their progress achieved to 2009

Sector	Action	GHG reduction goals		Progress to 2009	
		$MtCO_2e$	%	$MtCO_2e$ reduction	% of progress
Energy	Promote renewable energy use	0.02	0.45	0.007	35.0
	Increase energy efficiency	0.41	9.26	0.41	100.0
	Total	0.43	9.71	0.42	97.0
Water	Maintain and improve water infrastructure	0.07	1.58	0.06	85.7
	Reduce wastewater treatment emissions	0.40	9.03	In progress	
	Decrease water consumption	0.05	1.13	0.046	92.0
	Total	0.52	11.74	0.11	20.4
Transport	Promote high capacity public transport	0.88	19.86	0.87	98.9
	Improve and build corridors and highways	0.44	9.93	0.07	15.9
	Support non-motorized transport	0.04	0.90	0.04	100.0
	Renew vehicle fleet	0.43	9.71	0.12	27.9
	Advance clean transport	0.12	2.71	0.11	91.7
	Total	1.91	43.12	1.21	63.4
Waste	Build a compost plant to process organic waste	0.17	3.90	In progress	
	Capture and use biogas from garbage dumps and sanitary landfills	1.40	31.6	In progress	
	Total	1.57	35.44	–	–
Total		4.43	100.00	1.73	39.12

SMA 2008a, b, c, 2009a, b, 2012

rainwater storage, and native crop recovery and rotation, as well as programs designed to assist people who are vulnerable to extreme weather events. Long-term adaptation measures are mainly oriented to the development of adaptive capacity in rural areas that face severe marginalization by promoting organic farming, rural development, and natural resource conservation. The CAP also emphasizes climate change communication and education aimed at influencing the behavior, habits and attitudes towards M&A of the population. The latest initiatives from the city government were the publication of the GHG Emissions Inventory for the Metropolitan Area of Mexico City in 2006 and passing of the Climate Change Mitigation and Adaptation Law (LMACC) in 2010 aimed at enforcing M&A within the city. The latter law authorizes the city's government to regulate actions for addressing climate change, promote financial instruments to achieve these objectives by establishing the Climate Change Environmental Fund (FACC), control the elaboration of GHG emission inventories, and create the carbon emissions trading system. Table 2 summarizes Mexico City's M&A strategies that are currently underway and Table 3 lists the expected contributions of these actions to emission reduction.

To date, there are no clear assessment mechanisms or indicators to evaluate advances in coping with climate change, and M&A are still considered the responsibility of the Ministry of Environment—a situation that limits inter-institutional coordination and collaboration. This demonstrates the complexity of intersectoral and interagency coordination (mainstreaming) among different levels of government, which compete for resources and power. Given the limited human, financial and technological resources, integrating and enhancing existing strategies is a sound approach to reduce costs and increase effectiveness. In addition, differential impacts and exposure levels must also be considered because climate change vulnerability and hazards are not homogeneously distributed throughout the city's territory. Enforcement of the city's M&A strategies through the LMACC is an important aspect of ensuring a successful policy since the creation of programs does not guarantee that they will be effectively carried out. Additionally, some national adaptation strategies have not been implemented in Mexico City to tackle climate change; it is hoped that soon they will be. Among these yet-to-be-implemented actions are incorporating climate information in water management and agriculture, forest conservation, energy, and transport planning; promoting the use of flood and drought insurance; using different crop varieties resistant to climate change; reducing deforestation and forest degradation; implementing drought alert systems; and reducing people's need to use vehicles. Identified obstacles to successful M&A in the city include a lack of understanding of the strategies' objectives, process and outcomes by governmental agencies and inhabitants, as well as a lack of participation and public awareness about climate change. These problems have resulted in poor coordination and collaboration among these participants to address climate change impacts. Indeed, various levels of government have refused to allocate resources to reducing sectoral and local vulnerability. Furthermore, illegality and corruption stand in the way of developing the city's M&A capacity. Mexico and Mexico City's climate change policy advances, contradictions and challenges are assessed in the next section.

4 Advances and contradictions in mitigation and adaptation: methodology and findings

A literature review of reports, news, and national communications to the United Nations Framework Convention on Climate Change (UNFCCC) was conducted to determine the progress achieved in meeting M&A objectives at the federal and city levels. In terms of national emission reductions, information on the evolution of carbon dioxide equivalent (CO_2e) generated by sector was gathered from the national inventories (INE-II-UNAM 2008; Arvizu Fernández 2008; de Jong et al. 2008; Ordóñez Díaz and Hernández Tejeda 2008; Sheinbaum Pardo and Robles Morales 2008; INE-Semarnat 2006, 2005; INE-Semarnat 1990). For Mexico City, this information was obtained from the Criteria Pollutant Emission Inventories and the GHG Emission Inventories, both of which cover the Metropolitan Area of Mexico City (MAMC) (SMA 2008b, c). When no information was available, in particular for land-use changes due to deforestation, values of CO_2e were estimated based on the generalized emission factors of the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (UNFCCC 2009; IPCC 2000, 1996). Through these factors, determined by the fuel type and technology used, amounts of CO_2e were calculated (directly or indirectly) from estimates of CO, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and SO_2 emissions. Finally, statistics from the national and the city's energy balance (SENER 2010) were used to calculate reductions in energy and emission intensity.

