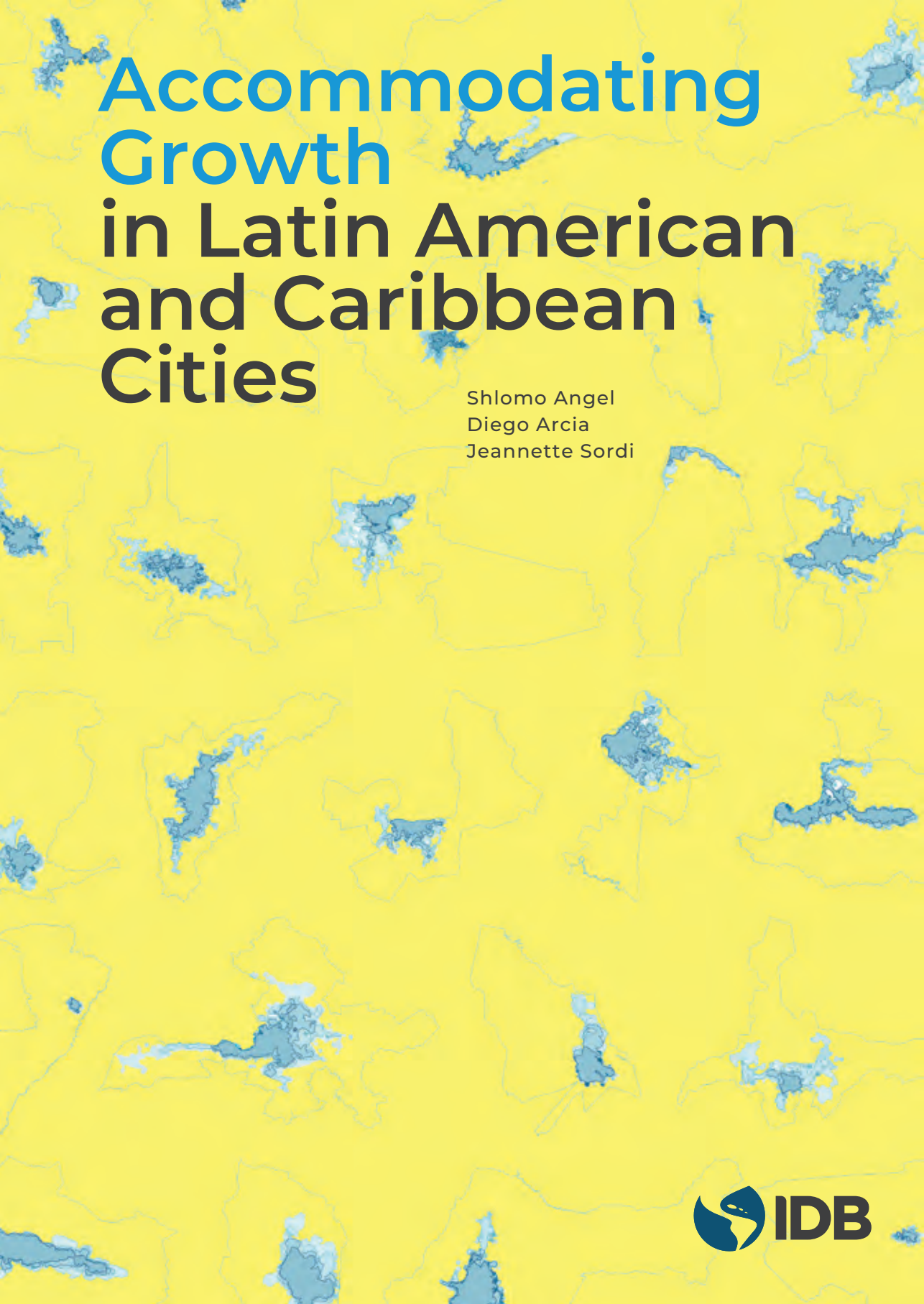
Accommodating Growth in Latin American and Caribbean Cities

Shlomo Angel
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IDB

Accommodating Growth in Latin American and Caribbean Cities

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IDB
NYU
KRIHS
Korea Research Institute for Human Settlements

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library
Accommodating growth in Latin American and Caribbean cities / Editors, Shlomo Angel, Diego Arcia, Jeannette Sordi.
p. cm. — (IDB Monography ; 1245)

Includes bibliographic references.
1. City planning-Latin America. 2. City planning-Caribbean Area. 3. Cities and towns-Growth-Latin America. 4. Cities and towns-Growth-Caribbean Area. I. Angel, Shlomo, editor. II. Arcia, Diego, editor. III. Sordi, Jeannette, editor. IV. Inter-American Development Bank. Housing and Urban Development Division. V. Series.
IDB-MG-1245

ISBN: 978-1-59782-580-1

JEL CATEGORIES
R14 Land Use Patterns
R28 Government Policy
R31 Housing Supply and Markets
R41 Transportation: Demand, Supply, and Congestion
R42 Government and Private Investment Analysis ; Road Maintenance; Transportation Planning
R52 Land Use and Other Regulations
R58 Regional Development Planning and Policy
O18 Urban, Rural, Regional, and Transportation Analysis; Housing; Infrastructure
O21 Planning Models; Planning Policy
Q01 Sustainable Development
Q24 Land
Q56. Environment and Development; Environment and Trade; Sustainability; Environmental Accounts and Accounting; Environmental Equity; Population Growth.

KEYWORDS
Urban Expansion, Urban Densification, Urban Growht, Spatial Planning, Territorial Planning, Land Use Planning, Urban Governance, Sustainable Development, Urban Development, Emergent Technologies, Urban Governance, Latin America And The Caribean, Cities, Sustainable Cities, Territorial Planning.

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Accommodating Growth in Latin American and Caribbean Cities investigates how cities can accommodate new urban populations and elevate the standard of living of current dwellers. The first section introduces a new conceptual framework and international best practices in accommodating urban growth and reviews the emerging empirical evidence gathered in 70 cities across Latin American and Caribbean Region. The second section builds on this work to present an Atlas of Latin American and Caribbean Cities. Cartographies and graphics portray the anatomy of density of the cities through a series of parameters that allow to depict their transformation over the past four decades and assess their potential for future growth. Campo Grande, Mérida, and San Salvador are presented as case studies. Finally, the third section includes a series of strategies to plan for urban growth: guidelines for urban expansion and densification, new frameworks for sustainability, and emerging technologies.

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PEER REVIEW
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PUBLICATION
BID / LOTS OF ARCHITECTURE —publishers

ART DIRECTION, EDITORIAL DESIGN, AND MANAGEMENT
Santiago Bogani & Isabella Moretti

GRAPHIC DESIGN
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TRANSLATION
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COPY EDITING
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All the images and text contained in this publication were summarized and transferred by the Inter-American Development Bank (IDB). LOTS OF ARCHITECTURE —publishers are not responsible for the opinions, data and use of references, images and photographs expressed by the authors.

ACKNOWLEDGEMENTS

This publication was developed within the framework of a technical cooperation between the Inter-American Development Bank (IDB) and the Korea Research Institute for Human Settlements (KRIHS): Sharing lessons from Korea and LAC Experiences for Spatial Planning, Integrated Urban Development, and Housing Policies. We sincerely thank KRIHS and the Global Development Partnership Center (GDPC) for the crucial contribution as a key donor. KRIHS, a leading think tank in Korea specialized in territorial planning, has provided invaluable contributions and experience that have deeply enriched this project.

The publication includes the results of the study on the expansion of Latin American cities led by Professor Shlomo Angel at the Marron Institute of Urban Management. The study was developed within the framework of a consulting contract between the Inter-American Development Bank and New York University.

The publication includes contributions from specialists and consultants in housing and urban development and climate change from the Inter-american Development Bank, specialists at the Korea Research Institute for Human Settlements, and international experts. We thank all the contributors, the reviewers, and editors for their insights and support.





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Latin America and the Caribbean (LAC) is one of the most urbanized regions in the world, experiencing rapid metropolitan expansion and growing urban complexity. As cities continue to evolve, they face pressing challenges related to spatial inequality, infrastructure deficits, climate resilience, and governance. Addressing these issues requires a comprehensive, multi-sectoral approach that integrates urban planning with economic, environmental, and social policies. At the Inter-American Development Bank (IDB), we are committed to strengthening the urban management capacities of national and local governments to foster sustainable territorial development.

A well-designed territorial planning system is essential for guiding urban growth, improving connectivity, and ensuring the efficient allocation of resources. Over the past decade, the IDB has worked with policymakers to advance integrated urban planning strategies, emphasizing sustainable mobility, climate adaptation, and social inclusion. *Accommodating Growth in Latin American and Caribbean Cities* builds upon this ongoing research and regional dialogues, offering empirical evidence and actionable recommendations for managing urban expansion effectively.

Developed in collaboration with the Korea Research Institute for Human Settlements (KRIHS) and New York University (NYU), this publication provides a comprehensive analysis of urban growth trajectories across seventy cities in the region. It examines key drivers of metropolitan expansion and explores policy interventions that promote equitable, climate-resilient, and well-managed urban environments. The study underscores the importance of multi-level governance, integration of housing and mobility planning, and data-driven decision-making in enhancing urban management.

This initiative reaffirms the IDB's commitment to supporting cities in their transition toward sustainable, inclusive, and resilient urban development. We extend our appreciation to the authors, researchers, and partner institutions for their contributions and look forward to continued collaboration in addressing the region's evolving urban challenges. The insights presented in this book will serve as a valuable resource for policymakers, planners, and stakeholders working to shape more balanced and inclusive urban growth across LAC.

Tatiana Gallego
Division Chief, Housing and Urban Development Division
Inter-American Development Bank (IDB)

Urbanization is a global challenge, and South Korea's experience highlights the importance of strategic planning in managing rapid growth. Over the decades, Korea has established comprehensive territorial planning frameworks, integrated infrastructure investments, and innovative housing policies. A clear vision, strong leadership, and adaptable strategies have been essential in addressing urban challenges. Effective spatial planning requires ongoing policy analysis, evaluation, and monitoring. With a solid institutional foundation, decentralized planning enables regions to implement context-specific strategies while ensuring national cohesion. A robust national information system further supports data-driven policymaking.

Recognizing the broader relevance of these lessons, the Korea Research Institute for Human Settlements (KRIHS) has actively collaborated with Latin American and Caribbean (LAC) countries to support urban development. Since 2012, in partnership with the Inter-American Development Bank (IDB), KRIHS has strengthened capacities in spatial planning, sustainable urban management, technology-driven governance, and housing policy in the LAC region. This collaboration has facilitated knowledge exchange, policy dialogues, and research to address urbanization challenges. *Accommodating Growth in Latin American and Caribbean Cities* reflects this ongoing partnership and shared commitment to sustainable urban development.

This study analyzes urban expansion trends in LAC, providing empirical insights to inform planning strategies. By examining seventy cities, it identifies key drivers of urban growth and offers actionable recommendations for policymakers and practitioners. The twelve guidelines underscore the need for a proactive, locally driven, and well-planned approach to urban expansion, emphasizing infrastructure development, regulatory reform, and land management to promote sustainability, inclusivity, and economic productivity.

KRIHS is honored to support this initiative as part of its broader efforts to enhance urban governance and planning capacity. We trust that the insights in this publication will contribute to more resilient and well-managed cities across Latin America and the Caribbean.

We extend our gratitude to the research teams from IDB, NYU, and other contributors and look forward to continued collaboration in advancing sustainable urban development.

Gyo-Eon Shim
President
Korea Research Institute for Human Settlements (KRIHS)

INTRODUCTION

26 Growing Cities in an Urban Region: Goals, Challenges, and Scenarios

Diego Arcia, Jeannette Sordi

FRAMEWORK - LESSONS - FINDINGS

58 Accommodating Urban Growth in the Latin American and Caribbean Region

Shlomo Angel

62 A New Conceptual Framework for Territorial Planning

63 Territorial Planning and the Mitigation of Climate Change

64 Territorial Planning and the Compact City Paradigm

66 Territorial Planning and the Containment of Urban Expansion

74 Strategic Densification Coupled with 'Green' Expansion as an Alternative to Containment

80 Key Lessons for Territorial Planning from 21 International Experiences in Accommodating Urban Growth

86 01 / Historical Examples of Urban Expansion at Scale
The 1811 Commissioner's Plan for New York City, United States; The Ildefons Cerda 1858 Ensanche Plan for Barcelona, Spain; The James Hobrecht 1862 Expansion Plan for Berlin, Germany

92 02 / Non-Market Forces that Drive or Prohibit Urban Expansion
Abandoned Homes in Distant Housing Estates Financed by INFONAVIT in Mexico (2000s, 1998-2014); The Proliferation of Gated Communities in the Periphery of Buenos Aires, Argentina (1990s Onwards); The Impact of Insecurity on Urban Expansion in Bogotá, Colombia (1989-2000)

96 03 / Urban Containment: The State of the Art
The London, England, Green Belt. (greater London plan, 1944); The Deregulation of the Seoul, Korea, Green Belt (1998, 2000s); The Portland, Oregon, Urban Growth Boundary (1978)

102 04 / Accommodating Urban Population Growth in the New Towns
Milton Keynes and the New Towns on the Periphery of London, England (1967-1970, 1980s); Accommodating Urban Growth in New Towns in the Republic of Korea (new town since 1960s, still happening); The New Town of Kilamba, Angola (2004)

108 05 / Successful Programs for Accommodating Growth through Densification
Accessory Dwelling Unit (ADU) Legislation in California (2017); The TAMA38 Program in Israel: Improving Earthquake Resistance in Condominium Buildings by Adding Floors (2005); Upzoning in Auckland and the Shift from Detached to Multi-Unit Housing (2016)

112 06 / Jurisdictional Issues in Planning for Urban Expansion at Scale
The Large Jurisdiction of Zhengzhou, China, Facilitates Planning for its Expansion (2000-2010, 2020); Hawassa, Ethiopia Expanded its Jurisdiction through Negotiations with Neighboring Rural Councils (2012-2020); Metropolitan Planning at the Departmental (Provincial) Level Facilitated Planning for Expansion in Barranquilla, Colombia (2013 Low for Areas Metropolitanas)

118 07 / Laying Out the Urban Periphery in Advance of its Occupation
The Expansion Plan for Valledupar, Colombia (30 Year Plan Development); Town Planning Schemes in Ahmedabad, India - Gujarat Town Planning and Urban Development Act, 1976; Revised Development Plan for Ahmedabad in 1997; Planned Informality in Lima, Peru, 1960s

130 Emerging Empirical Evidence for Territorial Planning in the LAC Region

131 The Growth of Populations and Urban Extents in the Region
The State of Urbanization in the LAC Region; Four New Data Sets with Evidence for Territorial Planning in the Region: A Brief Introduction; Changes in Population, Extent, Densities and Urban Form in Cities in the Region in Recent Decades.

158 The Changing Quality of Urban Footprints

166 Accommodating Population Growth by Densification and Expansion

182 The Anatomy of Density: A Regional Perspective

202 Mapping Urban Growth in Latin America and the Caribbean

Diego Arcia, Julia Paiva, Olivia Serra, Jeannette Sordi

204 Introduction

214 Notes on the Methodology: Defining the Urban Footprint

218 Insights from Three Case Studies

224 Glossary

228 An Atlas of 68 Cities in the Region

234 How to Read the Atlas

238 Atlas of Cities
Arequipa, Greater Asunción, Ayacucho, Greater Barranquilla, Belize City, Greater Belo Horizonte, Greater Bogotá, Bridgetown, Greater Buenos Aires, Greater Cali, Campo Grande, Greater Cartagena de Indias, Greater Cochabamba, Greater Córdoba, Cuenca, Greater Culiacán, Greater Curitiba, Cusco, Greater Florianópolis, Greater Fortaleza, Georgetown, Greater Guadalajara, Greater Guatemala City, Greater Guayaquil, Hermosillo, Ilhéus, Jequié, Greater La Paz, La Serena, Greater Léon, Lima, Linhares, Macapá, Greater Managua, Greater Medellín, Greater Mendoza, Greater Mérida, Greater Mexico City, Greater Monterrey, Greater Montevideo, Nassau, Greater Niterói, Palmas, Greater Panama City, Greater Paramaribo, Pasto, Greater Porto Alegre, Greater Port-au-Prince, Greater Quetzaltenango, Greater Quito, Greater Recife, Reynosa, Ribeirão Preto, Rosario, Greater San José, Greater San Salvador, Greater Santa Ana, Santa Fe, Greater Santiago, Greater Santo Domingo, Greater São Paulo, Greater Tarija, Tegucigalpa, Tijuana, Valledupar, Valparaiso, Villavicencio

510 Assessing Urban Growth in Campo Grande, Mérida, San Salvador

512 Campo Grande, Brazil
Julia Paiva, Martim Furtado

540 Mérida, Mexico
Salvador Herrera Montes, Tania Romero López, Daniela Olivares Sánchez

566 San Salvador, El Salvador
Salvador Herrera Montes, Tania Romero López, Daniela Olivares Sánchez

594 Innovations in Planning for Urban Growth: Guidelines, Instruments, and Emerging Technologies

596 Twelve Guidelines for Action on Urban Expansion
Shlomo Angel

638 Guidelines for Sustainable and Inclusive Urban Densification
Diego Arcia, Camila Maleronka, Hyuna Lee

678 Transit Oriented Development in the Context of Accelerated Urban Growth in Latin America and the Caribbean
Julia Paiva, Jason Hobbs

694 Strategies for the Self-constructed City. Urban Expansion, Densification and Resilience
Jeannette Sordi, Felipe Vera

716 Climate Urbanism
Pedro Henrique de Christo

728 Measuring Cities Together with their Citizens: Data and Algorithmic Transparency for Urban Planning
Mar Santamaria-Varas, Pablo Martinez-Díez

740 Managing Urban Growth in South Korea
Hye Jung Park





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Growing Cities in an Urban Region: Goals, Challenges, and Scenarios

Diego Arcia, Jeannette Sordi

Accommodating Growth in Latin American and Caribbean Cities is the result of a collaboration the Inter-American Development Bank (IDB) and New York University (NYU) initiated in 2021 with both technical and financial support from the Korea Research Institute for Human Settlements (KRIHS). This research constitutes a pivotal output of the Technical Cooperation (TC) project, financed by KRIHS through a Project-Specific Grant (PSG) for the 2021-2024 period. Since 2014, KRIHS has extended financial support to Latin America and the Caribbean (LAC) aimed at formulating policies and frameworks in spatial planning, integrated urban development, and housing; with the objective of identifying practical responses to the challenges posed by accelerated urbanization, which manifests itself in the form of densely populated cities with limited infrastructure and public services.

The book builds on a series of initiatives and publications led by the Inter-American Development Bank as well as the ongoing Accommodating Urban Growth project led by Shlomo Angel at New York University. In 2020 and 2021, two Regional Policy Dialogues organized by the IDB convened high-level public officials—including ministers and

representatives from urban and territorial planning authorities—across the LAC region. These dialogues provided a comprehensive examination of the region's land use and urban planning landscape, focusing on emerging issues such as climate change and evolving socio-economic dynamics. The publication *Territorial Planning Systems in Latin America and the Caribbean* was released as part of this initiative in 2023, offering a detailed assessment of land use planning systems across 26 LAC countries.[1] The publication explores the legal frameworks, policies, and mechanisms for territorial and urban development alongside an analysis of the laws, programs, and institutions that address urbanization dynamics in the region. In 2016, Shlomo Angel and the Marron Institute of Urban Management at NYU published the *Atlas of Urban Expansion*, an interactive platform featuring 200 cities worldwide.[2] The *Atlas* includes 26 cities in Latin America and the Caribbean region. *Accommodating Growth in Latin American and Caribbean Cites* expands these studies by providing empirical evidence on the trajectories of urban growth of seventy cities in Latin America and the Caribbean. The primary goal of *Accommodating Growth in Latin American and Caribbean Cities* is to strengthen the capacity of national and sub-national governments across the region to design and implement effective territorial planning strategies in response to the urban growth that occurred over the past three decades. Territorial planning has historically played a critical role in preparing land for urban development, improving existing neighborhoods, and guiding sustainable growth. However, despite its importance,

planning efforts have frequently struggled to keep pace with the rapid and often unregulated urbanization that characterizes many regions. This has led to a range of challenges, including the proliferation of poorly planned urban areas, the degradation of critical ecosystems, and insufficient protection of natural resources. Additionally, many cities and regions remain inadequately prepared to address the growing threats posed by climate change, such as extreme weather events, rising sea levels, and prolonged droughts. Providing empirical insights into the urban trajectories observed in LAC cities over recent decades, this publication aims to equip policymakers, urban planners, and stakeholders with the framework, knowledge, and tools required to foster more resilient, inclusive, and sustainable urban development.

The rapid and unplanned urbanization in Latin America and the Caribbean (LAC) over recent decades has produced significant challenges that impact social equity, economic development, and environmental sustainability. Currently, approximately 55% of the world's population—about 4.2 billion—lives in cities, a number projected to rise to 68% by 2050.[3] The United Nations calls urbanization one of four "demographic mega-trends"[4] along with population growth, aging, and international migration. Yet patterns of urbanization are highly heterogeneous, both within and across countries.[5] Urban areas are critical centers for wealth production, with over 80% of the global GDP generated in cities.[6] Today, over 80% of the population in Latin America and the Caribbean lives in urban areas. The concentration of economic activity is evident: in 2010,

the 289 cities with populations exceeding 200,000 produced more than three-quarters of the region's GDP, despite representing only half of its population.[7]

However, while cities in Latin America and the Caribbean remain the main centers of innovation and of concentration of social and economic capital, poverty continues to rise in the region. High levels of inequality, along with inadequate access to housing and infrastructure, also remain prevalent in the urban landscape. Furthermore, the climate crisis exacerbates urban inequality, as precarious and unregulated settlements are more vulnerable to recurrent floods and are disproportionately affected by extreme weather events, rising temperatures, and the urban heat island effect.

The exponential growth of major Latin American cities over the past decades is primarily driven by historical factors that have favored labor concentration in the largest urban centers.[8] Since the colonial era in the sixteenth century, cities in LAC have served as hubs of wealth accumulation and power. The cities, supported by resource-rich hinterlands, became focal points for population growth and economic activity. The transition from a predominantly rural society to an urbanized one accelerated during the industrialization of the late twentieth century, resulting in massive migrations from rural areas to urban centers.[9] Population increasingly concentrated in central areas that offer employment opportunities, while those in peripheral regions faced restricted accessibility due to inadequate public transport and insufficient road infrastructure. This dynamic contributed to

the high population density and significant levels of segregation and unplanned areas characteristic of cities in Latin America and other developing regions.[10] Notable cities such as Caracas, Medellín, Bogotá, São Paulo, Santiago, and Mexico City experienced unprecedented and often unregulated growth during this period. Local governments frequently exacerbated social inequalities by prioritizing specific interests over comprehensive urban planning, leading to fragmented urban development. This phenomenon created spatial segregation, as marginalized populations were often pushed to the peripheries of urban centers, where they faced limited access to resources and public services.[11] The rapid growth of Latin American and Caribbean cities over the past decades, and the consequences of unplanned urbanization, manifest in various socio-economic challenges that are still very pressing and need to be urgently addressed in a comprehensive way. These challenges include:

Disproportionate Land Occupation: The rapid urban expansion has resulted in an unsustainable relationship between land occupation and population growth. Low-density urban sprawl fails to optimize land use, leading to inefficient urban layouts.

Housing and Infrastructure Deficits: The rapid influx of populations into urban areas has outpaced the provision of adequate housing and infrastructure, resulting in poorly serviced informal settlements that often lack essential services (e.g., clean water, sanitation, electricity).

Poverty and Inequality: The increasing proportion of the population living in poverty, alongside growing environmental and social inequities, highlights the systemic failures of urban policies. High levels of inequality persist, as those in peripheral areas experience restricted access to employment opportunities and essential services.

Environmental Vulnerabilities: The proliferation of unregulated settlements in risky and degraded areas exacerbates vulnerability to environmental hazards. These communities often face recurrent flooding, extreme weather events, and the urban heat island effect, compounding the challenges posed by climate change.

Institutional Challenges: Many local governments lack the capacity and resources needed to manage urban growth effectively. This includes inadequate planning tools and mechanisms to address the needs of the urban majority.

Addressing these issues requires urgent and comprehensive policy responses with a focus on equitable urban planning, improved institutional capacities, and strategies that prioritize both environmental sustainability and social inclusion. Almost all countries in Latin America and the Caribbean are expected to continue experiencing population growth from 2020 to 2050. However, estimates indicate that many of these countries may enter a declining trajectory between 2050 and 2100.[12] This demographic shift is largely driven by population momentum, with a modest contribution from

improvements in mortality rates. In contrast, fertility rates are expected to play a significant role in future population declines. Moreover, there is substantial empirical evidence showing a steady decline in the average household size across most countries worldwide over the past several decades, further driving urban expansion.[13] This trend reflects broader socio-economic changes and has implications for urban planning and resource allocation. The increase in the spatial extent of cities and the resulting decline in population densities increases the municipal costs of providing public services as well as the social costs associated with increasing congestion, pollution, and longer commutes.[14] Several studies confirm the expectations that more sprawling cities have higher transportation costs, more socioeconomic segregation, and lower labor productivity, resulting in economic loss.[15] Unmanaged urban expansion increases the costs of service provision, deepens spatial inequities, and imposes heavy economic and environmental burdens. According to the World Resources Institute, there are three key equity challenges linked to rapid outward expansion in cities of the Global South: distorted land markets, deficient services in growing areas, and disjointed informal expansion.[16]

However, more often than not, unregulated urban expansion is driven by the lack of affordable land near city centers and job opportunities. The high price of land in Latin America contributes to the shortage of affordable housing as well as the persistence of informal land markets and speculative nature of land markets,[17] often resulting in self-built settlements or informal land subdivisions. According

to Angel, “informal land subdivisions are areas that have been subdivided for urban use, but that lack visible evidence of conformity to land subdivision regulations such as regular plot dimensions, paved roads, streetlights, or sidewalks.”[18] While there is some consensus in the literature that a consistent effort should be made to reduce informality, there is recognition that doing so may exacerbate affordability challenges with perverse effects on poverty.[19] As we shall see in detail in the following chapters, urban expansion is mostly unavoidable and, if it is well planned, can provide an opportunity to reduce inequality and foster a sustainable transformation of territories and regions.[20]

Most contemporary cities face the challenge of managing population growth and urban expansion sustainably. To achieve this, it is essential to combine strategies of orderly expansion[21] and densification in existing urban areas, fostering a compact and diverse city model.[22] Well-planned urban expansion and densification allows cities to meet land needs without compromising sustainability or causing uncontrolled sprawl. Low-density urban areas, for example, could facilitate the deployment of renewable energy systems. Unlike high-density urban areas, where space constraints and land-use conflicts often limit the integration of renewable energy infrastructure, low-density areas offer ample space for solar panels, wind turbines, and other decentralized energy systems.[23] The International Energy Agency global analysis of renewable energy potential highlights how low-density urban expansion in regions like Australia and the American West has enabled the development of large-scale solar and wind projects,

leveraging the affordability and availability of land. These findings suggest that low-density urban areas can play a critical role in the global transition to renewable energy.[24] Similarly, low-density urban expansion can offer unique opportunities for integrating productive landscapes, such as urban agriculture, green spaces, and conservation areas. If well planned, these landscapes not only contribute to environmental sustainability but also enhance the economic and social resilience of urban areas.[25] Densification, in turn, optimizes existing infrastructure, increasing urban efficiency and reducing CO2 emissions, as demonstrated by studies on fuel consumption in dense areas.[26] Various authors have examined the effects of densification, highlighting its relationship with economic progress, innovation, and social interaction.[27] However, excessive and unplanned densification can lead to issues such as pollution, congestion, and a decline in quality of life.[28] This underscores the need for a balanced approach between expansion and densification adapted to each urban context. Jan Gehl notes that while high density is often linked to urban vitality, what is truly essential are spaces that are attractive and accessible to the community.[29] As urban areas continue to evolve, the need for inclusive urban policies that provide adequate access to housing, infrastructure, and opportunities for all residents is paramount for fostering resilient and sustainable cities in the region. As urban growth continues, it is essential to consider various environmental factors, including biodiversity, biomes, and climate projections, to inform sustainable urban development strategies. Incorporating regional maps

and empirical data will enhance our understanding of these dynamics and support effective policymaking in the context of urbanization.
Based on the needs outlined above, the book is organized into three sections to provide a comprehensive framework for understanding urbanization dynamics and guiding effective policy responses.

The first section—**Framework, Lessons, Findings**—presents the results of the study conducted by Prof. Shlomo Angel and the Marron Institute for Urbanization at New York University. The study investigates how cities can accommodate new urban populations and elevate the standard of living of current dwellers, portraying the anatomy of density of 70 cities in the region. In the first chapter, Angel presents a new conceptual framework for urban planning, one in which cities and governments accept the fact that territorial expansion is often inevitable and urban densification is not the only sustainable response to urban population growth. If planned for, urban expansion can help mitigate unequal access to opportunities and housing in cities as well as prepare cities for climate change. In the second chapter, Angel introduces twenty-one examples of international best practices in accommodating urban growth, starting with historical examples of urban expansion at scale, such as New York City's grid and Ildefons Cerda's plan for Barcelona. He also looks at non-market forces that have driven or prohibited urban expansion, plans that focused on urban containment, such as the Green Belt in London, the plans for new towns,

and successful programs to accommodate growth through densification and jurisdictional issues in planning for urban expansion. Finally, he presents successful examples of laying out the urban periphery in advance of its occupation, such as Lima's allotment in the outskirts of the city. In the third chapter, he presents a series of projections for the Latin American and Caribbean Region based on data and cartographies that map the anatomy of density of seventy cities in the region. Shlomo Angel's concept of the "anatomy of density" provides a framework for understanding urban density and its implications for city planning and development. Angel's concept is rooted in the observation that density is not merely a measure of how many people or buildings occupy a given area, but rather a complex interplay of various factors that shape urban environments. Angel's study presents a series of questions and trends that drive possible strategies and policies based on how cities have grown over the past decades and their future projected growth. Finally, he provides twelve guidelines for action to accommodate urban growth in the LAC region.

The second section presents the **Atlas** of cities in Latin America and the Caribbean through the framework of urban expansion and the anatomy of density, mapping their growth over the past four decades. Sixty-eight cities have been mapped through three parameters that together provide a more accurate understanding of urban density, defined as a ratio of the number of people per unit of area. As per Angel's definition, Urban Density can be defined by three main factors: floorspace occupancy—the ratio of

the total population of a city and its total residential floor area; gross residential floor area, including wall thicknesses and common areas; floor area ratio, calculated by dividing the allowable building area by the total area of the plot; and residential share—the total area of the city's urban footprint taken up by residential plots, a common metric used in quantifying urban land-use plans.[30] These three factors can also be understood as the result of seven more factors that ultimately provide us with an even more accurate understanding of urban density: dwelling occupancy, occupancy rate, dwelling unit packing, and floor plan efficiency, all of which define floor space occupancy; building heights and plot coverage determine floor area ratio; and finally residential share. Thirty of the sixty-eight cities in the atlas are analyzed through these seven factors.

The Atlas shows how each city densified over the past four decades, mapping their process of urban expansion through extension areas, which are all urban areas added in the new period that constitute contiguous urban clusters that are attached to the urban extent of the earlier period; inclusion, urbanized areas which were not contiguous to the central urban extent and, after a certain period, do merge into the central urban extent as the city expands; and leapfrog, new areas categorized as urban extent which are not attached to the main urban extent.[31]

The Atlas also includes three essays that present the expansion of three cities in the region—Campo Grande in Brazil, San Salvador in El Salvador, and

Mérida in Mexico—following Angel's methodology. The three case studies, characterized by different contexts, populations, and processes of urbanization, highlight the significance of a unified planning framework for effective urban growth management. Campo Grande has achieved notable compactness and density, benefiting from coherent planning, likely due to its non-metropolitan status. In contrast, the San Salvador Metropolitan Area demonstrates strong coherence in its planning and policy framework, supported by national regulations like the Law of Territorial Development and Planning. Mérida's Metropolitan Area, however, exhibits a more dispersed planning approach, primarily relying on national and state land use guidelines as its main planning instruments.

The third section of the book—**Strategies**—presents a series of objectives, methodologies, and tools to plan for urban growth in Latin America and the Caribbean region. **Shlomo Angel** provides twelve guidelines to accommodate urban expansion. **Diego Arcia**, **Hyuna Lee**, and **Camila Maleronka** provide a series of guidelines to promote a compact city. **Jason Hobbs** and **Julia Paiva** provide a framework to link transit-oriented development and urban expansion in the region. **Jeannette Sordi** and **Felipe Vera**'s essay presents a series of strategies to adapt vulnerable settlements to climate change by anticipating their future transformation and connecting them to the larger metropolitan area. **Pedro Henrique de Christo**'s essay provides climate urbanism as a framework to plan for urban expansion based on environmental risk and presents new tools that allow us to evaluate

such risks in informal settlements. **Pablo Martínez** and **Mar Santamaria** present new technologies and approaches that include citizens in data-collection process of developing indicators for urban quality. Finally, **Hye Jung Park** explores the socio-economic challenges arising in the urbanization process in South Korea and the lessons learned, considering the country's responses and initiatives through the Comprehensive National Territorial Plan (CNTP).

Over the past decade, the collaboration between Korea and LAC has been a pivotal conduit for knowledge sharing, particularly in urban expansion and strategic territorial planning. The partnership between KRIHS and the IDB has facilitated the development of practical responses in order to manage unregulated urban growth through land use planning, innovative solutions to address housing and infrastructure deficits, and integrating environmental management into urban planning initiatives. This publication is also one of the key outputs of these collaborative activities, contributing to forward-looking urban development strategies tailored to the region's evolving challenges.

A central focus of Accommodating Growth in Latin American and Caribbean Cities is the meticulous documentation of urban growth and its defining characteristics. By analyzing the expansion of seventy cities across the region over the past four decades, the study provides a comprehensive understanding of how urbanization has unfolded in response to population growth, economic shifts, and socio-political changes. This documentation goes

beyond mere data collection; it reveals patterns and trends that have shaped the urban landscape, such as the disproportionate relationship between land occupation and population growth. For instance, the study highlights how low-density sprawl has often led to inefficient land use, with cities expanding outward without optimizing available space. By capturing these dynamics, the publication creates a foundation for identifying the root causes of urban challenges and designing targeted interventions to address them.

The publication leverages cartography and data visualization to transform complex urban dynamics into accessible and actionable insights. Through detailed maps, charts, and visual representations, the study makes it easier for policymakers, planners, and stakeholders to grasp the metrics and problems associated with urban expansion. For example, the Atlas of Urban Expansion included in the book maps the growth of sixty-eight cities using parameters such as floorspace occupancy, floor area ratio, and residential share. These visual tools not only illustrate the spatial dimensions of urban growth but also reveal disparities in access to infrastructure, housing, and public services. By presenting this information in a clear and engaging manner, the publication empowers institutions to identify gaps, prioritize interventions, and develop evidence-based policies that address the root causes of urban challenges.

By mapping and analyzing the expansion of seventy cities in Latin America and the Caribbean, the study identifies both commonalities and

differences in how cities have grown. The study takes a nuanced approach to understanding urbanization by grouping cities into clusters based on shared dynamics of urban expansion and population growth. This clustering method recognizes that cities with similar characteristics may face comparable challenges and opportunities. For example, cities experiencing rapid outward expansion due to rural-to-urban migration may share common issues such as housing shortages and inadequate infrastructure. By identifying these clusters, the publication enables policymakers to develop tailored strategies that address the specific needs of different types of cities. This approach not only enhances the relevance of policy recommendations but also fosters regional collaboration, as cities within the same cluster can share best practices and learn from one another's experiences. This comparative approach allows policymakers and planners to learn from the experiences of other cities, adapting successful strategies to their own contexts. For instance, the case studies of Campo Grande (Brazil), San Salvador (El Salvador), and Mérida (Mexico) demonstrate how different planning frameworks—ranging from coherent metropolitan planning to dispersed approaches—have influenced urban outcomes. By fostering a shared understanding of urbanization dynamics, the publication can promote regional collaboration and innovation, enabling cities to address common challenges such as informal settlements, infrastructure deficits, and climate vulnerabilities.

The cartographic analysis and data translate into actionable guidelines for accommodating urban growth in a sustainable and equitable manner. Drawing on empirical evidence from 70 cities, the study provides 12 key recommendations for policymakers and planners. These guidelines emphasize the importance of forward-looking urban planning, which anticipates future growth and prepares cities to meet the needs of their populations. For instance, the study advocates for orderly urban expansion that balances the demand for land with the protection of natural resources and the promotion of low-carbon technologies. It also highlights the need for inclusive policies that address the housing and infrastructure deficits faced by marginalized communities. By grounding these recommendations in data and real-world examples, the publication offers a practical roadmap for transforming urban areas into resilient, sustainable, and equitable spaces. By integrating new technologies and approaches, such as citizen-driven data collection and climate urbanism frameworks, the study empowers local governments to address the challenges of urbanization in innovative ways. For example, the essay by Pablo Martinez and Mar Santamaria explores how participatory mapping and data collection can engage communities in the planning process, ensuring that policies reflect the needs and priorities of residents. Similarly, Pedro Henrique de Christo's essay introduces tools for assessing environmental risks in informal settlements, enabling planners to design interventions that enhance resilience and reduce vulnerability. These tools and methodologies not only

strengthen institutional capacity but also foster a culture of evidence-based decision-making.

By documenting urban growth, visualizing key metrics, and providing actionable guidelines, Accommodating Growth in Latin America and Caribbean Cities equips policymakers and planners with the tools and knowledge needed to design effective interventions. The emphasis on cross-city comparisons, clustering, and knowledge transfer fosters regional collaboration, while the integration of new technologies and participatory approaches ensures that planning processes are inclusive and responsive to community needs. Ultimately, the publication underscores the importance of forward-looking urban planning in creating resilient, sustainable, and equitable cities for future generations.

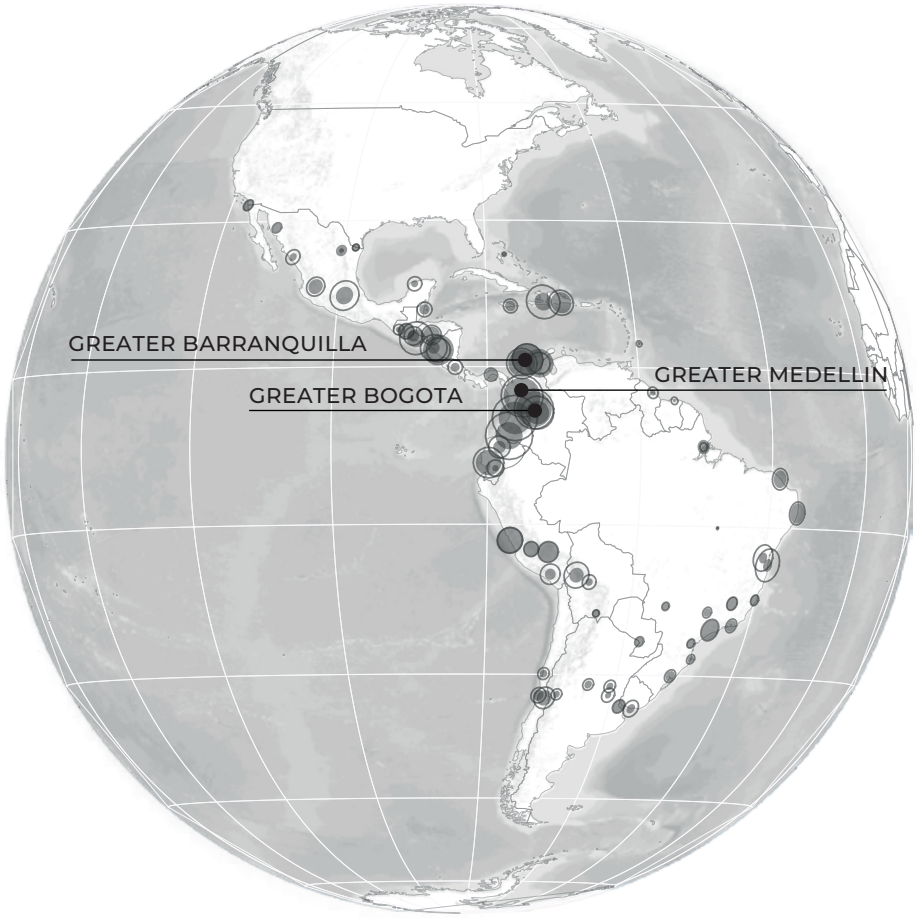
Absolute Density

1990's – 2020's

The average absolute density for the analyzed cities in Latin America and the Caribbean has decreased from 75 people per hectare in 1990 to 59 people per hectare in 2020. The majority of cities in the sample have become less dense over the last three decades—more than three-fourths. Amongst the 68 cities, those in Colombia stand out as having the highest densities in the 1990s as well as in the 2020s. Even so, most Colombian cities following the region's trend in decreasing density. Greater Medellín and Greater Bogotá—the two most dense cities in 2020—doubled their urban extent over the past thirty years; however, their population almost doubled as well, a proportion that explains how the cities kept their high densities.

The Absolute Density map compares average inhabitants per hectare in sampled cities for two periods: early 1990s (T1) and early 2020s (T4). It divides the total population by the urban extent for each period, indicating density changes over 30 years.

01.



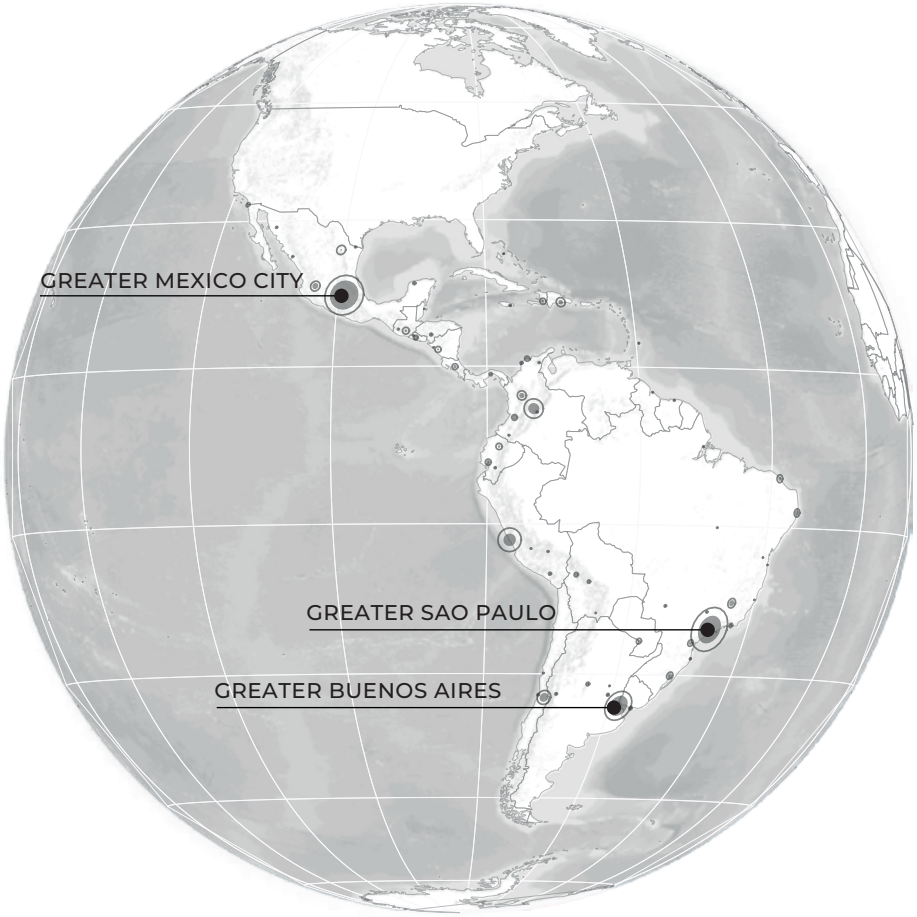
T4
T1
179 to 7 ppl/ha

Absolute Population

1990's – 2020's

Over the last three decades, Latin American and Caribbean cities in the sample have undergone significant population change as the region progressively urbanized. In terms of absolute population, national capitals and relevant cities to the region's economy have continued to see their population grow. As an example, Greater São Paulo, Greater Buenos Aires, and Greater México City have remained as the three most populous urbanized areas during the period stretching from 1990 to 2020. The already high population in these cities have significantly increased, as each grew respectively 59%, 44%, and 36%—totaling approximately 18 million inhabitants in the region between the three. In this process, the three cities followed the LAC region's trend in significantly decreasing population density—yet they remain substantially denser than the region's average.

