Tools and Strategies for Decision-making on Climate Change, Air Quality and Sustainable Development in the Megalopolis of the Valley of Mexico

Alma Mendoza-Ponce
Francisco Estrada
Óscar Calderón-Bustamante
Miguel Ángel Altamirano del Carmen
Amparo Martínez-Arroyo
Juan Felipe Espino Ruiz
José Manuel Saniger-Blesa
Programa de Investigación en Cambio Climático, Universidad Nacional Autónoma de México
Instituto de Ciencias de la Atmósfera y Cambio Climático, Universidad Nacional Autónoma de México
Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam
Instituto de Ciencias Aplicadas y Tecnología, Universidad Nacional Autónoma de México
feporrua@atmosfera.unam.mx

UCCRN Case Study Docking Station (2025)
DOI: 10.7916/6gh2-xs06

Keywords	Integrated assessment modeling, climate data, UHI
City Population	9,209,944
City Area	1485 km^2
City GDP	176.6 billion USD
Climate Zone	Cwb (subtropical highland)
ARC3.3 Linkage	Data and Technology Element

Introduction. The Megalopolis of the Valley of Mexico (MVM) is one of the most populated areas in the world, with more than 30 million inhabitants distributed across 202 municipalities. The MVM landscape has faced many human transformations for centuries. Phenomena like lake draining, earthquakes, high-level pollution, agricultural and urban expansion, water scarcity, and biodiversity depletion tell the history of this territory where many cultures have coexisted. In the XIX century, national policies supported agricultural and livestock expansion in the MVM (Kemper and Royce, 1979), while at the beginning of the XX century, urban and industrial development were favored, displacing agricultural lands and the diversion of water for domestic or industrial uses in the MVM (Losada et al., 1998). From 1940 to 1985, urban areas expanded by almost six-fold in Mexico City, but the rate was higher in the hinterlands (Aguilar and Olvera, 1991). Cities in MVM continue to expand in size and in population. Consequently, it is essential to develop scenarios of future development to identify the main challenges, trade-offs, and synergies of threats like climate change, pollution, and land use/cover change in MVM. To address these challenges, we designed a project to provide tools and strategies for decision-making to enhance adaptation to climate change and decrease air pollution and land use/cover change risks in the MVM. The project is structured in six components with explicit interactions between them (C1) socioeconomic; (C2) emissions and air quality; (C3) land use/cover change; (C4) local and global climate change; (C5) impacts on human and natural systems, and (C6) adaptation strategies and policies. Two main tools are expected from the project: a regional integrated assessment model for supporting decision-making in the MVM, and a data portal for sharing, visualizing, and modelling information about climate change, air pollution and sustainability.

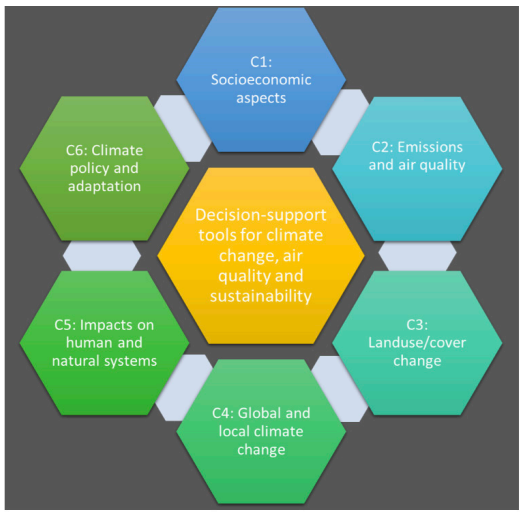

Figure 1. *Schematic representation of the project structure and thematic components.*

Brief History. The project *Tools and strategies for decision making on climate change, air quality and sustainable development in the Megalopolis of the Valley of Mexico* started in 2021, lead by the National Autonomous University of Mexico (UNAM) and sponsored by the National Council of Humanities, Sciences and Technology (CONAHCYT). The aim of the project is to provide scientific information and technological tools about:

1) urban climate, its drivers, and observed changes in climate at the local scale since the beginning of the last century until the present, as well as projections for future horizons (short, medium,

and long term) based on models and emissions scenarios included in the Coupled Model Intercomparison Project Phase 6 (CMIP6);

2) Impacts of climate change, atmospheric pollution, vulnerability, adaptation, and resilience;

3) Mitigation of emissions related to air quality and climate change in the short, medium, and long term;

4) Social and political-administrative transformations to improve resilience and adaptation capacities in the MVM;

5) Planning and management instruments, technological innovation, and interaction mechanisms between sectors to provide alternatives of adaptation and mitigation under a climate change and sustainability context.

In particular, one of the intervention priorities that has been identified by the project is the reduction of the urban heat island (UHI) effect. In some parts of Mexico City, the UHI has a magnitude of about 4ºC-5ºC and shows a rapid increase in areas that are in transition from rural to urban in the outskirts of urban centers in the MVM.