4.1 Federal climate change policy assessment

To date, progress on M&A in Mexico has been deficient. With a production of 711.6 $MtCO_2e$ in 2009 (1.5 % of the world's total GHG emissions), Mexico is the 12th highest country in terms of emissions (Semarnat-INE 2009; WRI 2012). The largest contribution comes from the energy sector (61.4 % of the total), with fossil fuel consumption being the main source (53.8 % of the total yearly emissions). These emissions are mainly generated by the transport sector (20.33 %) and power generation industry (15.80 %). The other contributors are the waste management sector (14.4 %); land-use changes and forestry (9.9 %); industrial processes (8.9 %); and agriculture (6.4 %) (Table 4). Emissions from the energy sector, mainly CO_2 and CO, include those from power generation; power

Table 4 Total GHG emissions generated by sector in Mexico from 1990 to 2006 and their growth rate

Category/Year	$MtCO_2e$ (Metric ton of Dioxide Carbon Equivalent)									Percentage									Growth rate
	1990	1992	1994	1996	1998	2000	2002	2004	2006	1990	1992	1994	1996	1998	2000	2002	2004	2006	1990–2006
Energy	311.2	321.8	342.9	346.9	394.1	398.6	392.7	417.5	430.1	61.3	63.2	63.9	59.7	62.7	63.3	60.2	60.5	60.4	38.2
Fossil fuel consumption	279.9	291.0	308.9	311.2	351.8	356.8	350.4	375.6	382.7	55.2	57.2	57.6	53.6	56.0	56.7	53.7	54.4	53.8	36.7
Power generation	104.7	108.0	120.9	120.1	149.4	156.8	152.5	108.4	112.5	20.6	21.2	22.5	20.7	23.8	24.9	23.4	15.7	15.8	7.4
Transport	87.8	108.0	101.3	97.5	104.8	110.6	112.0	129.0	144.7	17.3	21.2	18.9	16.8	16.7	17.6	17.2	18.7	20.3	64.8
Industrial process	34.7	32.9	39.2	45.2	51.0	55.9	52.2	55.2	63.5	6.8	6.5	7.3	7.8	8.1	8.9	8.0	8.0	8.9	83.1
Agriculture	47.4	46.0	45.5	44.1	45.4	45.5	46.1	45.6	45.6	9.3	9.0	8.5	7.6	7.2	7.2	7.1	6.6	6.4	−4.0
Waste	33.4	36.9	46.9	60.0	62.7	63.2	76.2	86.2	102.3	6.6	7.3	8.7	10.3	10.0	10.0	11.7	12.5	14.4	206.3
Land-use change & forestry	80.6	71.4	62.2	84.6	75.4	66.2	84.9	86.2	70.2	15.9	14.0	11.6	14.6	12.0	10.5	13.0	12.5	9.9	−11.3
Total	507.3	509.1	536.7	580.8	628.6	629.4	652.2	690.7	711.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	40.3

Based on Semarnat 2009; INE-II-UNAM 2008; Arvizu Fernández 2008; de Jong et al. 2008; Ordóñez Díaz and Hernández Tejeda 2008; Sheinbaum Pardo and Robles Morales 2008; INE-Semarnat 2006; INE-Semarnat 2005; INE-Semarnat 1990 consumption; and fugitive emissions of methane (from mining, coal handling and oil and natural gas exploitation). Emissions from the waste management sector, chiefly CH_4, are associated with the disposal and treatment of solid waste and wastewater, and waste incineration. Emissions from industrial processes, primarily CO_2, come from the production and use of minerals, metals, paper, food, beverages, halocarbons, sulfur, and the chemical industry. Emissions associated with land-use change and forestry are related to biomass combustion, forest conversion to other uses, and emissions from mineral soils and agricultural areas—managed forests and abandoned lands can reduce emissions of some gases, in particular CO_2 and CH_4. Emissions from agriculture, predominantly CH_4 and N_2O, are determined by crop, soil and livestock management. Table 4 synthesizes the total GHG emissions by sector, their contribution to the total, and their growth rate.

From 1990 to 2006, emissions in Mexico rose by 204.36 $MtCO_2e$—an increase of 40.3 %, with an annual growth rate of 2.4 %—as a result of higher energy consumption that reached 7,779.02 petajoules (PJ) in 2006 (SENER 2010). All sectors, except for land-use change and agriculture, increased their total emissions during this period. The greatest increase occurred in the waste management sector, whose emissions doubled due to additional solid waste disposal and wastewater treatment in response to demographic and economic growth. Industrial emissions increased by 83.1 % due to growth in the cement industry, and more intense mining and steel production. Although the actual emissions from the energy sector increased by 38.2 % with more intensive use of fossil fuels, this sector's contribution to the total emissions decreased by almost 1 % because of more intensive consumption of natural gas—replacing coal and oil. These modest advances have slowed the annual energy intensity growth to 30.2 % and the annual emission intensity growth to 34.1 % (Table 5); nevertheless, insufficient energy efficiency intensification has led to a rise in emissions despite the various measures and programs implemented. In part, this is explained by the cost of the CDM estimated to be between US$120,000 and US$250,000—along with long wait times for project approvals (Semarnat 2012). Although the Mexican Government has sponsored has committed to sponsor several projects, not all interested companies receive the financial support needed for developing and implementing these mechanisms due to limited technical, economic and human resources. These obstacles have discouraged local and regional initiatives that may benefit local communities.