The map of Absolute Population compares population assessments from the early 1990s (T1) with those in the early 2020s (T4) for cities in the sample. Thus, it allows a comparison in population changes amongst cities in the region.

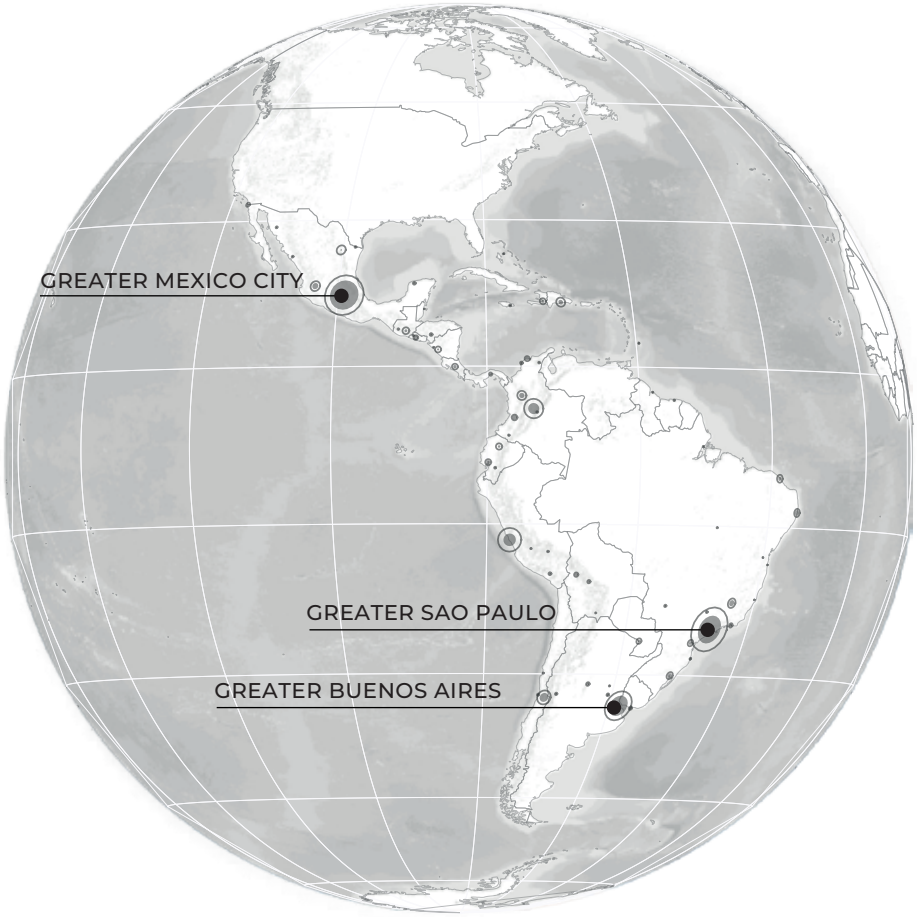


Absolute Urban Extent

1990's – 2020's

Cities in Latin America and the Caribbean have significantly increased their urban extent over the past thirty years when considering the sample of 68 cities. More than three-quarters have at least doubled their urban extent since the 1990s, and one quarter has more than tripled. In absolute values, Greater México City presented the highest increase in urban extent, at 144,181 Hectares in three decades—multiplying its original area in the 1990s by 1.2. The resulting city density dropped significantly from 170 inhabitants per hectare to 100. The same trend can be seen in the other two cities with the greatest urban extent area in the 2020s, Greater Buenos Aires and Greater São Paulo, as well as for most of the cities portrayed in the sample.

The Absolute Urban Extent map compares the area identified as the Urban Extent of each sampled city in the early 1990s (T1) to the early 2020s (T4). Hence, it is possible to contrast how much cities in the region have expanded their urban extent over the last three decades.



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Guayaquil, Ecuador. Ph: Andrés Medina. Source: Unsplash.





Cusco, Perú. Ph: Kieran Proctor. Source: Unsplash.


CELSIO

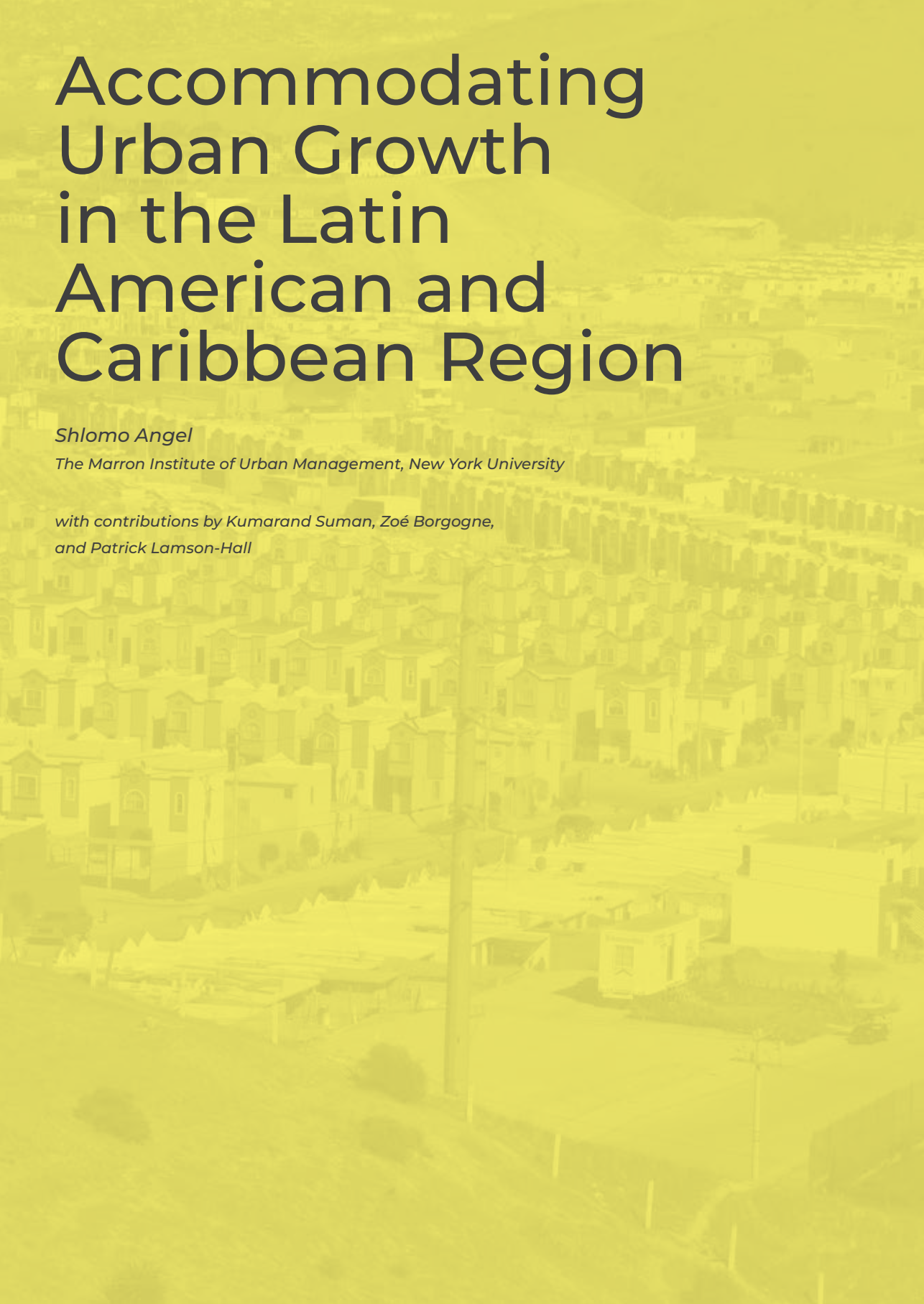


Cartagena de Indias, Colombia. Ph: Leandro Loureiro. Source: Unsplash.

Accommodating Urban Growth in the Latin American and Caribbean Region

Shlomo Angel
The Marron Institute of Urban Management, New York University

with contributions by Kumarand Suman, Zoé Borgogne, and Patrick Lamson-Hall





PART ONE

FRAMEWORK - LESSONS - FINDINGS

A New Conceptual Framework for Territorial Planning **P.62** // Key Lessons for Territorial Planning from 21 International Experiences in Accommodating Urban Growth **P.80** // Emerging Empirical Evidence for Territorial Planning in the LAC Region **P.130**

The Inter-American Development Bank (IDB) seeks to increase the capacity of national and sub-national governments in the Latin American and Caribbean region to carry out and put effective territorial planning into action at the scale required to accommodate the projected growth of cities in the region during the 2020-2050 period. While territorial planning has historically been successful in many cities in the region and the world in preparing land for urban use ahead of development, as well as regenerating and improving existing neighborhoods, it has not kept up with rapid urbanization. Because of this, large swaths of existing cities were developed without proper layouts, adequate protection of natural assets, or adequate resilience against climate risk. Other problems include a lack of access to the urban job market, as well as substandard housing and infrastructure services. Municipal governments and their planning and public works agencies—typically charged with regulating development and with the provision of roads and infrastructure services—have been saddled with often-inappropriate and complex regulatory regimes and with inadequate human, fiscal, and financial resources to provide territorial development management at scale. Territorial plan preparation has become lengthy and complex, and their execution often requires the hiring of foreign consulting firms. They are rarely owned and properly implemented by municipal officials. At the same time, city economies have flourished, and their lands greatly appreciated in value, value that has rarely been captured to fund municipal services at scale.

Traditional territorial planning is now at a crossroads and there is a healthy dialogue in planning and policy circles about its direction in the years to come. This book is a novel contribution by the Inter-American Development Bank (IDB) to this debate. The Bank is committed to a long-term engagement with member states in this dialogue, promoting effective, evidence-based, territorial planning of cities and metropolitan areas in the region. This planning will make them more productive, inclusive, and sustainable, as well as more responsive and resilient to climate change.

This section presents a novel conceptual framework for territorial planning in the LAC region. Based on a research program undertaken by New York University and sponsored by the IDB, it is focused on a representative sample of 70 cities in the region and regional and international case studies. Chapter I presents the new conceptual framework. Chapter II introduces twenty-one examples of international best practices in accommodating urban growth. Chapter III reviews the emerging empirical evidence gathered in 70 cities for territorial planning in the LAC Region. In the third section of this book, “Innovations in Planning for Urban Growth,” I present twelve guidelines for action on urban expansion for territorial planners in the region.

A New Conceptual Framework for Territorial Planning

TERRITORIAL PLANNING AND THE MITIGATION OF CLIMATE CHANGE

The challenge of accommodating future population growth in cities in the region is now bound with the twin challenge of responding effectively to climate change. Concerns with accelerating climate change have now resulted in urgent calls to reduce energy use and greenhouse gas emissions by promoting the densification of cities, as higher densities have been shown to decrease Vehicle Kilometers Travelled (VKT) and to increase public transit use, walking, and biking. Decreasing total vehicle-kilometers-traveled in cities can be accomplished in a number of different ways. Higher urban population densities—of both trip origins and destinations—will bring more of them within walking or biking distance of each other, thus reducing the number of vehicle trips made, and possibly the number of vehicles owned as well.[1] Higher densities—of both trip origins and destinations—will make public transit operations more viable, increasing the share of trips made by public transport and thus reducing the number of vehicle trips made and possibly the number of vehicles owned as well.[2] And higher densities will require smaller urban footprints to accommodate a given population, thus shortening the average travel distance between trip origins and destinations, leading to reductions in total vehicle-kilometers-traveled.[3] The 2022 IPCC report[4] highlights the importance of integrated territorial planning in reducing greenhouse gas (GHG) emissions. The report states that "[i]ntegrated spatial planning to achieve compact and resource-efficient urban growth through co-location of higher residential and job densities, mixed land use, and transit-oriented development (TOD) could reduce GHG emissions between 23% and 26% by 2050 compared to the business-as-usual scenario.[5] Increased urban densities, in other words, are advanced as a key intervention on the part of territorial planners to mitigate climate change.

We must ask ourselves, however, how much of a reduction in GHG emissions can be achieved given that the region is already so highly urbanized. In the Latin America and Caribbean region, we can only expect the urban population to increase by one-quarter (27%) between 2020 and 2050 (UN Population Division, 2018). This implies that even if cities remained in their entirety within their

existing footprints and did not expand at all—a highly unlikely scenario—their densities would only increase by one-quarter. This increase in density implies—according to the 2022 IPCC report mentioned above—that GHG emissions in the region can decrease at most by one-quarter of 23-26%, in other words by 6-7%. We must then consider that carbon emissions are related to levels of economic growth. Poor countries produce less carbon emissions than richer ones. This is clearly seen in Figure 1.1. In fact, when we look at carbon emissions by countries and regions (Figure 1.2), we see that in 2020 for example, one-third of carbon emissions were produced in the Global North and one-third in China, with the remaining one-third in the Global South outside China.

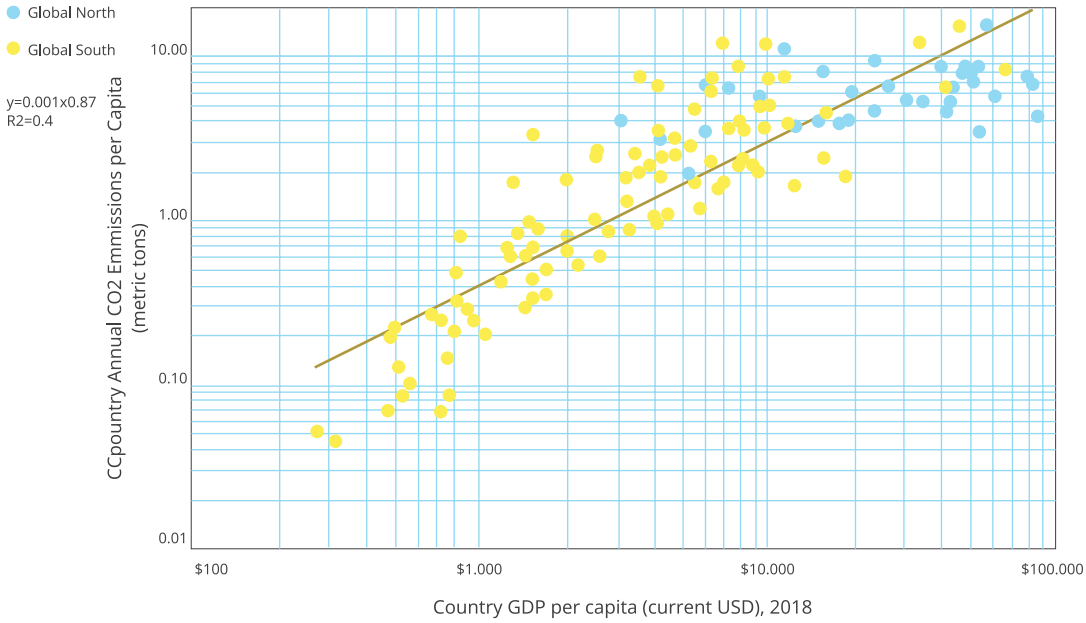
Of the 33 million tons of carbon emissions produced globally in 2020, the Latin America and Caribbean region produced 4.4%: Brazil produced 1.4%, Mexico 1.1%, Argentina 0.5%, and the rest of the countries in the region 1.5%.

Returning to the expected reduction in carbon emissions through the densification of cities in the region, if we can expect a maximum reduction of 6-7% of carbon emissions through urban densification, and if the region produces 4.4% of global carbon emissions, then maximum densification in the region can at most contribute a 0.3% reduction in global carbon emissions between 2020 and 2050. This is not an insignificant reduction, of course, but it does raise the question of whether the costs of maximalist densification outweigh its prospective benefits, at least from the perspective of mitigating climate change.

There are, of course, other benefits of densification over and above its contribution to mitigating climate change, benefits that have often been articulated under the compact city paradigm.

TERRITORIAL PLANNING AND THE COMPACT CITY PARADIGM

Urban planners and policy makers have understood for decades that densification can be made to address environmental challenges—by limiting depletion of natural resources, by slowing down the loss of cultivable lands, by reducing air and water pollution, and, of course, by lowering greenhouse gas emissions. The various claims that the denser a city is, the better it is—not only in environmental terms, but in economic and social terms as well—make up the *compact city paradigm*, a paradigm or worldview that is now "enshrined in land use planning policy in many countries."[6] Indeed, most countries in the Global North now pursue policies that implicitly or explicitly promote compact urban form,[7] as do many in the Global South. The 2008 plan for Amman, Jordan, for example,[8] encourages compact urban growth, infill, and mixed land use. The World Bank's Urbanization Review of Mexico,[9] for example, concluded that "Mexican policy makers included compact development and densification of cities as key goals in the national urban policy framework launched in 2013."[10]



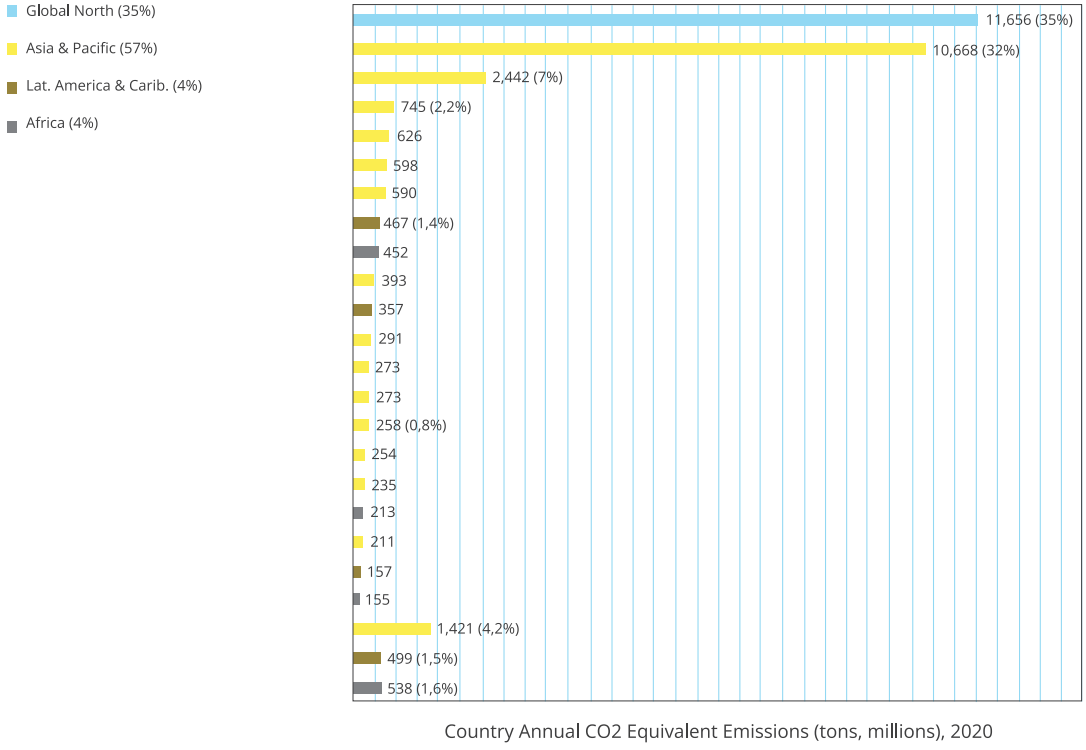


Figure 1.1: Carbon emissions in countries as a function of their GDP per capita in 2020. Source: New York University, The Marron Institute of Urban Management.

Figure 1.2: Carbon emissions by countries and regions in 2020. Source: New York University, The Marron Institute of Urban Management.

The compactness of cities has been defined and measured in a number of different ways. Since the advent of the compact city paradigm there has been a steady flow of findings—some more robust than others—showing, for example, that more compact cities can be more productive and more innovative; that they can deliver public services at a lower cost; that they can enhance social and economic mobility as well as diversity; that they can increase public transit use; that they can reduce energy use and greenhouse gas emissions; and that they can improve health and well-being.[11] In a review of evidence from 300 studies, Ahlfeldt and Pietrostefani have shown that the measurable effects of compact urban form have tended to become more positive over time, possibly driven by the application of more rigorous research techniques.[12]

That said, the compact city paradigm has had a number of detractors as well.[13] Compact city policies that seek to contain urban expansion—such as greenbelts or urban growth boundaries—have been criticized for their adverse effects on housing affordability through the creation of residential land supply bottlenecks.[14] In cities in the Global south, compactness has been associated with serious overcrowding, and increased compactness has been suspect of exacerbating traffic congestion, water, sewerage and drainage shortages, fire risk, and emergency vehicle access. It may also have led to an increase in a range of health risks.[15]

Still, the prevailing consensus among many territorial planning constituencies has favored the compact city paradigm over its antithesis, urban "sprawl," typically described as low-density, fragmented, unplanned, and uncontrolled expansion of cities into their rural peripheries. This has led many territorial planners the world over to advocate for the containment of urban expansion.

TERRITORIAL PLANNING AND THE CONTAINMENT OF URBAN EXPANSION

The containment of urban expansion—by green belts, urban growth boundaries, or other restrictions on the conversion of land from rural to urban use—is now the prevailing urban planning paradigm in most cities, in both the Global North and the Global South. Notable recent examples of efforts at containment in the Latin American and Caribbean regions are the green belt of Santo Domingo in the Dominican Republic,[16] and the new Jardín Circunvalar in Medellin, Colombia.[17]

In a survey of a global sample of 200 cities conducted by NYU for UN-Habitat in 2016,[18] respondents were posed the question "Is containing the expansion of the city an explicit goal of the zoning and land use plan?" Informants in two-thirds of the cities—71% in the Global South and 53% in the Global North—answered "yes."[19] Unfortunately, our survey did not obtain information on two important questions: One, whether containment was fully effective, only partially effective, or not effective at all; and two, what was the justification given, if any, for pursuing



Figure 1.3: Frankfurt, Germany has a green belt, but it surrounds only its city core. Source: City of Frankfurt am Main.

containment. The answer to the first question must, for now, remain anecdotal. Observations regarding the prevalence of effective containment in cities in the world at large are, at this stage, educated guesses. Yet, because the commitment to containment is so prevalent among territorial planners, we discuss it in this introductory chapter in greater detail.

Broadly speaking, containment may be successfully enforced when a well-managed public authority—with jurisdiction over the entire extent of the city and beyond—manages to withstand the pressure to expand over a long period of time. That pressure to expand is largely fueled by the demand for more room—in other words, for more floor space for both residences and workplaces—a demand which is fueled by both population growth and income growth, or by one of them in the absence of the other. When the supply of floor space within the existing footprints of cities is not able to respond to this demand—either because of regulations, because of NIMBYism ("Not in my Back Yard"), or simply because of the lack of construction finance—then the pressure to expand in the face of unaffordable floor space is typically irresistible. Except for a few known outliers, preliminary observations in the global sample of cities suggest that cities with *effective* containment—namely, containment that can accommodate urban population and income growth within a prescribed perimeter—appear to be few and far between. Containment is indeed on the books in many cities—that is, in official vision statements and master plans that have no statutory authority and are not enforced—and in many others, good intentions coupled with weak efforts at enforcement have, until now, simply failed.

We focus here briefly on three examples of failed containment: Frankfurt, Germany; Tokyo, Japan; and Beijing, China. Figure 1.3 shows that Frankfurt has a green belt that encircles the city core, which has 750 thousand people. But the metropolitan area of Frankfurt, including outlying cities with strong commuting relations to the city core, is more than three times larger and has expanded beyond the greenbelt: The greenbelt was incapable of containing its outward expansion. Its role is now limited to the provision of wide swaths of open space that, while providing important urban amenities, actually lengthen commutes and contributes to higher-than-necessary greenhouse gas emissions.

A very similar situation now exists in Brasilia, the Brazilian capital. The city was designed from scratch in the late 1950s and surrounded by a wide green belt to house no more than 500,000 people. Satellite cities beyond the greenbelt now house the majority of the 2.5 million people that inhabit its metropolitan area and workers living there commute daily across the green belt.[20]

Figure 1.4 shows the abandoned 1941 green belt in Tokyo, superimposed on its built-up urban extent in 2014. The area within this abandoned green belt is 450 square kilometers.[21] The area of Tokyo in 2014 was 14 times larger, 6,400+ square kilometers. The lands for the Tokyo green belt were acquired by the municipality and then taken over by the air defense and civil defense forces during the Second



Figure 1.4: The abandoned Tokyo green belt of 1941 encompassed an area of 450 square kilometers. The urban extent of Tokyo in 2014 was 14 times larger: 6,400+ square kilometers. Source: New York University, The Marron Institute of Urban Management.

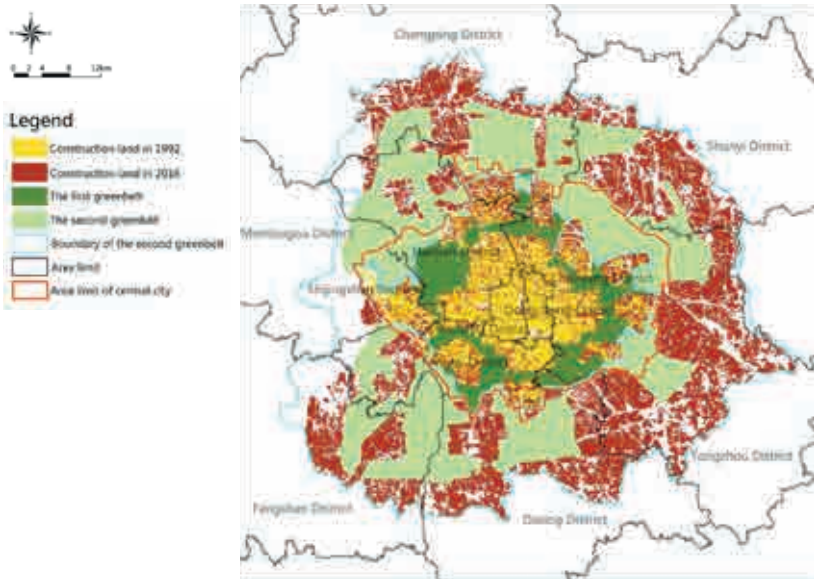
World War. After the war they were sold off by the occupation government to farmers, and then eventually urbanized.[22]

In China, to take a different example, metropolitan governments typically have planning jurisdictions over their entire expansion areas and beyond. They regularly prepare metropolitan expansion plans that seek to limit their expansion. The central government in China has issued numerous decrees limiting metropolitan expansion plans, typically in the name of preserving agricultural land to protect the country's food security. It reserves the power to review and approve such plans to ensure compliance. On paper, Chinese provinces are mandated to keep fixed the amount of cultivated land in the province. Any reduction due to urban expansion must be compensated by an equivalent increase in cultivated land somewhere else in the province.

Still, urban expansion in China proceeds at a much faster pace than that prescribed in official plans. The 2010 plan for the city of Zhengzhou, for example, submitted in 1998, estimated its 2010 population at 2.3 million and its area at 189 square kilometers. Both were surpassed by 2003. The fate of the green belt of Beijing, shown in Figure 1.5, is illustrative of this failure to limit urban expansion in China as well. The red area in this map is the area within Beijing's 2003 officially designated green belt (light blue boundary) that has been built upon by 2016. Much of the remaining area of the original green belt has been fragmented, and much of it now stands as a barrier between the older city and its newer suburbs, rendering the city less compact than before, and increasing the average travel distance in the city unnecessarily. But the story does not end here. President Xi Jinping has stepped into the fray. In an important address to the Communist party in 2017 he emphatically declared: "We will complete works on drawing red lines for protecting the ecosystems, designating permanent basic cropland, and delineating boundaries for urban development."[23] Whether these boundaries will be respected remains to be seen.

What is the rationale behind the call for containment in these cities? In China, as we saw, containment has been mandated to conserve the limited amount of cultivated land in the country in the name of food security, an important national security issue for China. The original justification for the English green belts, to be discussed in a later section, was "controlling further urban growth...avoiding the merge of cities into each other...and separating the typical characters of town and countryside."[24] Much of that justification did not stand the passage of time. The green belts could not halt urban population growth. Green belts are not the ideal solution for granting urban residents access to green open space either.

In fact, a hierarchy of public open spaces, such as those of Toronto, Canada (Figure 1.6), provides much better access to open space for its citizenry. Access to the open countryside is better provided by green wedges rather than by green belts, like those of the 1947 Finger Plan of Copenhagen, for example, shown in Figure 1.7.





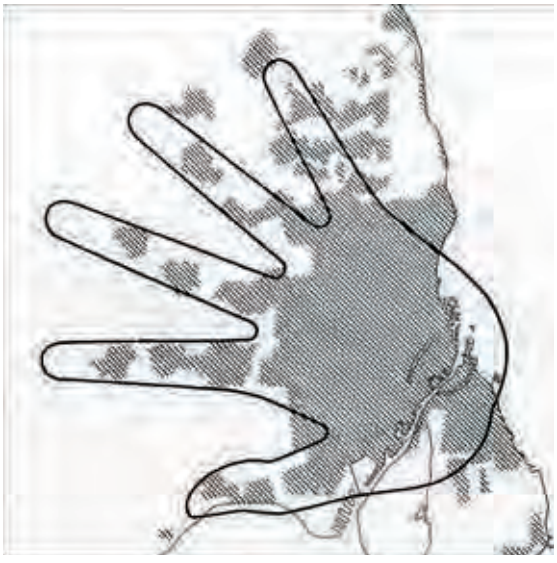


Figure 1.5: The red area is the area within Beijing's 2003 green belt (light blue boundary) that has been built upon by 2016. Source: Li et al. "Urban Green Space Fragmentation and Urbanization: A spatiotemporal perspective," Forests 10 (4) (2019): 333. CC BY 4.0.

Figure 1.6: In 2011, Toronto, Canada, had a hierarchy of public open spaces that constituted 11 percent of its area. Source: New York University, The Marron Institute of Urban Management.

Figure 1.7: The Copenhagen, Denmark, 1947 Finger Plan, proposing urban development along public transport corridors, leaving wedges of the open countryside between them. The planning framework for the city was published in 1947 by Steen Eiler Rasmussen and Christian Erhardt Bredsdorff.

The justification for containment in the United States—which has successfully limited outward expansion in many cities, largely through regulatory barriers to development—not through strict peripheral containment—was largely motivated by a distaste for 'sprawl.' This visceral distaste for large expanses of low-density, single-family homes dependent on the despised car—among planners and urban intellectuals, to be sure, but not necessarily among the population at large—was, at its root, aesthetic. Sprawled expanses and their commercial strip malls do not look like or feel like a city. A real city is more compact. Atlanta does not feel like Barcelona, where you can walk everywhere. Houston does not feel like Amsterdam, where you can bike everywhere. A 2021 World Bank report—titled *From Pancakes to Pyramids*—[25] preaches containment and compact cities in the Global South, calling for massive densification coupled with massive investments in public transport. It also calls for a massive increase in construction and mortgage finance that will provide a multi-story housing alternative than can replace the self-built, low-rise, informal settlements that now constitute some 70 percent of new housing in Sub-Saharan Africa, for example.

There are good reasons to believe that this is yet another well-intentioned pipedream, one that is not likely to materialize in the near future, when cities in several developing regions—most notably in Sub-Saharan Africa and the Indian subcontinent—are still growing in leaps and bounds. The containment of urban expansion, as it is preached and practiced, is largely found to be wanting, especially when it is attempted in rapidly growing cities in the Global South, where most urban growth is now taking place. Like Tokyo and Beijing mentioned earlier, many city governments in these countries are simply too weak to practice effective containment in the face of overwhelming demand for land on the urban fringe of cities, by both formal and informal developers. Containment there is most likely to fail. And where strict containment has been successful, we see three problematic outcomes.

First, once the contained area is largely filled, we typically witness a rapid increase in land prices and a subsequent affordability crisis. This has been well documented in both London, England[26] and Seoul, Korea.[27] Containment is now seen by more and more people as excluding them from the cities that they would like to live and work in but cannot afford to, because of housing supply bottlenecks that result in exorbitant house price inflation.

Second, containment policies have often been pursued without a comprehensive strategy for densification. Namely, planners that have advocated containment have relied on the private sector to densify the existing footprints of cities—be it through the infill of vacant plots or through the more intensive use of existing plots—without much concern of whether existing regulations, existing infrastructure, or existing transportation modes support or hinder such densification and whether it can be implemented in a way that does not compromise affordability, does not generate implacable neighborhood resistance, does not

The continued commitment of territorial planners to containment presents a real intellectual barrier to accommodating urban growth in cities in the region. In most cities, there are good reasons to believe that it will fail. In a few where it may succeed, its adverse consequences—be they unaffordable housing and economic discrimination or the lengthening of commutes—may outweigh its benefits, be they in mitigating climate change or in protecting some green areas from urban development. This report challenges the containment paradigm and raises an important question for territorial planners in the region: Is there a ‘green’ alternative to containment?

compromise access to open space, and does not reduce the city's resilience in the face of climate change.

Third, city mayors and territorial planners committed to containment are more than likely to underestimate the lands needed for urban expansion, hoping against hope that their cities will not expand. City mayors and urban planners committed to containment are thus less likely to plan for orderly and climate-sensitive urban expansion on the fringe of their cities. After all, how can you plan for something that, in your heart, you really don't want to happen?

To conclude, the continued commitment of territorial planners to containment presents a real intellectual barrier to accommodating urban growth in cities in the region. In most cities, there are good reasons to believe that it will fail. In a few where it may succeed, its adverse consequences—be they unaffordable housing and economic discrimination or the lengthening of commutes—may outweigh its benefits, be they in mitigating climate change or in protecting some green areas from urban development. This report challenges the containment paradigm and raises an important question for territorial planners in the region: Is there a 'green' alternative to containment? There are good reasons to believe there is.

STRATEGIC DENSIFICATION COUPLED WITH 'GREEN' EXPANSION AS AN ALTERNATIVE TO CONTAINMENT

Making cities more compact—and greener as well—does not call for strict containment but rather for a proper *balance* between densification and expansion, which are, in our view, two complementary strategies—and often substitutes as well—for making enough room for the inclusive growth of cities the world over. The densification and expansion of Panama City, for example, is shown in Figure 1.8.

This proper balance can be attained, in our view, through the regular operations of land and housing markets once resistance to development is overcome, the distortions created by inappropriate regulations and incentives are removed, and making room through densification and expansion takes place on a level playing field. How this balanced is achieved will depend on a realistic assessment of the shares of the populations added to cities that are accommodated through the strategic densification of their existing footprints as compared to the share accommodated in expansion areas. This is an empirical question that the present study has sought to answer by focusing on a representative group of 70 cities in the region. As we shall see later, in recent decades, 1990-2020, some four-fifths of the added population to cities in the region was accommodated in their expansion areas, while one-fifth was accommodated within the 1990 footprints. That share can, no doubt, be increased, possibly in a substantial way, by effective



Figure 1.8: Densification and expansion—The upward and outward growth of Panama City, Panama, 1930 (top) and 2009 (bottom).

and comprehensive densification policies but, realistically speaking, it cannot be increased to a unity, where 100% of the added population and economic activity will be accommodated within the existing footprints of cities.

Containment plans and policies have rarely, if ever, been accompanied by comprehensive plans for the densification of existing urban footprints, plans that prescribe how densities are likely to be increased over time beyond simply relying on the infill of the remaining vacant plots within these footprints. Indeed, where we have seen densification—as we shall report later—it has been largely confined to the infill of vacant plots, and often at floor area ratios that were not any higher than those of adjacent plots. Prescribing containment and then hoping that densification will occur naturally—through the regular operations of real estate markets—is typically misguided. Surely, containment may create land supply bottlenecks thereby increasing the price of land, but in the absence of regulatory reforms that relax floor area ratios, single-family zoning, minimum plot sizes, or minimum dwelling unit areas, increased prices will simply be translated to higher, and less affordable housing prices.

Our proposed alternative is the *Anatomy of Density framework*,[28] a comprehensive strategic planning framework for making cities more compact by looking at all the factors that constitute density. In a later section, we show how to decompose urban density into three and then seven factors and then examine a large number of territorial planning tools for addressing densification through each one of these factors.

We also introduce a conceptual framework and a set of tools for territorial planners to ensure that the urban expansion that goes hand in hand with strategic densification is 'green' rather than a continuation of business-as-usual urban sprawl.[29] Green urban expansion seeks to ensure that the rural periphery is converted to urban use in a way that conserves areas of high environmental risk or high amenity value, in a way that connects the periphery to the urban job market with a grid of arterial roads that carry public transport, in a way that enables the plots adjacent to these arterial roads to develop as high density areas of 'transit-oriented development', and in a way that makes local neighborhoods easier for walking and biking, and—most importantly—in a way that keeps housing in cities accessible and affordable to all their inhabitants.

We have chosen to introduce territorial planners in the region to the balanced approach to densification and expansion using three approaches. The first one, introduced in section II of this report, is a review of twenty-one international experiences in accommodating urban growth, experiences that highlight many of the lessons embedded in this approach. The second, introduced in section III, is the exposition of a new set of findings and their implication of our study of four new data sets focusing on a group of 70 cities in the region. In section IV, we conclude the report by summarizing its major findings and its key lessons for territorial planning in the region in the coming decades.

In recent decades, 1990-2020, some four-fifths of the added population to cities in the region was accommodated in their expansion areas, while one-fifth was accommodated within the 1990 footprints. That share can, no doubt, be increased, possibly in a substantial way, by effective and comprehensive densification policies but, realistically speaking, it cannot be increased to a unity, where 100% of the added population and economic activity will be accommodated within the existing footprints of cities.

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Key Lessons for Territorial Planning from 21 International Experiences in Accommodating Urban Growth

One of the main responsibilities of territorial planners—at least since Hippodamus, one of the early practitioners of the art of city planning, laid out the city of Miletus in Greece in the fifth century B.C. (Figure 2.1)—has been to prepare plans to accommodate urban growth through orderly urban expansion, allocating lands for public works, and laying out areas for occupation before they are settled. Unfortunately, for numerous reasons to be discussed below, few cities today practice orderly urban expansion at scale.

The failure to organize the orderly expansion of cities has been costly, particularly for cities in the Global South and, more specifically, in cities in the Latin American and Caribbean region. In those cities, lack of effective planning at scale has meant that expansion areas on the urban periphery are not well-connected to the city center and its income earning opportunities and often lack basic services like water, sewerage, and drainage. Evidence from a global sample of cities shows that urban peripheries built between 1990 and 2014 have fewer planned layouts, smaller shares of their areas in streets, larger blocks, fewer 4-way intersections, and a lower density of arterial roads than areas built before 1990.[1] More recent evidence from a sample of cities in the Latin American and Caribbean region, to be discussed later in Section III, points to similar conclusions. Unchecked, unplanned expansion has been taking place with little concern for nature preservation—or long-term climate risks—productivity, inclusiveness, or gender balance.

To take one prominent example, Figure 2.2 shows a 60-square-kilometer expansion area in northeast Bangkok, Thailand, that has been largely unplanned. Rural land holdings have been converted to urban use by local village headmen that have negotiated among rural landowners for narrow lanes between their land holdings that guaranteed road access to every plot. The absence of arterial roads has made it difficult to connect this area to the rest of the metropolitan labor market, and resulted in extreme congestion along its peripheral arterial roads. This is but one example of unplanned urban expansion. It does raise a question of 'why?' Why was urban expansion unplanned?

There are five mundane answers to this question. First, for some, all urban expansion is undesirable, typically denigrated as 'sprawl,' blamed for destroying productive lands and natural habitats. If it is undesirable, then why plan for it? Our answer to this question is mundane too. Cities growing in population and income inevitably expand, whether their residents and governments support or resist that expansion. In quantitative terms, as we shall see later, four-fifths of the population added to cities in the LAC region between 1990 and 2020 was accommodated in expansion areas, while one-fifth was accommodated within their 1990 footprints. And if neglected, expansion proceeds anyway, but it an unplanned manner with numerous adverse consequences.

Second, while in principle "prevention is better than cure," cities fail to invest both human and financial resources in preparing for the future—even though returns on such investments are enormous—because they are too busy dealing with the burning issues of the present. That said, however, when housing is in short supply and unaffordable, for example, coalitions that demand the opening new land for housing do form, as we shall show later in this section, demanding either urban expansion or densification so as to make housing more affordable.

Third, officials and civic leaders often underestimate the amount of expansion that will take place, having little access to realistic population and area projections. Not surprisingly, it is difficult for them to imagine that their city will double in population and triple in size in a matter of two to three decades, a not uncommon occurrence as this report will clearly demonstrate. Now, with the proliferation of satellite imagery, we can easily see how fast cities grow and expand, making it more difficult for city officials to ignore the scale of the problem.

Fourth, the tools being employed to manage urban expansion and densification—either traditional master plans or zoning and land use regulations—are often costly, inappropriate for the task, difficult or impossible to implement, and largely ignored by key stakeholders in the process. That said, there are new tools now being employed which are simple and effective, and specifically tailored to the needs of municipal planners in the Global South. Trained municipal planners with simple tools and techniques and adequate resources to manage expansion and densification are still in short supply, but the means of providing them with the necessary training are already available.

Fifth, jurisdictional issues in both expansion areas and existing urban footprints, contested land ownership, inter-agency conflicts, speculation, and corruption in land transactions make it difficult to implement even the best laid plans. This need not be surprising because the conversion of lands from rural to urban use, or zoning changes from one urban use to another, generate enormous value and the appropriation of this value is highly contested. Still, orderly urban expansion, as we shall see below, does take place where there is trust that this surplus value will be allocated fairly among all parties involved in the process.





Figure 2.1: The fifth century BC plan of Miletus, Greece, attributed to Hippodamus.

Figure 2.2: A 60km^2 area in northeast Bangkok, Thailand, with arterial roads on its periphery, in 1984. Source: Angel et al, 1987. The Land and Housing Markets of Bangkok: Strategies for Public Sector Participation, Volume 2, Map 4-13, page 1-65.