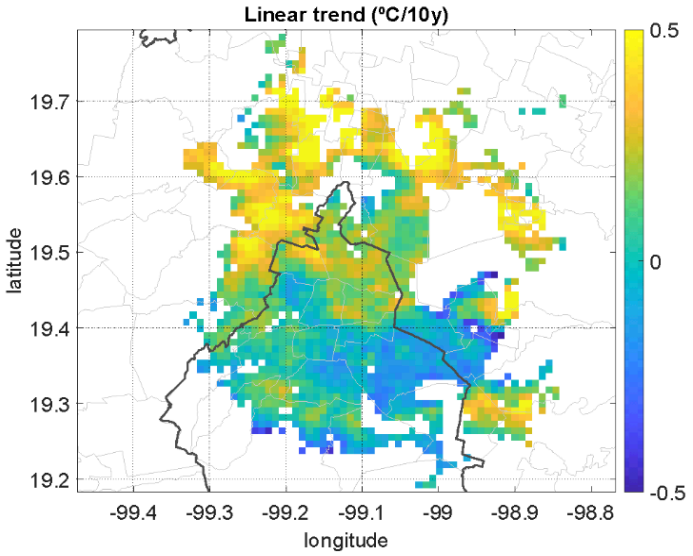

Figure 2. *Linear trend estimates of the surface urban heat island for the 2003-2020 period. Data source: T. Chakraborty, X. Lee, 2019.*

Analysis, Evaluation, and Implementation. Large urban centers are dynamic, complex systems. They are composed of interconnected socioeconomic and environmental components. These characteristics determine challenges for decision-making, as well as for impact, vulnerability, and risk assessments. To offer useful information and to develop strategies to decrease current and future impacts, we are developing a regional integrated assessment model that considers the MVM as a dynamic system and uses statistical simulation, network analysis, process-based physical modeling, and machine learning. We rely on a transdisciplinary approach that integrates diverse disciplines, as well as social actors. The project team is generating products such as local scale climate change scenarios using a regional physical climate model, assessments of current and future vulnerability, and of the impacts of climate change, land use/cover change scenarios, and adaptation and mitigation strategies. Based on the historical analysis and future projections, we identify hotspots of urban heat islands, deforestation, urbanization, and social vulnerability. Moreover, tools to document, share, and visualize information about the effects of implementing various adaptation and transformation measures are being developed. This visualization platform will help inform decision-making on climate change, atmospheric pollution, and sustainability, helping to improve our understanding of the systems that compose the MVM. It will facilitate collaborative work among actors in the government, society, and academia, and to communicate the challenges, opportunities, and transformative actions.

The project has four guiding characteristics:

1) Multiscalar. The project analyzes the MVM as an entity, but it recognizes the interconnection with areas outside its boundaries, as well as the differences among the ecosystems, and the 202 municipalities that constitute it. The project considers time horizons starting from the recent past, the present, and the future through the simulation and analysis of business-as-usual and alternative policy scenarios;

2) Integrality. The analyses, modeling, and recommendations aim for a comprehensive approach in which the MVM is considered as a system and its interactions among actors, drivers, and their interactions are explicitly addressed;

3) Incidence and impact. All products generated in this project have the objective of supporting decision-making in different sectors of society, promoting collaborative work, having high impact and scientific rigor, as well as contributing to socializing knowledge;

4) Training of human resources and strengthening of climate change research in the country.

One of the main tools the project will provide is a data portal for sharing, visualizing, and modelling data on climate change, air quality, and sustainability for the MVM. This project is gathering and producing large amounts of data about:

1) present and future socio-environmental conditions;
2) socioeconomic scenarios;
3) land use/cover change scenarios;
4) description of the current climate and future climate change scenarios;
5) assessment of the impacts and risks, both present and future, produced by climate change, land use cover and changes, and atmospheric pollution from various sectors, and;
6) adaptation and risk reduction strategies.

This body of information constitutes an unprecedented col-

the information for decision making and research by reducing information scatteredness, as well as barriers many users face in terms of computational costs and technical requirements. This tool is scalable and can integrate databases generated by other research groups and projects. This development is part of DataPINCC, a massive data portal devoted to climate change that was developed by the Climate Change Research Program of the National Autonomous University of Mexico. The incidence of these types of tools is illustrated by other data portals like the National Atlas of Vulnerability to Climate Change of Mexico's federal government and the Risk Atlas of Mexico City. Both tools have contributed considerably to the development of public policies and adaptation measures in different levels of government, including the Nationally Determined Contribution of Mexico (https://atlasvulnerabilidad.inecc.gob.mx/infografia/).