Table 5 Energy and emission intensity advances in Mexico from 1990 to 2006

Year	Fossil fuel consumption (PJ)	GHG emissions ($MtCO_2e$)	GDP at 2000 US$ prices (Million)	Energy intensity [EI] (MJ/US$)	EI annual growth based on 1990's emissions	Emission intensity [GHGI] (Emissions/Million US$)	GHGI annual growth based on 1990's emissions
1990	4307.0	507.3	883,193.4	4.9		0.57	
1992	4,484.5	509.1	1,111,219.5	4.0	−8.6	0.46	−10.1
1994	4,705.0	536.7	1,178,818.9	4.0	−9.1	0.46	−10.4
1996	4,765.4	580.8	413,508.5	11.5	68.2	1.40	72.3
1998	5,137.6	628.6	435,769.3	11.8	70.9	1.44	75.6
2000	5,199.0	629.4	580,791.0	9.0	41.8	1.08	44.3
2002	5,317.3	652.2	635,168.1	8.4	35.8	1.03	39.4
2004	5,654.1	690.7	572,286.5	9.9	51.3	1.21	55.1
2006	5,760.0	711.7	736,407.7	7.8	30.2	0.97	34.1

Based on SENER 2010; Banxico 2012, b; Sheinbaum Pardo and Robles Morales 2008

From 1990 to 2006, agricultural emissions dropped by 4 % with decreases in livestock and grain crops (especially rice and corn) and increased food importation. Although this reduction in agriculture activity has positively impacted emission generation, it threatens food security and farmers' economic stability. Land-use change reduction and forest conservation decreased emissions by 11.3 %, but this figure may be an overestimate because there is insufficient information to reliably calculate this sector's contribution to CO_2 generation and capture. Consequently, the increase in Mexico's emissions might be higher if emissions from land-use change and forestry were accurately assessed. Indeed, these emissions are not considered in the inventories even though forest loss is the third largest source of emissions, as shown by figures from 1990. According to the National Forestry Commission (Conafor) (2010a), from 2005 to 2010, forest conservation programs have reduced the deforestation rate to 155,000 ha/year, placing Mexico in 5th place worldwide. This figure only takes into account the number of trees planted, but does not consider those still surviving after 1 year, whether the species planted matched the flora of recovered areas, or forest degradation, nor does it match the rate reported by the National Institute of Statistics and Geography (INEGI), which is three times higher (478,920 ha/year) (INEGI 2010b; Lund et al. 2002). Lack of knowledge and administrative capacity for sustainable forest management, excessive regulation, and poverty within local communities have promoted illegal—and sometimes legal—forest overexploitation. For example, permits to exploit forests (which cost US$220–600 per 500 m^3) are more expensive than permits for changing forests to agricultural land-use (which cost US$73/ha or US$6,550/200 ha) (CCMSS 2008). Payment for environmental services (PES) provided by forests to local communities has been reduced to subsidies for not deforesting. This approach avoids local capability building and effective community participation in managing its natural resources (Hawkins 2012). The failure of the Mexican climate change policy to act effectively in regard to forest conservation has limited M&A success. Although several programs have been in place for over two decades, they have not been translated into actions; rather, they remain at the level of governmental discourse. To date, Mexican forests are net emissions generators, with emissions exceeding CO_2 capture. However, efforts to determine the carbon sequestration capacity of such forests are hampered by the scale used in available cartographic information. The lack of detailed mapping information, forest surveys, and more active participation of local communities living in these areas are major challenges to sustainable forest management and consolidation of a carbon market.

4.2 Advances and contradictions in Mexico City's climate change policy

In 2008, Mexico City produced 29.77 $MtCO_2e$, which represents 4.18 % of the total national emissions (SMA 2008a). The low contribution of the city to the total national emissions is attributed to the absence of the petrochemical industry within its territory (one of the main emissions generators nationwide), in addition to the decentralization of industry away from the city and the concentration of services (chiefly financial and information services). The majority of the emissions were generated by the transport sector (47.08 % of the total), followed by industry (27.21 %) and the waste (14.28 %), housing (6.37 %), commercial (3.44 %), public (1.01 %), land-use change and forestry (0.51 %), and agricultural (0.10 %) sectors. The city's M&A actions have had positive results, reducing the total GHG emissions by 3.76 $MtCO_2e$ between 2000 and 2008 (Table 3). This can be explained by more efficient energy consumption in all sectors, the use of less polluting energy sources such as natural gas and solar energy (e.g., solar water heaters and public lighting), and the introduction of cleaner and high-capacity transport systems (e.g., the Metro, Metrobus and Ecobus). Other advances include replacing old public transport vehicles with newer (less polluting and higher capacity) models, improving water supply pumping systems, rehabilitating the city's water network to reduce water losses, installing water-and-energy saving devices in houses and buildings, and promoting non-motorized mobility by constructing bikeways (Table 3). It is expected that the infrastructure currently under development to improve the public transport system, capture biogas, produce compost, and treat sewage will reduce GHG emissions by at least 7 $MtCO_2e$, meeting the main objective of the CAP.