To conclude, there are many good reasons why cities do not plan properly for neither expansion nor densification. And it is for this reason that we must turn to cities that did attempt to manage their expansion and densification—some in more successful ways than others—and to begin to understand why they did what they did, how they did it, and what did they achieve or fail to achieve in the process. The broad aim of this section is to give territorial planners—as well as other stakeholders—a deeper understanding of what their available options are, given the specific context of their own cities, to address future urban expansion and densification at scale in an orderly, effective manner.

We begin with three historical examples of urban expansion at scale: The 1811 Commissioners' Plan for New York City, the United States, the 1858 Cerda's *Ensanche* Plan for Barcelona, Spain, and the 1868 Hobrecht's expansion plan for Berlin, Germany. These three plans include most of the innovations embedded in orderly urban expansion, from planning at scale to social inclusion, from resolving jurisdictional issues to value capture, and from the provision of public open spaces to the allocation of adequate land for streets.

Second, we look at three examples of non-market forces that drive or prohibit urban expansion: Misguided incentives driving the abandonment of large residential tracts developed in distant locations by INFONAVIT in Mexico, concerns for security driving the development of large tracts of gated communities on the periphery of Buenos Aires, Argentina, and the constraints on low-density suburbanization in Bogotá, Colombia, driven by fears of kidnapping during the civil war there. These three examples provide a broader perspective on the multiple forces—outside the normal operations of real estate markets or the ambit of municipal planning authorities—acting to push or constrain urban expansion.

Following the introduction of these examples, we review the state of the art of urban containment and introduce three classical examples of efforts to contain urban expansion and their consequences: The London, England, green belt of 1944, the Seoul, Korea, green belt of 1971 and the Portland, United States, Urban Growth Boundary of 1973. These three examples include most of the innovations involved in seeking to contain urban expansion, as well as the consequences of such containment.

Next, we introduce three examples of successful densification: the Accessory Dwelling Unit (ADU) legislation in California, the TAMA38 program in Israel for improving earthquake resistance in condominium buildings by adding floors, and the elimination of single-family zoning in Auckland, New Zealand.

We then focus on efforts to accommodate urban growth in new towns, seeking to direct urban growth away from the immediate periphery of the existing footprints of cities and creating free-standing new cities in the countryside. Again, we focus on three examples: The new towns program in the Republic of Korea; the new towns surrounding London, England, with a special focus on Milton Keynes; and the new town of Kilamba, Angola. These three examples again include most of the innovations, as well as the limitations, of accommodating urban growth in new towns.

Next, we focus on the jurisdictional issues involved in planning for urban expansion at scale. Again, we present case studies of three cities and metropolitan areas: Zhengzhou in China, Hawassa in Ethiopia, and Barranquilla in Colombia. The large jurisdiction of Zhengzhou facilitates planning for its expansion. Hawassa had to expand its jurisdiction over its expansion area through negotiations with its neighboring rural councils. Metropolitan planning at the provincial level in the Department of Atlantico, Colombia, facilitated planning for urban expansion. Together, these three examples introduce most of the lessons involved in obtaining jurisdiction over expansion areas.

Finally, we focus on three recent examples of the orderly conversion of the rural periphery of cities to urban use through the introduction of arterial road grids and urban street grids. We look at the expansion plan for Valledupar, Colombia; at Town Planning Schemes in Ahmedabad, India; and at planned informality in Lima, Peru.

Together, these twenty-one examples provide a comprehensive narrative of established practices in planned urban expansion, introducing city planners to many of the most important innovations in this field as well as to the complexities involved in getting it right.

01 / HISTORICAL EXAMPLES OF URBAN EXPANSION AT SCALE

The 1811 Commissioner's Plan for New York City, United States

The 1811 Commissioners' plan for New York City (Figure 2.3) was both a response to rapid population growth and an expression of confidence that the city was destined to grow and prosper. Manhattan's population tripled between 1790 and 1810, from 32,000 to 96,000. The plan projected the population to quadruple to 400,000 by 1860.[2] To make room for the projected growth, the plan prepared the ground for the built-up area of the city to increase six-fold.

The built-up area of New York city in 1807 was largely concentrated at the Southern tip of Manhattan, near its port.[3] The city's Common Council was under severe and often conflicting pressures from powerful landowners to open new streets to improve access to their properties. To relieve the political pressures on the Council, it turned to a higher authority—the New York State legislature—that in 1807 enacted a stature appointing three commissioners and empowering them to submit a binding street plan for the entire city in four years.[4] The commissioners opted for a rectilinear street grid, observing that "a city is to be composed principally of habitations of men and that strait-sided and right-angled houses are the cheapest to build and the most convenient to live in."[5] All blocks had a regular width of 60 meters and varied in length from 80 to 200 meters, the smallest lots measured 6-by-30 meters. City blocks were formed by 155 20-meter-wide streets running East-West and 12 33-meter-wide avenues running North-South.[6]

The commissioners made their own back-of-the-envelope population projections. In their comments on the plan, they remark: "To some it may be a matter of surprise that the whole island has not been laid out as a city. To others it may be a subject of merriment that the commissioners have provided space for a greater population that is collected at any spot this side of China."[7]

The plan faced stiff resistance from landowners. It could withstand it in part because the grid did not favor one landowner over another and in part because its geometric rigidity could not be compromised without drawing undue attention.[8] The statute appointing the commissioners mandated the payment of compensation for the taking of rights-of-way for the streets, as well as assessments on lands in accordance with the increase in value due to the opening of streets. Street-adjacent properties were assessed three times, once when the street was opened, once when it was paved, and once when infrastructure services such as water, sanitation, and drainage were introduced. Even though many instances of corruption and mismanagement were recorded over the years, the street network paid for itself through these assessments.[9]

Attempts to modify the plan or to change its financing continued for many years, with little success. The grid plan was largely unchanged and continued to be implemented through numerous city administrations. The 1811 Commissioners' plan for New York City is one of the few successful examples of the creation of a viable political and legal expansion planning structure, by way of a street grid.[10]



Figure 2.3: The Commissioner's Plan for New York City (1807). Source: Wikipedia. (2023).

The Ildefons Cerda 1858 *Ensanche* Plan for Barcelona, Spain

By 1859, Barcelona, Spain was badly overcrowded and very unhygienic, with a density more than twice that of Paris and a life expectancy of only 23 years for members of the working class.[11] The city, trapped within its medieval walls, needed room for population growth and industrialization. In response to this crisis, the City Council of Barcelona organized an architectural competition to plan the city's expansion. Ildefons Cerdà, an engineer, city planner, and social reformer studying and working in the old city, prepared a topographical map that was used in the competition.[12] He lost the competition, but the city council was overruled, and he was awarded the commission by royal decree. At that time, the fashion in Europe was the radial plan with one center and big avenues disposed as the rays of the sun. Indeed, the plan that won the competition was a radial one. However, Ildefons Cerda presented the contrary, an orthogonal plan, the grid (Figure 2.4).[13]

Unlike the radial layout in the winning plan, Cerda's gridded expansion plan for the city did not distinguish rich and poor areas. All blocks were the same. The grid, as Adrian Gorelik[14] has observed, is an egalitarian plan. The plan expanded the area of the old city tenfold—the old Barcelona was almost 200 hectares and the new one was 2,000—[15] allowing for its decongestion.

It is important to note that a substantial share of the expansion area was devoted to streets. Ildefons planned that the streets had to be minimum 20 meters wide: 5 meters on each side for pedestrians and 10 in the middle for transport. At that time cars didn't exist, which, in retrospect, made the plan more visionary. The plan also allowed buildings only on two sides of city blocks, reserving plenty of open space within each block, but pressure from developers quickly led to construction on most of that open space. Cerda was aware of the need to distribute social services, including hospitals and markets, throughout the area, accessible to everyone. Indeed, he allocated areas in the plan for different facilities in every quarter. By 1977, more than a century after its implementation, Cerda's plan was nearly built-up in its entirety as the city expanded in all directions.[16]

Because of the simple and egalitarian vision of Cerda's plan, the city could be decongested along transportation lines and ample room was created for Barcelona to grow.

By allocating adequate lands for streets, the plan facilitated the provision of public transportation and infrastructure systems that Cerda himself never considered. Most importantly, the Cerda plan set a standard for implementation that cities in the Global South, and in the LAC region in particular, could emulate: growth plans must be large enough to make room for future land uses, but simple enough to become a reality on the ground.

The James Hobrecht 1862 Expansion Plan for Berlin, Germany

The James Hobrecht 1862 expansion plan for Berlin is a good example of a plan designed and implemented under constrained circumstances such as those facing cities in the Global South.

Hobrecht's plan for Berlin was not a strict geometric grid, but an irregular grid that mostly followed existing roads and property lines (Figure 2.5), to minimize conflicts with landowners



Figure 2.4: Ildefons Cerda's 1859 Ensanche plan for Barcelona. Source: Bausells, M. (2016). Stories of Cities #13: Barcelona's unloved planner invents science for "urbanization." *The Guardian.*

and expropriations.[17] Although, according to Prussian law, land for roads and streets had to be yielded without compensation, Hobrecht tried to minimize the appropriation of lands for public use. Since roads had to be financed and constructed by landowners, he needed to ensure their support and continued prosperity. His sensitivity to the economic and political realities of his environment is an important lesson for planners in the Global South today.[18] He was acutely aware of the lack of planning controls over land use, plot coverage, setbacks, building height, or minimal requirements for light and air in buildings. The few enforceable regulations available were those that protected public streets and public squares.[19] To manage the separation of uses, Hobrecht planned for different block sizes, allowing for larger blocks for factories on the periphery of the city as well as along shipping routes and railway lines. Most residential blocks were 2 to 5 hectares in area, and only industrial blocks were larger than 5 hectares.[20]

The plan had nothing to say about private land uses within blocks. Instead, Hobrecht sought to promote public health and integrate the city into an economic and social whole using three inter-related design principles.[21] First, ensuring that public streets were wide enough to form public outdoor spaces in addition to providing good overall access. Streets were planned to be 26-meters-wide, considerably wider than the streets in the existing city.[22] Second, dividing the plan into districts with similar street grid structures that did not distinguish between rich and poor, offering them the same access both to local streets and to the city as a whole. And third, creating a hierarchy of public squares, at street intersections, in the centers of districts, along the ring promenades, and along the River Spree.[23] The main criticism of the Hobrecht plan was that the blocks in the plan—left to speculators and housing developers—were quickly constructed with 6-story walk-up tenements, *Mietskasernen* in German, that became overcrowded. In truth, the strong regulatory framework needed to control zoning and land use did not exist at the time.[24]

In the present context of planning for pragmatic and realistic urban expansion in the Global South with climate, inclusiveness, and gender equality in mind, the Hobrecht plan provides important contemporary lessons. It allows for maximum densification and for mixed uses by not restricting what can be built within blocks. Its grid does not create social divisions but instead treats all urban spaces equally without distinction between rich and poor, and it distributed accessible public open spaces throughout urban districts.

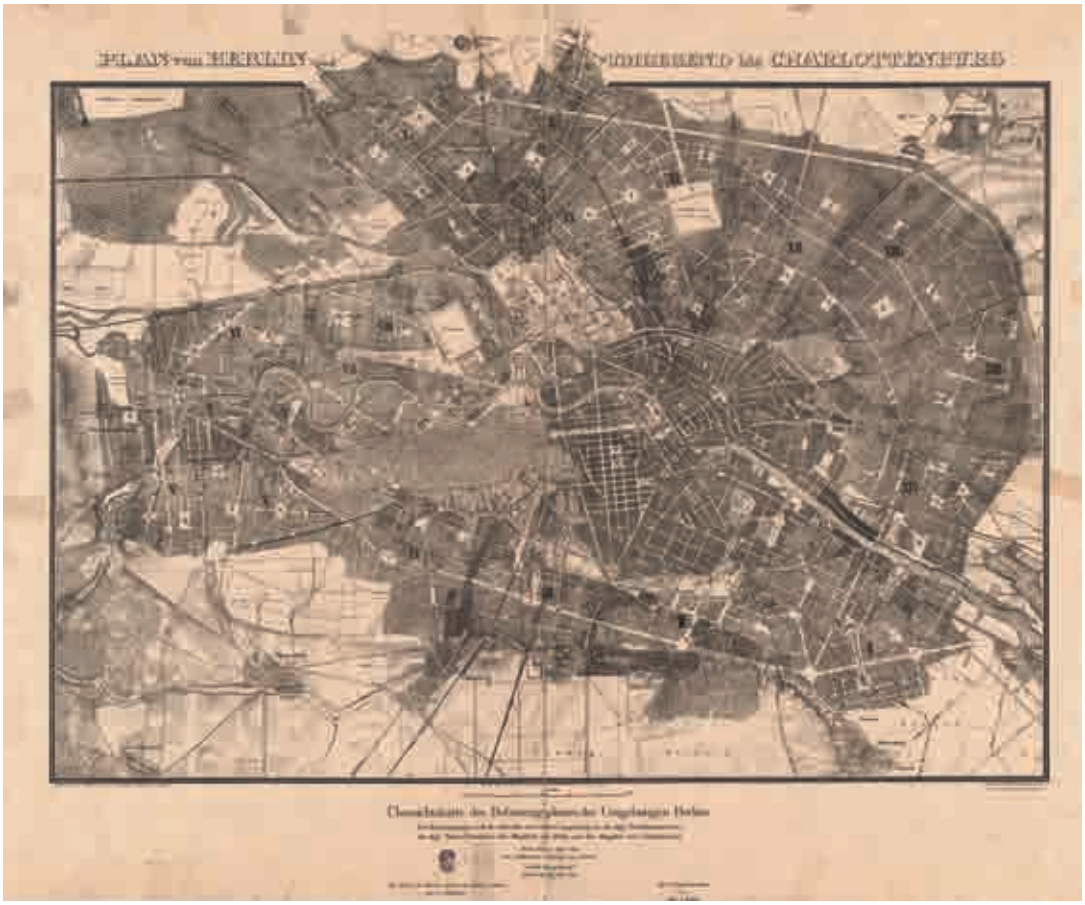


Figure 2.5: The 1862 Hobrecht plan for Berlin. Source: Wikipedia. (2022). Hobrecht-Plan. *Hobrecht-Plan* - Wikipedia

02 / NON-MARKET FORCES THAT DRIVE OR PROHIBIT URBAN EXPANSION

Abandoned Homes in Distant Housing Estates financed by INFONAVIT in Mexico

The National Housing Fund for Workers (INFONAVIT), founded in 1972 to produce housing for formal and private sector workers, is governed by business, government, and labor representatives. From 1998 to 2014, INFONAVIT sponsored about 5.4 million housing mortgages.[25] In the 2000s, this mortgage-lending expansion allowed the six largest housing development companies to produce approximately 50% of the country's new housing and to operate in most Mexican cities.

During this period, INFONAVIT guaranteed a credit flow to finance the quick and mass production of housing, effectively absorbing much of the risk away from developers. Developers were expected to build affordable housing but were not restricted as to the location of such housing, nor were they responsible for marketing the housing. They produced the housing and transferred them to INFONAVIT, which then allocated them to its members. Notably, INFONAVIT's fiscal capacity is contingent on a 5% tax on workers' earnings and on loan recovery, and its loan volume has made it the third largest mortgage institution in the world.[26]

This great financial engine—along with the important support and incentives provided by pro- development state governments—steered housing development to the peri-urban fringes of Mexico's urban and economic centers. A handful of large private developers have seen in INFONAVIT a profitable opportunity of building housing with lower quality on cheap peri-urban land with almost no development regulation.[27] This model not only incentivizes construction, but also the purchase of houses: loans from INFONAVIT have interest rates below market and acquiring a house was the main way for employees to use their mandatory contributions. With such incentives, houses were being purchase as a financial asset, not necessarily with an actual intention to move in. The massive amount of vacant houses across Mexico, therefore, should not come as a surprise: 14%, which is 4% higher than the international average.[28]

Additionally, multiple case studies in Mexican states found peri-urban neighborhoods with high concentrations of vacant homes, and housing vacancy has been particularly problematic on urban peripheries that experienced quick and expansive growth in the 2000's.[29] One of such studies analyzed Mexico Census (2010) and found that the percentage of vacant houses in peri-urban neighborhoods is higher than the average (16.3%) of the country. This research also found that the strongest correlation to high vacancy rates is the frequency of housing finance from public agencies, especially INFONAVIT.[30]

Particularly in the case of INFONAVIT housing, abandonments surpass 20%, mainly due to peripheral locations without access to jobs, urban amenities, infrastructure, or services.[31] This is verified by a 2015 report by INFONAVIT which describes the statistically significant correlation between abandonment of houses and their distance to employment: one additional kilometer away from employment centers correlates to the abandonment of 500 housing units.[32] The problem of abandonment is still ongoing, which many authors attribute still to lack of transportation, infrastructural services[33] (water, sanitation, and electricity, among others), and urban services. Furthermore, there is a spatial concentration of abandoned units: 13 municipalities concentrate 30% of abandoned housing across the country, particularly in Juarez and Tijuana, with 6% and 4% respectively.[34]

To an important extent, numerous projects financed by INFONAVIT entailed urban expansion in the form of leapfrog development beyond the urban fringe, accelerating urban sprawl rather than containing it. It is an example of an incentive system that failed to produce more compact cities, at least in part because concerns with housing affordability, namely with the cost of housing, trumped concerns for access to jobs. Orderly urban expansion must go hand in hand with keeping the urban periphery connected—typically with a grid of arterial roads carrying public transport—to urban job markets.

The Proliferation of Gated Communities in the Periphery of Buenos Aires, Argentina

The history of gated communities in Buenos Aires began during the 19th century. After the epidemics of cholera in 1867 and yellow fever in 1871, the wealthy inhabitants of Buenos Aires opted to spend their summer outside the polluted city.[35] Sport clubs and outdoors facilities were developed on the urban periphery. At the beginning of the 20th century, railroads and cars improved access to country residences.[36] By then, sport clubs merged with country homes to form country clubs. Later, during the 1970's, Argentina went underwent social unrest, accompanied by growing insecurity in the capital, which pushed the upper classes to move permanently into their country homes, many of which were located at distances to the city center that made the daily commute possible.[37] These enclosed housing developments with restricted access were a guarantee of safety.[38] In parallel, between the 1940's and the 1970's, poor immigrants from the rural areas of Argentina moved to the periphery of Buenos Aires, largely because the city center was still too expensive for them at that time. They settled in poorly serviced plots on the outskirt of the city.[39]

From 1990 onwards, gated communities have grown massively in the suburbs of Buenos Aires.[40] Better-off families could afford a home away from the crowded city. Indeed, for the price of an apartment in the city, people could purchase a house with a garden in a safer neighborhood.[41] The suburban motorways network was extended at that time, allowing easier commuting to and from the city center.[42]

These gated communities developed mostly North of the city center and now cover almost 400 square kilometers, twice the area of the Buenos Aires federal district known as CABA (Figure 2.6).[43] This fast-growing phenomenon has several consequences. First, the development of these peripheral wealthy communities has changed the distribution of social groups in urban space. In these communities, as all neighbors came from similar socio-economic levels, there was no economic diversity. Moreover, they were surrounded by low-income communities: "[T]he two extremes of the social spectrum in Argentina coexist through the settlement of gated communities amongst this desolate suburban landscape."[44] Rich gated communities with more and better infrastructure stand next to poor neighborhoods with almost no urban amenities.[45] The relationship between these two social groups can be ambiguous. Some poor people work in the gated communities but others feel excluded, and their increased animosity renders the gated communities less safe.[46]

After Argentina's economic meltdown in 2001, gated communities remained attractive because of the return of insecurity in the

city center. Malls, café, and stores were built near the gated communities, and headquarters of companies moved out to these areas. The fast-growing suburban population put a strain on health and school systems as well as the road network.

In addition to these social and economic consequences, the gated communities have had a large impact on natural resources.[47] Often built on wetlands, with artificial lakes and canals, they have affected ecosystems vital to water drainage. Indeed, some of these neighborhoods have worsened flood risk.[48]

In conclusion, the construction of gated communities in the periphery of Buenos Aires has changed the urban fabric. It has led to a significant decline in urban densities—from an average of 79 persons per hectare in 1989 to 72 persons per hectare in 2014—and made the metropolitan area less sustainable both in terms of social justice and environmental conservation and the mitigation of climate change.

The Impact of Insecurity on Urban Expansion in Bogotá, Colombia

One of the most important drivers of rural to urban population movement is organized violence. In Colombia, for example, organized violence has a deep-rooted history with periods of conflict ranging from pre-colonial times to modern confrontations with drug cartels.[50] Violence, although changing in nature, has consistently plagued the nation. Rural to urban migration intensified during the 1950's La Violencia period when villagers sought refuge from violence in urban areas. Despite a 1958 peace agreement, organized violence persisted, with the government negotiating numerous peace treaties.[51] The rise of drug-related income in the 1980s intensified the conflict, which has displaced no less than 7.7 million Colombians.

90% of the Bogota's population growth between 1989 and 2010 occurred through the infill and densification of areas of the city that were already developed in 1990. While its population almost doubled, only little urban expansion occurred.

One possible explanation for Bogotá's patterns of urban growth is that the city densified in response to residents' perceptions of safety. The wealthiest inhabitants settled in the central and the northern part of the city and on the mountain slopes, seeking security and safety, while the poor settled in the south of the city mostly in dense informal settlements created by people forced to flee to the city because of the civil war. The division of the city into service zones with varying levels of service further exacerbated the process of socio-spatial segregation and exclusion,[52] leading to tensions and escalated levels of internal violence, not unlike the violence that those seeking refuge in the city sought to leave behind.

It is interesting to note that the reaction of the well-to-do in Bogotá and in Buenos Aires were in stark contrast to each other. In Buenos Aires, lower levels of urban crime resulted in a flight to outlying gated communities. In Bogotá, higher levels of violence and the fear of kidnap-ping while driving to and from the suburbs kept the well-to-do in the dense city center.





Figure 2.6: Abandoned INFONAVIT-funded homes in the Villa del Prado community on the outskirts of Tijuana, Mexico. Source: Reploge, J. (2014). *Mexicans are abandoning their suburban dreams and their "birdcage" homes. TheWorld.*

Figure 2.7: Plots and houses in gated communities in the Metropolitan Area of Buenos Aires. Source: Thuillier, G. (2005). Gated Communities in the Metropolitan Area of Bueno Aires, Argentina: A challenge for Town Planning. Housing Studies, Vol 20. (No. 2), 255-271.

03 / URBAN CONTAINMENT: THE STATE OF THE ART

The London, England, Green Belt

The idea of a green belt was first formally proposed in the Greater London Plan of 1944, authored by Sir Patrick Abercrombie.[53] The plan featured four concentric zones: one for the county of London and three for the region. The first zone was the one with the highest density of inhabitants, the second was supposed to be composed of residential districts with lower density and was to be surrounded by the green belt,[54] a belt of open land around London. This zone was supposed to form a buffer between London and its surrounding regional communities.[55]

The proposed green belt was a response to fears that the countryside would be replaced by low-density suburbs and industries. That all the quaint villages and towns outside of London would be swallowed by the big city, and that Londoners would no longer have access to the recreational and health benefits of the countryside.[56] The concept of the green belt was codified into law through the Town and Country Planning Act of 1947. This act introduced the legal framework for local authorities to designate land as green belt, restricting certain types of development within those areas.[57]

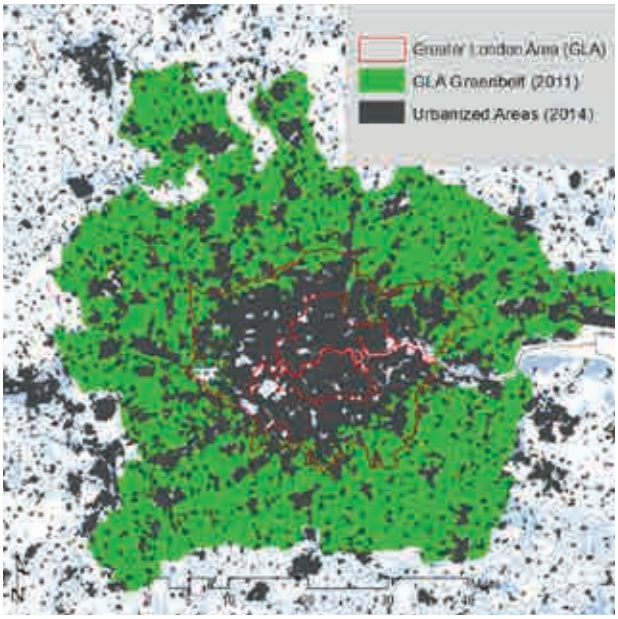
One of its consequences was the increase in house prices.

Indeed, in the 1950s, the green belt choked the residential land supply while London was experiencing rapid population and job growth.[58] And while despite its effects on house prices, the London greenbelt continues to be politically popular, it is now seen by more and more people as excluding them from the cities that they would like to live and work in but cannot afford to, because of housing supply bottlenecks that have resulted in exorbitant house-price inflation.[59]

Furthermore, even though the primary purpose of the green belt was environmentally sound, recent urban development in the Greater London Area has now leapt across it, increasing commuting costs, energy consumption and greenhouse gas emissions,[60] and raising the question of whether it is still environmentally sound.

The Deregulation of the Seoul, Korea, Green Belt

In response to a surge in population growth during the 1960's industrialization, President Park Chung-hee introduced the British green belt concept, naming areas all around Korea "Restricted Development Zones."[61] The goal was to manage urban sprawl and population growth, particularly in the Seoul Capital Area. The Urban Planning Act of 1971 laid the groundwork for designating Restricted Development Zones.[62] Green belts were established in Seoul and 13 other cities between 1971 and 1987 (Figure 2.9).[63] Seoul's green belt was modeled after London's but adjusted for South Korea's context. The military government firmly prohibited any development within the greenbelt, with severe penalties for violations.[64] Indeed, it was initially established as a tool for shaping urban development. During the military government period under Park Chug-hee and later following democratization, the greenbelt's boundaries remained relatively constant, primarily based on political decisions rather than on scientific



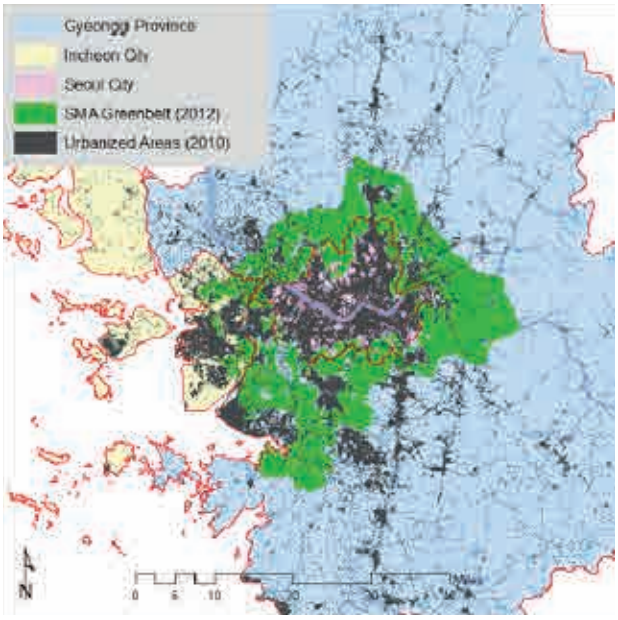


Figure 2.8: Map of the London Metropolitan green belt, 2010. Source: Angel, S., Lamson-Hall, P., Junca, J., Roy, N. (2022, October). Accommodating Urban Growth [Online course]. The Maroon Institute of the New York University.

Figure 2.9: The green belt of Seoul, Korea, 2012. Source: Angel, S., Lamson-Hall, P., Junca, J., Roy, N. (2022, October). Accommodating Urban Growth [Online course]. The Maroon Institute of the New York University.

analysis.[65] Urban issues emerged over the decades due to these strict regulations, leading to pressure for deregulation.[66] Indeed, in the 1980's, the economic growth of Korea led to the increase in the urban population, which caused severe housing shortages.[67]

In the 1980's the Korean green belt came under political pressure.[68] As Korean politics democratized, the need for restrictive land use regulations was increasingly questioned. Furthermore, the land speculation and the urban development across the green belt made the government rethink about development restrictions in the green belt areas.[69]

In 1998, the strict green belt regulations were named unconstitutional by the Korean constitutional court[70] and the Committee for Green Belt System Improvement was formed, which, after investigations, surveys, consultations, and visits from UK green belt-specialists, established an improvement plan by 1999.[71] Private property rights of inhabitants living in the green belt could be secured and parts of the green belt were allowed to be released.[72] Furthermore, land use regulations became less strict and five new towns were created around the Seoul metropolitan area to calm the unstable housing market. This has encouraged the urban development across the green belt,[73] leading to increases in leap-frog phenomenon, commuting costs, energy consumption and greenhouse gas emissions.[74]

By September 2001, the Korean government released greenbelt areas in seven major cities due to urbanization pressures and housing shortages. About 27.7% of the nation's green belt land and 8.6% of the Seoul Metropolitan Area's green belt area were released through deregulation from 2000 to 2010.[75]

Deregulation of the Seoul's green belt has significantly impacted land markets, influencing both urban land availability and prices.[76]

The Portland, Oregon, Urban Growth Boundary

A key strategy for securing the authority to plan for urban expansion is the creation of a new jurisdiction that covers all municipalities in a metropolitan area. In the case of Portland, Oregon, in the United States, the protection of the rural countryside from excessive urban sprawl prompted the creation of a metropolitan government with the key objective of managing urban expansion.[77]

The state of Oregon underwent extensive suburbanization in the 1950s and 1960s. By the early 1970s, citizen frustration with the rapid loss of rural areas made urban planning a key issue in state electoral politics.[78] Governor Tom McCall was elected in 1967 because of his strong support for growth controls and integrated land use planning. The state legislature passed Law No. SB 100 in 1973, creating a planning framework that required municipalities in the state to establish urban growth boundaries, limiting new urban growth outside prescribed areas (Figure 2.10).[79] To coordinate planning and management of these urban growth boundaries, the state of Oregon passed a law in 1978 creating an institutional structure for metropolitan-area planning.[80]

The Portland metropolitan area now contains 24 municipalities and covers 1,051 square kilometers, an area three times larger than the city of Portland itself. This new level



Figure 2.10: The urban growth boundary in Portland, Oregon, USA. Source: Angel, S., Lamson-Hall, P., Junca, J., Roy, N. (2022, October). Accommodating Urban Growth [Online course]. The Maroon Institute of the New York University.

of government, called "Metro" in Portland, is the only directly elected regional government and metropolitan area planning organization in the United States.[81] Over and above planning and administering the urban growth boundary, Metro is focused on issues of metropolitan relevance. These include transportation routes, housing policy, land use, waste management, and the maintenance of large parks and public spaces. From 2000 to 2014, 75% of new constructions in the Portland Metro jurisdiction occurred through the infill of its 2000 footprint, and only 25% through the expansion of that footprint, still within its growth boundary.[82] At the same time, the limited supply of residential land has made housing in the metro area less affordable. Median house price in Metro in 2020 was $420,000, ranking the 14th highest among the 100 largest U.S. metropolitan areas. Infill housing in Portland, Oregon is gradually replacing single-family homes.[83]

But Portland sits on the border between two states, Oregon and Washington, separated by the Willamette River. The Metro government has jurisdiction on the Oregon side of the Portland metro area, but not in Vancouver, Washington, across the Willamette River to the North (Figure 2.11).[84] The metropolitan authority has been able to maintain a strict urban growth boundary on the Oregon side of the border, with only minor adjustments to that boundary since it was enacted in 1973.[85] Still, suburbanization—largely in the form of single-family homes on individual plots—has continued unabated in Vancouver, Washington, to the North, which is still an integral part of the Portland metropolitan labor market. People preferring more affordable single-family homes now have longer commutes from Washington State to the job centers on the Oregon side of the border.[86]

Portland Metro has made great strides in planning for growth at the metropolitan level, but still struggles with jurisdictional fragmentation of its labor market between two different states and its inability to contain expansion on the Washington side of its metropolitan area. Effective planning for urban expansion and for a host of other key regional prerogatives must include the *entire* metropolitan area, even when this area encompasses different jurisdictions.[87]

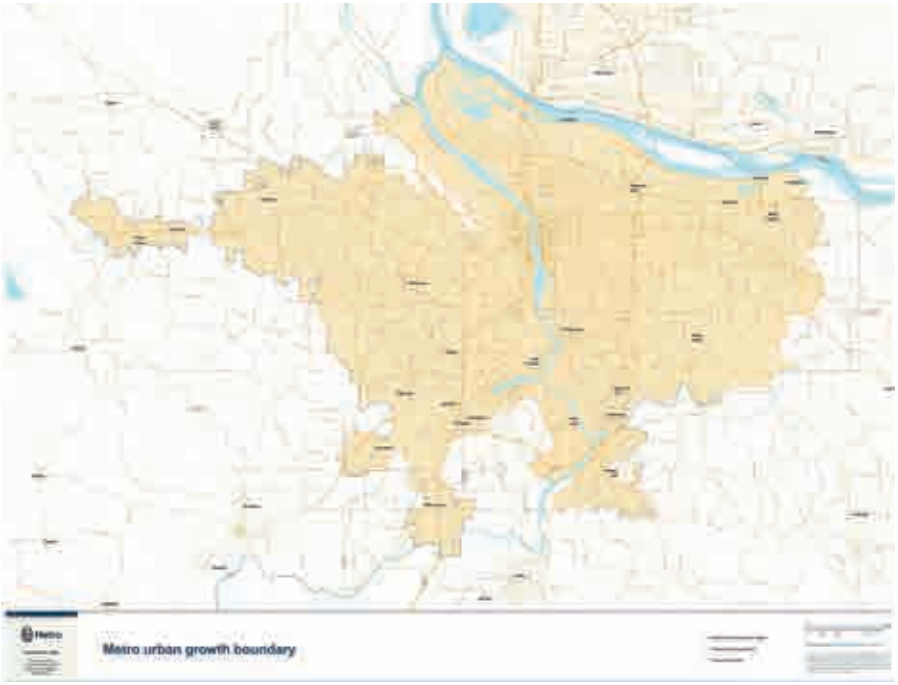


Figure 2.11: The Portland Metro Urban Growth Boundary. Vancouver, Washington, across the Willamette River, is outside the boundary. Source: Metro. (2023). Urban growth boundary maps. Urban growth boundary maps | Metro (oregonmetro.gov).

04 / ACCOMMODATING URBAN POPULATION GROWTH IN THE NEW TOWNS

Milton Keynes and the New Towns on the Periphery of London, England

The planning of New Towns in Great Britain originated in 1937 when Lord Barlow took the initiative to plan the distribution of the population across the territory. His idea was to create garden-city influenced new towns to solve the environmental and urban landscape issues linked to unplanned Victorian industrial cities.[88] After the Second World War, when the country endured a housing crisis, the Ministry of Town and Country Planning was created.[89] The first majority Labour Government passed The New Town Act of 1946.[90] Under this Act, a segment of the population originally living in bombed out cities was relocated to planned new towns scattered in the English provinces.[91] Over 20 new towns were created, most of them in England and eight of them (Basildon, Bracknell, Crawley, Hatfield, Harlow, Hemel Hempstead, Stevenage, and Welwyn Garden City) on the periphery of London. They were designed for accommodating at least 50,000 people each.[92]

This measure was not sufficient to accommodate population growth during the "baby-boom" year following WWII, and lasting into the 1960's. The rapid growth of the number of households coupled with the garden city designs of the towns have led to pressures for building new ones.[93] Indeed, from 1959 on, the Conservative government launched the construction of other new towns that had similar goals to the London New Towns, relieving population pressures, but this time it was focused on Liverpool.[94] At that time, the Commission for New Towns (CNT) was created by the government. However, that said, it was the Labor government of Harold Wilson that created the largest New Towns of the postwar Britain. The most famous and the largest of them was Milton Keynes in Buckinghamshire, 70 kilometers north of London.[95] Initially, this area was composed of little villages and green fields. Once the New Town was planned, more and more London population was relocated there and since 1980, people from everywhere came to settle there. Today, Milton Keynes extends to 8,900 ha and houses 195,687 inhabitants (Figure 2.12).[96] Furthermore, in England, "today, over two million of people are living in urban entities constructed mostly from a tabula rasa during the second half of the twentieth century."[97]

It is important to note that the success of these New Towns stands on fundamental planning principles that were applied carefully.

The first one was the creation of socially mixed and balanced communities. It was applied by building dwellings for all classes in the right proportions.[98] The second is the encouragement of an active community and neighborhood life. This principle was largely achieved thanks to the fact that a strong feeling of belonging existed in these New Towns. In addition to this, there is evidence that active civic associations were way more popular in these towns compared to old urban settlements.[99] This was also in response to the actions by the 1945-46 New Town Committee that provided at least one building as a multi-purpose meeting place.[100]

The third principle was the separation between pedestrians and road traffic planning "for safety as well as freedom of movement and amenity."[101] This principle was applied in the most expansive manner in Milton Keynes.[102] Indeed, in this new city, planned between 1967



Figure 2.12: Every road on the one-kilometer-wide Arterial Grid of Milton Keynes, England, carries a bus line.

and 1970, roads were designed as the American grid style. The busiest roads are dual carriageways while the less busy roads were one-way. The green borders of the roads carry electric cables on both sides. This extra space was also created to widen the roads in case of heavy traffic.[103] To complement this road network, a green network was designed especially for walking and cycling to minimize interactions between cars and pedestrians or bikers.[104] Today, there is a debate in Milton Keynes between urban planners with a more "sustainable vision of the city," who would like to introduce mixed-use streets, reduce the space for cars, and fill parklands with housing, and citizens that would like to preserve low-density motorized living.[105]

The fourth planning principle that shaped the New Towns was their economic self-containment. The goal of these new cities was not to become dormitories like garden suburbs. They were planned so people who live there can also work there.[106] The goal was to avoid mass commuting and also to provide a tax base for funding local government and urban infrastructure.[107] Even if some new towns were not able to generate enough work for all its residents, the New Town Development Corporations subsidize companies investing in New Towns which has brought several businesses.[108] A report from 2015 written by the Center for Cities has shown that Milton Keynes has the highest number of start-ups in the United Kingdom.[109]

Still, despite an improved job-housing balance, many residents of Milton Keynes commute to jobs in the Greater London Area, while many jobs there are held by workers living elsewhere. In 2023, for example, Milton Keynes was ranked the top commuting town to London.[110]

Accommodating Urban Growth in New Towns in the Republic of Korea

After the Korean War (1950-53), "Five Year Economic and Social Development Plans" were established in South Korea. Their goal was to increase wealth and the political stability of the country. At that time, Korea experienced rapid economic growth which led to rapid urbanization. Indeed, one of the consequences of these plans was the migration of a large part of the country's population to Seoul, followed by extensive slum formation because of insufficient housing supply, traffic congestion, and water and air pollution.[111]

To tackle these challenges, Korea has been building New Towns since 1960 (Figure 2.13). These new towns were able to disperse the concentrated population of the Capital to new residential areas by supplying new houses in new places. Furthermore, the added value obtained through the conversion of rural lands to urban use using extensive land pooling and readjustment was invested in urban infrastructure and green public spaces.[112]

Each of the New Towns was designed to response to specific needs.[113] They were built in accordance with national development objectives and policies. From 1962 to 1981 the challenge was industrialization. This is why the New Towns of phase I were built for industrial development (Figure 2.14). They were more like industrial complexes.[114] The lack of housing in Seoul was the main issue during the phase II (from 1967 to 1986), and New Towns were built as large-scale land readjustment projects. Yeoido and Gangnam were designed as new sub-centers of Seoul, and other towns were built in strategic places to disperse manufacturing industries, central-business-district functions, and administrative functions.[115] Later,



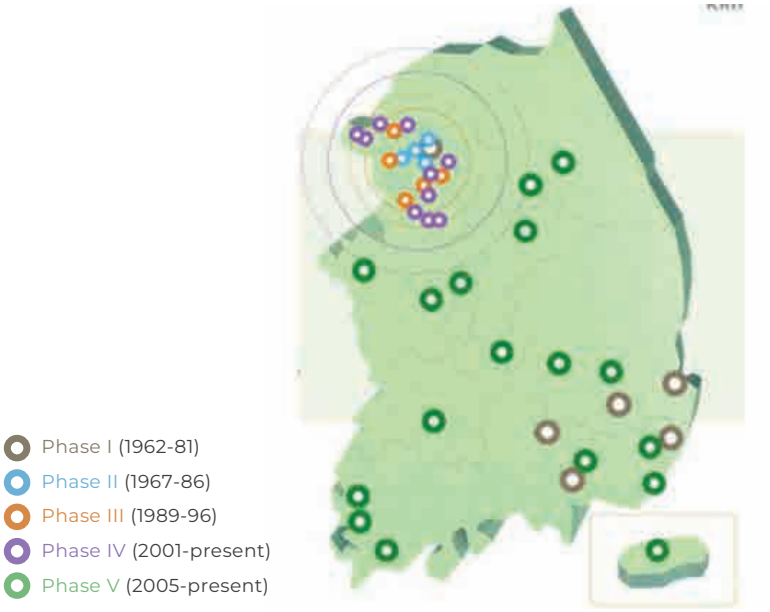


Figure 2.13: Bundang New Town.

Figure 2.14: Map of New Towns Developed from 1960's to 2015 in Korea. Source: Lee, S. K., You, H., Kwon, H. R. (2015). *Korea's Pursuit for Sustainable Cities through New Town Development: Implications for LAC.* (Discussion Paper N°IDB-DP-390.) Inter-American Development Bank.

during phase III (1989-1996), as Seoul became denser and its housing prices sky rocketed, several New Towns were built in its outer ring. The government developed a new master plan for New Towns which led to phase IV: the more intensive construction of New Towns in the Capital Region. Ten towns were planned to share the burden of housing demand, and were connected to Seoul and other areas by a transport network.[116] From 2005, the government tried to disperse the over-concentrated functions of Seoul by creating New Towns with specific roles across Korea. Some were dedicated to administration, some to enterprise, and other to innovations.[117]

Korean plans to accommodate urban growth in new towns were successful, in part because of their concrete implementation of strategies; their institutional organization and the legal support; the feasibility of their lands acquisition methodologies; and their sustainable design criteria.[118]

However, certain problems occurred during the development of these towns. Some conflicts among stakeholders did surface. Indeed, some landowners didn't want to sell their property.[119] Some social inequalities issues also occurred because, at first, these towns were not adapted to different socio-economic classes.[120] The self-sufficiency challenge also had to be tackled. Indeed, in phase III, new towns were mostly mono-functional: they were mainly residential, and the transport network was not optimal. These issues were better addressed during phase IV and V.[121] It is important to note, in closing, that the success of the planning of Seoul urban growth strongly depended on the administrative support and the political ambitions of the national government.

The New Town of Kilamba, Angola

In 2004, Angola accepted a credit line from China of US$4 billion that was rolled over several times.[122] Today, this credit is worth more than US$15 billion.[123] This credit was used for different projects: the reconstruction of damaged transport infrastructure, airports, sport stadiums and, more importantly, urban projects called "centralidades."[124] These new centers were presented as "strategic urban infrastructure geared to slum prevention and land readjustment."[125] These New Towns built on a blank slate were quick solutions offered by Chinese investors. No preliminary assessments were conducted to analyze housing demand or to assess urban management capacity.[126]

Kilamba, 22 kilometers north of Luanda, the capital, is one example of these new "centralidades." It cost US$3.5 billion and was financed, among others, by the China International Fund, a private group of companies based in Hong Kong.[127] Kilamba included 750 apartment buildings, schools, and retail outlets. Its 20,000 flats, costing between US$120,000 and US$200,000, could house 160,000 people (Figure 2.15)].[128] The project ended in 2012 and, until 2013, these apartments stayed empty.