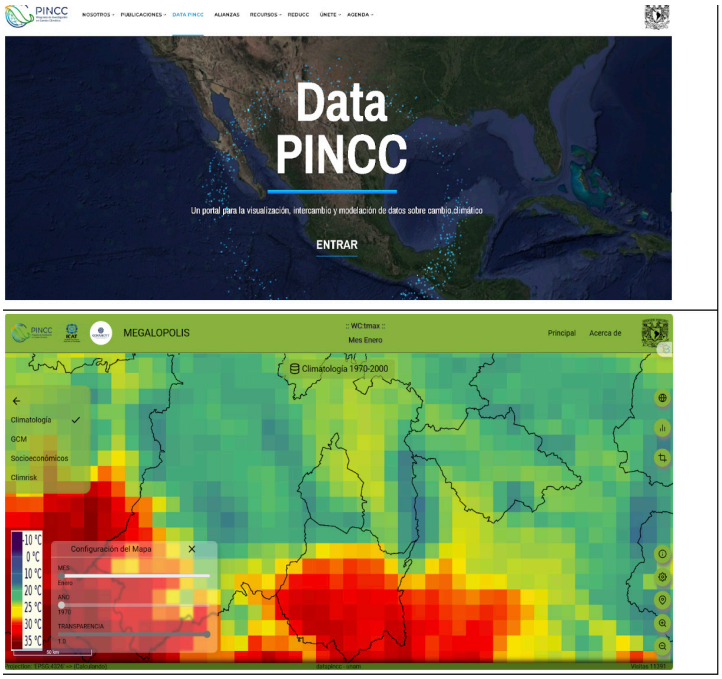

Figure 3. *Data portal developed for sharing, visualizing, and modelling socio-environmental information on climate change and sustainability. The upper panel shows the DataPINCC (https://www.pincc.unam.mx/data-pincc/), while the lower panel shows the data portal devoted to the MVM (https://datapincc.unam.mx/megalopolis/#).*

Future Implementation and Concluding Thoughts. Data, information, and knowledge are necessary conditions for successful design, planning and implementation of adaptation and risk reduction strategies. Producing useful and updated information for decision making on topics such as climate change, air pollution and sustainability requires commitment for long-term financial support. Moreover, capacity-building is crucial to address the ever-growing challenges large urban areas such as the MVM face now and in the future. The development of tools that demonstrate the relevance of science-based information are crucial for the involvement of decision-makers and society in general in addressing current and future socio-environmental problems, and for increasing support for sustained research efforts.

During this project, our research team has underlined the precarious conditions population groups and ecosystems in the MVM currently face and future challenges climate change entails. Concrete adaptation strategies that can be implemented in the present have been proposed and tools are being developed to address information requirements from the government and other societal sectors. Preliminary results from our project suggest that implementing cool roofs, recovering green areas, and controlling urban sprawl would have important climate effects with considerable benefits for health, biodiversity conservation, pollution, and sustainability. To ensure free access to the data and information that has been produced, the research team is developing an efficient data portal for storing, sharing, and modelling that aims to become a permanent, constantly updated, digital resource that provides the best knowledge available for decision-making. The data portal is under constant development, and the current version of it is available at: https://datapincc.unam.mx/megalopolis/.

References

Aguilar, A. G., & Olvera, G. (2015). *The control of urban growth in Mexico City. Suppositions regarding poor planning*. Estudios Demográficos Y Urbanos. https://api.semanticscholar.org/CorpusID:44451825

Altamirano, M.A., Estrada, F., Gay, C. (2021). A new method for assessing the performance of general circulation models based on their ability to simulate the response to observed forcing. *Journal of Climate*. https://doi.org/10.1175/JCLI-D-20-0510.1.

Estrada F., Botzen W.J.W., Tol R.S.J., 2017. A global economic assessment of city policies to reduce climate change impacts. *Nature Climate Change,* 7, 403–406. doi:10.1038/nclimate3301.

Estrada, F., Velasco, J.A., Martínez-Arroyo, A., Calderón, O. (2020). An analysis of current sustainability of Mexican cities and their exposure to climate change. *Front. Environ. Sci., Interdisciplinary Climate Studies*. doi: 10.3389/fenvs.2020.00025.

Estrada, F., Botzen, W.J.W. (2021). *Economic impacts and risks of climate change under failure and success of the Paris Agreement*. Ann. N.Y. Acad. Sci. https://doi.org/10.1111/nyas.14652

Haro, A., Mendoza-Ponce, A., Calderón-Bustamante, O., Velasco, J.A., Estrada, F. (2021). Evaluating risk and possible adaptations to climate change under a socio-ecological system approach. *Frontiers in Climate*. doi: 10.3389/fclim.2021.674693.

Kemper, R. V., & Royce, A. P. (1979). Mexican Urbanization Since 1821: A Macro-Historical Approach. *Urban Anthropology, 8*(3/4), 267–289. http://www.jstor.org/stable/40552884

Losada, H., Martínez, H., Vieyra, J., Pealing, R., Zavala, R., & Cortés, J. (1998). Urban agriculture in the metropolitan zone of Mexico City: Changes over time in urban, suburban and peri-urban areas. *Environment and Urbanization, 10*(2), 37–54. https://doi.org/10.1177/095624789801000214

Acknowledgments

Gustavo Manuel Cruz Bellois thanked for providing an in-depth review of this case study.

Additional Data

- **Population Density:** 6,201 people/km^2
- **Gross National Income (GNI):** 11,980 USD (Higher-Middle Income)
- **Gini Coefficient:** 43.5
- **Human Development Index (HDI):** 0.781(High)
- **Type of Climate Intervention:** Hybrid