Mitigation actions, along with the PROAIRE II, have fostered emissions reductions in all sectors except for the industry and waste sectors, which increased their relative and total emissions from 2000 to 2008. The increase in emissions by the waste sector can be explained by population and consumption growth. In the case of industry, by contrast, the increase in emissions was related to improvements in emission accounting rather than to an actual increase, as verified by a lowering of this sector's energy consumption over the same period. The majority of these emissions were generated by the chemical industry (38 %), the food and beverages industry (21 %) and the machinery, metal and transport equipment industry (17 %). For the transport sector, because the total vehicle fleet swelled from 861,000 to 2.91 million units between 2000 and 2008, energy efficiency improvements, cleaner fuels, and the introduction of hybrid vehicles in the Mexican market have not resulted in a significant reduction in emissions (SMA 2004, 2008b). For the residential and commercial sectors, use of energy-saving devices has lowered the relative and total emissions of these sectors. In particular, the residential sector has reduced its energy consumption as a result of more intensive use of natural gas replacing liquefied petroleum gas (LPG), increased fuel prices, and energy-saving technologies applied to home appliances (SENER 2003, 2004). In general, energy efficiency improvements and energy-saving devices have successfully decreased consumption from 342.54 to 328.72 PJ in the period of 2000–2008 (Table 6). All sectors reduced their energy consumption, except for the transport sector; the 7.35 % increase for the latter sector can be explained by the 237.98 % growth in vehicle numbers in the same period. Energy savings from the commercial sector (46.27 % reduction) and industry (26.23 % reduction) provide evidence that technology transfer through the CDM has furthered the city's mitigation. Table 6 shows the evolution of GHG emissions and energy consumption by sector from 2000 to 2008.

The spatial distribution of GHG emissions is associated with the distribution of industry, which is concentrated at the city's north and east. Industrial emissions mainly affect the most disadvantaged groups, who live close to production plants due to the low rents and land prices in those areas. The distribution pattern of waste facilities is also associated with that of industry. For the transport sector, emissions are related to the mobility of the population and economic activities; therefore, if people must drive long distances to work, study, and use the city's amenities, it will be difficult to significantly reduce this sector's emissions and improve air quality. Hence, federal and city authorities need to decentralize economic activities, schools, hospitals and other infrastructure, in addition to promoting public transport use by improving the quality and efficiency of these systems. To date, public transport systems have been inefficient in terms of time of travel, accessibility, and comfort; these problems have encouraged the city's inhabitants to rely heavily on vehicles, increasing the vehicle fleet by more than double from 2000 to 2010. A 2008 study indicated that 29.50 %' of the total vehicle fleet are 1990 or older models which do not have emission control systems, and 10.48 % of the total are 1991–1993 models

Table 6 Total GHG emissions and energy consumption by sector in Mexico City from 2000 to 2008 and their growth rate

Sector	2000				2008				Energy consumption growth 2000–2008	Emissions growth 2000–2008
	Energy consumption (PJ)	%	GHG emissions ($MtCO_2e$)	%	Energy consumption (PJ)	%	GHG emissions ($MtCO_2e$)	%		
Transport[a]	209.2	61.1	15.1	45.2	224.5	68.3	14.0	47.1	7.4	−7.5
Industry	62.8	18.3	7.3	21.8	46.3	14.1	8.1	27.2	−26.2	11.1
Housing	47.4	13.8	4.5	13.4	43.7	13.3	1.9	6.4	−7.8	−57.6
Commercial/Services	18.1	5.3	2.0	5.9	9.5	2.9	1.0	3.4	−47.2	−48.5
Agriculture	0.5	0.2	0.0	0.1	0.4	0.1	0.0	0.1	−19.6	4.0
Waste	NA	0.0	3.6	10.7	NA	NA	4.3	14.3	NA	18.5
Public	4.6	1.3	0.8	2.5	4.2	1.3	0.3	1.0	−8.9	−64.0
Land-use change and forestry	NA	0.0	0.2	0.5	NA	NA	0.2	0.5	NA	−10.2
Total	342.5	100.0	33.5	100.0	328.7	100.0	29.8	100.0		

SMA 2004, 2008a, b, c, 2009a, b, 2012

NA not available

[a] Includes the Metro and the Electricity Transport Systems

which have two-way catalytic converters for reducing hydrocarbons and CO emissions (SMA 2008b). Efforts to replace older vehicles with less polluting and higher capacity models are expected to have a positive impact on reducing emissions and promoting the use of public transport. So far, the PROAIRE II has been one of the most important programs in the last decade, as its actions have reduced the concentration of criteria pollutants, some of which are also GHGs. For instance, from 1990 to 2008, CO and NO_x emissions were reduced by 79.38 % (from 3.78 to 0.78 million tons/year) and 44.63 % (from 184.48 to 102.14 thousand tons/year), respectively (SMA 2008b). These reductions are primarily attributed to fuel improvements and low-carbon and energy-efficient technology use in industry and the transport sector. In addition, highly polluting industries were relocated outside the city and highly polluting fuels were banned.