Kilamba was called "the ghost town" by the media.[129] Indeed, the proposed dwellings were way too expensive for the Angolan population: Poor Angolans earn less than US$2 per day. But the selling price of a Kilamba flat was unaffordable even for senior civil servants.[130] The state was forced to subsidize a rent-to-purchase scheme. The price of the cheapest units was lowered from US$120,000 to US$84,200. Thanks to that, middle-level civil servants could afford them.[131]



Figure 2.15: Turnkey housing estates in *Kilamba, Angola. Source: Kilamba (Angola*). (2022). Wikipedia.

05 / SUCCESSFUL PROGRAMS FOR ACCOMMODATING GROWTH THROUGH DENSIFICATION

Accessory Dwelling Unit (ADU) legislation in California

Homeowners, who understandably fear changes in the character of their neighborhood, typically resist the demolition of single-family homes and their replacement with larger structures—buildings with a higher volume and, by extension, higher plot coverage. As we shall see later, higher plot coverage in cities is associated with higher urban densities. One effective strategy to obtain higher plot coverage—and thus higher urban density— without disrupting the neighborhood or changing its character is to permit the construction of Accessory Dwelling Units (ADUs). These are small buildings, also known as 'granny flats,' that can be added above a garage or built as a detached structure elsewhere on the property (Figure 2.16). Accessory Dwelling Units are, quite possibly, the least disruptive form of infill development. These dwelling units may also provide extra income for homeowners, allowing retirees and other people living on fixed incomes, for example, to stay in their neighborhoods. Many cities in the United States have passed laws permitting accessory dwelling units in some neighborhoods, but California has gone one step further by passing in 2017 a statewide law that allows ADUs in all areas zoned for single family homes. Updates to the law now allow ADUs to be constructed concurrently with new residential construction and to benefit from reduced parking requirements.[132] Critically, the law has also introduced a process for the retroactive legalization of illegally constructed ADUs: Los Angeles alone may have as many as 50,000 illegal ADUs.[133] These actions have already led to a massive increase in ADU applications, with applications in Los Angeles increasing 25-fold from 2015 to 2017.[134]

California's Government Code recognizes that "California faces a severe housing crisis." "The state is falling far short of meeting current and future housing demand with serious consequences for the state's economy, our ability to build green infill consistent with state greenhouse gas reduction goals, and the well-being of our citizens, particularly lower and middle-income earners. Accessory dwelling units offer lower cost housing to meet the needs of existing and future residents within existing neighborhoods, while respecting architectural character. Accessory dwelling units are, therefore, an essential component of California's housing supply."[135]

The State of California has identified a clear interest in facilitating the supply of Accessory Dwelling Units (ADUs) as a way to ameliorate the housing affordability crisis in the state. Most of the legislative follow-up to the initial law has been to make it more difficult, if not impossible, for local authorities to prevent or delay the construction of ADU within their jurisdictions.

More recent amendments mandate that ADU applications must be approved within 60 days, without a hearing or discretionary review. They also mandate that cities and counties must generally approve attached or detached ADUs under 1,200 square feet (11 square meters) unless they adopt local development standards. If adopted, such local standards must have the following limitations: No minimum lot size requirement and no height limit under 16 feet (5 meters) and no side or rear setback requirements over 4 feet (1.2 meters).





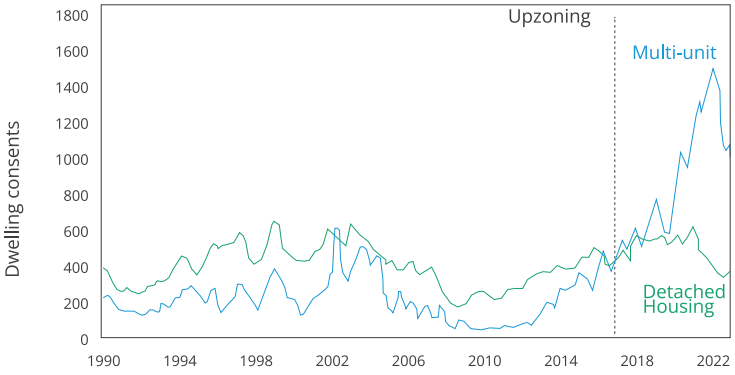


Figure 2.16: Different configurations for incorporating Accessory Dwelling Units on plots with existing homes. Source: American Planning Association.

Figure 2.17: A condominium renovation project under National Outline Plan 38 (Tama 38) in Israel before (left) and after (right) renovation. Source: Hanani, 2015.

Figure 2.18: The increase in building permits (dwelling consents) for multi-unit housing in Auckland, New Zealand, following the upzoning in 2016. Source: New York University, The Marron Institute of Urban Management.

The TAMA38 Program in Israel: Improving Earthquake Resistance in Condominium Buildings by adding Floors

As we shall see later in section III, most densification now takes place through infill, either through construction on vacant plots or through the construction of additional space on occupied residential plots. There are only a few examples of densification through the construction of more floor space within existing building footprints. In 2005, Israel passed a law (National Outline Plan 38 or Tama38) that was aimed at bringing some 1.1 million condominium dwelling units built before 1980—typically in 4-story walk-up buildings with an open ground floor—into conformity with the new earthquake building code.

The law envisioned the engagement of a developer who would add floors on the roof, as well as fill in the ground floor in exchange for making the building earthquake resistant while enlarging the apartments, adding elevators, replacing aging utilities, and reconstructing the façade at no cost to homeowners (Figure 2.17).

Homeowners could remain in their apartments while the building was being remodeled or receive allowances to rent apartments elsewhere. The law was amended several times to ensure that homeowners do not have to pay capital gains taxes on the increased value of their apartments, and to make it possible to engage a developer and initiate the renovation with two-thirds of the homeowners agreeing to the proposed deal. Later revisions also allowed the complete demolition of structures, their replacement by structures with double the floor area, and the allocation of new apartments to the original homeowners. National Outline Plan 38 has been quite successful, and, by the end of 2016, some 15,000 units have been created or renovated under the plan, with some 30,000 additional ones in the pipeline.[136] Not surprisingly, critics of the plan charge that most of the construction is taking place in highly desirable central-city locations in Greater Tel Aviv and Greater Jerusalem, while towns in the Jordan Valley, more likely to get damaged by an earthquake, have land values that are too low to attract developers. There has also been some pushback from municipalities, claiming that higher densities require more municipal services, and new revisions to the law aim to address this issue by channeling some of the developer profits to them. Still, the plan has clearly managed to densify residential neighborhoods by increasing building height.

Upzoning in Auckland and the shift from Detached to Multi-unit Housing

One of the more effective strategies for densification has been shown to be the abolition of single-family zoning. This is what the Auckland (New Zealand) City Council did in November of 2016: It "upzoned approximately three-quarters of its residential area by abolishing single-family zoning, under the Auckland Unitary Plan (AUP)."[137]

A draft of the plan had already been published in 2013, so developers had time to observe the new rules and to make plans before the plan came into effect. The upzoning has resulted in the addition of 20,000 new dwelling units to the Auckland housing stock over a five-year period.[138] The share of new

dwellings in single-family homes dropped from 70 to 50%, while the share of multi-unit housing increased to 50% (Figure 2.18).

The increase in the supply of dwelling in multi-unit structures has also improved affordability.[139] The ratio of median rents to median incomes in Auckland fell from 22.7% in 2016 to 19.4% in 2023. In addition, Auckland's house prices have risen by 15% in comparison with a 65% average increase in the rest of the country. The success of the Auckland Unitary Plan has now inspired new reforms aimed at urban densification in New Zealand, and support for higher density living among residents in Auckland has increased: less than one-third of Aucklanders perceive the shift towards more dense housing as a negative development.

06 / JURISDICTIONAL ISSUES IN PLANNING FOR URBAN EXPANSION AT SCALE

The Large Jurisdiction of Zhengzhou, China, facilitates Planning for its Expansion

Zhengzhou is the central city of the densely populated Henan province in China, home to 100 million people in 2020. Metropolitan Zhengzhou is the largest city in the province. In 2020, its population exceeded 10 million people. Planning for urban expansion in Zhengzhou was facilitated by the large area of its municipality, 7,446 km^2, which has been under the jurisdiction of the local government since 1983. In 1990, for example, the urban extent of metropolitan Zhengzhou, 178 km^2, amounted to only 2.4% of the area of its municipality. In other words, the area under its planning jurisdiction was more than 20 times larger than the area of the city of Zhengzhou at the time. It was only slightly larger by 1995 (Figure 2.19).[140]

There is no question that having a large jurisdiction with a single governing authority makes it much easier to plan for urban expansion. But other challenges arose in Zhengzhou. Government concerns about food security in China mean that urban master plans are required to limit the amount of agricultural land converted to urban use.[141] The plans for Zhengzhou are approved both by the Henan provincial government and by the State Council, the chief administrative authority in the country, and compliance with guidelines limiting expansion is mandatory. To avoid crossing any red lines, Zhengzhou submitted plans to the State Council that complied with the regulations, but that unfortunately underestimated future growth [3]. The master plan for 2000-2010 for the metropolitan area of Zhengzhou estimated the 2010 population at 2.3 million and the urban footprint of the city at 189 km^2. The 2009 metropolitan master plan for 2010-2020 estimated the 2020 population at 4.5 million and its urban footprint at 400 km^2. Both plans underestimated Zhengzhou's population growth and the growth of its urban footprint.[142]

The 2020 master plan for the city of Zhengzhou, China, lies within one of the eight districts of the municipality that approximates its current metropolitan area.[143] By 2020, according to the latest census, the population of the Zhengzhou metropolitan center exceeded 10 million. By 2015, its urban area was likely greater than 1,000 km^2.

The municipality of Zhengzhou had control over enough area to plan for long-term growth, but the need to protect agricultural lands discouraged it from doing so. This did not prevent the city from growing, it simply kept the municipality from effectively planning for that urban expansion.[144]

Hawassa, Ethiopia Expanded its Jurisdiction through Negotiations with Neighboring Rural Councils

Hawassa, a regional capital in Ethiopia, negotiated with and obtained planning authority from adjacent rural *kebeles* for the projected areas of its expansion.[145] To support secondary cities like Hawassa in managing their rapid growth, the Government of Ethiopia partnered with New York University (NYU) in 2013 to launch the Ethiopia Urban Expansion Initiative. This program started in four regional capitals—Hawassa, Adama, Bahir Dar, and Mekelle—and eventually expanded to include 14 additional cities. Local city planners and political leaders

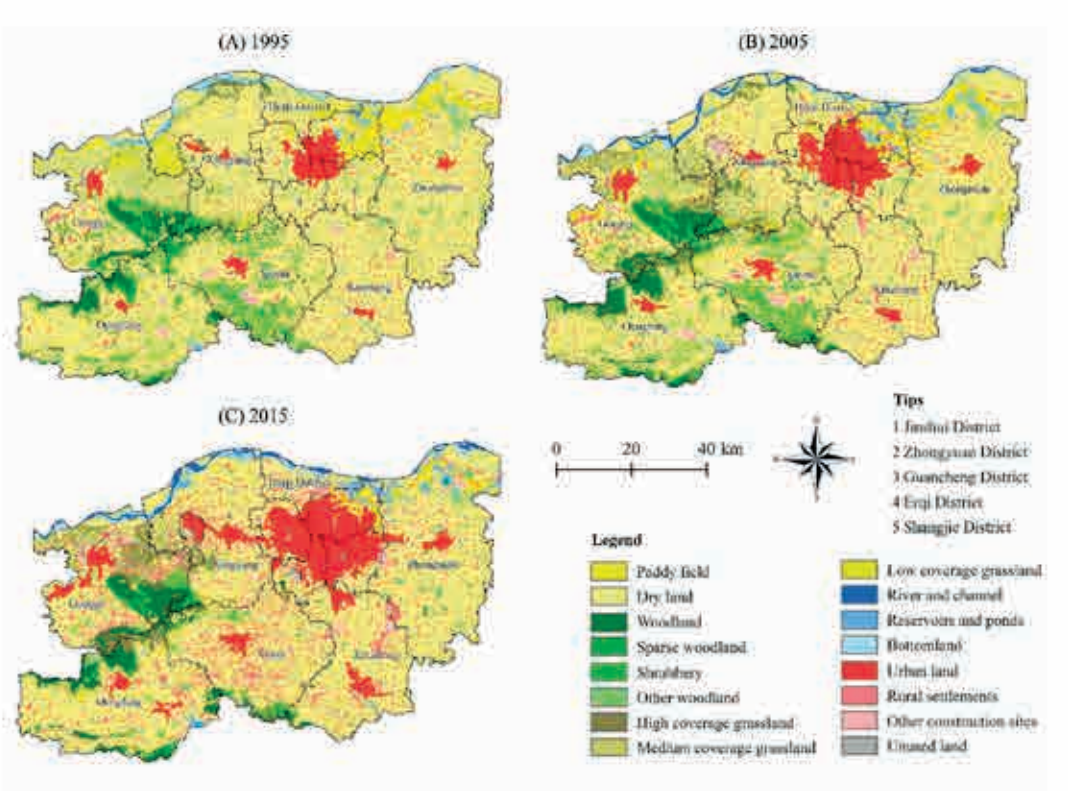


Figure 2.19: Land use changes in the municipality of Zhengzhou 1990-2015.

were trained to prepare lands for future urban growth by planning a simple network of arterial roads in the future areas of expansion, securing the rights-of-way for these roads, and gradually constructing them. Hawassa emerged as a leader in expanding its planning jurisdiction and in preparing its periphery for expansion.[146]

When Hawassa city leaders looked at preliminary projections of city growth over the next thirty years, they understood that much of the growth would take place beyond their existing jurisdiction, in rural lands outside their municipal boundary.[147] Small rural districts in Ethiopia are governed by *kebeles*, which are essentially rural councils. The *kebeles* do not engage in physical planning and their jurisdictions are largely unplanned.[148] In Hawassa, city leaders were concerned that unplanned growth in surrounding *kebeles* would make it impossible for them to plan for the orderly expansion of the city, and that their urban centers would be surrounded by poorly laid out informal settlements.

Officials in Hawassa identified the expansion areas that would be needed by 2040 with a view of planning and constructing an arterial road grid—with wide roads one kilometer apart— throughout this area. This made it possible to determine which kebeles, rural councils, were likely to be affected by the city's growth (Figure 2.20).[149]

Ultimately, city and *kebele* jurisdictional boundaries are determined by regional governments, but the city could not simply ask the regional government to expand its boundaries to include the *kebeles*, realizing that *kebele* councils would fear a takeover and object. Instead, the city organized consultations with both *kebele* and regional government officials and explained the pressing need to include the *kebele* areas in their official expansion plan.[150] They sought to expand the planning jurisdiction of the city without diminishing the role of the *kebele* councils. Still, they expected pushback. *Kebele* council officials were aware of the urban-oriented growth taking place in their jurisdictions.[151] In fact, many of them noted that new informal settlements were creating new demands for services such as roads, water, and sanitation, demands they were unable to meet. They also knew that the proposed arterial roads would provide faster access to urban markets, benefitting farmers in their *kebeles*. They therefore agreed to expand the planning boundary of Hawassa, recognizing that being included in the plan meant that their residents would eventually be provided with urban services, and that growth within their jurisdictions would be more orderly. The regional government approved the change, and the city planning boundary was expanded.[152]

Hawassa officials attribute this success to their limited, specific objective and their consultative rather than domineering approach to the *kebele* governments. Collaboration with the *kebele* governments allowed the municipal government of Hawassa to plan an entire network of arterial roads on the urban periphery, some of which have now been opened and are in heavy use.[153]

Metropolitan Planning at the Departmental (Provincial) Level facilitated Planning for Expansion in Barranquilla, Colombia

Barranquilla is the fourth largest city in Colombia. In 2020, the city proper had a population of 1.27 million. Barranquilla is the capital city of the Department of Atlantico.[154] Atlantico is located on the Caribbean coast (Figure 2.21).

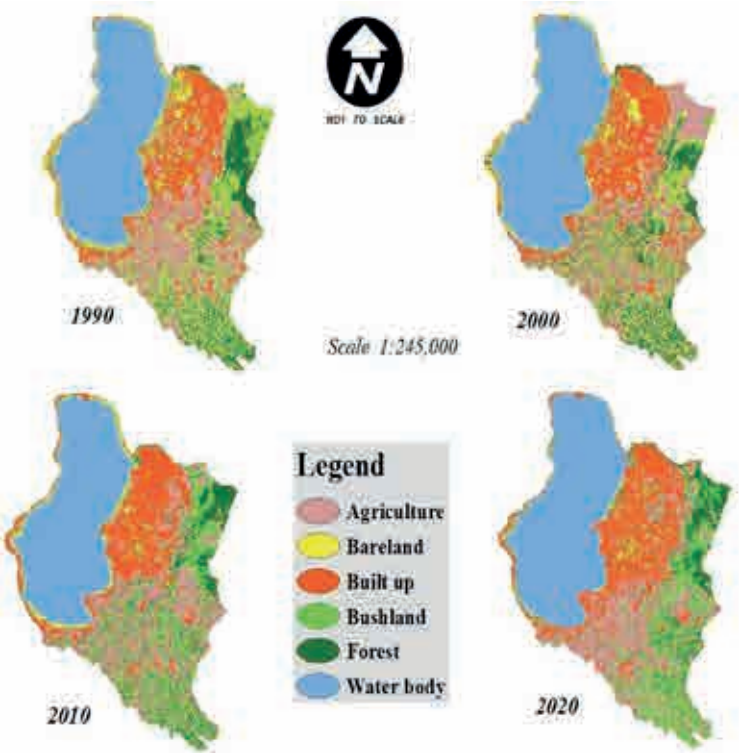


Figure 2.20: Land use development of Hawassa. Article: Content may be subjected to Copyrights.
Source: US Geological Survey (USGS) (http://glovis.usgs.gov)

It is the third smallest of the 31 departments in the country, with an area of 3,388 km^2 and a population in 2020 of 2.72 million.[155]

The municipal area of Barranquilla is only 101 km^2 and by 2018, the urban footprint of Barranquilla had expanded into four adjacent municipalities: Soledad and Malambo in the south, and Galapa and Puerto Colombia to the east. These adjacent municipalities grew faster than Barranquilla both in population and in urban extent between 2005 and 2018,[156] and one third to one half of their workforce commuted to Barranquilla in 2018.[157] By 2018, Barrranquilla no longer overshadowed its neighboring municipalities: the population of the four together constituted 41% of the population of the metropolitan area.[158]

Most future urban expansion in Barranquilla is projected to take place in its neighboring municipalities, which already function, together with the central city, as a single urban labor market.[159] Facing a number of key challenges, these municipalities need to be planned and managed as a single entity. People commute across the entire metropolitan area, making efficient transport a metropolitan issue. Housing affordability is a metropolitan issue as well, as is flood control, waste management, and environmental conservation.

In 2013 the national government of Colombia passed the Law on Metropolitan Areas (*Ley de Áreas Metropolitanas*), creating the ability to form metropolitan governments in multi-jurisdictional cities such as Barranquilla.[160] These metropolitan governments were empowered to engage in territorial land use and transportation planning and to collect revenues from multiple sources. The formation of metropolitan areas was voluntary. It required municipal councils to come together and propose the formation of a metropolitan area, and their proposals had to be approved by the national government and by referendums in the municipalities.[161]

The Metropolitan Board of Barranquilla, like other metropolitan boards in Colombia, was charged with the preparation of a Comprehensive Metropolitan Development Plan.[162]

The plan required the Metropolitan Board to locate arterial roads and to establish the hierarchy of public open spaces, to develop a metropolitan housing policy, and to coordinate public transport throughout the metropolitan area.

Planning for orderly urban expansion in the metropolitan area of Barranquilla was made possible by the 2013 law that created a strong metropolitan organization and a metropolitan jurisdiction that was large enough to contain its projected expansion in 2050.[163] The law also allowed for the annexation of additional municipalities in the future, as the need arises, and as urban development reaches and crosses the limits of existing metropolitan areas.

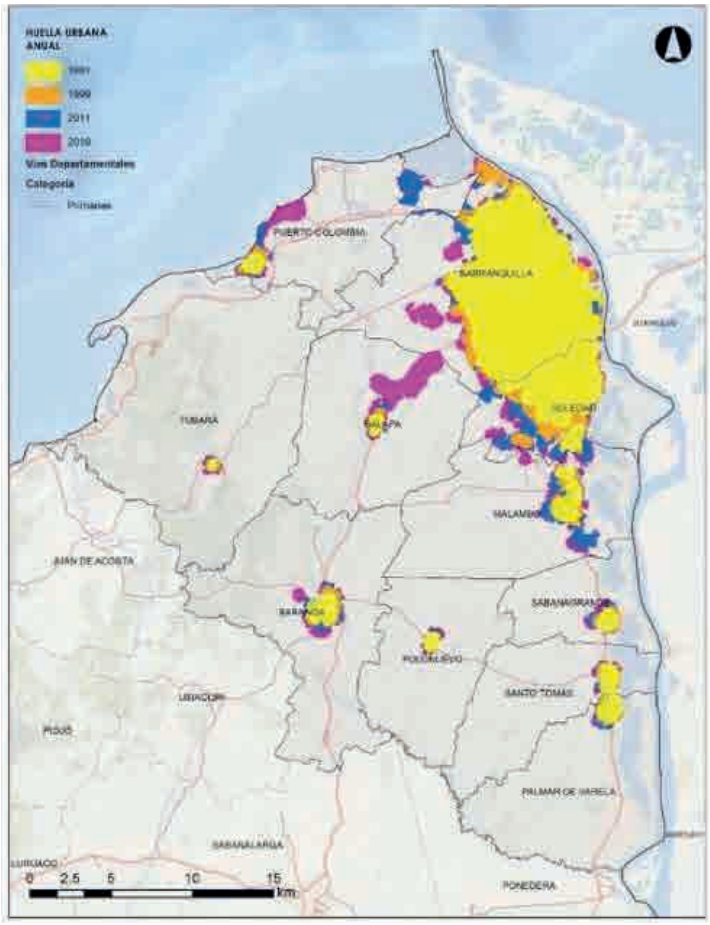


Figure 2.21: Urban expansion in Barranquilla, Colombia in recent years has been into neighboring municipalities, prompting the preparation of a metropolitan expansion plan by the Department (Province) of Atlantico (shown in light grey). Source: New York University, The Marron Institute of Urban Management.

07 / LAYING OUT THE URBAN PERIPHERY IN ADVANCE OF ITS OCCUPATION

The Expansion Plan for Valledupar, Colombia

The expansion plan for Valledupar, developed by local officials with support from New York University, is based on four simple steps. First, the establishment of a map of the expansion area able to accommodate the projected 30-year population growth. Second, obtaining planning jurisdiction over this area. Third, the planning and the securing of the rights-of-way of a network of arterial roads. And finally, the creation of an institutional framework to protect defined open spaces in the expansion areas.[164] Major importance is given to rapid legal and administrative actions to secure lands allocated to future open spaces and arterial roads before development takes place.[165] In Valledupar, the municipality had the power to carry out the project. Indeed, the local government had the capacity of expropriating land with compensation.[166] However, the expropriation was the last option since most landowners with larger plots were willing to donate land free of charge for the arterial road grid.

It was estimated that the expansion area needed in Valledupar to accommodate its future population growth amounted to 5,222 hectares.[167] A map of the land needed for this expansion was created taking into consideration the existing constraints. Lands in the east and the northeast of the city were used for intensive agriculture, and because the northwest has steep slopes that make urbanization impossible, expansion was projected on the southern, southwestern and the western parts of the city (Figure 2.22).[168] The total expansion area was divided into two phases: the first one with a 12-year horizon and the second one is the remaining 18 years horizon.[169] Once the expansion area was defined, the land ownership pattern had to be reviewed to plan the arterial road grid. The arterial road grid was designed taking into consideration existing property boundaries, existing arterial roads, existing intercity and rural roads and steep slopes.[170] The grid was planned using existing roads, avoiding the slopes, and minimizing the number of 3-way intersections.[171] Using existing roads allowed for minimizing the number of plots affected by the expansion and lowered the cost of compensation for the rights-of-way.[172] A legal study was conducted to determine the best way to secure the rights-of-way for the grid. Since much of it would only be needed in the future, it was decided to plant local trees along the future sidewalks of arterial roads. A nursery was created, and some tree planting took place.

Furthermore, securing lands for public parks was also a challenge in Valledupar. Each inhabitant only has 3.3 square meters of open public space while a minimum of 10 to 15 square meters is recommended.[173] In order to acquire and manage sustainably lands for public open space, several measures were taken by Valledupar. First, an administrative reform was made to unify the management of public spaces in one single office. Second, a citizen-based organization, the Allianza, was created to foster citizen engagement with public open spaces. The third measure was the development of sustainable financing mechanisms using public spaces. Indeed, in a project of a linear park along the shore of the river Guatapuri, the city has already proposed granting additional building rights to developers in exchange for financing the purchase of land for the public park.[174]

To conclude, the success of the urban expansion plan of Valledupar relied on several interconnected elements: its long-term vision; the realistic

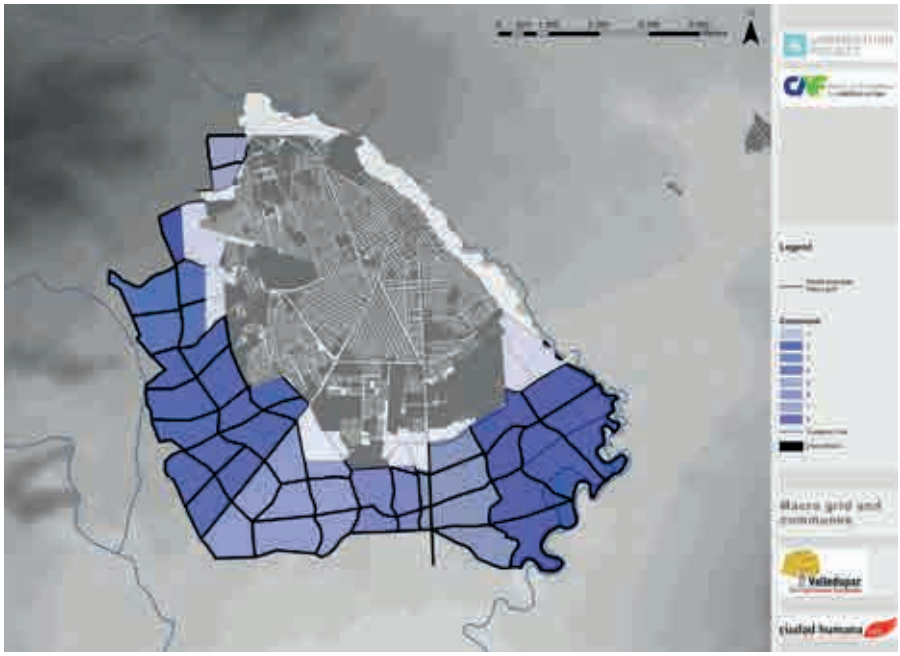




Figure 2.22: The urban expansion area of Valledupar and its division into macro-blocks (commune) by the final arterial roads grid. Source: Vásconez, J., Sánchez, N. G., Angel, S., Montezuma, R., Fonseca, S. (2015). *Preparing rapid growing cities for their expansion: a report on Valledupar and Montería*, Colombia. NYU Marron Institute of Urban Management.

Figure 2.23: Aerial Photograph of Valledupur in 2024. Source: Google Earth.

design of its layout; the financial management of the stakeholders impacted by the project; the administrative tools set up to make its management easier; and, finally, on the political support by local leaders.

Town Planning Schemes in Ahmedabad, India

An efficient mechanism for converting land from rural to urban use was articulated by the Gujarat Town Planning and Urban Development Act, 1976.[175] Under the provision of this Act, Development Authorities were created to plan and to implement urban plans.[176] These authorities have the responsibility to draw up statutory, 10-year, development plans for cities, showing areas of expansion and the future network of major roads.[177] During the second stage of the process, detailed Town Planning Schemes (TPSs) for smaller areas within the plan are developed. Town Planning Schemes are based on a participatory land pooling and readjustment process. The lands within the TPS area are pooled and planned. A share of the land is allocated to public roads and open spaces, and another, smaller share is taken to finance road and infrastructure services construction. The remaining lands, which are expected to appreciate considerably in value, are reallocated to landowners.[178]

The process ensures that rural lands—instead of being divided up and sold in the informal market—are subdivided and registered properly, and that adequate rights-of-way are left for streets and arterial roads as well as for public open spaces (Figure 2.23).[179]

This tool was used effectively to plan the expansion of the city of Ahmedabad in Gujarat.

The Ahmedabad Urban Development Authority (AUDA) published the Revised Development Plan for Ahmedabad in 1997. This plan showed where the city was expected to expand and where a major ring road was to be constructed (Figure 2.24).[180] The AUDA received a lot of objections from landowners located close to the proposed ring road during public hearings.[181] In 1999, it came up with a revised proposal that was approved in 2002. The proposed ring road measured 76 kilometers long and 60 meters wide, and the right-of-way for it was obtained with a series of TPSs in four years.[182]

The AUDA decided to use a combination of minimal land acquisition and an extensive use of the Town Planning Schemes (TPS) mechanism. During the publication of the revised Development Plan, AUAD outlined Town Planning Schemes for the proposed Ring Road and engaged landowners affected by the project and those owning land in the surrounding area through an outreach program, encouraging their participation. Most landowners agreed, yielding a large portion of the Right of Way for the road's construction. Through subsequent planning and documentation, land within an approximately 1-kilometer-wide belt along the road was converted to urban use and about 60% of the original land was returned to the owners near the ring road.[183] Even if a part of the lands in the area have changed, original landowners were able to retain a share of their propriety.

This fair land development process has allowed the authorities of Ahmedabad to plan its urban expansion in a sustainable and equitable manner that could inspire other fast-growing cities that have agricultural plots irregularly shaped in their surroundings.





Figure 2.24: A town planning scheme on the fringe of Ahmedabad, India, converts rural land to urban use by pooling rural plots, securing rights-of-way for roads, obtaining land for public use, and reallocating the remaining land among the original landowners. Source: Angel, S., Lamson-Hall, P., Junca, J., Roy, N. (2022, October). Accommodating Urban Growth [Online course]. The Maroon Institute of the New York University.

Figure 2.25: The Comas squatter invasion on the outskirts of Lima, Peru, was laid out with 10-meter-wide street and 10-by-20-meter plots before it was occupied. Source: Google Earth.

Planned Informality in Lima, Peru

In Lima, Peru, informal settlements were established on two types of land: wastelands owned by the government and privately owned agricultural land.

In the first case, a leader selects the land and recruits around 30-150 families to "invade" it together.[184] In the second case, an intermediary organizes an "association" of 30-150 families who purchase the land to the owners without urban authorization. In both cases, the occupation of land is rapid, requiring immediate definition of individual lots, giving control over distribution to the leader organizer.[185] These leaders have incentives to maximize share of the salable land for two reasons: first, for financial gains as more settlers means more money and second, more settlers mean more political influence: A stronger constituency to put pressure on local governments to obtain public services.[186]

The potential inhabitants of these informal settlements were fully aware of the problems generated by small share of lands allocated to public uses.[187] This problem arises because occupants primarily focus on their individual lots, undervaluing public areas.[188] Furthermore, the lack of options with more land reserved for public spaces exacerbates the situation. Respondents in Lima expressed a willingness to pay more for plots in "planned" informal urbanizations that offer adequate public space, recognizing that the costs of living in poorly planned neighborhoods far exceed the benefits of a higher initial payment. This suggests that a market of "planned" informal settlements could be created and could reduce the costs that chaotic urban sprawl generates for new settlers and society.[189] It would allow the alignment of potential supply and demand. On the demand side, it would entail a reduction of the discount rate used when evaluating the worth of public space during the occupation phase.[190] On the supply side, it would include the value of land reserved for public spaces in the pricing of residential lots. This adjustment, estimated to cost around 15 to 35 percent more than an unplanned lot, would incentivize organizers and landlords to allocate more space for public use.[191] This would, of course, require informal land developers to plan land subdivisions before selling or assigning residential lots.[192]

The historical study of an informal settlement, Comas, on the outskirt of Lima, between the 1960's and 1980's offers insights into planning such settlements.

During the 1960s, the Peruvian government permitted informal occupations on condition that plots adhered to basic urban standards to obtain eventual property rights.[193] Indeed, Comas was laid out with adequate lands for streets and public spaces because it was promised tenure regularization and public services by the government if it was properly laid out (Figure 2.25).[194]

This policy resulted in an organized urban layout with aligned plots, proper roads, and designated areas for infrastructure. A well-defined plot plan not only reduces potential conflicts among neighbors and allocates space for public use, it also enhances the credibility and feasibility of "planned" informal settlements,[195] engaging both the suppliers of land in informal settlements, the buyers of plots, and the local authorities in planning for expansion.[196] There are now several tools to facilitate and encourage the consolidation of demand and supply sides for a market of planned informal settlements.[197]

These include awareness videos for potential land buyers and sellers, a manual guiding those responsible for distributing land lots in new settlements to create plot plans adhering to proper planning standards, and a free mobile app for designing land subdivisions.[198] This app, available in both Swahili and Spanish, can automatically generate functional plot plans for any land area selected on Google Maps.[199] To encourage the creation of a market for planned informal settlements, the government could provide subsidized plot plans or accessible site planning tools for timely urbanization. Incentives for private planning, awareness campaigns, and quantifying long-term social costs of urban expansion are also suggested.[200]

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Emerging Empirical Evidence for Territorial Planning in the LAC Region

THE GROWTH OF POPULATIONS AND URBAN EXTENTS IN THE REGION

The objective of this section is to provide a broad perspective on the growth of cities in the Latin American and Caribbean region, with a special focus on a representative group of cities in the region during the 1990-2020 period. The first part of this section reviews urbanization trends and the state of urbanization in the region. The second part introduces the main findings from the recent study of urban growth in a representative group of 70 cities in the region.

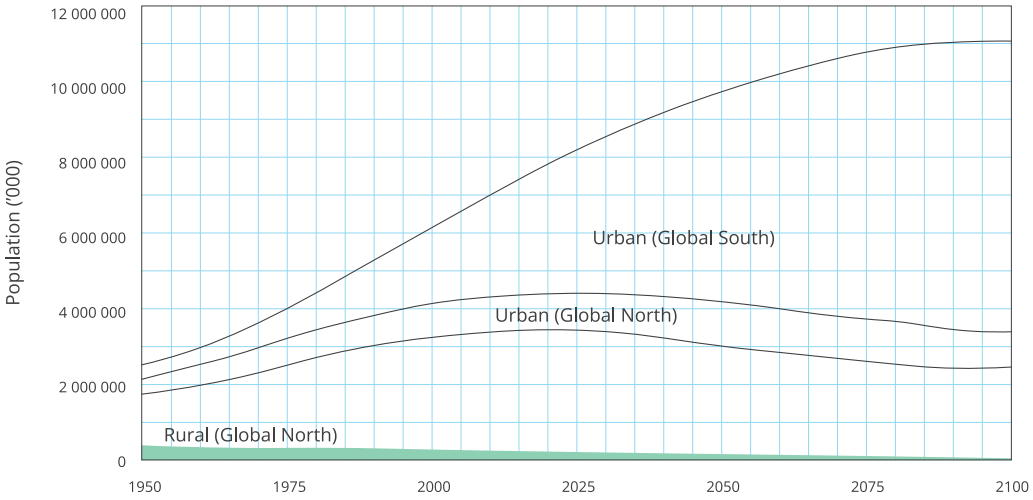
The State of Urbanization in the LAC Region

We refer to the great shift in the world population from the village to the city—a shift that started in earnest at the beginning of the 19th century and will end by the end of this century—as *The Urbanization Project*.[1] It is a project that will take only 12 generations for humanity to complete. By the end of this century, therefore, the world population and its urban population are projected to stabilize (see Figure 3.1). By then, most cities in most regions will have largely been laid out and built. We now have a small window of opportunity, a few decades, to create cities that are better able to sustain us for centuries to come.

Urbanization has largely come to an end in the Global North and is now a phenomenon observed largely in the Global South. Between 2020 and 2050, for example, 2.3 million people will be added to cities in the world at large, but for every person added to cities in the Global North 18 persons will be added to cities in the Global South.[2]

How do trends in the Latin America and Caribbean region fit into the global urbanization project? The region is by now, together with North America, one of the two most urbanized regions in the world: 81% of the region's population lived in cities in 2020, compared to 83% in North America and 75% in Europe.

By the end of this century, the world population and its urban population are projected to stabilize. We now have a small window of opportunity, a few decades, to create cities that are better able to sustain us for centuries to come.



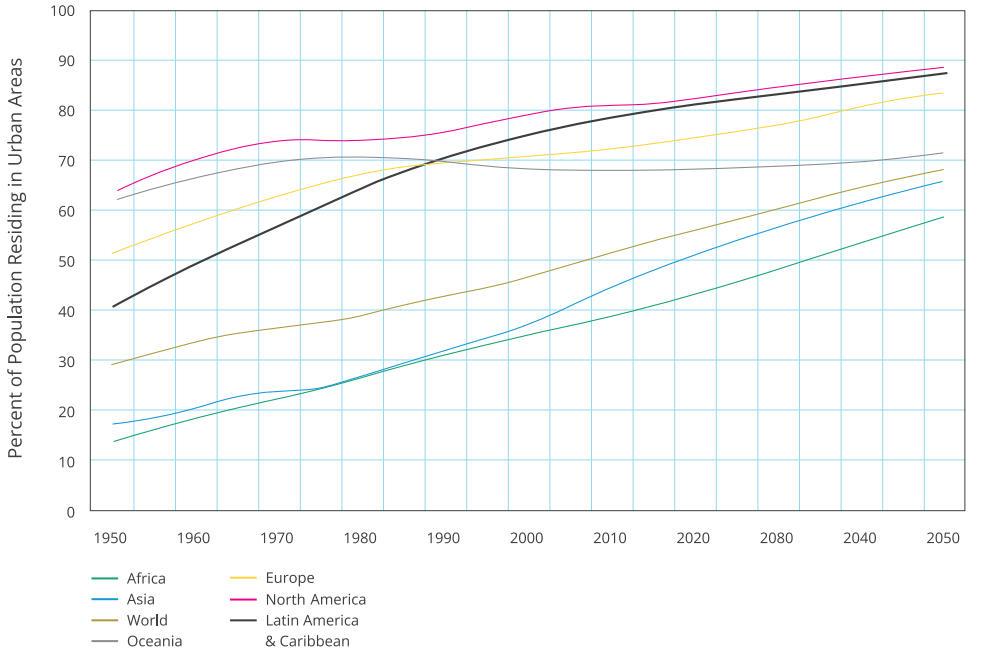


Figure 3.1: The growth of the world's urban and rural populations from 1950 to 2100, when the population of the world is expected to stabilize at 11 billion people. Source: New York University, The Marron Institute of Urban Management.

Figure 3.2: The share of the population residing in urban areas in the LAC region was the second highest among world regions from 1990 onwards. Source: New York University, The Marron Institute of Urban Management.

These percentages are expected to climb to 88%, 89%, and 84% respectively by 2050 (see Figure 3.2).

The rate of growth of its urban population has slowed down markedly and is now likely to come to a standstill by 2070. In other words, the Urbanization Project in the LAC region will have largely come to an end by that year. More specifically, we can look at the doubling of the urban population in the region since 1950, shown in Figure 3.3 below. We can see that the region's urban population doubled in 15 years between 1950 and 1965. It doubled again in 20 years by 1985, and again in 35 years by 2020. But it is not expected to double again. It is projected to grow by only 27% by 2050[3] and by a maximum of 32% by 2070 when it will have stopped growing (our own projection). In other words, the region's urban population will grow by less than one-third during the next 50 years before it stabilizes at 700-750 million people (Figure 3.3).

But this one-third average value does not tell the whole story. Some countries in the region, especially the poorer ones, are still urbanizing. And while no country in the region is expected to double its urban population by 2050, seven countries will increase it by over 50%. Haiti, Honduras, Guatemala, Bolivia, Paraguay, Ecuador and, surprisingly, Panama as well are projected to increase their urban populations by 50% or more between now and 2050 (Figure 3.4). Guatemala, an outlier, is expected to almost double its urban population between 2020 and 2050.

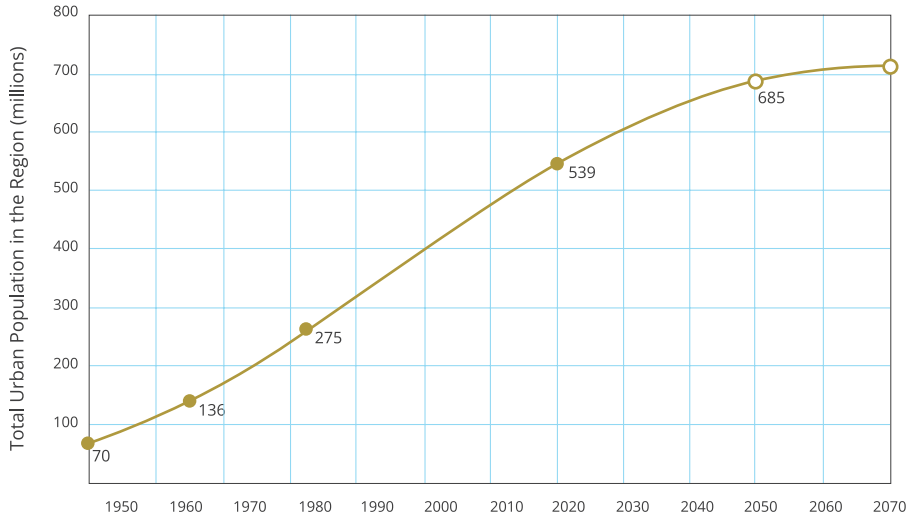
While many countries are not expected to add large numbers of people to their urban areas in percentage terms, they will add large numbers in absolute terms.

Overall, the region is expected to increase its urban population between 2020 and 2050 by 146 million people (27% of its 2020 population), and almost all this increase (99%) will be in eighteen countries (Figure 3.5) that will add one million or more to their urban populations during this period. Mexico, Brazil, and Argentina will each increase their urban populations by more than 10 million people. Brazil, for example, even though its increase will only constitute 15% of its 2020 population, will still increase it by 28.8 million by 2050.[4]

Four New Data Sets with Evidence for Territorial Planning in the Region: A Brief Introduction

This study generated four new data sets that can be used as evidence for territorial planning in the region, evidence that can assist territorial planners and policy makers in understanding current patterns and trends and in acting on them.

The data sets were put together by a team at the Urban Observatory at Valectus Inc. in Navi Mumbai, India, using methods developed by Angel and colleagues at the Marron Institute of Urban Management at New York University (NYU). These methods are described in several documents.



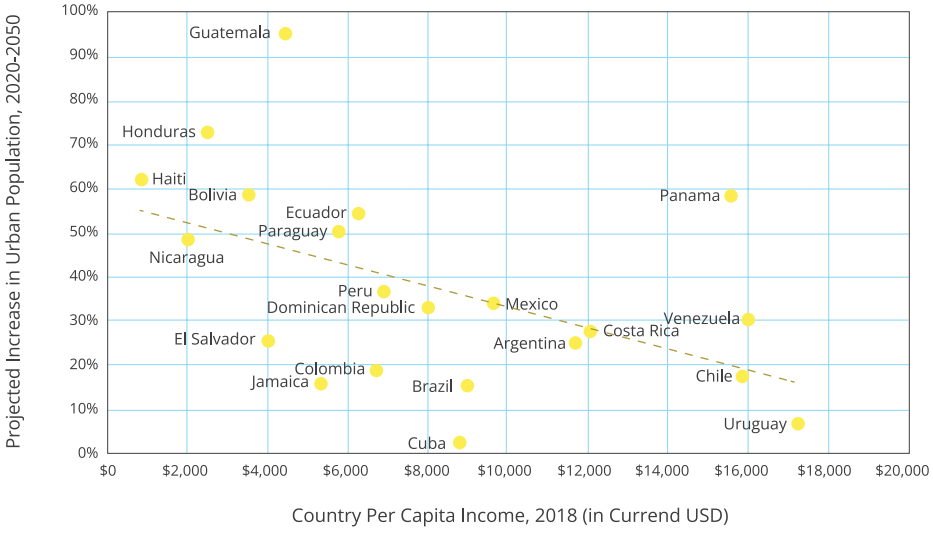


Figure 3.3: The growth of the urban population in the Latin American and Caribbean region, 1950-2070. Source: New York University, The Marron Institute of Urban Management.

Figure 3.4: The projected increase in the urban population between 2020 and 2050 in 21 countries in the LAC region that had urban populations of 1 million or more in 2020. Source: New York University, The Marron Institute of Urban Management.

Overall, the region is expected to increase its urban population between 2020 and 2050 by 146 million people (27% of its 2020 population), and almost all this increase (99%) will be in eighteen countries (see Figure 3.5) that will add one million or more to their urban populations during this period. Mexico, Brazil, and Argentina will each increase their urban populations by more than 10 million people. Brazil, for example, even though its increase will only constitute 15% of its 2020 population, will still increase it by 28.8 million by 2050.[4]

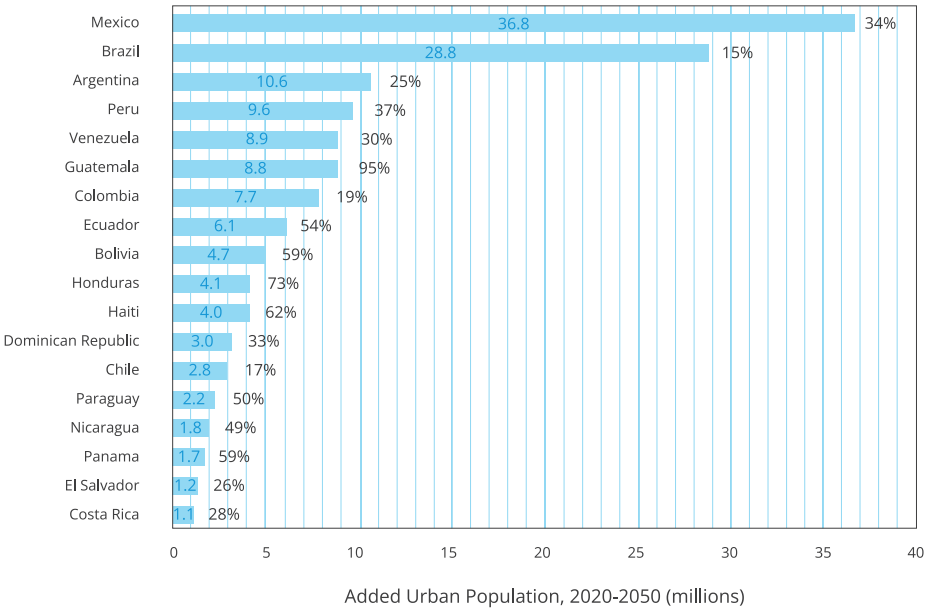


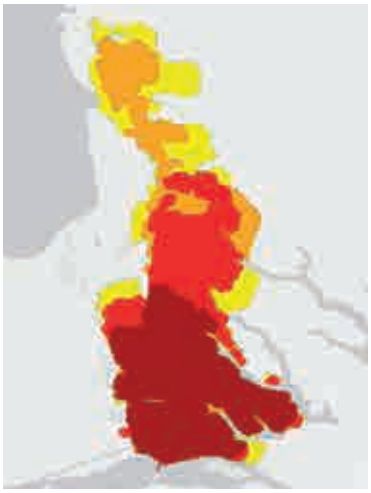
Figure 3.5: 18 countries in the LAC region that will need to accommodate more than 1 million people in urban areas between 2020 and 2050. The labels on the right of columns indicate the added population as a share of their 2020 urban population. Source: New York University, The Marron Institute of Urban Management.

The methodology for measuring changes in population, extent, densities, and urban form in cities is described in Chapter I(3) of Angel *et al's Atlas of Urban Expansion:* "Understanding and Measuring Urban Growth". This methodology has been used to map and measure several key attributes of urban expansion in 70 cities in the region—the overall urban extent of cities, the average population density of that extent, the fragmentation of the built-up area within it by open spaces, the compactness of its overall geographic shape, and the shares of infill, extension, leapfrog, and inclusion in the added built-up areas within new urban extents—in four time periods: Circa 1990, 2000, 2010, and 2020 (Figure 3.6). This methodology required the classification and analysis of medium-resolution *Landsat* satellite imagery as well as census data associated with enumeration zones that contained the urban extents of these cities.

The methodology for measuring changes in the quality of urban footprints is described in Chapter II(3) of Angel *et al's Atlas of Urban Expansion:* "Understanding and Measuring Urban Layouts". Was aimed at answering one question: How well laid out were recently built urban peripheries (areas built between 1990 and 2020) in comparison to urban areas built before 1990 in the 70 cities studied? The focus is on the areas devoted to streets, on the distinctions between different land uses, and on the shares of formal and informal settlements. This phase required digitizing and analyzing a sample of randomly selected 10-hectare locales in each city, using high-resolution *Bing* and *Google Earth* imagery (Figure 3.7).

The methodology for measuring the shares of the added populations to cities in the region accommodated by densification and expansion is described in Angel et al's 2021 article in *Sustainability* titled "Densify and Expand: A Global Analysis of Recent Urban Growth." It used the expansion maps obtained earlier together with a *WorldPop* population grid with a one-kilometer resolution (Figure 3.8), to determine the changes in population between 1990 and 2020 in four zones in each of the 70 cities in the region in four time periods: (1) The areas inhabited before 1990, (2) the areas inhabited during the 1990-2000 period, (3) the areas inhabited during the 2000-2010 period, and (4) the areas inhabited during the 2010-2020. This made it possible to determine the share of the population that densified the pre-1990 footprints of these cities and to compare it with the shares accommodated in expansion areas built in later time periods.

Finally, the methodology for analyzing the anatomy of density, applied only to a subset of 30 cities in the region, is described in Angel et al's 2022 article in *Buildings and Cities* titled "Anatomy of density: measurable factors that constitute urban density," as well as in a UN-Habitat's Urban Futures online lecture on YouTube titled The Anatomy of Density. It is a novel methodology that makes it possible to represent the average density of the urban extents of cities as a product of three, and even seven measurable factors (Figure 3.9) that when multiplied together reconstitute urban density. The breakdown of average densities





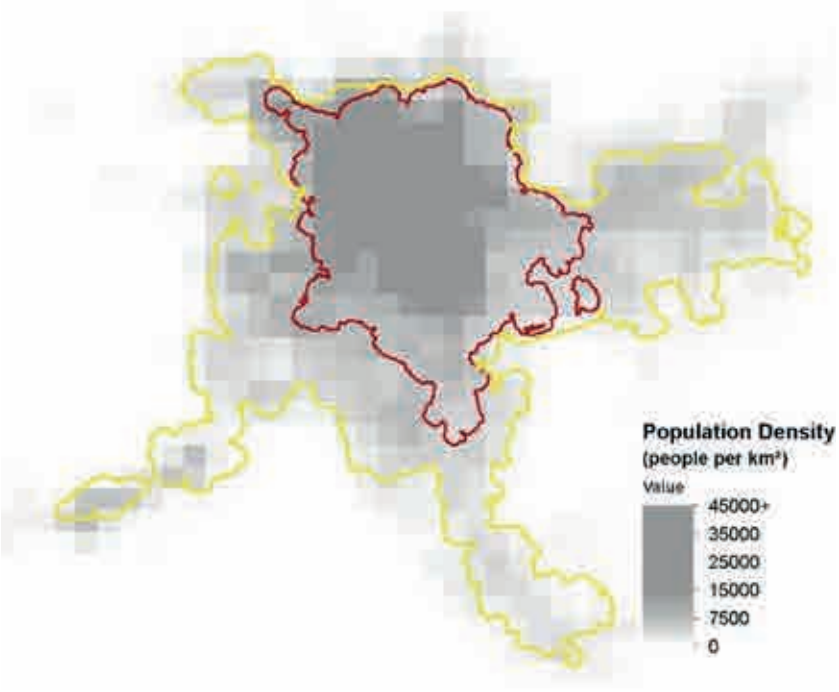


Figure 3.6: The expansion of Linares, Brazil, showing the urban footprint of the city in four time periods – circa 1990, 2000, 2010, and 2020. Source: New York University, The Marron Institute of Urban Management.

Figure 3.7: The division of a high-resolution satellite image of a 10-hectare locale in Accra, Ghana, into road space (light brown) and block space (orange borders). Source: New York University, The Marron Institute of Urban Management.

Figure 3.8: Superimposing a *Worldpop* population grid on a three-zone map of Addis Ababa, Ethiopia, to estimate population within each zone circa 1990, 2000, and 2014. Source: New York University, The Marron Institute of Urban Management.

into measurable factors makes it possible to create comprehensive densification strategies for cities, strategies that are based on interventions focused each one of the factors that make up urban density.

In this study, we applied these four methodologies, for the first time, in cities in the region, the first three in 70 cities and the fourth one in 30 cities. We have identified a total of 483 cities and metropolitan areas in the Latin American and Caribbean region that had 100,000 people or more in 2010 (Figure 3.10, left). Of these we have selected 70 cities (Figure 3.10 right).

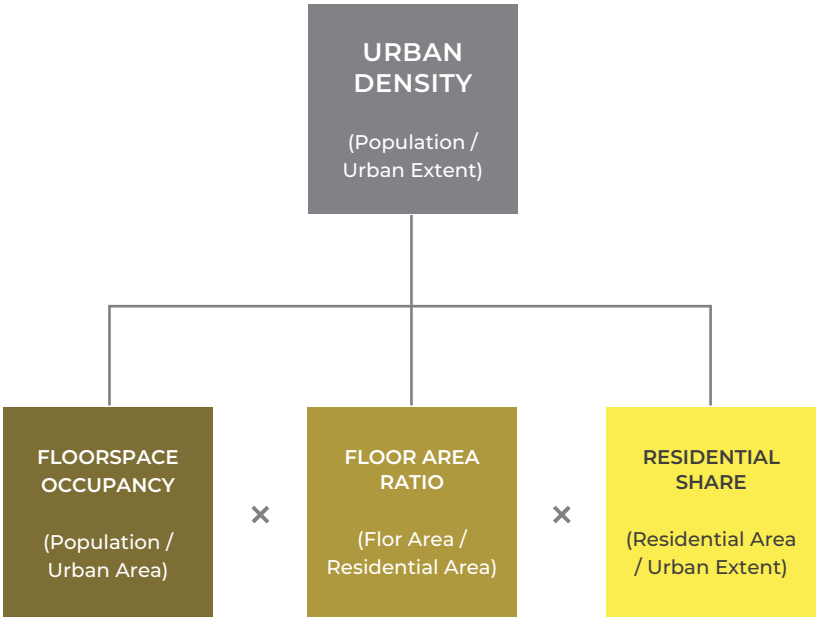
We then selected a subgroup of 30 cities from these 70 cities for a study of the anatomy of density. The groups of cities for which we have collected data, 70 cities for the study of urban expansion and densification and 30 cities for the study of the anatomy of density, are listed in Figure 3.10.

It is important to note that the selected cities are not a random sample of cities. The *Atlas of Urban Expansion* identified a total of 483 cities and metropolitan areas in the LAC region that had 100,000 people or more in 2010. These cities had a total population of 320 million that year. The representative group of 70 cities we are studying now had 67 cities with 100,000 people or more in 2010, and thus comprised some 14% of these cities in the region.

This group of cities had a total population of 152 million in 2010, and thus accommodated 48% the population of cities with 100,000 people or more in the region that year. The group, however, is not a representative sample of cities in the region. The average population of the city in this group in 2010 was 2.2 million, while the average population of all cities in the LAC region was 660,000 that year (Figure 3.11). In other words, this group of cities is biased towards the larger cities in the region. This must be kept in mind when exploring the statistical findings in the following sections.

Changes in Population, Extent, Densities, and Urban Form in Cities in the Region in Recent Decades

The objective of this section is to present the key findings pertaining to recent changes in populations, urban extents, densities, and urban form from our study of a representative group of 70 cities in the region during the 1990-2020 period. These findings are highlighted because they have important implications for territorial planning and policy making in the region. They are presented in the form of hypotheses that are then subjected to statistical tests using the data collected for this study. From the perspective of territorial planning, it is important to understand how fast cities grow in population and expand in area, if only because the traditional goal of effective territorial planning, since time immemorial, was to prepare cities to accommodate the growth in their population, commerce, and civic life by laying out streets and public open spaces at the anticipated scale on the urban periphery in advance of its occupation, and then ensuring



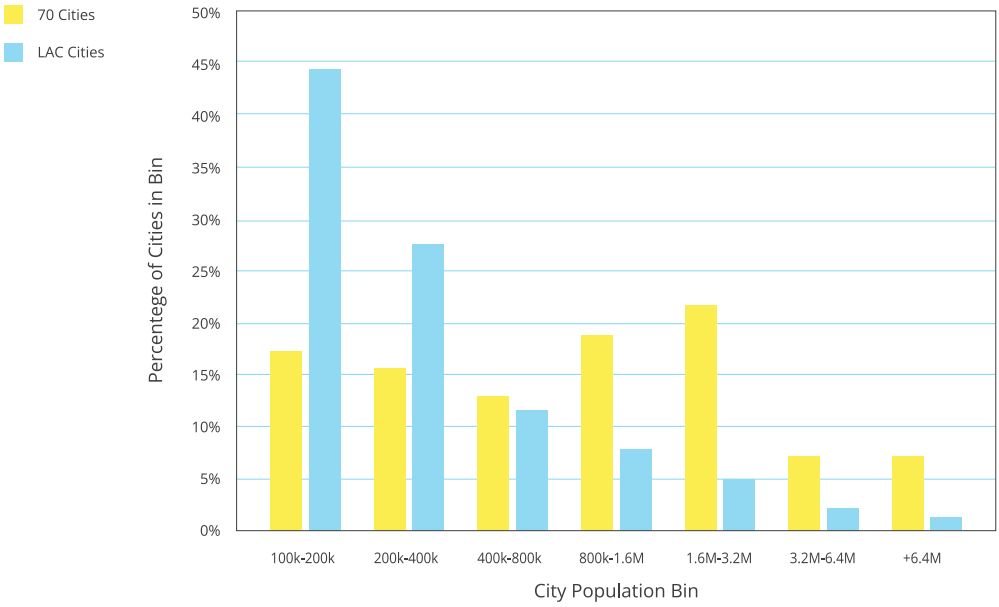


Figure 3.9: Factoring urban density into three factors than when multiplied together yields urban density. Source: New York University, The Marron Institute of Urban Management.

Figure 3.11: The sample of 70 cities studied here is skewed toward larger cities when compared to the actual distribution of cities with 100,000 people or more in 2010 in the LAC region. Source: New York University, The Marron Institute of Urban Management.

#	CITY	COUNTRY
01	Arequipa*	Peru
02	Greater Asunción**	Colombia
03	Ayacucho**	Colombia
04	Greater Barranquilla**	Colombia
05	Belize City*	Belize
06	Greater Belo Horizonte**	Brazil
07	Greater Bogotá**	Colombia
08	Bridgetown**	Barbados
09	Greater Buenos Aires**	Argentina
10	Greater Cali*	Colombia
11	Campo Grande**	Brazil
12	Greater Cartagena de Indias**	Colombia
13	Greater Cochabamba**	Bolivia
14	Greater Córdoba*	Argentina
15	Cuenca*	Ecuador
16	Greater Culiacán**	Mexico
17	Greater Curitiba*	Brazil
18	Cusco*	Peru
19	Greater Florianópolis**	Brazil
20	Greater Fortaleza*	Brazil
21	Georgetown*	Guyana
22	Greater Guadalajara**	Mexico
23	Greater Guatemala City**	Guatemala
24	Greater Guayaquil**	Ecuador
25	Hermosillo**	Mexico
26	Ilheus*	Brazil
27	Jequié*	Brazil
28	Kingston*	Jamaica
29	La Serena*	Chile
30	Greater La Paz**	Bolivia
31	Greater León*	Nicaragua
32	Lima**	Peru
33	Linhares*	Brazil
34	Macapá*	Brazil
35	Greater Managua*	Nicaragua
36	Greater Medellín*	Colombia
37	Greater Mendoza**	Argentina
38	Greater Mérida**	Mexico
39	Greater México City**	Mexico
40	Greater Monterrey*	Mexico
41	Greater Montevideo**	Uruguay
42	Nassau*	Bahamas
43	Greater Niterói*	Brazil
44	Palmas*	Brazil
45	Greater Panamá City**	Panama
46	Greater Paramaribo*	Suriname
47	Pasto*	Colombia
48	Greater Porto Alegre**	Brazil
49	Greater Port-au-Prince*	Haiti
50	Greater Quetzaltenango*	Guatemala
51	Greater Quito**	Ecuador
52	Greater Recife**	Brazil
53	Reynosa*	Mexico
54	Ribeirão Preto*	Brazil
55	Rosario*	Argentina
56	Greater San José**	Costa Rica
57	Greater San Salvador**	El Salvador
58	Greater Santa Ana	El Salvador
59	Santa Fé	Argentina
60	Greater Santiago**	Chile
61	Greater Santo Domingo**	Rep. Dominicana
62	Greater São Paulo*	Brazil
63	Greater Tarija*	Bolivia
64	Tegucigalpa**	Honduras
65	Tijuana*	Mexico
66	Valledupar*	Colombia
67	Valparaiso*	Chile
68	Villavicencio*	Colombia

*Cities assessed for Expansion and Densification
** Cities assessed for Expansion and Densification and Anatomy of Density

Figure 3.10: There were 483 cities in Latin America in 2010 with populations of 100,000 or more, shown here as black points on the left. Of these, 70 cities were selected for this study: 68 were assessed for Expansion and Densification, 31 of which also include an analysis of the Anatomy of Density through 7 factors. Source: New York University, The Marron Institute of Urban Management. The cities in the Latin American and Caribbean region selected for this study.


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that the lands required for these public works remain in public use when the urban periphery is populated over time. The objective of this research effort is to revive this tradition, to create the capacity in the countries in the region to accommodate its expected urban growth in an effective manner, at scale, with climate change in mind, and with the goal of developing its cities in an inclusive, sustainable, and resilient manner. To that effect, it is important to understand recent trends in the growth of populations and in the urban extents of cities.

Concerns with climate change have also resulted in calls for its mitigation by curtailing greenhouse gas emissions in cities. This calls, as we noted earlier, have resulted in calls for energy savings and in the reduction in the use of fossil fuels, especially in urban transport, and in consequent efforts to make cities denser.

It is important to know, therefore, if cities in the region are densifying. It is of prime interest to find where urban growth is occurring and whether larger cities and mega cities are growing at faster rates than secondary cities. It is also critical to understand how urban expansion is taking place, to what extent it is contiguous or fragmented, and what shares of that expansion are infill, extension into the urban periphery, leapfrog development, or the inclusion of peripheral villages and towns into the urban footprint.

We have sought to provide answers to these questions by analyzing the evidence in a rigorous manner, by presenting a set of hypotheses, and testing these hypotheses with statistical tools to determine whether they should be accepted or rejected.

In this section, we present seven questions pertaining to changes in population, urban extents, and densities of cities in the region:

In this section, we present seven questions pertaining to changes in population, urban extents, and densities of cities in the region:

01 Is there a direct relation between the density of cities' urban extent in the region and their sizes? In other words, do large cities have similar densities to small ones?

02 Are larger cities in the region growing at a faster rate than smaller ones?

03 Are the urban extents of cities in the region growing at the same rate as their populations?

04 Did the average density of urban extent and built-up area, as well as city saturation in the region change over time?

05 Did urban extent densities in cities in the region change at the same rate in cities with different population growth rates?

06 Did the compactness of the urban footprints of cities in the region change over time?

07 Was most of the built-up area added to cities in the region over time in the extension of the city? Did most of new construction take place in the urban periphery?

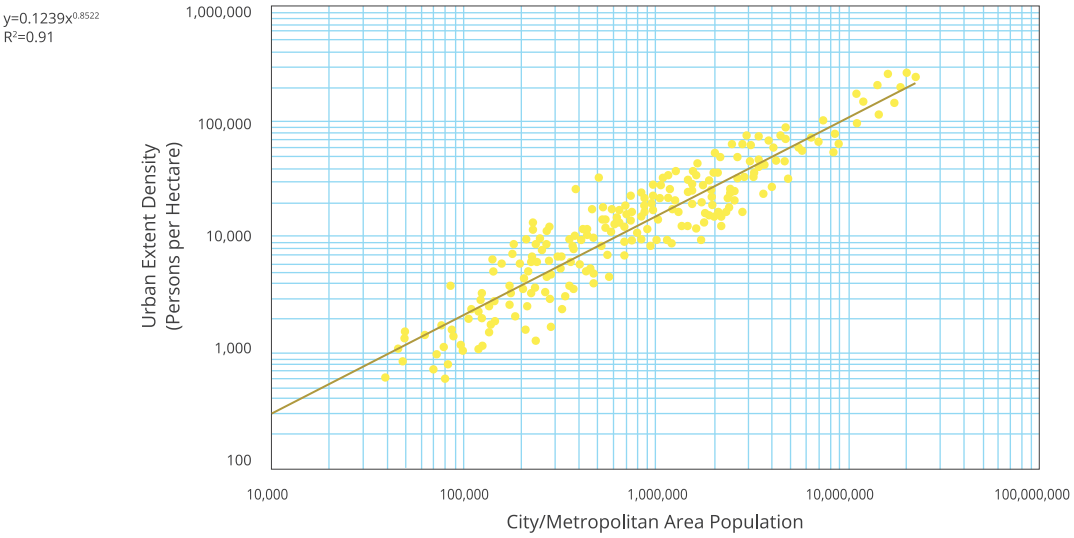
01 Is there a direct relation between the density of cities' urban extent in the region and their sizes? In other words, do large cities have similar densities to small ones?

A graph matching the populations and urban extents of 68 cities in the LAC region in four time periods is presented in Figure 3.12, which displays the logarithm of the urban extents of cities (on the Y-axis) against the logarithm of their populations (on the X-axis). It shows, first, that the log-log relationship between population and urban extent is linear and very robust (R2=0.91), suggesting that the city population is a very strong factor in explaining their urban extents. Second, the equation of the trend line in Figure 3.12 shows that the log-log relationship between population and urban extent of cities in the region is $Urban\ Extent = 0.1239 \times Population^{0.8521}$.

This means that a city with double the population of a smaller one had an urban extent that was 85.21% larger than that of the smaller one. In other words, the urban extent did not double when city population doubled; it only increased by 85%. Urban Extent Density, which is the ratio of population and urban extent, increased in a city with double the population of a smaller one by $1/0.8521 = 17.4\%$.[5] On average, larger cities in the region had higher densities: When the population of a city doubled, density increased, on average, by 17.4%. The implication for this finding for territorial planning in the region is that urban population growth goes hand-in-hand with their 'natural' densification, and that smaller cities cannot be expected to have the same densities as larger ones.

02 Are larger cities in the region growing at a faster rate than smaller ones?

A graph matching the 1990 populations of 69 cities in the LAC region and their average population growth rates during the 1990-2020 period is presented in Figure 3.13, which displays the 1990-2020 population growth rate (on the Y-axis) against the logarithm of their populations (on the X-axis). A multiple regression test shows that the relationship between the population and the population growth rate is not statistically significant (R2=0.16), suggesting that city populations are not a factor in explaining their population growth rates: The larger the city, the slower its growth rate. For this group of cities in the LAC region, a city with double the size of another one has an annual growth rate than is smaller by 0.35%.[6] Larger cities are growing at a slower rate than smaller ones. The implication of this finding for territorial planning in cities in the region is that urban population growth in countries in the region is a system- wide property and that allocation of resources for accommodating this growth can and should be done with the entire urban system in the country in mind, rather than with a focus either on a few mega cities or on the larger secondary cities.



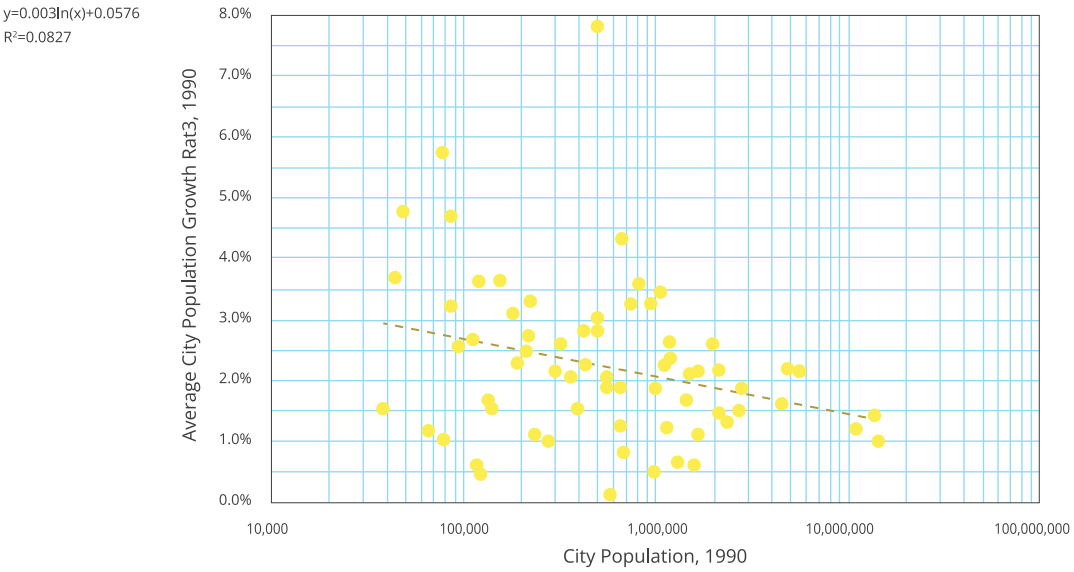


Figure 3.12: The log-log relationship between population and urban extent in 67 cities in the region in 4 time periods: 1990, 2000, 2010, and 2020. Source: New York University, The Marron Institute of Urban Management.

Figure 3.13: The relationship between 1990 city population in cities in the region and their average city population growth rates in the 1990-2020 period. Source: New York University, The Marron Institute of Urban Management.

03 Are the urban extents of cities in the region growing at the same rate as their populations?

Figure 3.14 shows the average growth of the population and urban extents of cities in the region in four time periods—1990-2000, 2000-2010, 2010-2020, and 1990-2020—in terms of multiples, where the value at the beginning of each period is taken to be equal to 1. It shows, for example, that between 1990 and 2020, cities in the region increased their population, on average, by a multiple of 2.05 (blue column on right) and their urban extents by a multiple of 2.75 (red column on right). The difference between these two multiples (grey column on right) was 0.70. The 95% error bars of the difference between the multiples are above the X-axis during all four time periods, which means that the urban extent multiple was significantly larger than the population multiple in all four time periods. Urban extents in cities in the region have been growing at a significantly faster rates than their populations in recent decades,[7] despite efforts of many territorial planning institutions in the region to contain urban expansion. More generally, urban populations doubled during the last three decades, while urban extents tripled. The implication for territorial planning in cities in the region is that present efforts at containing urban expansion, with the given planning toolkit at hand, are not bearing fruit and that territorial planners must prepare large areas for the projected expansion of cities.

04 Did the average density of urban extent and built-up area, as well as city saturation in the region change over time?

In formulating and testing this hypothesis, we need to define these terms more precisely. Urban extent, for example, refers to the total area of the city, including both its built-up areas and its urbanized open spaces. Saturation is the level to which the urban extent is saturated with built-up areas. There is an important relationship between urban extent and built-up area density, and saturation:

(1) Urban Extent Density = Population / Urban Extent.

(2) Built-up Area Density = Population / Built-Up Area.

(3) Saturation = Built-Up Area / Urban Extent.

Therefore:

(4) Saturation x Built-up Area Density = (Built-Up Area / Urban Extent) x (Population / Built-Up Area) = Population / Urban Extent = Urban Extent Density.

In other words, urban extent density—which is the overall gross density in the city—increases when saturation increases and built-up area density increases.

The data pertaining to the previous hypothesis has already confirmed that the urban extents of cities in the region grew at a faster rate than their populations, implying that urban extent densities declined in recent decades.

Urban extents in cities in the region have been growing at a significantly faster rates than their populations in recent decades,[7] despite efforts of many territorial planning institutions in the region to contain urban expansion. More generally, urban populations doubled during the last three decades, while urban extents tripled.

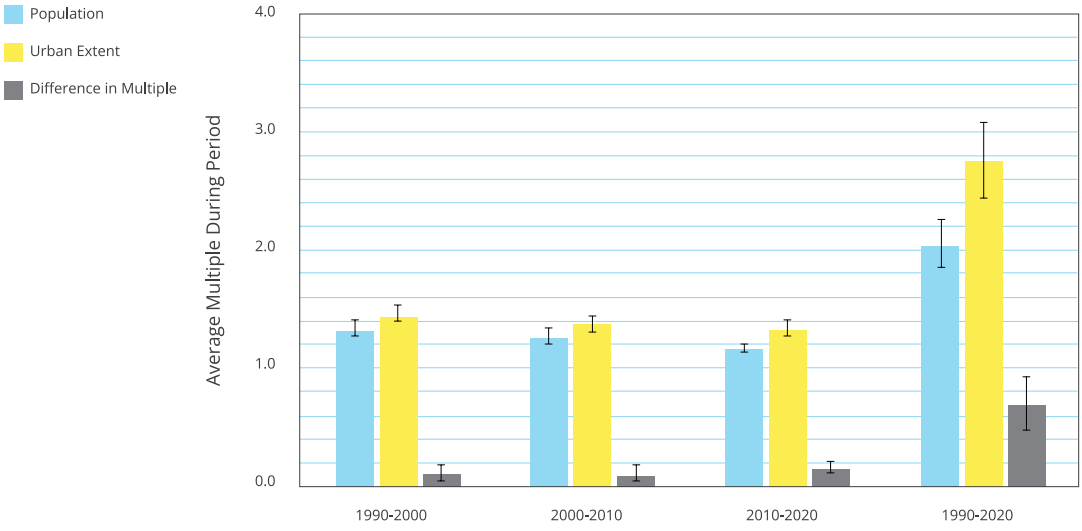


Figure 3.14: Multiples of the population and the urban extent of cities in the region at the end four time periods, where values were equal to 1 at the beginning of each period. Source: New York University, The Marron Institute of Urban Management.

To test this hypothesis, we looked at the annual rates of change in urban extent density, built-up area density, and saturation during each decade—1990-2000, 2000-2010 and 2010-2020—as well as during the 1990-2020 period. The results are shown in Figure 3.15 which displays the average annual rates of change in these three metrics in cities in the region. The graph in Figure 3.15 shows that average urban extent densities declined in all three periods and declined significantly during two of the three decades as well as during the three-decade period; that average built-up area densities declined significantly during each decade as well as during the three-decade period;[8] and that saturation increased in each decade and increased significantly during two of the three decades as well as during the three-decade period. It is not surprising that saturation increased over time as vacant spaces were built upon through the infill of existing urban footprints. Since urban extent density, as we explained before, is the product of saturation and built-up area density, its decline must be explained by the persistent decline in built-up area densities: The built-up areas of cities in the region continued to be built at lower—rather than higher—densities, despite the efforts of territorial planners at densification. That suggests that—if this trend is to be reversed—territorial planning must be equipped with more effective new tools and practices that enable and promote building at higher densities.

05 Did urban extent densities in cities in the region change at the same rate in cities with different population growth rates?

This hypothesis addresses the question whether cities that are growing at a faster rate experience more rapid decline in their urban extent densities than cities that are growing at a slower rate. The data for testing this hypothesis is given in Figure 3.16 which posits the annual population growth rate of a city on the X-axis and the annual rate of urban extent density change on the Y-axis. The graph shows that the rate of density change increases significantly (R^2 = 0.29) in cities that have populations that are growing more rapidly. More rapid density decline in cities in the region is associated with slow population growth, while slower decline or an increase in urban extent density is associated with rapidly growing cities.[9] One implication for territorial planning in the region is that rapidly growing cities have greater potential for densification and that it should be easier to implement densification strategies in rapidly growing cities than in slower growing ones.

Saturation increased over time as vacant spaces were built upon through the infill of existing urban footprints. The built-up areas of cities in the region continued to be built at lower—rather than higher—densities, despite the efforts of territorial planners at densification. That suggests that—if this trend is to be reversed—territorial planning must be equipped with more effective new tools and practices that enable and promote building at higher densities.

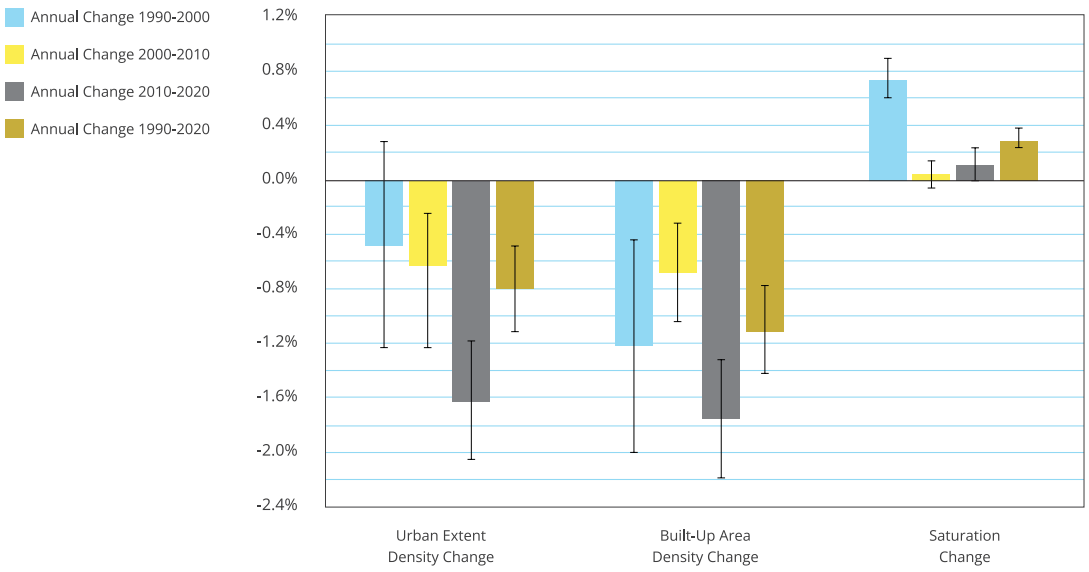


Figure 3.15: Annual rates of change in urban extent and built-up area density, as well as city saturation in the region in four time periods. Source: New York University, The Marron Institute of Urban Management.

06 Did the compactness of the urban footprints of cities in the region change over time?

In this study, following the *Atlas of Urban Expansion* methodology, we defined metrics of two compactness attributes of cities that are highly correlated with each other. Both rely on comparing the shape of the urban extent to the shape of the *equal area circle*, a circle with the area of the urban extent, centered at city hall. The *proximity index* is the ratio of the average beeline distance of all points in the equal area circle to city hall and the average beeline distance of all points in the urban extent to city hall. The *cohesion index* is the ratio of the average beeline distance of all points to all other points in the equal area circle and the average beeline distance of all points to all other points in the urban extent. Both indices vary between 0 and 1, with higher values corresponding to urban extents that are closer in shape to the circle.

To test whether the compactness of the urban footprints changed over time, we calculated the Proximity Index and the Cohesion Index for the group of 70 cities in the region. The results are displayed in Figure 3.17. Overall, the compactness of cities in the region decreased slowly during the past three decades, but it decreased significantly only during the 1990-2000 decade and during the 30-year period between 1990 and 2020.[10] If we focus on the long-term trend, the compactness of cities did change over time, and specifically, the compactness of cities in the region is declining significantly over time, and it is certainly not increasing. From a territorial planning perspective, cities in the region are becoming less circular, requiring longer travel distances, as well as longer infrastructure lines, than more circular ones with the same areas. This is often due to their extension along inter-city roads and, if so, it is an indication of the relative absence of arterial roads in the peripheral areas stretching between inter-city roads.

07 Was most of the built-up area added to cities in the region over time in the extension of the city? Did most of the new construction take place in the urban periphery?

In this study, following the *Atlas of Urban Expansion* methodology, we defined four types of newly built-up areas that together constitute all the built-up area added to the earlier urban extent between two time periods: *Infill* consists of all built-up areas added in the new period that occupy urbanized open space within the urban extent of the earlier period; *extension* consists of all built-up areas added in the new period that constitute contiguous urban clusters that are attached to the urban extent of the earlier period; *leapfrog* consists of all built-up areas added in the new period that constitute new contiguous urban

More rapid density decline in cities in the region is associated with slow population growth, while slower decline or an increase in urban extent density is associated with rapidly growing cities.[9] One implication for territorial planning in the region is that rapidly growing cities have greater potential for densification and that it should be easier to implement densification strategies in rapidly growing cities than in slower growing ones.



Figure 3.16: The average annual change in urban extent densities in cities in the region during the 1990-2022 period as a function of the annual rate of population growth in these cities during this period. Source: New York University, The Marron Institute of Urban Management.

From a territorial planning perspective, cities in the region are becoming less circular, requiring longer travel distances, as well as longer infrastructure lines, than more circular ones with the same areas. This is often due to their extension along inter-city roads and, if so, it is an indication of the relative absence of arterial roads in the peripheral areas stretching between inter-city roads.

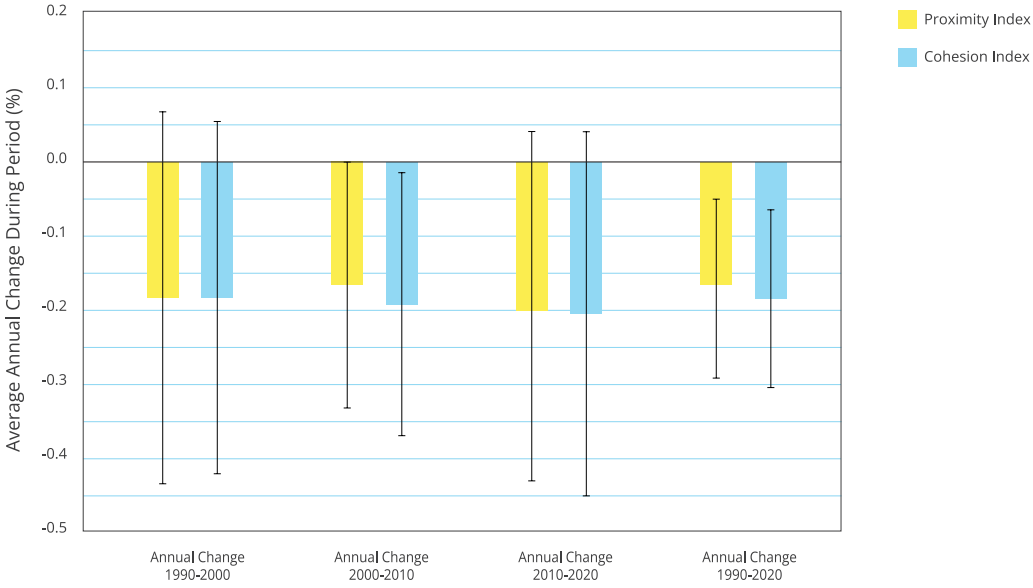


Figure 3.17: The average annual change in the Proximity and Cohesion Index that measures compactness in cities in the region in each of four time periods. Source: New York University, The Marron Institute of Urban Management.

24% Inclusion

11% Leapfrog

29% Extension

37% Infill

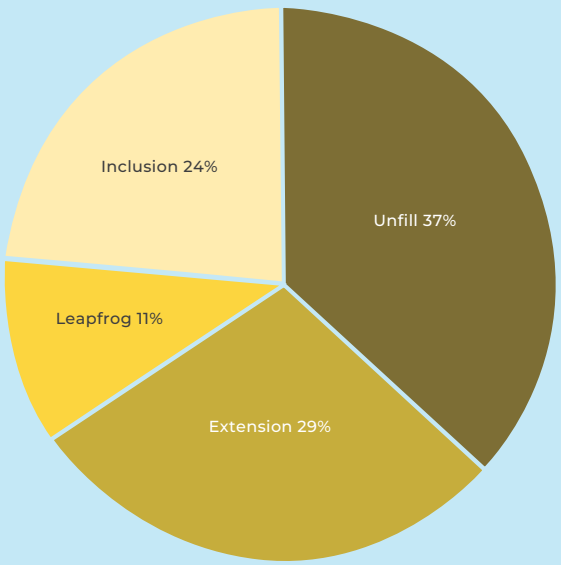


Figure 3.18: The average share of the built-up areas added to cities in the region in every decade—1990-2000, 2000-2010, and 2010-2020—in four categories: Infill, extension, leapfrog, and inclusion. Source: New York University, The Marron Institute of Urban Management.

clusters that are not attached to the urban extent of the earlier period or to new extension clusters; and *inclusion* consists of all urban, rural, or suburban built-up areas that were outside the urban extent in the earlier period and are now within the urban extent of the new period.

Figure 3.18 shows the average share of the added built-up area in cities in the region during each one of the three decades—1990-2000, 2000-2010, and 2010-2020—in infill, extension, leapfrog, and inclusion. In a typical single decade, 37% of new built-up areas are in the infill of vacant plots, within existing urban footprints, contributing to the densification of these footprints. Twenty four percent of the built-up areas added to cities is through the inclusion of villages and towns built in earlier periods into the new urban footprints. Only the remaining 40% of the added built-up area is added through new construction on the urban periphery, either as the contiguous extension of earlier footprints (29%) or through leapfrogging, new construction that is nearby yet not directly contiguous to earlier footprints.

Figure 3.19 combines the categories of extension and leapfrog into one category that encompasses all new construction on the urban periphery and provides data on the actual shares of the added built-up area of cities in the region in each of three decades—1990-2000, 2000-2010, and 2010-2020—as well as data for the 30-year period 1990-2020. There are no statistically significant differences in the shares of the added built-up area in the different categories (error bars all overlap). During the 30-year period, 1990-2020, one-quarter of the added built-up area was in the infill of the 1990 footprint, one-quarter was in the inclusion of areas built earlier into the 2020 footprint, and one-half was in new construction—in both extension and leapfrog—in the 1990-2020 expansion area.[11] The implication of these findings for territorial planning are, first, that infill is a natural process of city-building, and it continues hand in hand with urban expansion: Areas, especially on the urban periphery, that are initially built with large areas of vacant lands are gradually filled in. Second, the inclusion or incorporation of settlements built in earlier periods is an important component of overall urban expansion. Third, in a typical decade, new construction on the urban periphery forms less than half of the built-up areas added to cities during the decade. In the longer run, over a 30-year period, it amounts to half the added built-up area over the period, while infill and inclusion each form one-quarter of the added built-up area. Each of these forms of adding built-up area requires a special focus.