Despite authorities' efforts to publish GHG emission inventories, the information provided in these documents is incomplete and structured in a complex way. Similar to the national inventories, emissions from land-use change and forestry are underestimated due to a lack of reliable inventories of green areas and forests, scale problems in the cartographic information that do not consider the degradation of these ecosystems, and the low relevance they have attributed in public policy. Based on these inventories, changes in land-use and forestry have had minimal impacts on the city's total emissions; however, the city's conservation areas have an extension of more than half of its territory (59 % of the total), which may provide important benefits in terms of enhanced climate resilience. Unfortunately, the city's forests and green areas, like their national equivalents, are net emitters. The degradation of these ecosystems is mainly caused by the growth of urban areas and informal settlements. Indeed, although forests and conservation areas are regulated, their illegal exploitation and human settlements within these areas are tolerated rather than sanctioned. This highlights the need to strengthen enforcement of zoning and land-use laws.

Advances in adaptation include the creation of the Climatological Contingency Program (to help farmers in cases of extreme weather events), the Native Corn Protection Program, the Rural Soil Recovery Program, and the Forest Fires Prevention Program in 2008. In the same year, another program was implemented to provide financial support for environmental services preservation in marginalized agricultural areas by carrying out works such as the creation of terraces, dams, green barriers, green manures, and infiltration trenches. The city authorities are also regulating transgenic seeds, recovering native herbal crops, and promoting organic and urban agriculture, in addition to organizing brigades during the cold and rainy season to assist the most vulnerable groups by providing them with medical care, food and shelter (SMA 2009a, b, 2012). Since marginalized groups are forced to live in high risk areas that often lack access to basic services, making such groups more vulnerable to climate hazards, an essential strategy to address climate change is to reduce poverty. Regrettably, temperature increases, floods, droughts, and disease outbreaks will mainly affect these groups.

5 Conclusions

There is evidence that temperature and precipitation are changing both in Mexico as well as in Mexico City. This represents a great challenge, but also an opportunity to promote sustainable development. Currently, mitigation is a priority for all levels of government in Mexico; however, given the lack of financial and human resources available to develop technologies that support emissions reductions, and due to the irreversibility of some impacts, greater emphasis has been placed on adaptation. Nevertheless, barriers that limit M&A effectiveness and efficiency have been identified, including incompatibilities among the objectives and programs of the federal and city governments; weak governance structures which prevent effective and informed societal participation in climate change policy; a lack of mechanisms to monitor advances in and use of financial, human and technological resources; and underestimation of the emissions generated by land-use change and the benefits provided by forests to cope with climate change.

The success of Mexico City's mitigation strategies can be mainly attributed to the actions undertaken in the transport sector to promote clean transport systems and non-motorized transportation. Other factors that complemented this effort are reductions in energy consumption and improvements in energy efficiency. However, the modest impacts that renewable energy and energy efficiency strategies have had on emissions levels highlights the need to promote greater knowledge and technology transfer through CDM—projects that should be pursued further.

To date, adaptation actions have been focused on strengthening early warning systems. Thus, in efforts aimed at coping with climate change in the coming years, a key factor will be to effectively regulate land-use in order to reduce forest degradation and deforestation and to discourage illegal settlements in at-risk areas. Such settlements are the most exposed to shifts in climate due to their limited capacity to respond to such changes since they often lack basic services (water, sewer, electricity) and are located in areas exposed to floods, landslides and other natural events. Unfortunately, these groups often face political, social, economic and educational obstacles to their effective and informed participation in climate change policy at the federal and city levels.

The failure of Mexican climate change policy to act effectively in regard to forest conservation has limited M&A success. Excessive regulation, a lack of accurate information regarding forest degradation and deforestation, and high levels of poverty within local communities have promoted illegal forest overexploitation and the loss of the environmental services of forests, particularly in terms of carbon sequestration. Unfortunately, at present Mexican forests are net emissions generators, and authorities are losing the opportunity to turn this situation around by consolidating a carbon market and promoting sustainable development in poor rural communities. The low relevance attributed to this sector explains why emissions from land-use change and forestry are not considered in emissions inventories, even though forest loss has been estimated to be the third largest source of emissions in Mexico. Furthermore, M&A strategies have not been effectively communicated to society because Mexican authorities have lacked the required resources and have perceived such communications to be of low priority. In fact, in Mexico and Mexico City, climate change is still an issue restricted to the political, economic, and intellectual elites. Therefore, if climate change is to be tackled successfully, governance needs to be improved and all community members must participate. In addition, inter-institutional coordination and communication must be improved to ensure a proper fit and alignment of climate change policies and strategies at various governmental levels and reduce the current level of institutional fragmentation.

Acknowledgments This research was conducted with the financial support of the Mexican National Council for Science and Technology (CONACYT). Contributions from the Mexico City Water System (SACM) and the National Meteorological Service (SMN) from the National Water Commission (Conagua) are greatly appreciated. The author thanks Linda Mortsch, Jean Andrey and Mary McPherson (University of Waterloo, Canada) for their support and feedback.