This brings to a close the discussion of the findings related to population, urban extents, densities, the shape compactness of urban footprints, and the shares of the added built-up areas of cities in the region in infill, extension, leapfrog, and inclusion.

During the 30-year period, 1990-2020, one-quarter of the added built-up area was in the infill of the 1990 footprint, one-quarter was in the inclusion of areas built earlier into the 2020 footprint, and one-half was in new construction—in both extension and leapfrog—in the 1990-2020 expansion area.[11]

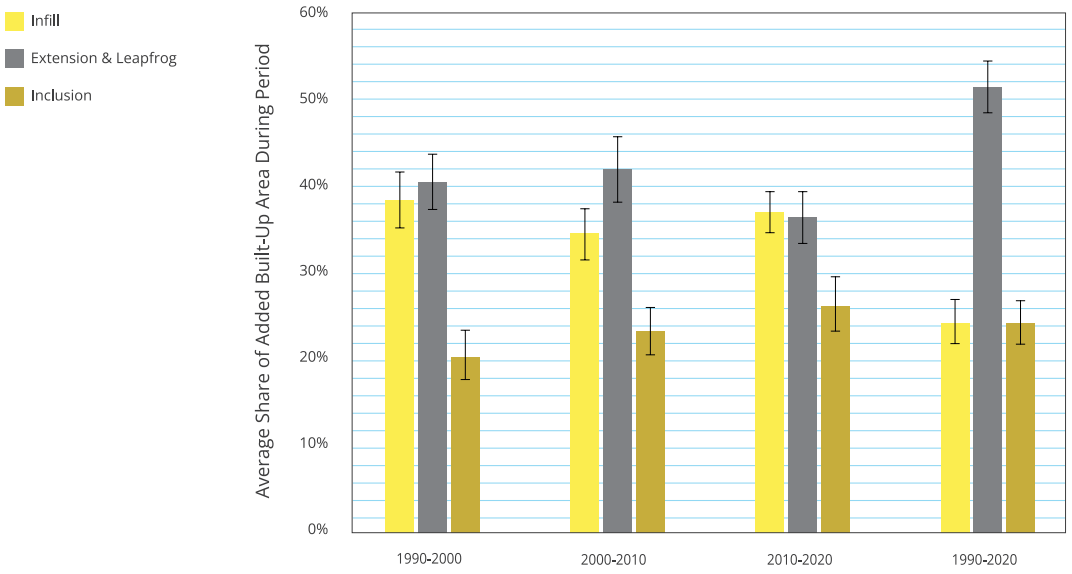


Figure 3.19: The average share of the built-up areas added to cities in the region in every decade—1990-2000, 2000-2010, and 2010-2020—and during the 1990-2020 period in three categories: Infill, extension & leapfrog, and Inclusion. Source: New York University, The Marron Institute of Urban Management.

THE CHANGING QUALITY OF URBAN FOOTPRINTS

A question of key importance to territorial planners in the region is whether planning efforts have been bearing fruit: Are the areas built more recently better planned than areas built earlier? This section begins to provide an answer to this question by focusing on changes in three parameters in recent decades: The share of the built-up area in informal settlements, roads and boulevards, and non-residential use. Our starting premise is that to the extent that territorial planning is successful in laying out arterial roads and street grids in advance of development, the higher the quality of the emerging urban footprints. Laying out the road network on the urban periphery, devoting adequate land for their rights-of-way, and providing neighborhoods with essential services along streets is the key to orderly, productive, inclusive, and sustainable urban development.

It is also the key to transforming areas built informally—with houses built over time—into regular urban neighborhoods and shedding the stigma associated with their informality. In contrast, carving new roads and providing services in areas that were developed irregularly earlier, has proven to be costly, both in terms of cost and in terms of local resistance. The third parameter, the share of land in non-residential use measured the extent to which new areas have mixed uses as well as the extent to which the job market is decentralizing. Typical values for two other parameters that measure the quality of urban footprints—density (both of the urban extent and of the built-up area) and saturation—are clearly lower in newly-built areas, but those are considered inevitable and self-correcting over time. As we shall see in the next section, our findings show that both densities and saturation levels were lower in newly occupied lands on the urban periphery, yet both increased over time. Below we present three questions that we tested with analytical tools to understand how new urban peripheries are developed and to what extent newly developed areas are better, or less, planned than areas developed earlier.

We present three questions that we tested with analytical tools to understand how new urban peripheries are developed and to what extent newly developed areas are better, or less, planned than areas developed earlier:

01 Did the average share of land in cities in the region devoted to **roads and boulevards** built in recent decades—1990-2000, 2000-2010, and 2010-2020—vary appreciably from the average share in their pre-1990 urban footprints or not?

02 Did the average share of the residential areas of cities in the region occupied by **informal housing** in recent decades—1990-2000, 2000-2010, and 2010-2020—vary appreciably from the average share in their pre-1990 urban footprints or not?

03 Did the average share of the built-up areas of cities in the region occupied by **non-residential development** in recent decades—1990-2000, 2000-2010, and 2010-2020—vary appreciably from the average share in their pre-1990 urban footprints or not?

01 Did the average share of land in cities in the region devoted to **roads and boulevards** built in recent decades—1990-2000, 2000-2010, and 2010-2020—vary appreciably from the average share in their pre-1990 urban footprints?

Figure 3.20 shows the share of the built-up areas devoted to roads and boulevards in urban zones developed in different periods in cities in the region. It shows that in the areas of cities built before 1990 (left column), an average 23±2% of the built-up area was devoted to roads and boulevards. It also shows that this share has been declining in later decades and that in areas built during the 2010-2020 period it was significantly lower than in pre-1990 areas: 18±2%. Overall, we can see that the share of roads in the expansion areas built during the 1990-2020 period (right column), 19±2%, is also significantly lower than the share in the 1990 footprints of cities. This should be a cause for concern for territorial planners in the region. It shows that investment in public works on the urban peripheries of cities may be lagging behind private investments by households and firms with the result that these peripheries are not as connected to the rest of the city, making it more difficult for people to get to jobs, and making it more difficult for the urban economy to reap the benefits of agglomeration in more integrated urban job markets.

02 Did the average share of the residential areas of cities in the region occupied by **informal housing** in recent decades—1990-2000, 2000-2010, and 2010-2020—vary appreciably from the average share in their pre-1990 urban footprints?

Figure 3.21 shows the shares of the residential areas in cities in the region occupied by formal and informal housing in different time periods. In the residential areas within the urban footprints built before 1990 (left columns), the respective shares of formal and informal housing are 72±6% and 28±6% respectively. Contrary to expectations, the share of informal housing has been increasing, rather than decreasing, in recent decades. In the areas built or included in the urban footprints of cities in the region during the 1990-2000 period, it increased to 50±6%; it then climbed to 59±7% in the areas built or included in the urban footprint during the 2000-2010 period; and it then climbed further to 67±6% in the areas built or included in the urban footprint during the 2010-2020 period. If we compare the shares of informal housing between the pre-1990 urban footprints of cities, 28±6%, and their expansion areas constructed during the 1990-2020 period (right columns), 58±6%, we can conclude that the share of informal housing increased. This conclusion reflects badly on territorial planning in the region: planning, taxation, regulations, and public infrastructure investments, have not been able to reduce the share of informal housing and have allowed it to increase. This finding calls for a deeper investigation of the process of informal housing formation and a re-examination of the tools available to territorial planners for engaging with informality.

Investment in public works on the urban peripheries of cities may be lagging behind private investments by households and firms with the result that these peripheries are not as connected to the rest of the city, making it more difficult for people to get to jobs, and making it more difficult for the urban economy to reap the benefits of agglomeration in more integrated urban job markets.

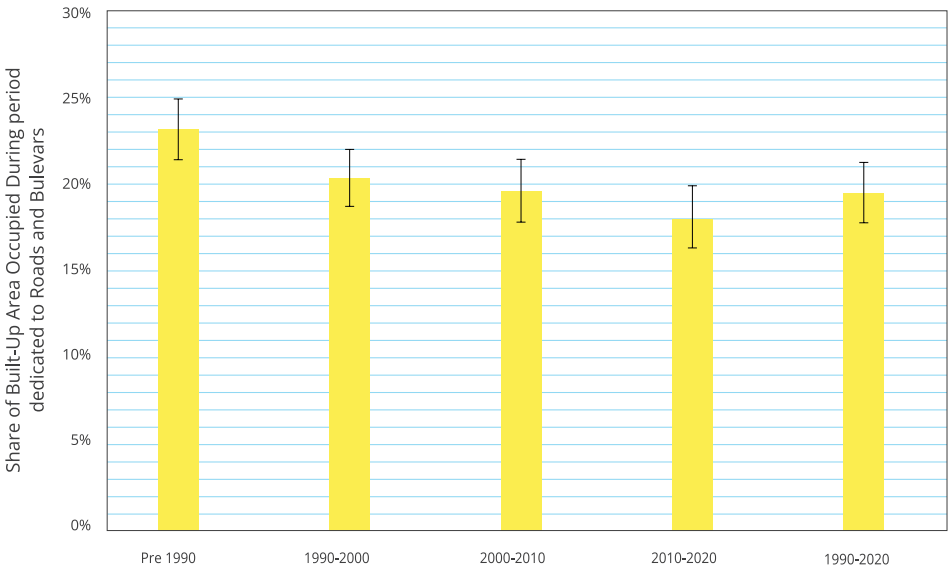


Figure 3.20: The average share of the built-up areas of cities in the region constructed in different periods that were dedicated to roads and boulevards. Source: New York University, The Marron Institute of Urban Management.

Planning, taxation, regulations, and public infrastructure investments, have not been able to reduce the share of informal housing and have allowed it to increase. This finding calls for a deeper investigation of the process of informal housing formation and a re-examination of the tools available to territorial planners for engaging with informality.

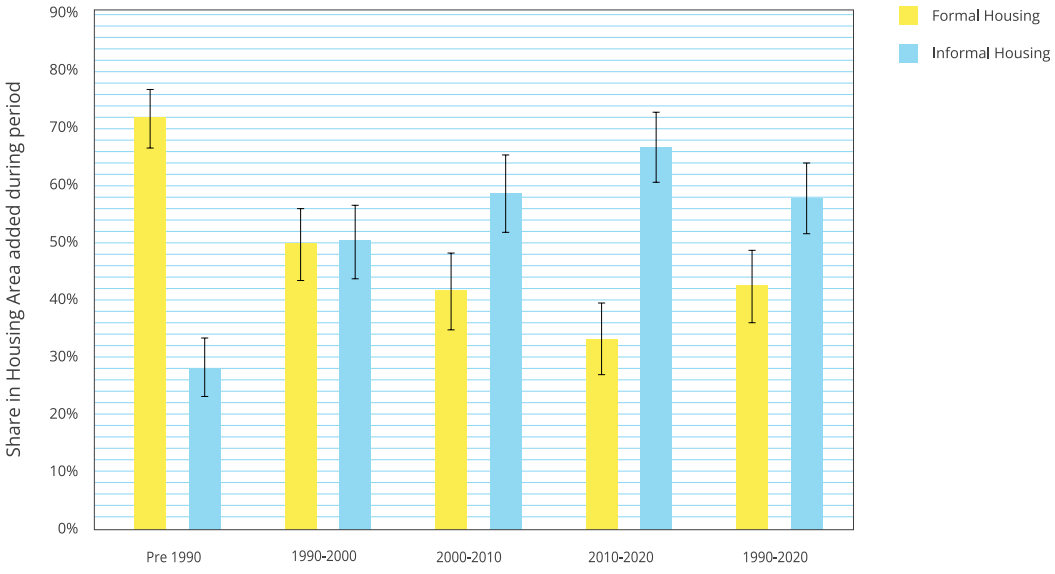


Figure 3.21: The average shares of the housing areas of cities in the region constructed in different periods that were formal or informal housing areas. Source: New York University, The Marron Institute of Urban Management.

There is more mixed use on the periphery of cities, and more jobs are being created on the urban periphery. This calls for regulatory changes that allow and exploit mixed use, as well as for transportation developments that increase the connectivity of the urban periphery to the urban job market.

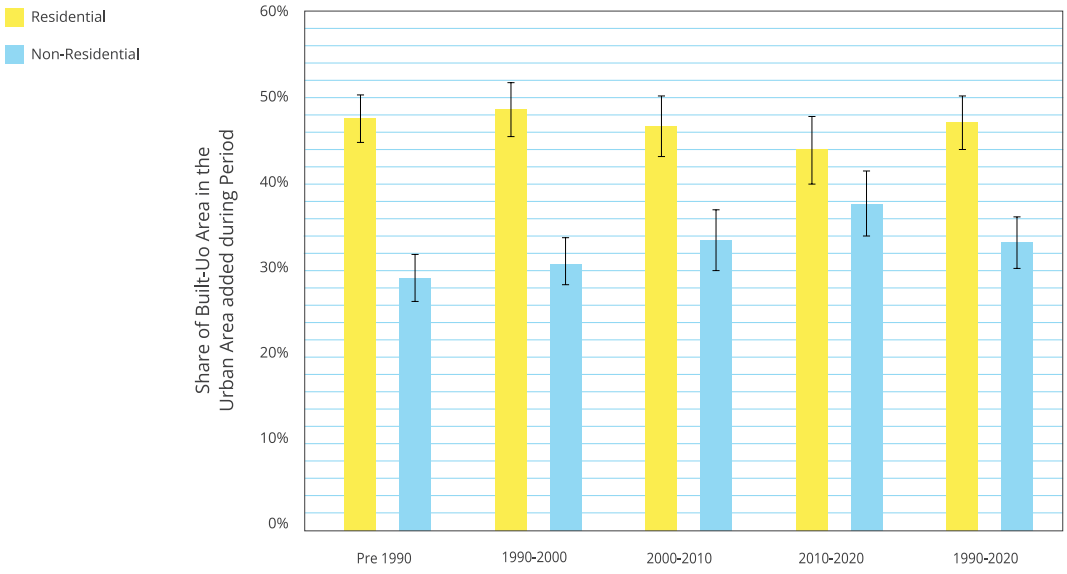


Figure 3.22: The average shares of the built-up areas of cities in the region built in different time periods that were occupied by residential and non-residential land uses. Source: New York University, The Marron Institute of Urban Management.

03 Did the average share of the built-up areas of cities in the region occupied by **non-residential development** in recent decades—1990-2000, 2000-2010, and 2010-2020—vary appreciably from the average share in their pre-1990 urban footprints?

Figure 3.22 shows the shares of the residential and non-residential areas in the built-up areas of cities in the region developed in different time periods. A cursory look at the Figure reveals that the share of residential areas has remained stable during recent decades: it amounted to 48±3% in the pre-1990 urban footprints of cities (left columns) and to 47±3% in their expansion areas (right columns). The share of non-residential areas in the built-up areas of cities has increased over time, from 29±3% in the pre-1990 urban footprint to 38±4% in the areas built during the 2010-2020 decade. That increase is statistically significant. This finding has important implication for territorial planning in cities in the region: There is more mixed use on the periphery of cities, and more jobs are being created on the urban periphery. This calls for regulatory changes that allow and exploit mixed use, as well as for transportation developments that increase the connectivity of the urban periphery to the urban job market.

This concludes the discussion of findings that focused on changes in urban form in the emerging peripheries of cities in the region, changes that have strong implications for territorial planning in these cities. These include changes in the provision of infrastructure, in the persistence and acceleration of informality in the housing sector, and on the emerging decentralization of jobs and the increasing mixed land use in peripheral areas. The next section in this chapter focuses on the complementarity of densification and expansion in accommodating urban growth in cities in the region.

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ACCOMMODATING POPULATION GROWTH BY DENSIFICATION AND EXPANSION

The key objective of this section is to provide a realistic assessment of the actual performance of cities in the region during the 1990-2020 period as it pertains to their densification. Clearly, no city was expected to accommodate all of its population growth during this period through the densification of its 1990 urban footprint. All the 70 cities studied, without exception, expanded outwards as we saw earlier. On average, the urban footprint of cities in the region grew by a factor of 3±0.5 during the 1990-2020 period. The city that expanded the least was São Paulo, Brazil, which expanded by a factor of 1.7, while the city the expanded the most was Palmas, Brazil, which expanded by a factor of 13.7 during this period.

There is also no question that cities densified during this period as well, namely that areas within them that were sparsely settled with many vacant plots became more saturated with buildings and that areas with lower buildings saw increases in the construction of taller buildings. What is not so clear, without looking at the evidence, is how important are the relative roles of outward expansion as against the densification of existing footprints, how important is densification through infill compared to densification through more intensive construction of built-up areas, or how dense are expansion areas.

Of key importance for territorial planning in the region is a deeper understanding of how cities densify and expand. This is a key question because, first, it may introduce an element of realism into a debate that in many cases has been ideological rather than pragmatic. One extreme ideological position in this debate, for example, calls for strict containment and no expansion at all. A more moderate one may call for minimal expansion. Can these positions be sustained in the face of evidence to the contrary? Second, such understanding may shed light on the contention that cities can densify by expanding outwards at higher densities. This position may also be difficult to maintain when there is evidence that renders it highly unlikely. We can shed light on these questions by testing a series of hypothesis with the statistical data obtained for the representative group of 70 cities in the region in response to the following questions:

We can shed light on these questions by testing a series of hypothesis with the statistical data obtained for the representative group of 70 cities in the region in response to the following questions:

01 Did the density of the 1990 footprint of all cities increase during the 1990-2020 period?

02 Did the overall densities within the 1990 footprints of cities increase mainly through the increase in density of built-up areas or through the infill of vacant plots?

03 Where was the share of population added to cities in the 1990-2020 period accommodated? Was the largest share of population accommodated within their 1990 footprints or within their expansion areas?

04 Did the share of the population added to cities in every decade during 1990-2020 period and accommodated within their earlier footprints increase significantly over time?

05 Did outward expansion during the 1990-2020 period take place at similar or higher population densities as those of areas built earlier?

06 Were built-up areas on the urban periphery constructed at similar or higher densities than areas built earlier?

07 Was newer development on the urban periphery as saturated by built-up areas as older areas of the city?

08 Did the initial overall densities, saturation, or built-up area densities at which newer expansion areas were built increase over time?

01 Did the density of the 1990 footprint of all cities increase during the 1990-2020 period?

A graph classifying 69 cities out of the 70 cities in the LAC region for which there is data on densification and expansion is presented in Figure 3.23. It shows, first, that all 69 cities gained population between 1990 and 2020. Second, it shows that only 43 cities (62%) had gained populations within their 1990 footprints, thus leading to the increase in density within these footprints during this period. But 38% of the cities in the group—including Mexico City (Mexico), Cali (Colombia), La Paz (Bolivia), San Salvador (El Salvador) (Figure 3.24), Tegucigalpa (Honduras), and Montevideo (Uruguay)—lost populations within their 1990 footprints and densities there declined during the 1990-2020 period. This finding suggests that, as things stand, there was a substantial number of cities that lost populations in their 1990 footprints, either because of land use changes from residential to office and commercial use or because of the suburbanization of residences and jobs. We cannot expect cities to increase the density in their central areas without concerted government actions to counter the strong tendencies of many urban centers to depopulate.

02 Did the overall densities within the 1990 footprints of cities increase mainly through the increase in density of built-up areas or through the infill of vacant plots?

The graph in Figure 3.25 also shows that of the 43 cities where overall densities within the 1990 footprints increased during the 1990-2020 period, built-up area density—the number of people per hectare of built-up area, or building footprints, exclusive of urbanized open spaces—within the 1990 footprints increased in only 17 cities (40%). It declined in 26 (60%) cities, including Asunción (Paraguay), Buenos Aires (Argentina), Guatemala City (Guatemala), Medellin (Colombia), and Quito (Ecuador), and the average decline in built-up area densities was 14±4%. In other words, the increase in overall densities of the 1990 footprints of these 26 cities was largely due to their saturation—namely to the infill of vacant plots—rather than to accommodating more people within residential building footprints. This finding suggests that densification through infill is easier and simpler than densification through the more intensive use of existing building footprints, a process often requiring massive disruption and dislocation.

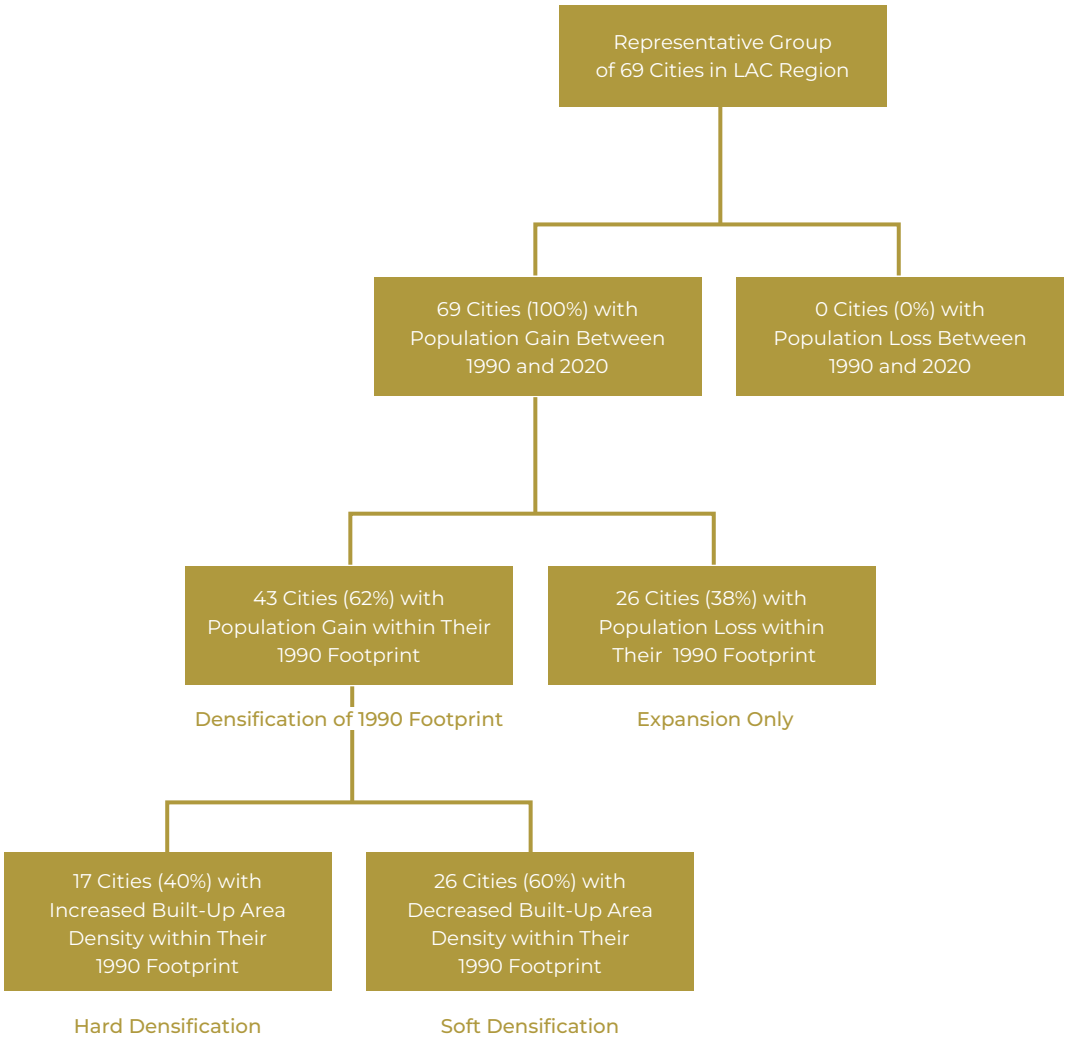


Figure 3.23: The classification of the 69 representative cities in the LAC region into discrete categories pertaining to the densification of their 1990 urban footprints. Source: New York University, The Marron Institute of Urban Management.

38% of the cities in the group—including Mexico City (Mexico), Cali (Colombia), La Paz (Bolivia), San Salvador (El Salvador), Tegucigalpa (Honduras), and Montevideo (Uruguay)—lost populations within their 1990 footprints and densities there declined during the 1990-2020 period. This substantial number of cities lost populations in their 1990 footprints, either because of land use changes from residential to office and commercial use or because of the suburbanization of residences and jobs.



Figure 3.24: Photo of office buildings in Mexico City.

Built-up area density within the 1990 footprints declined in 26 (60%) cities, including Asunción (Paraguay), Buenos Aires (Argentina), Guatemala City (Guatemala), Medellin (Colombia), and Quito (Ecuador), and the average decline in built-up area densities was 14±4%. This finding suggests that densification through infill is easier and simpler than densification through the more intensive use of existing building footprints, a process often requiring massive disruption and dislocation.



Figure 3.25: Plaza Miserere, key point of interest in the Comuna 3, the most densely populated Comune of Buenos Aires.

03 Where was the share of population added to cities in the 1990-2020 period accommodated? Was the largest share of population accommodated within their 1990 footprints or within their expansion areas?

An examination of Figure 3.23 shows that all cities grew in population during the 1990-2020 period, but 26 cities (38% of the total) lost population in the 1990 footprints during this period. This implies that the entire increase in population (100%) of these 26 cities was accommodated in their expansion areas. In the remaining 43 cities, an average of one-third (32±6%) of the added population was accommodated in their 1990 footprints and an average of two-thirds (68±6%) was accommodated in their expansion areas. The overall averages for all 69 cities were 18±5% and 82±5% respectively. In other words, the 1990 footprints of this representative group of cities in the region accommodated less than one-fifth of the population added during the 1990-2020 period, while their expansion areas accommodated more than four-fifths of this population. This finding suggests that, as things stand, we cannot expect densification to accommodate the lion share of the added populations of cities. Cities must therefore continue to rely on substantial urban expansion to accommodate their expected growth.

04 Did the share of the population added to cities in every decade during 1990-2020 period and accommodated within their earlier footprints increase significantly over time?

Figure 3.26 shows the respective shares accommodated by earlier footprints and by expansion areas in three time periods: 1990-2000, 2000-2010, and 2010-2020. The left two columns show that by the year 2000, 25±6% of the added population during the 1990-2000 period was accommodated within the 1990 footprint, while 75±6% were added to expansion areas built between 1990 and 2000. The next two pairs of columns show the results for the 2000-2010 and 2010-2020 periods. The figure shows that the shares accommodated by earlier footprints increased from 25±6% in 2000 to 33±7% in 2010, and to 39±8% in 2020. The increase between 2000 and 2010 is not statistically significant, but the increase between 2000 and 2020 is. There was a significant increase over time in the shares of the added population accommodated within earlier footprints. This finding suggests that it is not unreasonable to expect that the densification of existing urban footprints could accommodate an increasing share of the added populations of cities over time.

The shares accommodated by earlier footprints increased from 25±6% in 2000 to 33±7% in 2010, and to 39±8% in 2020. There was a significant increase over time in the shares of the added population accommodated within earlier footprints. This finding suggests that it is not unreasonable to expect that the densification of existing urban footprints could accommodate an increasing share of the added populations of cities over time.

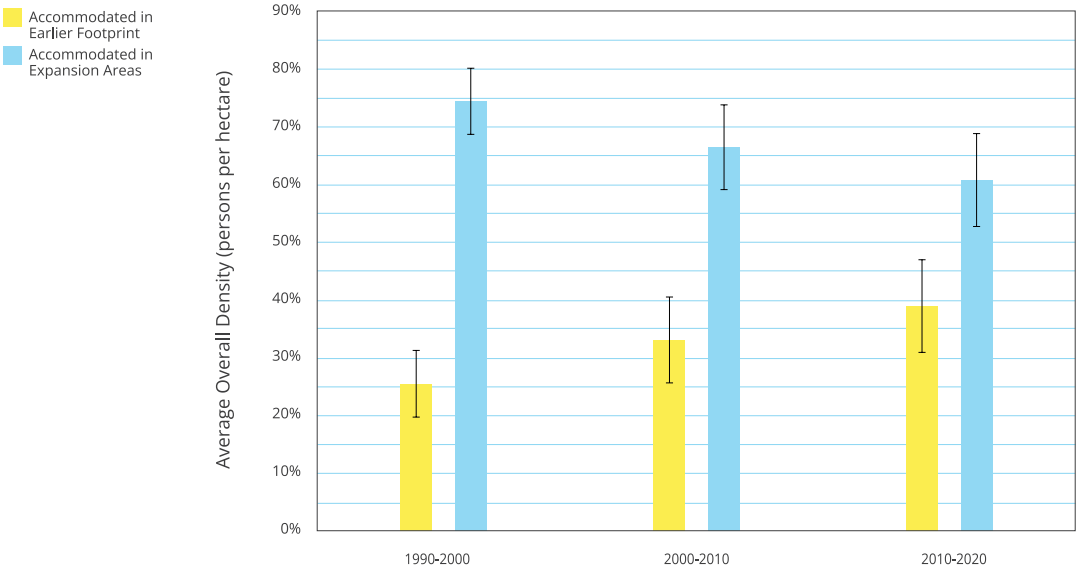
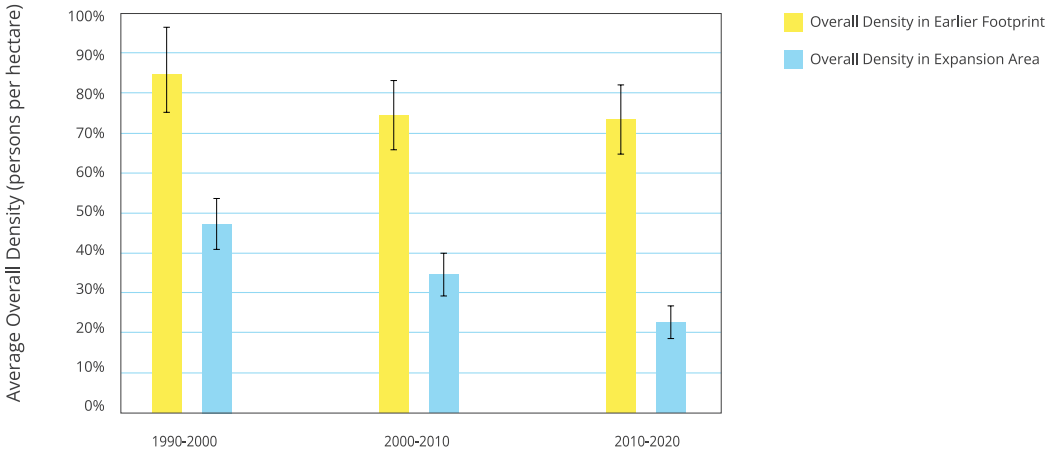


Figure 3.26: The respective shares of the added population accommodated by earlier footprints and by expansion areas in three time periods: 1990-2000, 2000-2010, and 2010-2020. Source: New York University, The Marron Institute of Urban Management.

Looking at the overall density in 2020 in areas built in four time periods, pre-1990, 1990-2000, 2000-2010, and 2010-2020. Overall density in the areas built in every later period was significantly lower than the density of areas built in the earlier period.



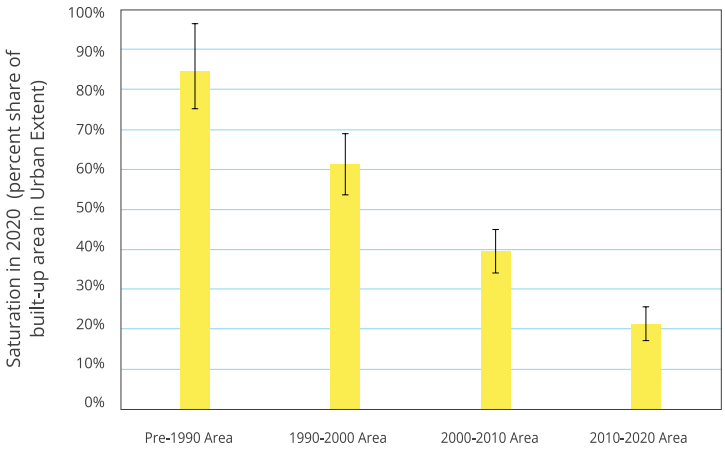


Figure 3.27: A comparison of average overall densities in earlier footprints and in expansion areas in three time periods.

Figure 3.28: Average urban extent densities in 2020 in areas built at different periods for the 69 cities of the sample.

Urban expansion typically takes place at lower densities than those prevailing in areas built in earlier periods. It suggests that, however desirable, the densification of cities by building at higher-than-average densities on the urban periphery is a pipedream. There are powerful economic forces that mitigate against building at high density on the urban periphery, where land values are typically lower.



Figure 3.29: Barranquilla's skyline, showing its sprawling urban landscape.

05 Did outward expansion during the 1990-2020 period take place at similar or higher population densities as those of areas built earlier?

Figure 3.27 shows the overall average densities in the 69 cities in the LAC region in three time periods: 1990-2000, 2000-2010, and 2010-2020. In each period, the left column shows the average density in the urban footprint that was built in the earlier date, and the right column shows the average overall density of the expansion area built during this period. In each period, the average density in the expansion area was significantly lower than the average density in the earlier footprint.

Another way to test this hypothesis is by looking at the overall density (or urban extent density) in 2020 in areas built in four time periods, pre-1990, 1990-2000, 2000-2010, and 2010-2020. Figure 3.28 shows that in 2020, overall density in the areas built in every later period was significantly lower than the density of areas built in the earlier period.

This finding suggests that urban expansion typically takes place at lower densities than those prevailing in areas built in earlier periods. It suggests that, however desirable, the densification of cities by building at higher-than-average densities on the urban periphery is a pipedream. There are powerful economic forces that mitigate against building at high density on the urban periphery, where land values are typically lower. Figure 3.29 shows that the areas built in different periods in the metropolitan area of Barranquilla, Colombia were built at lower densities than areas built in earlier ones.

06 Were built-up areas on the urban periphery constructed at similar or higher densities than areas built earlier?

Figure 3.30 shows the change in average urban extent densities in built-up areas in the four time periods and the change in these densities over time. Urban extent densities in the areas built before 1990 did increase slightly but the error bars all overlap. This implies that the increase is not statistically significant. The same is true for the areas built between 2000 and 2010. But in the areas built during the 1990-2000 period, densities did increase, and they increased significantly between 2000 and 2020 (the error bars do not overlap).

Since the data does not reveal a consistent picture, we must conclude that, in general, densities in areas built in different time periods do increase over time, but the increase is not always statistically significant. This finding suggests that while we cannot expect newly built areas to be built at high densities, we can expect these densities to increase over time.

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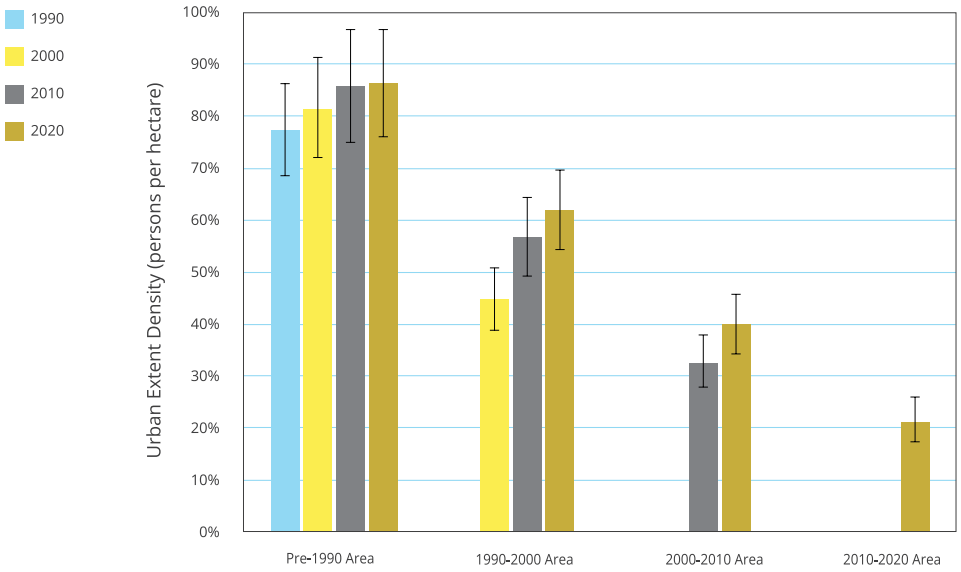


Figure 3.30: The change in average urban extent densities in the areas of cities built during different time periods. Source: New York University, The Marron Institute of Urban Management.

Levels of saturation in the year 2020 were significantly higher in areas built in earlier periods than those that were built later. The hypothesis must therefore be rejected. This finding makes clear that urban expansion initially takes place at low levels of saturation and that saturation then increases over time. We cannot expect newly built areas to be as fully saturated as areas that were built decades earlier.

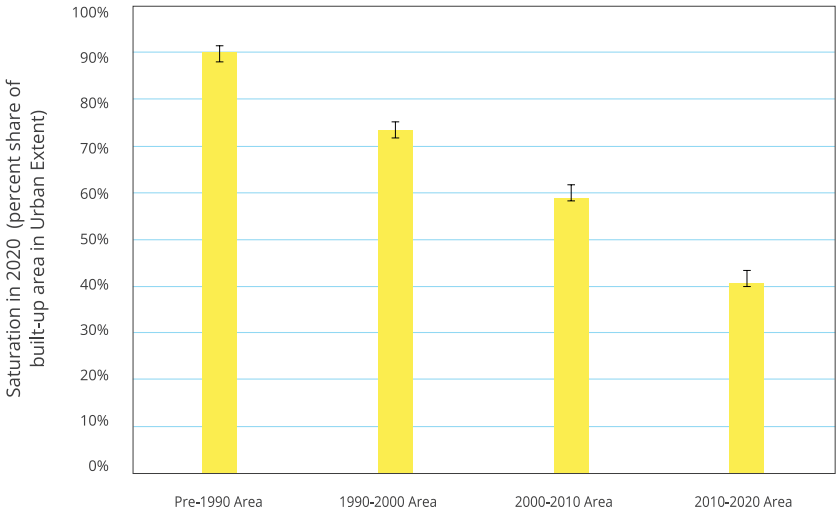


Figure 3.31: Levels of saturation in 2020 in the areas of cities built during different time periods.
Source: New York University, The Marron Institute of Urban Management.

Levels of saturation increased significantly over time both in areas built in earlier and later periods. This finding suggests that saturation is indeed a powerful tool for the densification of cities. The only caveat is that there are limits to saturation. Since some share of the areas of cities must be kept as open space for various public uses, saturation has its limits.

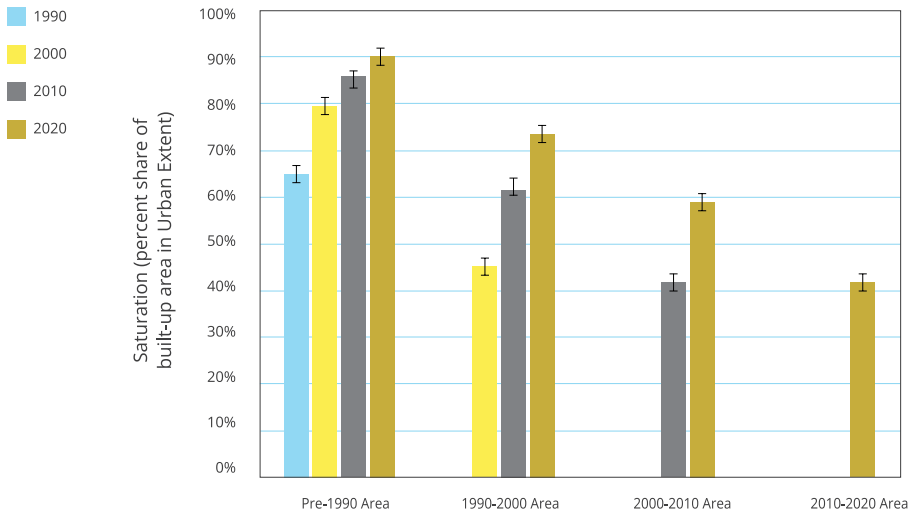


Figure 3.32: The significant increase in saturation over time in the areas of cities built during different time periods. Source: New York University, The Marron Institute of Urban Management.

07 Is newer development on the urban periphery as saturated by built-up areas as older areas of the city?

Figure 3.31 shows that average levels of saturation in the year 2020 were significantly higher in areas built in earlier periods than those that were built later. The hypothesis must therefore be rejected. This finding makes clear that urban expansion initially takes place at low levels of saturation and that saturation then increases over time. We cannot expect newly built areas to be as fully saturated as areas that were built decades earlier.

08 Did the initial overall densities, saturation, or built-up area densities at which newer expansion areas were built increase over time?

Figure 3.32 shows that levels of saturation increased significantly over time both in areas built in earlier and later periods. Hypothesis eight must therefore be rejected. This finding suggests that saturation is indeed a powerful tool for the densification of cities. The only caveat is that there are limits to saturation. Since some share of the areas of cities must be kept as open space for various public uses, saturation has its limits. In contrast, built-up area density can increase without limit by building higher, provided there are no barriers—be they regulatory, financial, or political—to building higher.

All the 70 cities studied, without exception, expanded outwards as we saw earlier. On average, the urban footprint of cities in the region grew by a factor of 3±0.5 during the 1990-2020 period. The city that expanded the least was São Paulo, Brazil, which expanded by a factor of 1.7, while the city the expanded the most was Palmas, Brazil, which expanded by a factor of 13.7 during this period.

THE ANATOMY OF DENSITY: A REGIONAL PERSPECTIVE

Serious concerns with global warming have now been translated into urgent calls for increasing urban densities or, at the very least, checking their decline. Lower densities have been found to be associated with higher carbon emissions from both vehicles and buildings. Yet, as we noted earlier, densification through containment of urban expansion has largely failed, and where it has been successful—like Seoul or London, for example—it has seriously compromised housing affordability by choking housing supply. Successful densification can complement "green" urban expansion, and for successful densification to go hand-in-hand with increased housing affordability, we must better understand the anatomy of density, or the factors that constitute urban density.

In our earlier research work, we proposed a way to decompose the average density of cities into three and then into seven factors that when multiplied together constitute urban density.

In this section, we first present the results of our measurement of these three factors in nine cities in the Latin American and Caribbean region. Such decomposition into factors allows us, for the first time, to understand how different cities acquire their density: Bogotá, for example, gets its density from higher-than-average floor area ratios; Santiago from higher-than-average floorspace occupancy (or, lower-than-average floor area per person); and Buenos Aires from higher-than-average residential share in land use.

We then focus on the seven factors that together constitute urban densities in a representative group of 30 cities in the region. In this section, we also outline a coordinated and comprehensive densification strategy as an integral component of territorial planning in the region, a strategy that addresses each and every one of these seven factors and seeks to remove the barriers that prevent it from contributing more effectively to increasing overall urban density in the interest of mitigating climate change and making urban housing more affordable in the years to come.

We first draw attention to the simple observation that average *urban density* in a city or metropolitan area can be represented as a product of three factors: *floor space occupancy* (the number of persons occupying one hectare of residential floor areas), *the floor area ratio* (the ratio of the total residential floor area and the total residential area in the city), and the *residential share* (the share of the residential area in the entire urban extent of the city). Examining Figure 3.9, we can see that when these three factors are multiplied by each other, everything cancels out and we end up with *population/urban extent*, namely with *urban density*.