References

Aguilar E, Peterson TC, Ramírez Obando P, Frutos R, Retana JA, Solera M, Soley J, González García I, Araujo RM, Rosa Santos A, Valle VE, Brunet M, Aguilar L, Alvarez L, Bautista M, Castañon C, Herrera L, Ruano E, Sinay JJ, Sanchez E, Hernandez Oviedo GI, Obed F, Salgado JE, Vazquez JL, Baca M, Gutierrez M, Centella C, Espinosa J, Martinez D, Olmedo B, Ojeda Espinoza CE, Nuñez R, Haylock M, Benavides H, Mayorga R (2005) Changes in precipitation and temperature extremes in Central America and northern South America, 1961–2003. J Geophys Res 110(D23):107–122. doi:10.1029/2005JD006119

Appendini K, Liverman DM (1994) Agricultural policy, climate change and food security in Mexico. Food Policy 19:149–164

Arriaga L, Gomez L (2004) Posibles efectos del cambio climático en algunos componentes de la biovidersidad de México (Possible effects of climate change in some parts of Mexico's biodiversity). In: Martinez J, Fernandez A (comp.) (2004) El cambio climático: una visión desde México (Climate change: a view from Mexico). INE/Semarnat, Mexico, pp 255–266

Arriaga L, Aguilar V, Espinoza JM (2009) Regiones prioritarias y planeación para la conservación de la biodiversidad (Priority regions and biodiversity planning for conservation). In: Capital natural de México. Vol II. Estado de conservación y tendencias de cambio (Natural Capital in Mexico. Vol II. Current situation and trends). Conabio, Mexico, pp 433–457

Arvizu Fernández JL (2008) Actualización del Inventario Nacional de Gases de Efecto Invernadero 1990–2006 en la categoría de desechos (Update of the National Greenhouse Gases Inventory 1990–2006, Waste sector). INE, Mexico

Banxico [Banco de México] (2012a) Serie histórica del tipo de cambio MXN por US$ (Historical series of the exchange rate MXN per US$). Banxico, Mexico

Banxico [Banco de México] (2012b) Serie histórica del PIB anual de México a precios corrientes (Historical series of the annual GDP in Mexico). Banxico, Mexico

BID (2012) The climate and development challenge for latin America and the Caribbean: options for climate resilient low carbon development. BID, Washington

Boulanger JP, Martinez F, Segura EC (2006a) Projection of future climate change conditions using IPCC simulations, neural networks and bayesian statistics. Part 1. Temperature mean state and seasonal cycle in South America. Clim Dyn 27:233–259

Boulanger JP, Martinez F, Segura EC (2006b) Projection of future climate change conditions using IPCC simulations, neural networks and Bayesian statistics. Part 2. Precipitation mean state and seasonal cycle in South America. Clim Dyn 28:255–271

Brown S, Burnham M, Delaney M, Powell M, Vaca R, Moreno A (2000) Issues and challenges for forest-based carbon-offset projects: a case study on the Noel Kempff climate action project in Bolivia. Mitig Adapt Strateg Glob Chang 5:99–121

CCCSN (Canadian Climate Change Scenarios Network) (2012) GCM outputs. Environment Canada, Canada

CCMSS (2008) Nota informativa no. 19. Red de monitoreo de políticas públicas. Junio 2008. Tramitología: un fuerte obstáculo para el sector forestal de México (Briefing Note No. 19. Public Policy Monitoring Network. June 2008. Paperwork: major obstacles for the forestry sector in Mexico)

Chandler W, Schaeffer R, Dadi Z, Shukla PR, Tudela F, Davidson O, Alpan-Atamer S (2002) Climate change mitigation in developing countries: Brazil, China, India, Mexico, South Africa, and Turkey. PEW Center. Global Climate Change, Arlington

Conabio (1998) La diversidad biológica de México: estudio de País (Biodiversity of Mexico: Country Study). Conabio, Mexico

Conafor (2010a) Inventario Nacional Forestal y de Suelo (National Forest and Soil Inventory). Semarnat/Conafor, Mexico

Conafor (2010b) Forest Fires Statistics, 1970–2010 (National Forestry Commission). Semarnat, Mexico

Conafor (2010c) Servicios ambientales y cambio climatico (Environmental Services and Climate Change). Sermarnat/Conafor, Mexico

Conagua (2011a) Climate variables 1921–2010. Conagua [National Water Comission], Mexico

Conagua (2011b) Estadísticas del Agua en México [Water Statistics from Mexico]. Conagua [National Water Comission], Mexico

Conde C, Ferrer R, Orozco S (2006) Climate change and climate variability impacts on rainfed agricultural activities and possible adaptation measures: a Mexican case study. Atmosfera 19:181–194

de Jong B, Olguin M, Rojas F, Maldonado V, Paz F, Etchevers J, Cruz CO, Abad Argumedo J (2008) Actualización del inventario nacional de emisiones de gases de efecto invernadero 1990–2006 en la categoría de agricultura, silvicultura y otros usos de la tierra (updating the national emission inventory of greenhouse gas from 1990 to 2006. Agriculture, forestry and other land uses sectors). INE, Mexico

Delgado M (2012) Water, energy and food security in Mexico City. In: Otto-Zimmermann K (ed) Resilient cities 2. Local sustainability. Part III toward the resilient city. Cities and adaptation to climate change–proceedings of the global forum 2011. Volume 2. Springer, Netherlands, pp 105–111

Eakin H (2005) Institutional change, climate risk, and rural vulnerability: cases from Central Mexico. World Dev 33:1923–1938

Eakin H, Lemos MC (2006) Adaptation and the state: latin America and the challenge of capacity-building under globalization. Glob Environ Chang 16:7–18

EuropeAid (2009) Climate change in latin America. European Commision-Development Cooperation in Latin America (Europe Aid), Belgium

Gallegos García A (2004) Clima oceánico: los mares mexicanos ante el cambio climático global (Ocean climate: mexican oceans under global climate change). In: Martínez J, Fernandez A (comp.) (2004) El cambio climático: una visión desde México (Climate change: a view from Mexico). INE/Semarnat, Mexico, pp 41–51

GDF (2002) Program to improve air quality in the valley of Mexico, PROAIRE II, 2002–2010. GDF/SMA, Mexico

Hawkins S (2012) Capitulo 1. Acuerdos de participación (Chapter 1. Participation agreements). In: FONAFIFO, CONAFOR y MMAE (eds) Lecciones aprendidas para REDD, desde los programas de pago por servicios ambientales e incentivos para la conservación. Ejemplos de Costa Rica, México y Ecuador (Lessons learned from REDD and incentives for conservation. Examples of Costa Rica, Mexico and Ecuador). El Banco Internacional de Reconstrucción y Fomento/WB, Mexico/Quito/San Jose, pp 1–39

Hernández Cerda ME, Valdez Madero G (2004) Sequia meteorológica [Meteorological drought]. In: Martínez J, Fernández Bremauntz A (comp.) El cambio climático: una visión desde México [Climate change: a view from Mexico]. Semarnat-INE, Mexico, pp 315–326

INE (2005) Indicadores básicos del desempeño ambiental de México 2005 (Basic Environmental Performance Indicators from Mexico 2005). UNDP/INE/Semarnat, Mexico

INE [National Institute of Ecology] (2006) Tercera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre Cambio Climático (CMNUCC) [Third National Communication to the UN Framework Convention on Climate Change (UNFCCC)]. Semarnat, Mexico

INEGI (2010) Tasa de deforestación en México. INEGI, Mexico

INE-II-UNAM (2008) Inventario Nacional de Gases de Efecto Invernadero 2006 [National Inventory of Greenhouse Gases (GHG) Emisions 2006]. National Institute of Ecology (INE), Institute of Engineering, National Autonomous University of Mexico (II-UNAM), Mexico

INE-Semarnat (1990) Inventario Nacional de Gases de Efecto Invernadero 1990 [National Inventory of Greenhouse Gases (GHG) Emisions 1990]. National Institute of Ecology (INE), Ministry of Environment, Natural Resources and Fisheries (Semarnap), Mexico

INE-Semarnat (2005) Inventario Nacional de Gases de Efecto Invernadero 2002 [National Inventory of Greenhouse Gases (GHG) Emisions 2002]. National Institute of Ecology (INE), Ministry of Environment and Natural Resources (Semarnat), Mexico

INE-Semarnat (2006) Inventario Nacional de Gases de Efecto Invernadero 1990–2002 [National Inventory of Greenhouse Gases (GHG) Emisions 1990–2002]. National Institute of Ecology (INE), Ministry of Environment and Natural Resources (Semarnat), Mexico

IPCC (1996) IPCC guidelines for national greenhouse gas inventories: reporting instructions and reference manual. IPCC, Geneva

IPCC (2000) Good practice guidance and uncertainty management in national greenhouse gas inventories. IPCC, Montreal

IPCC (2007) Summary for policymakers. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate Change 2007: impacts, adaptation and vulnerability. Contribution of workinggroup II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 7–22

León Diez C (2007) Análisis de vulnerabilidad y desarrollo de medidas de adaptación para el plan de cambio climático de la ciudad de México (Analysis of vulnerability and adaptation measures for the elaboration of the climate change plan in Mexico City). SMA-DF, Mexico

Lim B, Spanger-Siegfried E, Burton I, Malone E, Huq S (2004) Adaptation policy frameworks for climate change: developing strategies, policies and measures. UNDP/Cambridge University Press, New York and Cambridge

Liverman DM, O'Brien KL (1991) Global warming and climate change in Mexico. Glob Environ Chang 1:351–364

Lund HG, Torres V, Turner A, Wood L (2002) México. Análisis crítico de los estimados disponibles de deforestación (Critical analysis of deforestation in Mexico). USAID/SEMARNAT, Mexico

Magaña V, Matías Méndez J, Morales R, Millán C (2004) Consecuencias presentes y futuras de la variabilidad y el cambio climático en México [Present and future consequences of climate variability and climate