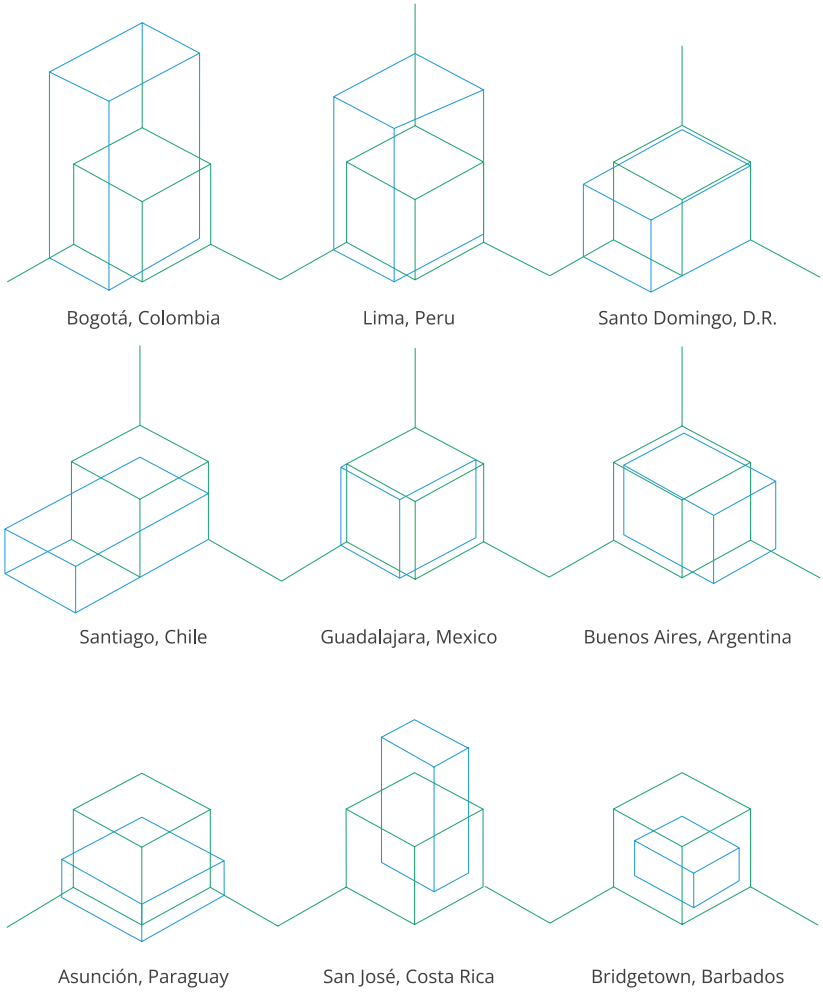


Figure 3.33: The urban densities of nine cities in the region represented as volumes of boxes (in blue lines) in decreasing order from right to left and from top to bottom. The cube (in green lines) represents the 30-city average values for each of the three factors that make up *urban density*: Floorspace occupancy on the X-axis, residential share on the Y-axis, and the floor area ratio on the Z-axis. Source: New York University, The Marron Institute of Urban Management.

Perceiving *urban density* as a product of three factors makes it possible to represent it as a box in three-dimensional space, where *floorspace occupancy*—measured on the X-axis—is its width, *residential share*—measured on the Y-axis—is its depth, and the *floor area ratio*—measured on the Z-axis—is its height. Because *urban density* is a product of these three factors, it can only increase if one or more of these factors increase and it can only decline if one or more of these factors decline. *Urban density* itself offers no hints as to which of the factors is responsible for a change; we can only discover that when we measure them one by one.

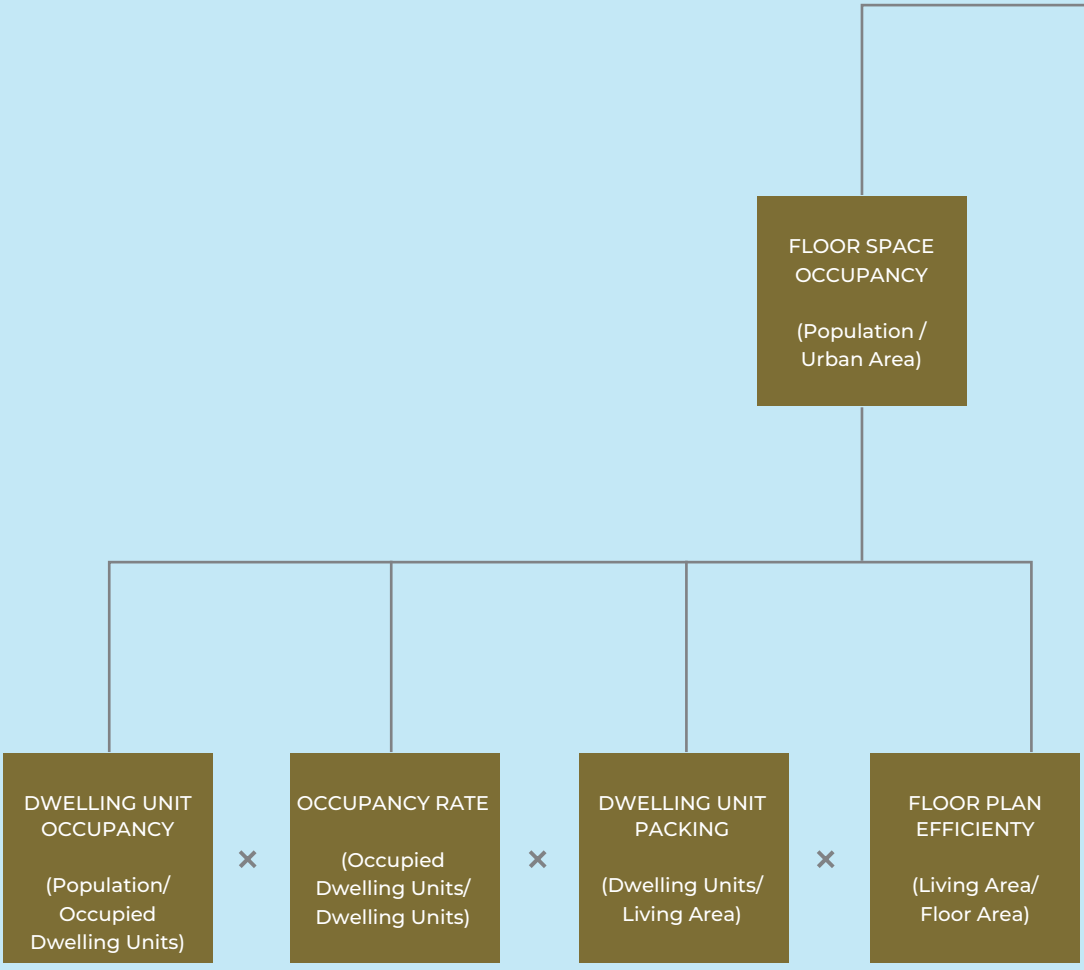
We measured these three factors in 2022 in 30 cities in the region and we found wide variations both in *urban density* and in the three factors that, when multiplied together, reconstitute *urban density*. We selected nine cities from the group of 30 that represented these variations in the group as a whole. The density boxes for these nine cities are shown in Figure 3.33. The two cities with the highest urban density in this group, Bogotá and Lima, both obtained their densities largely from their higher-than-average *floor area ratios*.

The cities with the third- and fourth-highest *urban density*, Santo Domingo and Santiago, obtained their densities largely from its higher-than-average *floorspace of occupancy* (or their lower-than-average floor area per person). Guadalajara had an urban density which was very close to the average for all 30 cities because its three factors were close to their average values for all cities. Buenos Aires obtained its density largely because of its higher-than-average *residential share*. Two of the three cities with the lower densities in this group had above average values for one or more factors: Asunción had above-average values for both floorspace occupancy and residential share, but a very low value for its *floor area ratio*. San José had an above average value for its *floor area ratio*, but its overall density was low because of its low *floorspace occupancy* and *residential share*. Finally, Bridgetown had the lowest density in the group because all its factors were below average.

What becomes obvious from examining Figure 3.33 is that it is impossible to second guess the values of the factors that constitute *urban density* when the only information available is about the value of *urban density*. The usefulness of breaking up density into measurable factors for territorial planning is that it provides planners with a deeper understanding of *urban density* and what needs to be done to increase it, realizing that it can only increase when one or more of its factors increases while others do not decline.

This can become more useful when we realize that the three-factor decomposition of *urban density* can be developed further into a seven-factor decomposition as shown in Figure 3.34: *Floor Space occupancy* can be decomposed into four factors that when multiplied together reconstitute *floorspace occupancy*, and the *floor area ratio* can be decomposed into two factors that when multiplied together yield the *floor area ratio*.

In this section, we first present the results of our measurement of these three factors in nine cities in the Latin American and Caribbean region. Such decomposition into factors allows us, for the first time, to understand how different cities acquire their density.


FLOOR SPACE OCCUPANCY
(Population / Urban Area)
DWELLING UNIT OCCUPANCY
(Population/ Occupied Dwelling Units)
×
OCCUPANCY RATE
(Occupied Dwelling Units/ Dwelling Units)
×
DWELLING UNIT PACKING
(Dwelling Units/ Living Area)
×
FLOOR PLAN EFFICIENTY
(Living Area/ Floor Area)

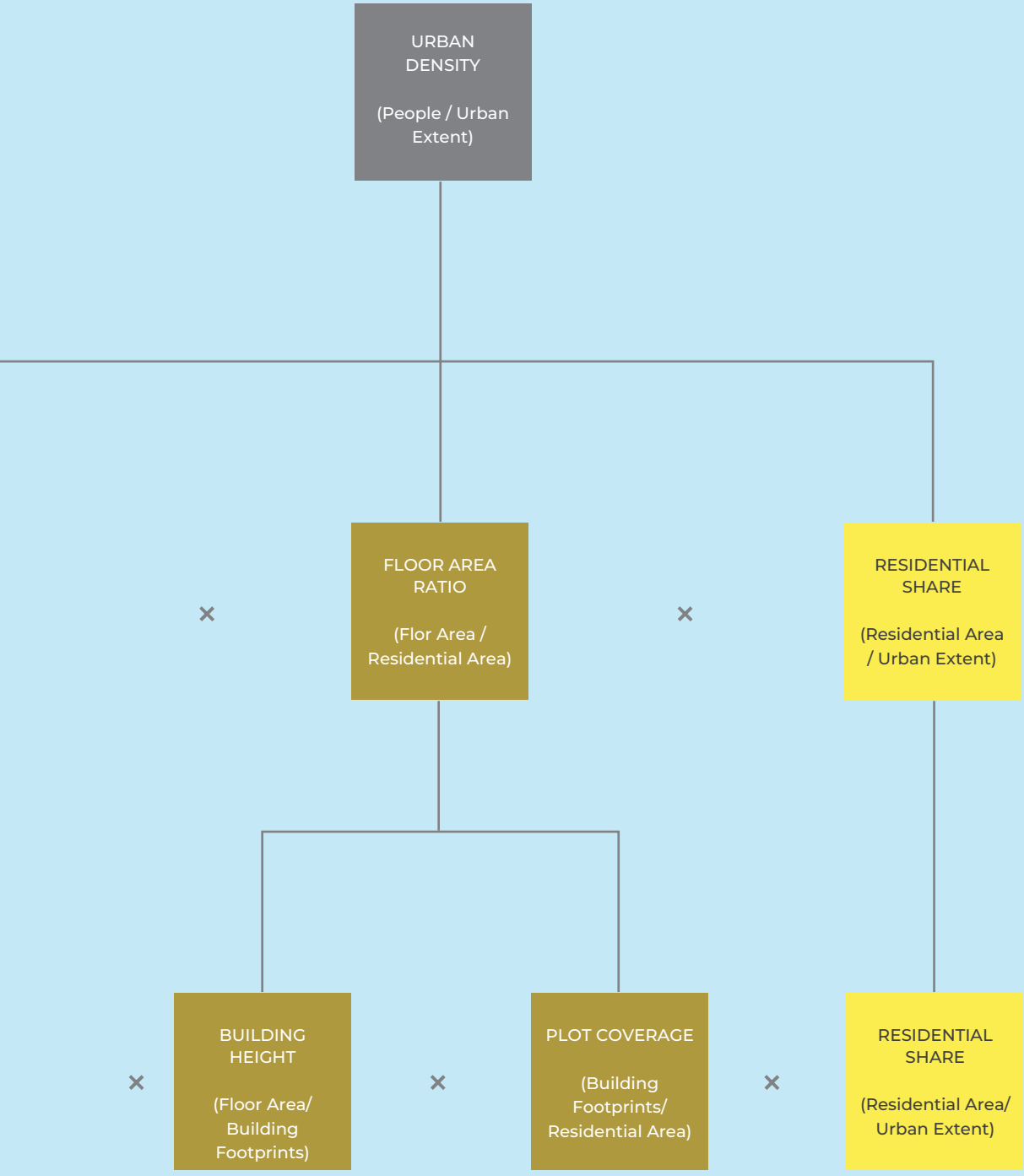


Figure 3.34: Urban density as a product of three factors and seven factors.

The decomposition of *urban density* into seven factors suggests that—other things being equal—an increase in any one of these factors can increase *urban density*. We can increase *urban density* if we increase the number of persons per dwelling unit or the *occupancy rate*; if we can make dwelling units smaller or floor plans more efficient; if we increase *building height, plot coverage*, or the share of residential land use. Territorial planners have access to several tools that can increase one or more of these factors or, at the very least, slow down its decline, as presented in the previous chapters.

What is important to emphasize is that these factors, even though they constitute *urban density*, do not necessarily go hand in hand with density. In the remainder of this section, we examine five hypotheses that seek to test whether an increase in a particular factor in the 30 cities studied was associated with a significant increase in *urban density*. These hypotheses are articulated in the following pages.

There was very little variation in the data collected for the group of 30 cities in both *occupancy rate* and *floorplan efficiency*, and the hypotheses that they did not matter to *urban density* had to be accepted.

What is important to emphasize is that these factors, even though they constitute urban density, do not necessarily go hand in hand with density. In the remainder of this section, we examine five hypotheses that seek to test whether an increase in a particular factor in the 30 cities studied was associated with a significant increase in urban density. These are articulated as follows:

01 Is an increase in dwelling unit occupancy (persons per dwelling unit) in the 30 cities of the sample associated with an increase in urban density?

02 Is an increase in dwelling unit packing (or a decrease in dwelling unit size) associated with an increase in urban density?

03 Is an increase in building height associated with an increase in urban density?

04 Is an increase in plot coverage associated with an increase in urban density?

05 Is an increase in residential share associated with an increase in urban density?

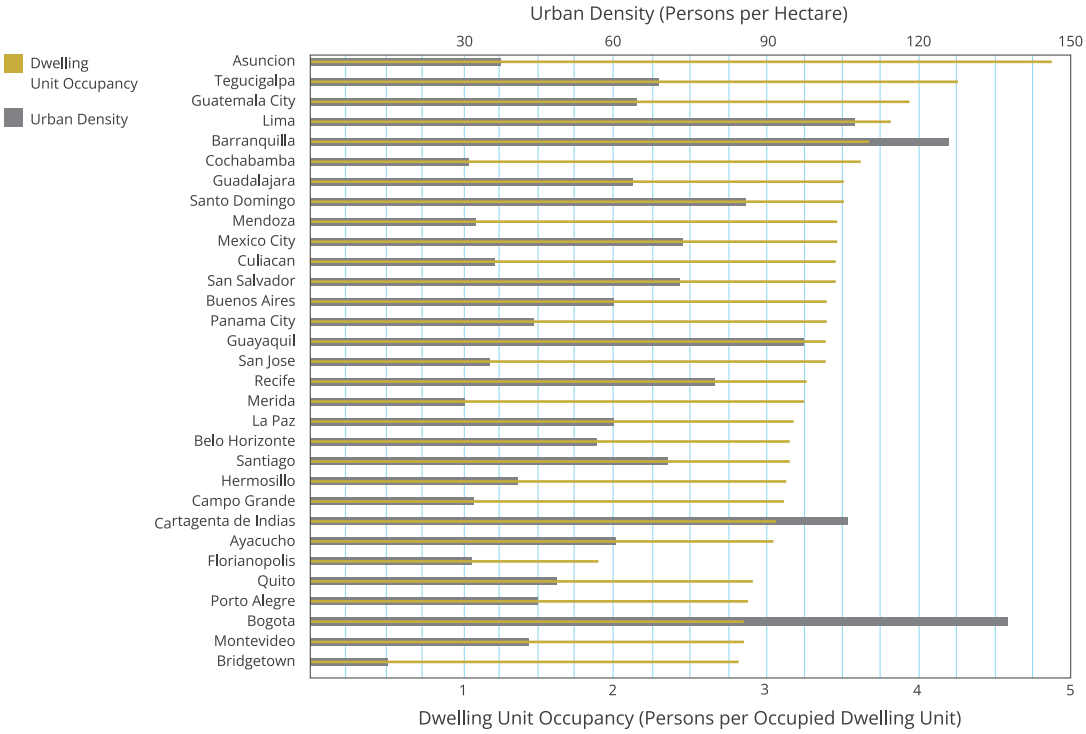
01 Is an increase in dwelling unit occupancy (persons per dwelling unit) in the 30 cities of the sample associated with an increase in urban density?

Figure 3.35 shows the values for *dwelling unit occupancy* (persons per dwelling unit) in descending order for all 30 cities in the region on the bottom X-axis (solid bars), ranging from a maximum average value of 4.9 in Asunción to a minimum of 2.8 in Bridgetown. On the top X-axis, it shows the values for *urban density* for these cities (hollow bars). A visual inspection of the graph in Figure 3.35 shows that there is no systematic relationship between *dwelling unit occupancy*—which is a measure of average household size as well as a measure of overcrowding—and overall *urban density*. Asunción has a high value for *dwelling unit occupancy* (4.9) and a low value for *urban density* (39 persons per hectare) while Lima has a low value for *Dwelling Unit Occupancy* as well (2.9) and a high value for *urban density* (108 persons per hectare). A regression test of the two metrics indicates that variations in *dwelling unit occupancy* do not explain variations in *urban density*.

02 Is an increase in dwelling unit packing (or a decrease in dwelling unit size) associated with an increase in urban density?

Figure 3.36 shows the values for *dwelling unit packing* (the reciprocal of dwelling unit size) in descending order for all 30 cities in the region on the bottom X-axis (solid bars), ranging from a maximum average value in Santiago to a minimum of 2.8 in San José. On the top X-axis, it shows the values for *urban density* for these cities (hollow bars).

A visual inspection of the graph in Figure 3.36 shows that there appears to be a systematic relationship between *dwelling unit packing*—which is a measure of average size of dwellings—and overall *urban density*. All the cities with higher urban densities are on the top half of the graph. A regression test of the two metrics (Figure 3.37) indicates that cities with high values of *dwelling unit packing*, or low dwelling unit sizes, have higher urban densities. This finding has important implications for territorial planning: When planning or lending regulations demand minimum dwelling unit sizes, prevent the subdivision of larger units into smaller ones, or promote single-family dwellings over multi-family ones, they act to prevent densification.



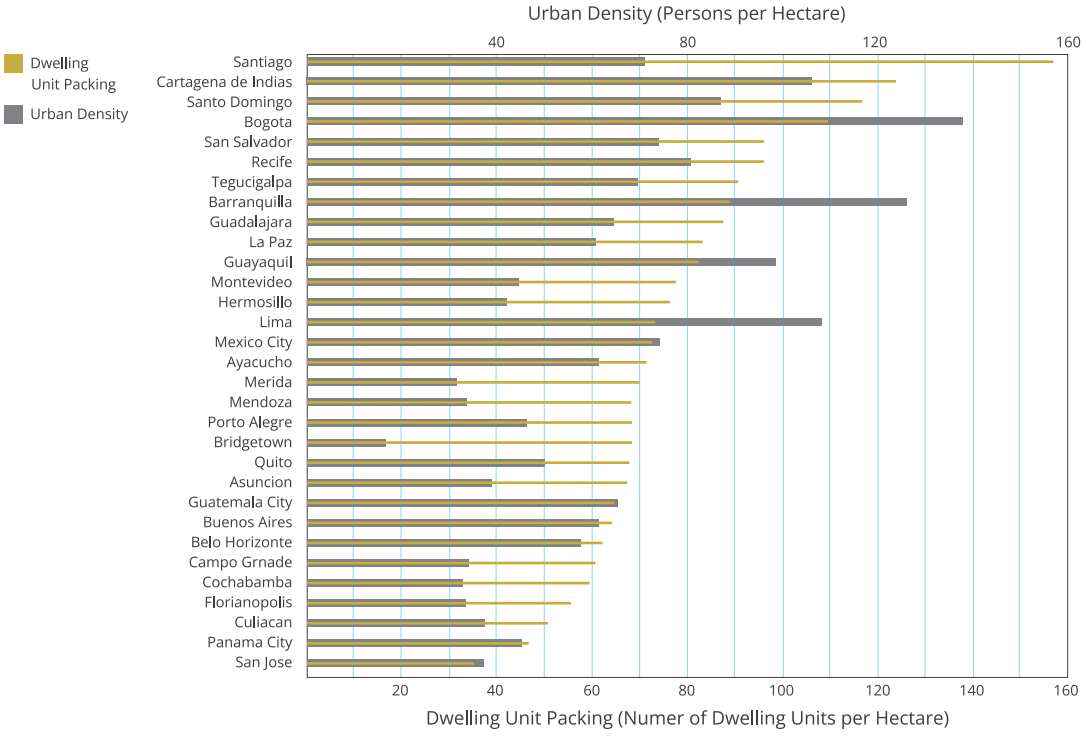


Figure 3.35: 2022 values for *dwelling unit occupancy* (solid bars, bottom X-axis) and *urban density* (hollow bars, top X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.

Figure 3.36: 2022 values for *dwelling unit packing* (solid bars, bottom X-axis) and *urban density* (hollow bars, top X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.

Cities with high values of dwelling unit packing, or low dwelling unit sizes, have higher urban densities. This finding has important implications for territorial planning: When planning or lending regulations demand minimum dwelling unit sizes, prevent the subdivision of larger units into smaller ones, or promote single-family dwellings over multi-family ones, they act to prevent densification.

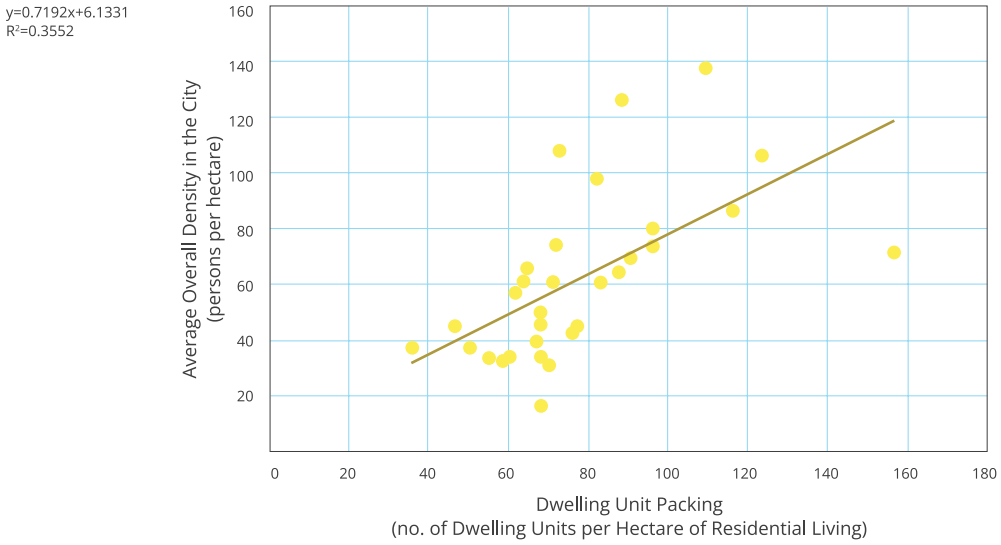


Figure 3.37: Urban density (Y-axis) as a function of *dwelling unit packing* (X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.

03 Is an increase in building height associated with an increase in urban density?

Figure 3.38 shows the values for *building height* (the average number of stories in residential buildings) in descending order for all 30 cities in the region on the bottom X-axis (solid bars), ranging for a maximum average value of 2.7 in Bogotá to a minimum of 1.2 in Asunción and Hermosillo. On the top X-axis, it shows the values for *urban density* for these cities (hollow bars). A visual inspection of the graph in Figure 3.38 shows that there does not appear to be a systematic relationship between *building height*—which is a partial measure of the density of floor space—and overall *urban density*. Anecdotal evidence does suggest a relationship: Bogotá, for example, has both the highest *urban density* and the highest average *building height* among the cities studied. A regression test of the two metrics indicates that cities in the region with higher average building height do not necessarily have higher urban densities. Or, to put it in other words, at present, cities in the region do not get their densities from building higher. In fact, the average *building height* for the cities in the region is only 1.6±0.1 floors. These findings have important implications for territorial planning for densification. The Bogotá example demonstrates the potential of increased *building height* as a tool for increasing urban density, and the low average *building height* for cities in the region indicates that this potential is quite large. Territorial planning can facilitate increased building height by relaxing building height and floor area ratio (FAR) limits, by allowing the construction of additional stories on existing buildings, and by removing zoning regulations that do not permit the construction of multi-family housing in residential areas.

04 Is an increase in plot coverage associated with an increase in urban density?

Figure 3.39 shows the values for *plot coverage* in descending order for all 30 cities in the region on the bottom X-axis (solid bars), ranging for a maximum average value of 71% in Barranquilla to a minimum of 26% in Bridgetown and 27% in Asunción. On the top X-axis, it shows the values for *urban density* for these cities (hollow bars). A visual inspection of the graph in Figure 3.39 shows that there appears to be a systematic relationship between *plot coverage*—which is a measure of the saturation of residential areas with building footprints—and overall *urban density*. The five cities with the highest urban density values, for example, also have the highest plot coverage values. A regression test of the two metrics (Figure 3.40) indicates that cities with higher values of *plot coverage* have higher values of *urban density*. This finding has important implications for territorial planning: The infill of vacant plots and the increase in the share

At present, cities in the region do not get their densities from building higher. Territorial planning can facilitate increased building height by relaxing building height and floor area ratio (FAR) limits, by allowing the construction of additional stories on existing buildings, and by removing zoning regulations that do not permit the construction of multi-family housing in residential areas.

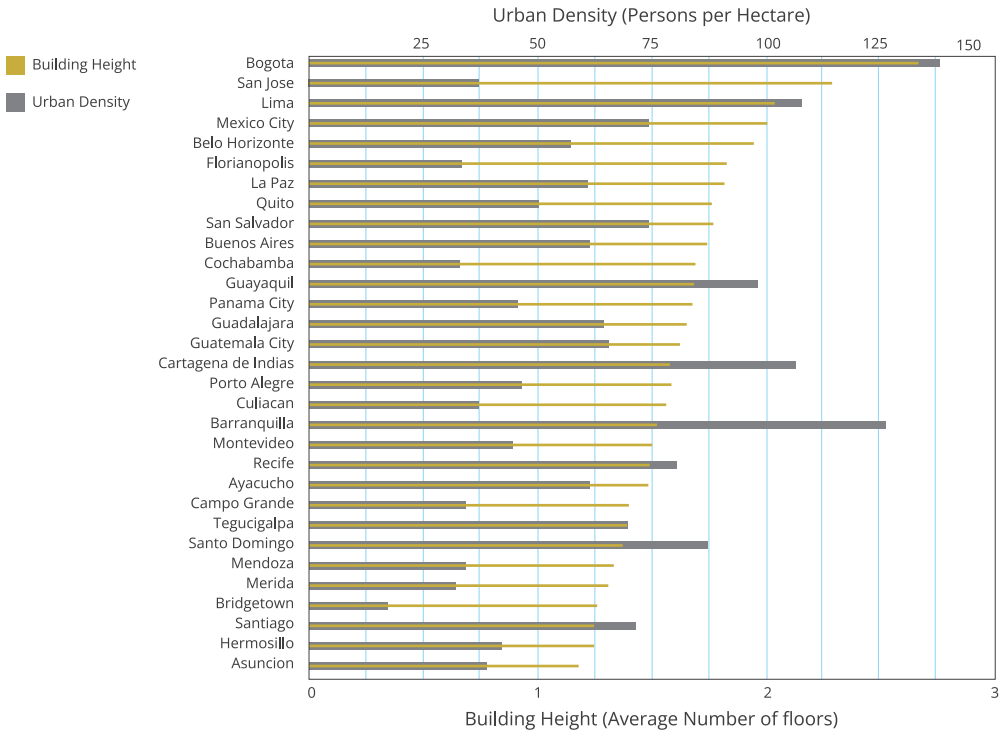
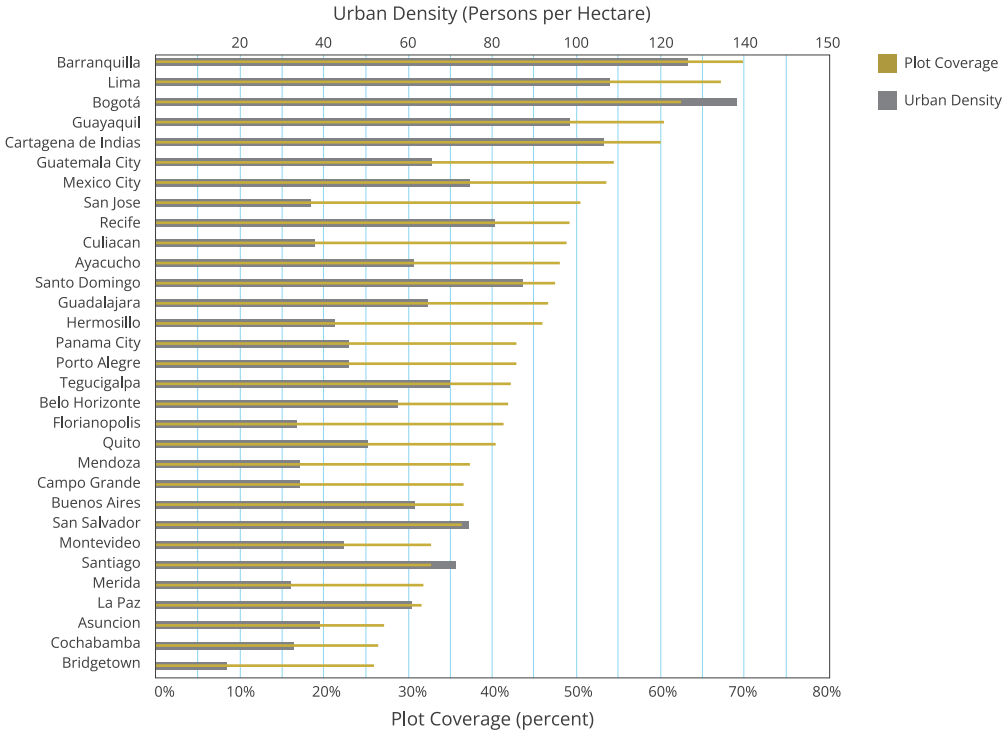


Figure 3.38: 2022 values for *building height* (solid bars, bottom X-axis) and *Urban Density* (hollow bars, top X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.



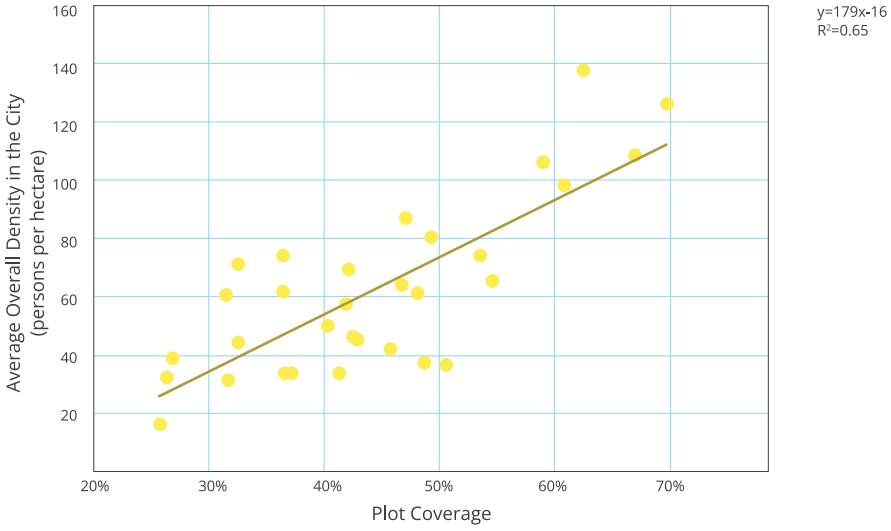


Figure 3.39: 2022 values for plot coverage (solid bars, bottom X-axis) and urban density (hollow bars, top X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.

Figure 3.40: Urban density (Y-axis) as a function of plot coverage (X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.

Cities with higher values of *plot coverage* have higher values of *urban density*. This finding has important implications for territorial planning: The infill of vacant plots and the increase in the share of building footprints in residential plots is, as we saw in the earlier section, the main tool for densification now available to cities. It is, in fact, easier to implement than increasing *building height*. Territorial planners can facilitate increases in plot coverage by relaxing restrictions on plot coverage and minimum setbacks, by allowing the construction of accessory dwelling units (ADUs) on single-family plots, by removing minimum lot sizes, and by relaxing floor area ratios (FARs).

of building footprints in residential plots is, as we saw in the earlier section, the main tool for densification now available to cities. It is, in fact, easier to implement than increasing *building height*. Territorial planners can facilitate increases in plot coverage by relaxing restrictions on plot coverage and minimum setbacks, by allowing the construction of accessory dwelling units (ADUs) on single-family plots, by removing minimum lot sizes, and by relaxing floor area ratios (FARs).

05 Is an increase in residential share associated with an increase in urban density?

Figure 3.41 shows the values for *residential share* (the share of the urban extent of the city in residential land use) in descending order for all 30 cities in the region on the bottom X-axis (solid bars), ranging for a maximum average value 47% in Buenos Aires to a minimum of 28% in San José. On the top X-axis, it shows the values for *urban density* for these cities (hollow bars). A visual inspection of the graph in Figure 3.41 shows that there does not appear to be a systematic relationship between *residential share* and overall *urban density*. A regression test of the two metrics indicates that cities in the region with higher average residential shares do not necessarily have higher urban densities. Or, to put it in other words, at present cities in the region do not get their densities from higher shares of the land in the city that are in residential use. A possible reason for this outcome is that large areas in cities are in suburban single-family homes that are typically of low density. This finding has important implications for territorial planning for densification. In principle, converting buildings—especially multi-story buildings from non-residential to residential use should increase overall urban density. In contrast, zoning large areas for single-family homes on large lots would ensure low density, so increasing *residential share* by itself would not lead to effective densification, unless it is accompanied by increased floor area ratios (FARs).

This concludes our discussion of the findings associated with the *Anatomy of Density* in cities in the region and their implications for territorial planning. Taken together, they suggest a comprehensive strategy for urban densification in the region, focusing on the individual factors that together make up urban density.

Cities in the region with higher average residential shares do not necessarily have higher urban densities. At present cities in the region do not get their densities from higher shares of the land in the city that are in residential use. A possible reason for this outcome is that large areas in cities are in suburban single- family homes that are typically of low density.

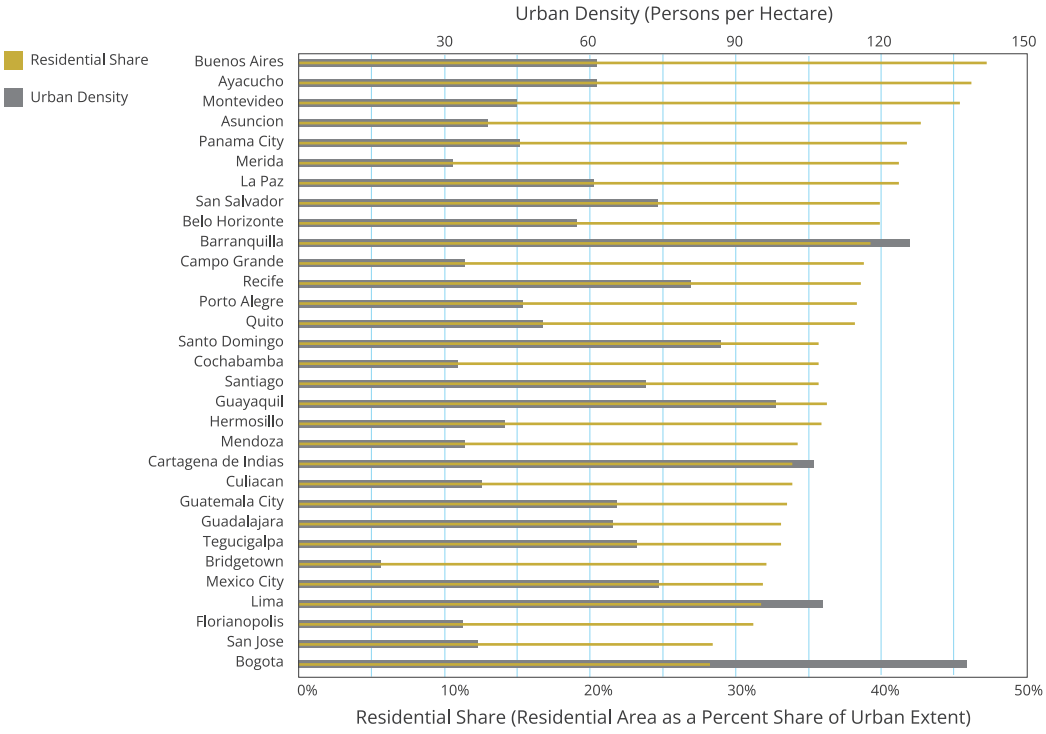


Figure 3.41: 2022 values for *residential share* (solid bars, bottom X-axis) and *urban density* (hollow bars, top X-axis) in a group of 30 cities in the region. Source: New York University, The Marron Institute of Urban Management.

Endnotes

1. See, among others, Angels S., *Planet of Cities*, Lincoln Institute of Land Policy. (2012).

2. United Nations, Department of Economic and Social Affairs, Population Division (2019). World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). New York: United Nations. Data: UN Population Report, File 3: https://population.un.org/wup/Download/.

3. U.N. Population Division. (2018).

4. Ibid.

5. We note that this result is higher than the result for the 3,470 cities and metropolitan areas in the world at large that had 100,000 people or more in 2020. For that group of cities, the scaling factor for density was 12.2%. We can conclude that the population of cities in the region had a more pronounced effect on density than cities in the world at large.

6. We note that the same overall result is true for the 2000-2020 period for the 3,470 cities and metropolitan areas in the world at large that had 100,000 people or more in 2020. For that group of cities, a city with double the population of another one has an annual growth rate that is smaller by 0.21%. We can conclude that the effect of the population of cities in the region on their growth rate is more pronounced than in cities in the world at large.

7. The same pattern was found in a group of 3,470 cities and metropolitan areas in the world at large. Between 2000 and 2020, for which we have comparable data, the population multiple for this group was 1.62±0.06, while the urban extent multiple was 1.87±0.04. The difference between these multiples was 0.25±0.04. The comparable figure for the same period for the 71 LAC cities were not significantly different: The population multiple for this group was 1.63±0.22, while the urban extent multiple was 1.96±0.21. The difference between these multiples was 0.33±0.14.

8. Similar results were observed for both the 71 LAC cities and the 3,470 cities and metropolitan areas in the world at large for the 2000-2020 period, for which we have comparable data. Urban extent densities in the LAC region cities declined at an annual rate of 0.94±0.29%, while densities in cities in the world at large declined at an annual rate of 0.72±0.06% during this period. It should be noted here that average urban extent densities in the cities in the LAC region in 2020 were significantly lower than those in the world at large that same year: 60±7 people per hectare as against 103±3 people per hectare.

9. This result is true for the 3,470 cities and metropolitan areas in the world at large as well for the 2000-2020 period for which we have comparable data. During this period, for every 1% increase in the rate of city population growth, there was a 0.26% increase in the rate of density change in the 71 LAC cities and an even higher 0.43% increase in the rate of density change in cities in the world at large.

10. We obtained very similar results for the global sample of 200 cities in the Atlas of Urban Expansion: During the 1990-2014 period, the average Cohesion Index and the average Proximity Index for these cities both decreased at an annual rate of 0.2±0.09% per annum.

11. We obtained similar results for the global sample of 200 cities in the Atlas of Urban expansion for the period 1990-2014. Over this period, the average share of the added areas to cities in infill was 31%, in extension and leapfrog in was 43%, and in inclusion it was 26%.

Mapping Urban Growth in Latin America and the Caribbean

Diego Arcia, Julia Paiva,
Olivia Serra, Jeannette Sordi

with contributions by Martim Furtado, Salvador Herrera, Tania Romero López, Daniela Olivares Sánchez, Salvador Herrera Montes.

Data and framework elaborated by the Marron Institute of Urban Management, New York University.



PART TWO
ATLAS



Introduction **P.204** // Glossary **P.224** //
An Atlas of 68 Cities in the Region **P.228** //
Assessing Urban Growth in Campo
Grande, Mérida, San Salvador **P.510**

Mapping Urban Growth in Latin America and the Caribbean

Diego Arcia, Julia Paiva, Olivia Serra, Jeannette Sordi

Managing urban growth is one of the greatest challenges facing cities worldwide, a situation that has become increasingly complex due to the effects of accelerated climate change. More than 80% of people in Latin America and the Caribbean live in urban areas, making it the most urbanized region in the world.[1] However, cities have historically struggled to provide infrastructure and housing that meet their populations' needs. Urban areas in Latin American and the Caribbean are expanding two to three times faster than population growth. While population in the region is growing at a lower rate than projected,[2] urban areas are growing, leading to reduced population density, and increased urban fragmentation. If not properly managed, all these factors potentially diminish urban sustainability.

The compact city paradigm has traditionally guided the approaches of planners, environmentalists, and policymakers in response to urban expansion. However, this model has proven insufficient to address current growth dynamics. To evaluate changes over the past 30 years, the research team led by Shlomo Angel at the Marron Institute of Urban Management at New York University (NYU) has developed a complex mapping methodology to capture and compare shifts

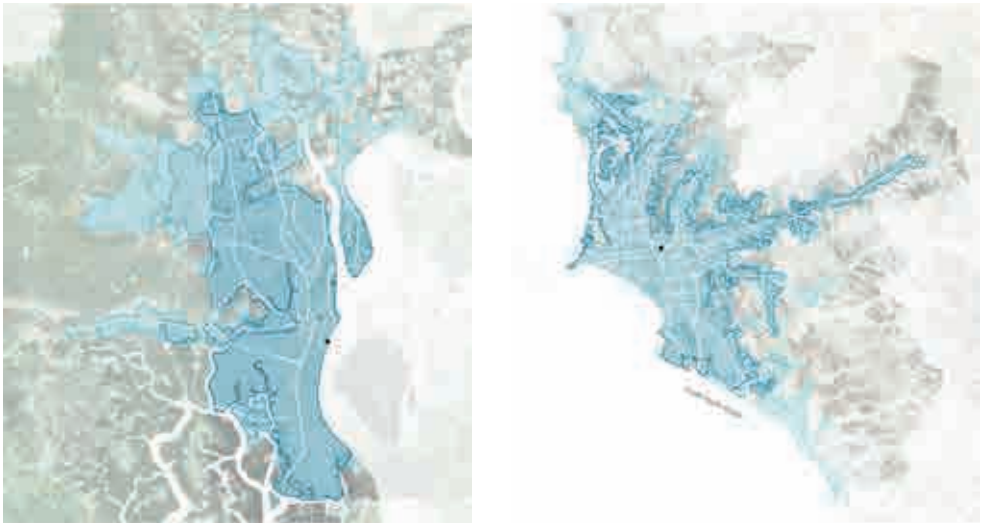
in population, urban area, and other critical growth characteristics, including different factors that contribute to a more precise understanding of urban density. In 2016, they published the Atlas of Urban Expansion,[3] an interactive platform that collects and analyzes data on the quantity and quality of urban expansion across a stratified global sample of 200 cities with populations over 100,000. Twenty-six cities in Latin America and the Caribbean region are included in the Atlas.