change in Mexico]. In: Martínez J, Fernández Bremauntz A (comp.) El cambio climático: una visión desde México [Climate change: a view from Mexico]. Semarnat-INE, Mexico
Magrin GO, Travasso MI, Rodríguez GR (2005) Changes in climate and crop production during the 20th century in Argentina. Clim Chang 72:229–249
Magrin G, Gay García C, Cruz Choque D, Giménez JC, Moreno AR, Nagy GJ, Nobre C, Villamizar A (2007) Latin America. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) Climate change 2007: impacts, adaptation and vulnerability. Contribution of working group ii to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp 581–615
Nagy GJ, Caffera RM, Aparicio M, Barrenechea P, Bidegain M, Jiménez JC, Lentini E, Magrin G (2006) Understanding the potential impact of climate change and variability in Latin America and the Caribbean. Report prepared for the stern review on the economics of climate change
Ordóñez Díaz JAB, Hernández Tejeda T (2008) Inventario Nacional de Emisiones de Gases de Efecto Invernadero 2006. Informe Final. Agricultura (National Greenhouse Gases Emissions Inventory, 2006. Final Report. Agriculture). INE, Mexico
Overpeck JT, Weiss JL (2009) Projections of future sea level becoming more dire. Proc Natl Acad Sci U S A 51:21461–21462
Romero Lankao P (2007) How do local governments in Mexico City manage global warming? Local Environ 17:519–535
Romero Lankao P (2011) Missing the multiple dimensions of water? Neoliberal Modernization in Mexico City and Buenos Aires. Policy Soc 30(4):267–283
Semarnat (2002) Air quality program in the metropolitan area of Mexico City, 2002–2010. Air quality program and emissions inventory direction. Semarnat, Mexico
Semarnat (2008) Volumen de recarga y extracción de acuíferos sobreexplotados: Compendio 2008 (Volume of recharge and extraction of overexploited aquifers: Compendium 2008). Semarnat/Conagua, México
Semarnat (2009) Programa especial de cambio climatico 2008–2012 (SCCP) (Special Program of Climate Change, 2008–2012). CICC, Mexico
Semarnat (2012) Mexico GHG program. Ministry of Environment and Natural Resources (Semarnat), WRI, CESPEDES, WBCSD, Mexico
Semarnat-INE (2009) Cuarta Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático-Mexico [Fourth National Communication to UNFCCC United Nations Climate Change-Mexico]. Semarnat/INE, Mexico
SENER (2003) Prospectiva del sector eléctrico 2003–2012 (Electricity Sector Outlook 2003–2012). Secretaría de Energía, Mexico, Available via DIALOG. http://www.sener.gob.mx/work/sites/SenerNva/resources/-LocalContent/3403/1/prospectiva_elect.pdf. Cited 20 Sep 2012
SENER (2004) Prospectiva del mercado de gas licuado de petróleo 2004–2013 (Market Prospective of LPG 2004–2013). SENER, México, Available via DIALOG. http://www.energia.gob.mx-/work/sites/Sener/resources/LocalContent/3995/12/glp0413.pdf. Cited 20 Sep 2012
SENER (2010) Balance Nacional de Energía 2010 (National Energy Balance 2010). SENER, Mexico
Sheinbaum Pardo C, Robles Morales G (2008) Inventario Nacional de Emisiones de Gases de Efecto Invernadero 2006. Informe Final. Energía (National Greenhouse Gases Emissions Inventory, 2006. Final report. Energy). INE, Mexico
SMA (2004) Inventario de emisiones de contaminantes criterio de la ZMVM, 2004 (Criteria Pollutant Emissions Inventory of the MAMC, 2004). SMA-GDF, Mexico
SMA (2008a) Programa de acción climática de la ciudad de México, 2008–2012 (Local Climate Action Program for Mexico City, 2008–2012). SMA-GDF, Mexico
SMA (2008b) Inventario de emisiones de contaminantes criterio de la ZMVM, 2008 (Criteria Pollutant Emissions Inventory of the MAMC, 2008). SMA-GDF, Mexico
SMA (2008c) Inventario de emisiones de gases de efecto invernadero de la ZMVM, 2008 (Greenhouse Gases Emissions Inventory of the MAMC, 2008). SMA-GDF, Mexico
SMA (2009a) Avances en el plan verde de la ciudad de Mexico (Progress in the Green Plan). SMA-GDF, Mexico
SMA (2009b) Avances reportados con respecto a las acciones del programa de acción climática (Progress in the Local Climate Action Program). SMA/GDF, Mexico
SMA (2011) Program to improve air quality in the valley of Mexico, PROAIRE III, 2011–2020. SMA, Mexico
SMA (2012) Informe de avances 2011. Programa de Acción Climática de la Ciudad de Mexico 2008–2012 (Progress Report 2011. Climate Action Program of Mexico City, 2008–2012). SMA/GDF, Mexico
Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) (2007) Climate change 2007: the physical science basis. Contribution of working group I. fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
Sosa Rodriguez FS (2010a) Impacts of water-management decisions on the survival of a City: from ancient tenochtitlan to modern Mexico City. Water Resour Dev 26:675–687

Sosa Rodriguez FS (2010b) Exploring the risks of ineffective water supply and sewage disposal: a case study of Mexico City. Environ Hazards 9:135–146

SPCDF (2010) Program storm unit. Secretaría de protección civil en el distrito federal (SPCDF). Department of Civil Protection in Mexico City, Mexico

Tompkins EL (2005) Planning for climate change in small islands: insights from national hurricane preparedness in the Cayman Islands. Glob Environ Chang 15:139–149

UNFCCC (2009) National greenhouse gas inventories for preparing the national communications of non-annex I parties. UNFCCC, Boon

Villers-Ruiz L, Trejo-Vazquez I (1997) Assessment of the vulnerability of forest ecosystems to climate change in Mexico. Clim Res 9:87–93

Weiss JL, Overpeck JT, Strauss B (2011) Implications of recent sea level rise science for low-elevation areas in coastal cities of the conterminous U.S.A: a letter. Climatic Change 105:635–645

World Resources Institute (WRI) (2012) Climate analysis indicators tool (CAIT) Version 9.0. WRI, Washington