The study presented in this book, which was developed by NYU and the Inter-American Development Bank (IDB) with the support of the Korea Research Institute of Human Settlement, expanded and updated the data set between 2020 and 2024 to include a larger sample of cities in Latin America and the Caribbeans. From the 483 Latin American cities with populations exceeding 100,000 in 2010, a sample of 70 cities was chosen for this study, 68 of which are represented in this Atlas. This selection highlights key centers and greater urban areas that serve as significant examples within the region, capturing a broad spectrum of economic, cultural, and demographic profiles. All the cities priorly included in the Atlas of Urban Expansion (2016) are included in the new study; 42 new cities were selected to include at least one city from each IDB member country in the region and include cities that are part of the IDB's strategic agenda. Although these cities do not constitute a statistically representative sample, they adequately reflect the diversity of urban, geographic, institutional, and sociodemographic contexts across the region as a whole. These cities represent a diverse array of urban landscapes and play pivotal roles within their respective national

contexts, making them valuable for examining broader urban trends across Latin America and the Caribbean. The methodology and regional trends obtained by analyzing the sample of cities are extensively described by Shlomo Angel in the first section of this book.[4] In this section we present an Atlas that portrays 68 cities from the sample, mapping and analyzing their transformation through several indicators and comparing their growth to the other cities represented in the sample.

In this Atlas, every city is represented within its geographical context, and we have represented the progression of urban expansion throughout the three decades under analysis, from 1990 to 2020 (Figure 1).[5] It is important to note that what has been mapped out are not the administrative boundaries but rather the contiguous area of expansion, or footprint, of each city, as defined in the NYU dataset. When multiple urban centers are included in the same conurbation of the study area[6] we refer to the city as "Greater." All the cities under review, without exception, expanded outwards. As noted by Angel in Chapter 2, on average, the urban footprint of cities in the region grew by a factor of 3±0.5 between 1990 and 2020. For example, Sao Paulo, which is the most populated city in the sample, is one of the cities that expanded the least, with an average yearly factor of 1.7%. The city that expanded the most was Palmas, Brazil, with a yearly average factor of 13.7% during the same period. Also, on average, urban expansion has been growing at a consistent rate over the three decades under study. And although urban population has also been growing on average, it grew at a lower rate during the last decade. (2010-2020) when compared to previous decades (Figure 2).

In this Atlas, as in Angel's Atlas of Urban Expansion, we define cities by the extent of their built-up area, rather than by their administrative or jurisdictional boundaries.



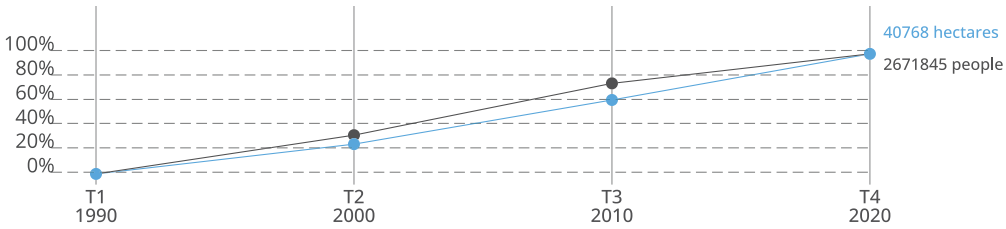


Figure 1: Left. Greater Guayaquil, Ecuador. Right. Cuzco, Peru. Right. Greater Monterrey, Mexico.

Figure 2: Average Urban Expansion and Population Growth for the analyzed sample of cities.

While cities like Greater Barranquilla, Greater Managua and Macapá increased their density over the analyzed period, for most cities, population density in 2020 was lower than in 1990. The average population density for the sample decreased from 75 people/ hectare to 59 people/hectare (Figure 3). In this process, almost half of the cities in the sample experienced an average annual decrease in density of 1% or more over the last three decades. Ilhéus presents the highest decrease at -3.4% a year, followed by Jequié at -2.9%. Future projections show that the trend will not change in the coming decades. According to the demographic study recently published by the CEPAL, population in the Latin America and Caribbean region is growing at increasingly slower rates and it is expected to peak at approximately 730 million by 2053.[7] Since the rate of urbanization in the region is already above 80%, and urban population has been growing at increasingly lower rates over the past three decades —as shown in this study—we can expect that urban population growth will follow a similar trend and stabilize in the next few decades. Even cities that rank the highest in terms of population growth, such as Palmas, Brazil, which was founded in 1989 and therefore has a recent history of urban development, are showing a steeper increase in urban extension compared to urban population growth (Figure 4).

Over the last decade, between 2010 (T3) and 2020 (T4), the cities that ranked the highest in terms of population growth are Villavicencio, Colombia; Palmas, Brazil; Greater Quetzaltenango, Guatemala;

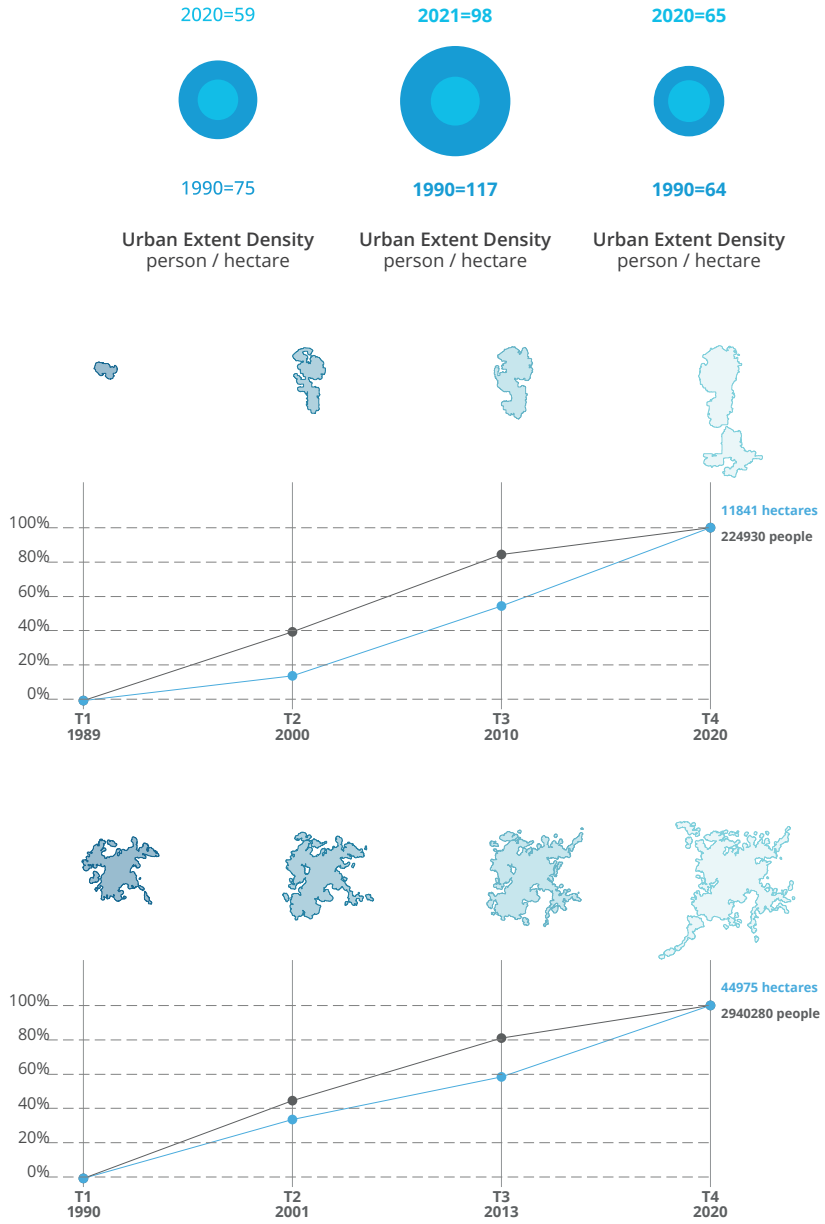


Figure 3: Urban Population Density, in 1990 (darker blue) and 2020 (light blue) for the average sample (left), Ilheus, Brasil (center) and Jequié, Brasil (right).

Figure 4: Growth of urban extent (in blue) and population (in black). Above, Palmas, Brazil. It ranked 2nd in urban population growth and 4th in urban extent, yet the city is expanding faster than it is densifying. Below, Greater Guatemala City, Guatemala. While both keep growing, the rate of population growth over the last decade has decreased while the urban extent has grown at a much faster rate.

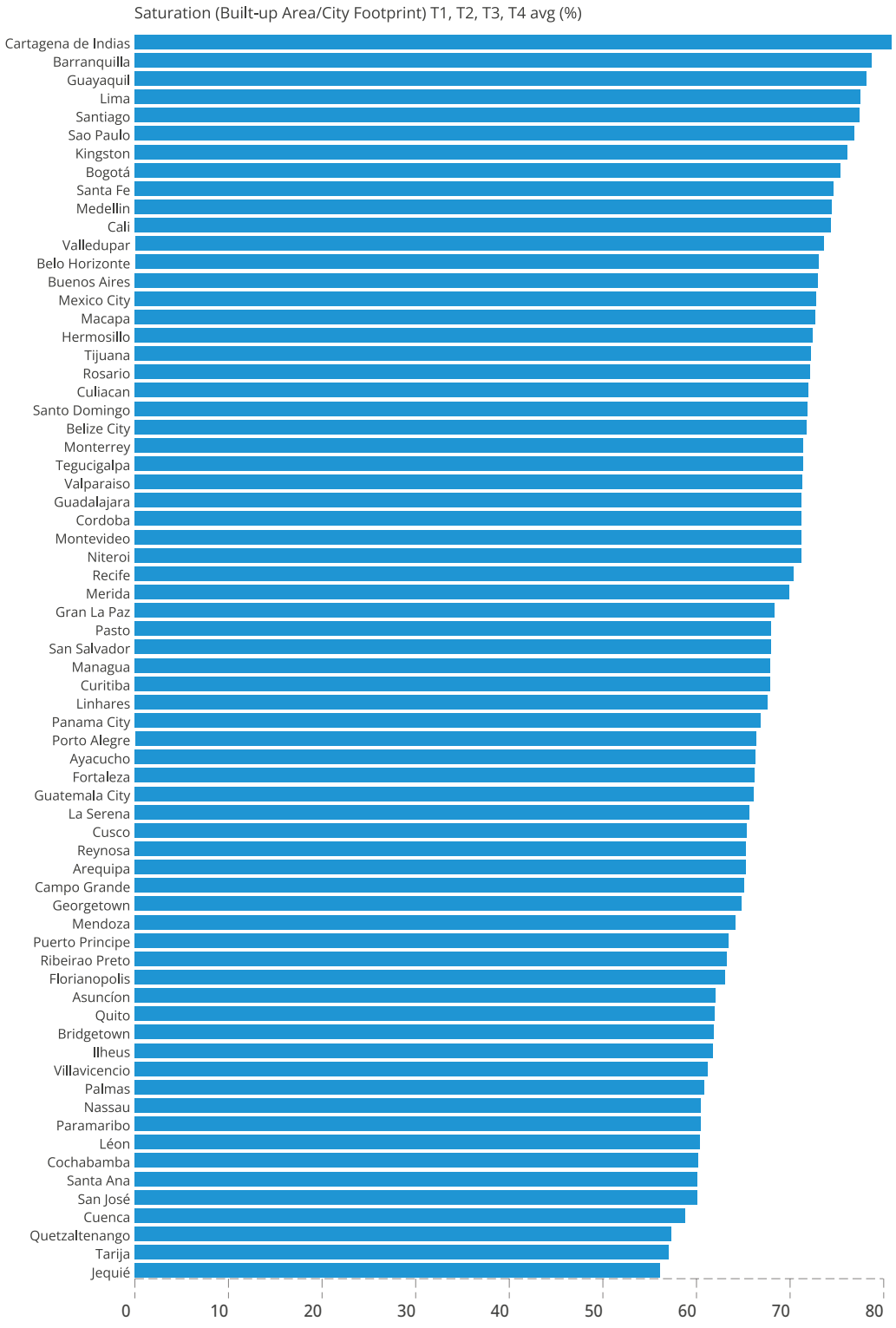
Greater Tarija, Bolivia, and Cuenca, Ecuador. Over the same period, the cities that experienced the highest rate of urban extent growth are Villavicencio, Colombia; Greater Tarija, Bolivia; Cuenca, Colombia; and Palmas and Ilhéus, Brazil. The cities that experienced the highest annual average change in urban population density, over the same decade, are Tijuana, Mexico; Belize City, Belize; Valledupar, Colombia, and Linhares and Campo Grande in Brazil.

Two other important factors that characterize urban density, and that have been analyzed for the sample, are compactness and saturation. In the context of this Atlas, compactness focuses on how compact the geometric shape of a city's urban extent is in terms of proximity and cohesion. Saturation instead "is the degree to which a city's urban extent is saturated by its built-up area (...). The urban extent of a city typically includes urbanized open spaces within it, be it public or private open spaces, or vacant lands awaiting development."[8] In this sense, more saturated cities have less vacant or open spaces. Valledupar, Colombia; Campo Grande, Brazil; Greater Culiacán and Greater Mérida, Mexico, and Tegucigalpa, Honduras, rank highest at T4. In terms of saturation, the cities that show the highest percentage are Greater Barranquilla and Greater Cartagena de Indias, Colombia; Greater Guayaquil, Ecuador; Kingston, Jamaica; and Belize City, Belize.

As we can see in Figure 5, cities experiencing the highest growth rates for urban extent—such as Palmas, Brazil; Greater Quetzaltenango, Guatemala;

and La Serena, Chile—exhibit moderate to low levels of urban saturation. Although these variables show limited correlation, the graphic suggests that rapid urban expansion is associated with less saturated urban areas. This is yet again indicated as the top-four cities in average saturation—Greater Cartagena de Indias, Greater Barranquilla, Greater Guayaquil and Lima—show low a low increase in urban extent over the last thirty years.

The Atlas also represented the process of urban expansion for each city. As we can see in Figure 6, on average in the sample, infill processes—urban areas added in the new period occupying urbanized open space within the urban extent of the earlier period—represented 38% of urban expansion between 1990 and 2000, 34% between 2000 and 2010, and 38% between 2010 and 2020. Extension—areas added in the new period that constitute contiguous urban clusters that are attached to the urban extent of the earlier period—represented 30% of the urban expansion between 1990 and 2000, 29% between 2000 and 2010, and 30% between 2010 and 2020. Leapfrog—new area categorized as urban extent which is not attached to the main urban extent—represented 11% of the urban expansion between 1990 and 2000, 12% between 2000 and 2010, and 10% between 2010 and 2020. Inclusion—urbanized areas which are not contiguous to the central urban extent and, after a certain period, do merge into the central urban extent as the city expands—represented 21% of the urban expansion between 1990 and 2000, 24% between 2000 and 2010, and 21% between 2010 and 2020. While the


Saturation (Built-up Area/City Footprint) T1, T2, T3, T4 avg (%)
Cartagena de Indias
Barranquilla
Guayaquil
Lima
Santiago
Sao Paulo
Kingston
Bogotá
Santa Fe
Medellin
Cali
Valledupar
Belo Horizonte
Buenos Aires
Mexico City
Macapa
Hermosillo
Tijuana
Rosario
Culiacan
Santo Domingo
Belize City
Monterrey
Tegucigalpa
Valparaiso
Guadalajara
Cordoba
Montevideo
Niteroi
Recife
Merida
Gran La Paz
Pasto
San Salvador
Managua
Curitiba
Linhares
Panama City
Porto Alegre
Ayacucho
Fortaleza
Guatemala City
La Serena
Cusco
Reynosa
Arequipa
Campo Grande
Georgetown
Mendoza
Puerto Principe
Ribeirao Preto
Florianopolis
Asuncíon
Quito
Bridgetown
Ilheus
Villavicencio
Palmas
Nassau
Paramaribo
Léon
Cochabamba
Santa Ana
San José
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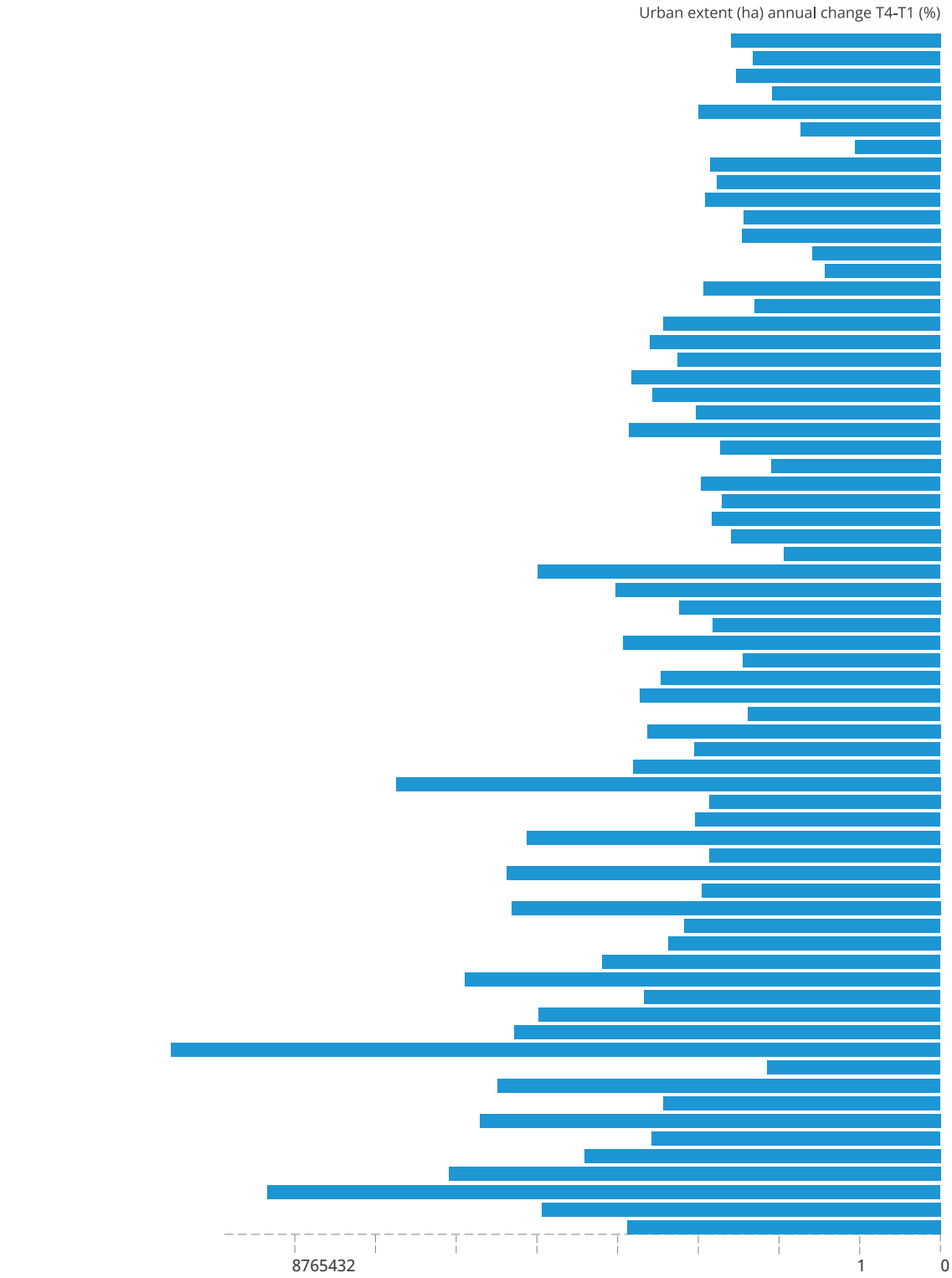


Figure 5: Comparing average saturation and change in urban extent in 1990 and 2020.

average numbers are relatively consistent, they vary considerably from city to city. For each city, the Atlas also includes a mosaic of satellite images representing areas of infill, extension, leapfrog, and inclusion.

Finally, for a sample of thirty cities, we have represented specific data that define the anatomy of density: plot coverage, building height estimates, and dwelling unit occupancy. In the next paragraphs we provide technical notes on the methodology, a guide on how to read the atlas, and an introduction to the three case studies examined in depth in this book: Campo Grande, Brazil; Mérida, Mexico, and San Salvador, El Salvador.

Notes on the Methodology: Defining the Urban Footprint

This publication is based on the results of the study on the expansion of Latin American cities led by Professor Shlomo Angel at the Marron Institute of Urban Management. This study follows Angel's methodology as developed for the Atlas of Urban Expansion published by the Marron Institute for Urban Management at New York University in 2016. Hence, the methodology described below builds on the description provided by the Atlas of Urban Expansion.[9]

Part of the data produced is assessed according to the "Area and Density" methodology and analysis. The source for the production of the Atlas relied on the analysis of cloud-free satellite imagery from Landsat 5 (1984), Landsat 6 (1993), Landsat 7 (1999), and Landsat 8 (2013), with a spatial resolution of 30-by-30 meters per pixel. The images were processed using human-assisted algorithms to classify land cover into three categories: built-up areas, open spaces, and water, achieving a high degree of classification accuracy. Notably, the urban class exhibited a user's accuracy of 91%, ensuring robust alignment between Landsat-derived classifications and high-resolution imagery.

Over the past decade, urban expansion occurred through processes of

infill **38%** extension **30%** leapfrog **11%** inclusion **21%**

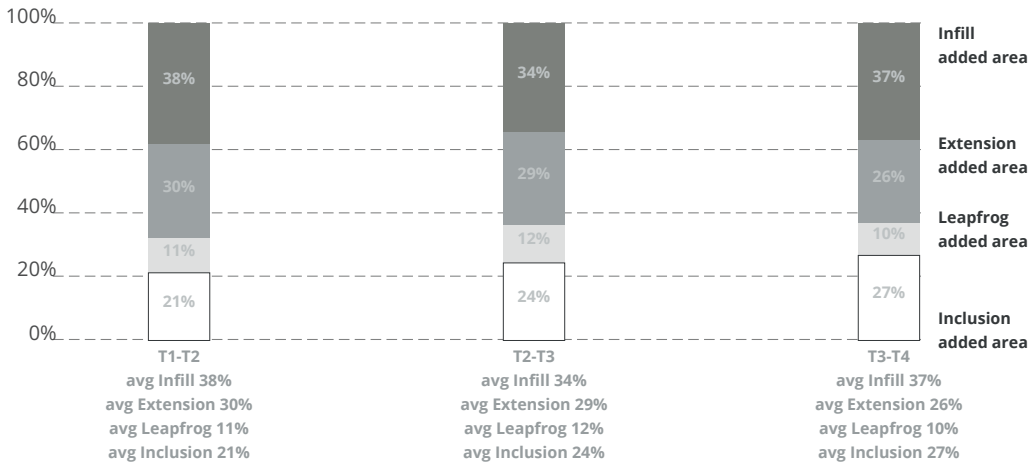


Figure 6: Average distribution of urban expansion for the cities under study.

The analysis further differentiated built-up pixels into three categories—urban, suburban, and rural—based on the proportion of built-up pixels within a walking distance circle, defined as a circular area of one square kilometer with a 584-meter radius, approximating a ten-minute walk. To enhance the precision of these classifications, a cutoff point of 25% was applied, ensuring that the spatial typologies accurately reflected the density characteristics observed within the study's global sample of cities.

Urban pixels are defined as those where 50% or more of the area within their walking distance circle is built-up. Suburban pixels, in contrast, represent areas where the built-up share ranges from 25% to 50%, while rural pixels are characterized by less than 25% built-up area within the same spatial unit. Fringe open space consists of all open space pixels located within 100 meters of urban or suburban pixels. Captured open space refers to clusters of open spaces smaller than 200 hectares, fully enclosed by urban, suburban, and fringe open space pixels. Rural open space includes all open spaces that are neither fringe nor captured. Together, fringe and captured open spaces comprise the urbanized open space of the study area.

The urban cluster is defined as the aggregation of urban built-up areas, suburban built-up areas, and urbanized open spaces within a study area. In attributing clusters to specific cities, the largest urban cluster in a study area is associated with the main city under analysis. The urban extent of a city is determined by combining the largest urban cluster with additional clusters identified through the inclusion rule. This rule operates by creating a buffer zone around each cluster, with the buffer's area equivalent to one-quarter of the cluster's area, uniting all clusters whose buffers intersect.

This assessment is conducted across all periods of interest in the database, enabling a cohesive comparison between years and providing insights into the city's growth. The analysis identifies four types of new built-up areas: infill, which consists of built-up pixels added in the new period that occupy urbanized open space within the urban extent of the previous period; extension, which includes built-up pixels that form contiguous urban clusters attached to the urban extent of the earlier period; leapfrog, referring to built-up pixels that create new contiguous urban clusters not connected to the urban extent of the earlier period or to extension clusters; and inclusion, which involves urban, rural, or suburban built-up pixels that were previously outside the urban extent but are now included in the urban extent of the new period.

The methodology focuses on utilizing the previously presented data to produce and assess various metrics. Beginning with density, it measures the intensity of

urban space usage by the population within a city's urban extent or built-up area. This is quantified in inhabitants per hectare. To estimate population, the study sought the most detailed enumeration zone maps available for cities in the global sample, drawing from sources such as CIESIN, citypopulation.de, the Chinese Academy of Sciences, and national census bureaus. For each zone intersecting the urban extent, the share of built-up pixels within the urban boundary was calculated and multiplied by the zone's total population, and the resulting figures were summed across all intersecting zones to estimate the urban extent population. Urban extent density is then derived as the ratio of the total population to the urban extent, measured in persons per hectare, while built-up area density is calculated similarly, but only for the built-up area itself. These metrics are used in the Atlas to assess population density within cities.
Fragmentation measures the degree to which the built-up area saturates the city's urban extent or, conversely, the extent to which this built-up area is fragmented by urbanized open space. Saturation, as defined in the methodology, is the ratio of the built-up area within the urban extent to the total urban extent, reaching its maximum when the urban extent contains no open space. This metric is used in the Atlas to assess fragmentation.

Compactness, on the other hand, measures the extent to which the geographic shape of the urban extent approximates a circle, the form that minimizes the average distance from any point within it to its center, or alternatively, the shape that minimizes the average distance between all points within it. To assess compactness, the proximity index is used, which is the ratio of the average beeline distance of all points in an equal area circle to the city hall and the average beeline distance of all points in the urban extent to the same central point. Higher values on this index indicate urban extents that are more circular in shape.

A different methodology is used to produce information for what is called "Anatomy of Density". Per Angel's definition, urban density can be defined by three main factors that together provide a more accurate understanding of urban density, defined as a ratio of the number of people per unit of area. They are floor-space occupancy—the ratio of the total population of a city and its total residential floor area, the gross residential floor area, including wall thicknesses and common areas—floor area ratio, calculated by dividing the allowable building area by the total area of the plot—and residential share—the total area of the city's urban footprint taken up by residential plots, a common metric used in quantifying urban land-use plans. These three factors can also be understood as the result of seven more factors that ultimately provide us with an even more accurate understanding of urban density: dwelling occupancy, occupancy rate, dwelling unit packing, floor plan efficiency, that together define floor space occupancy; building heights and plot coverage determine floor area ratio; and finally residential share.

In this methodology, several data sources are used for each metric. In this Atlas, for thirty cities we have represented plot coverage, building height estimates, and dwelling unit occupancy.

Plot coverage and building height estimates were obtained from Google Earth and Bing satellite imagery using an intra-urban spatial sampling methodology. For assessing the metrics, a set of quasi-random points within the urban extent, based on a Halton sequence to ensure a desired point density. Building height was estimated by counting the residential floors in the nearest residential building to each identified Halton point. Analysts excluded non-residential floors, such as those used for commercial purposes or parking. Plot coverage was calculated by digitizing the boundaries of blocks surrounding the first few hundred sampled points identified as 'residential.' These boundaries were either the streets surrounding residential city blocks or intra-block boundaries separating residential and non-residential areas. The total area of all residential buildings within the defined boundaries was then digitized and summed to estimate plot coverage.

The data source persons per dwelling unit (dwelling unit occupancy) was primarily derived from secondary sources. Dwelling unit occupancy was typically calculated using national census data, which provided the total population and the number of dwelling units. The empirical value for persons per dwelling unit, derived from census data, was adopted for the urban footprint as a whole, assuming that variations within the urban area were minimal and did not significantly deviate from this calculated value.

Using high-resolution imagery, robust databases and reliable secondary sources, such as national census, the methodology used to develop the Atlas of Urban Expansion for Latin America and the Caribbean provides a rich panorama for the region. This allows for important comparisons and a diverse overview of how the region has been urbanizing over the past three decades.

Insights from Three Case Studies

To gain a deeper understanding of urban growth in the LAC region, three cities—Mérida, Mexico; San Salvador, El Salvador; and Campo Grande, Brazil—were selected as case studies, each representing distinct contexts. These three cities were selected to represent each geographic region of Latin America: north, center, and south. Additionally, they were chosen for their extensive available data and their strategic importance in the Inter-American Development Bank's agenda, either as cities where growth management programs are

being developed or where there is an interest in better understanding the dynamics of their urban contexts. This diversity allows for an exploration of the relationship between urban expansion and sociodemographic dynamics, alongside local policies, ultimately providing valuable policy recommendations for sustainable urban growth.

Geographically, Greater Mérida and Greater Salvador are closer to each other than to Campo Grande, which is located in the middle of South America. Mérida is situated in the southernmost part of North America, while San Salvador lies in Central America. Despite geographic differences, Mérida and Campo Grande share mostly flat landscapes conducive to urbanization, whereas San Salvador faces significant topographical challenges. Additionally, Campo Grande is unique as it is not part of a metropolitan region.

In terms of population, all three cities are medium-sized capitals. Greater Mérida is the largest, with a population of 1,892,832, followed by San Salvador with 1,061,485, and Campo Grande with 897,938. Mérida's metropolitan area comprises 11 municipalities without a unified institutional mechanism for metropolitan planning. In contrast, the San Salvador Metropolitan Area includes 14 municipalities with some coordination through the Council of Mayors and its own planning office. All three cities host varying levels of governmental administration, with Mérida and Campo Grande having state governments, while San Salvador houses the national government.

Economically, all three cities have significant tertiary sectors. Campo Grande's economy is closely linked to agribusiness, while Mérida is a historical central economic hub that is now facing competition from Cancún. San Salvador has a predominantly service-oriented economy, with 87% of its population employed in commerce or services. These cities have attracted national and international migrants due to their economic growth.

Each city's assessment of urban growth posed unique methodological challenges, particularly concerning administrative structures and the availability of consistent data. The case studies drew inspiration from Angel's methodology (2018), which utilized satellite imagery, population databases, and census data to derive metrics for urban growth. Data sources varied: while Mérida and San Salvador relied mainly on Angel et al. (2023) and qualitative municipal data, Campo Grande used national census data and the Map Biomas database.

Despite these differences, the case studies shared common indices to evaluate urban expansion and compactness, focusing on indicators such as population growth, urban density, urban extension, and space saturation for development.

They reveal valuable lessons in urban management, highlighting the necessity of a cohesive planning framework for effective policy regulation. Campo Grande demonstrated significant compactness and density due to coherent planning, while San Salvador achieved some coherence through its national regulations. Mérida, however, faced challenges with its dispersed planning framework.

Coordination emerged as a critical factor in improving regulatory and institutional arrangements. In San Salvador, the Planning Office and the Council of Mayors work together to enhance planning coherence. Campo Grande's recent establishment of a Municipal Committee for Climate Change suggests a potential avenue for aligning urban policies, while Mérida's fragmented administration underscores the need for integrated planning frameworks.

A higher ratio of densification to expansion is generally preferred to minimize environmental impact; however, LAC cities have primarily experienced urban expansion. This trend is linked to challenges in land use and real estate dynamics. Mérida has seen rapid urbanization driven by speculation and national housing policies, while Campo Grande's expansion stems from land subdivision, despite a slower population increase. San Salvador's recent growth has been characterized by an increase in irregular settlements.

The findings from these case studies support the hypothesis that population and income growth are primary drivers of urban expansion, emphasizing the need for policies that leverage these dynamics to promote inclusivity, sustainability, and resilience. Recommendations for LAC cities include acknowledging that urban growth occurs through both densification and expansion, with a need for sustainable planning in both approaches.

Key recommendations include:

- Recognizing that urban growth comprises both densification and expansion, with expansion being the dominant trend in the case studies.
- Planning for sustainable expansion, ensuring community involvement and stakeholder engagement.
- Demarcating rights-of-way for arterial roads in projected expansion areas, as demonstrated in Campo Grande.
- Implementing zoning regulations to encourage high-density transit-oriented development along arterial routes and enhancing resilient infrastructure.

Despite Campo Grande's clear regulations for densification, in the city center, population density has been declining, reflecting a broader challenge across LAC cities. Thus, in strategic areas of the cities remains a persistent issue that requires overcoming regulatory and institutional barriers.

Altogether, this Atlas presents a portrait of the physical transformation that occurred in Latin American and Caribbean cities since 1990, through a sample of 68 case studies. As described in the previous sections, these cities serve as significant examples within the region, capturing a broad spectrum of economic, cultural, and demographic profiles. All the cities in the sample expanded their urban extent since 1990. Between 2010 and 2020, on average, urban extent increased at a higher rate than the average urban population. Projecting into the future, almost all countries in Latin America and the Caribbean are expected to continue experiencing population growth from 2020 to 2050. Projections indicate that many of these countries may enter a declining trajectory between 2050 and 2100. Mapping the transformation of cities over the past three decades, this Atlas becomes an instrument to assess, compare, and manage urban growth in the region for the years to come.

Endnotes

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4. See “Emerging Empirical Evidence for Territorial Planning in the LAC Region,” P.130.

5. See “Notes on the Methodology: Defining the Urban Footprint” in this chapter, P.216.

6. The study area encompasses the entire eventual urban extent of the city, meaning the urban extent should be completely surrounded by open space. For a complete definition and reference see the Glossary, “Study Area,” P.228.

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Glossary

BUILDING HEIGHT

In this context, Building Height is measured as the average number of residential floors—exclusive of commercial floors in mixed-use buildings—in the city as a whole (e.g. ASPO 1958; Bertaud & Brueckner 2005). The factor is achieved by dividing the Residential Floor Area by the Building Footprint.[1]

COHESION

Cohesion measures how close locations within a city are to each other. It's calculated as the ratio between two values: the average distance between any two points within an Equal Area Circle (a circle with the same area as the city) and the average distance between any two points within the actual city.[2]

COMPACTNESS

Several measurements can be used to assess the compactness of an urban extent. In the context of this Atlas, it focuses on how compact the geometric shape of a city's urban extent is. Thus, the metrics chosen are Proximity and Cohesion.[3]

DWELLING UNIT OCCUPANCY

Dwelling Unit Occupancy is a measure of the average number of people occupying a single dwelling unit. It is a more refined measure of overcrowding than floorspace occupancy because it measures occupancy in the net floor area of 'occupied dwelling units,' disregarding vacant ones (WHO 2009).[4]

DWELLING UNIT PACKING

Dwelling Unit Packing is a measure of the number of dwelling units that can be fitted in a hectare (ha) of commercial floorspace net of common areas—such as corridors, lobbies, staircases or elevator shafts.[5]

EXTENTION

Extension consists of all urban areas added in the new period that constitute contiguous urban clusters that are attached to the urban extent of the earlier period.[6]

FLOOR AREA RATIO

Floor Area Ratio is a metric used to regulate the allowable building volume on a given plot (e.g. ASPO 1958; Kogo et al. 2010). It is calculated by dividing the allowable building area by the total area of the plot.[7]

FLOOR PLAN EFICIENCY

Floor Plan Efficiency is a measure commonly used by developers to calculate the salable floor space of their buildings. It is the division of the net residential living area of the floor by the total floor area.[8]

FLOORSPACE OCCUPANCY

“Floorspace occupancy is the ratio of the total population of a city and its total residential floor area, the gross residential floor area, including wall thicknesses and common areas.”[9]

FRAGMENTATION

Fragmentation assesses the extent to which the built-up area of a city is fragmented by urbanized open space. For this, Saturation and Openness are the metrics chosen to evaluate this attribute of the Urban Extent in the Atlas.[10]

INCLUSION

Inclusions are urbanized areas which are not contiguous to the central urban extent and, after a certain period, do merge into the central urban extent as the city expands. Though this process is considered as added area, it does not constitute new land development.[11]

INFILL

Infill consists of urban areas added in the new period occupying urbanized open space within the urban extent of the earlier period.[12]

LEAPFROG

Leapfrog is a new area categorized as urban extent which is not attached to the main urban extent.[13]

OCUPANCY RATE

Occupancy Rate is a measure used in the real estate sector to assess the utilization of the available housing stock. The factor is calculated from the division of the number of occupied dwelling units by the total number of dwelling units in the city.[14]

OPENNESS

Openness measures the average share of open space around the urbanized area of a city. This is done by assessing the share of open space pixels within a circle with an area of 1km^2 around every built-up pixel within the urban extent and averaging the result.[15]

PLOT COVERAGE

Plot Coverage is measured as the average share of residential plots occupied by residential building footprints. That is, the division of Building Footprints by the Residential Area.[16]

PROXIMITY

Proximity focuses on the degree to which urban extent facilitates access to the Central Business District. It is measured as a=b/c where (a) is the average distance between the edge of the city's urban extent to its Central Business District, and (b) is the radius of the Equal Area Circle (a circle with the same area as that of the city).[17]

RESIDENTIAL SHARE

"Residential Share is the share of the total area of the city's urban footprint taken up by residential plots, a common metric used in quantifying urban land-use plans (e.g. Perez et al. 2004; Keys et al. 2007)."[18]

SATURATION

"Saturation is the degree to which the urban extent of the city is saturated by its built-up area (...). The urban extent of a city typically includes urbanized open spaces within it, be it the public or private open spaces or vacant lands awaiting development." In this sense, more saturated cities have less vacant or open spaces.[19]

STUDY AREA

"The study area is identified using Google Earth imagery and census boundaries from the national census, in most cases provided to us by CIESIN, but sometimes gathered from the census agency directly. The objective of the study area identification process is to select census boundaries that encompass the entire eventual urban extent of the city, meaning the urban extent should be completely surrounded by open space. This is eyeballed based on the visible built-up area of the city in Google Earth."[20]

URBAN DENSITY

"Urban Population Density, also defined as Urban Extent Density or Urban Density, represents the "ratio of the number of people per unit of area.""[21]

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An Atlas of 68 Cities in the Region

In this Atlas, as in Angel's Atlas of Urban Expansion, cities and greater conurbations are defined by the extent of their built-up area rather than by the administrative or jurisdictional boundaries.



01 / Arequipa
Peru
p.238



02 / Greater Asunción
Paraguay
p.242



03 / Ayacucho
Peru
p.246



04 / Greater Barranquilla
Colombia
p.250



05 / Belize City
Belize
p.254



06 / Greater Belo Horizonte
Brazil
p.258



07 / Greater Bogotá
Colombia
p.262



08 / Bridgetown
Barbados
p.266



09 / Greater Buenos Aires
Argentina
p.270



10 / Greater Cali
Colombia
p.274



11 / Campo Grande
Brazil
p.278



12 / Greater Cartagena de Indias
Colombia
p.282



13 / Greater Cochabamba
Bolivia
p.286



14 / Greater Córdoba
Argentina
p.290



15 / Cuenca
Ecuador
p.294



16 / Greater Culiacán
Mexico
p.298



17 / Greater Curitiba
Brazil
p.302



18 / Cusco
Peru
p.306



19 / Greater Florianópolis
Brazil
p.310



20 / Greater Fortaleza
Brazil
p.314



21 / Georgetown
Guyana
p.318



22 / Greater Guadalajara
Mexico
p.322



23 / Greater Guatemala City
Guatemala
p.326



24 / Greater Guayaquil
Ecuador
p.330



25 / Hermosillo
Mexico
p.334



26 / Ilhéus
Brazil
p.338



27 / Jequié
biome Deserts & Xeric Shrublands
p.342



28 / Kingston
Jamaica
p.346



29 / Greater La Paz
Bolivia
p.350



30 / La Serena
Chile
p.354



31 / Greater Léon
Nicaragua
p.358



32 / Lima
Peru
p.362



33 / Linhares
Brazil
p.366



34 / Macapá
Brazil
p.370



35 / Greater Managua
Nicaragua
p.374



36 / Greater Medellín
Colombia
p.378



37 / Greater Mendoza
Argentina
p.382



38 / Greater Mérida
Mexico
p.386



39 / Greater Mexico City
Mexico
p.390



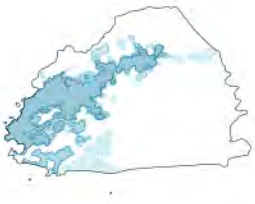
40 / Greater Monterrey
Mexico
p.394



41 / Greater Montevideo
Uruguay
p.398



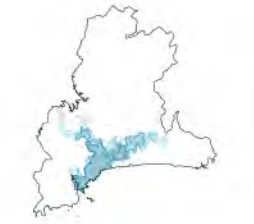
42 / Nassau
Bahamas
p.402



43 / Greater Niterói
Brazil
p.406



44 / Palmas
Brazil
p.410



45 / Greater Panama City
Panama
p.414



46 / Greater Paramaribo
Suriname
p.418



47 / Pasto
Colombia
p.422



48 / Greater Porto Alegre
Brazil
p.426



49 / Greater Port-au-Prince
Haiti
p.430



50 / Greater Quetzaltenango
Guatemala
p.434



51 / Greater Quito
Ecuador
p.438



52 / Greater Recife
Brazil
p.442



53 / Reynosa
Mexico
p.446



54 / Ribeirão Preto
Brazil
p.450



55 / Rosario
Argentina
p.454



56 / Greater San José
Costa Rica
p.458



57 / Greater San Salvador
El Salvador
p.462



58 / Greater Santa Ana
El Salvador
p.466



59 / Santa Fe
Argentina
p.470



60 / Greater Santiago
Chile
p.474



61 / Greater Santo Domingo
República Dominicana
p.478



62 / Greater São Paulo
Brazil
p.482



63 / Greater Tarija
Bolivia
p.486



64 / Tegucigalpa
Honduras
p.490



65 / Tijuana
Mexico
p.494



66 / Valledupar
Colombia
p.498



67 / Valparaiso
Chile
p.502



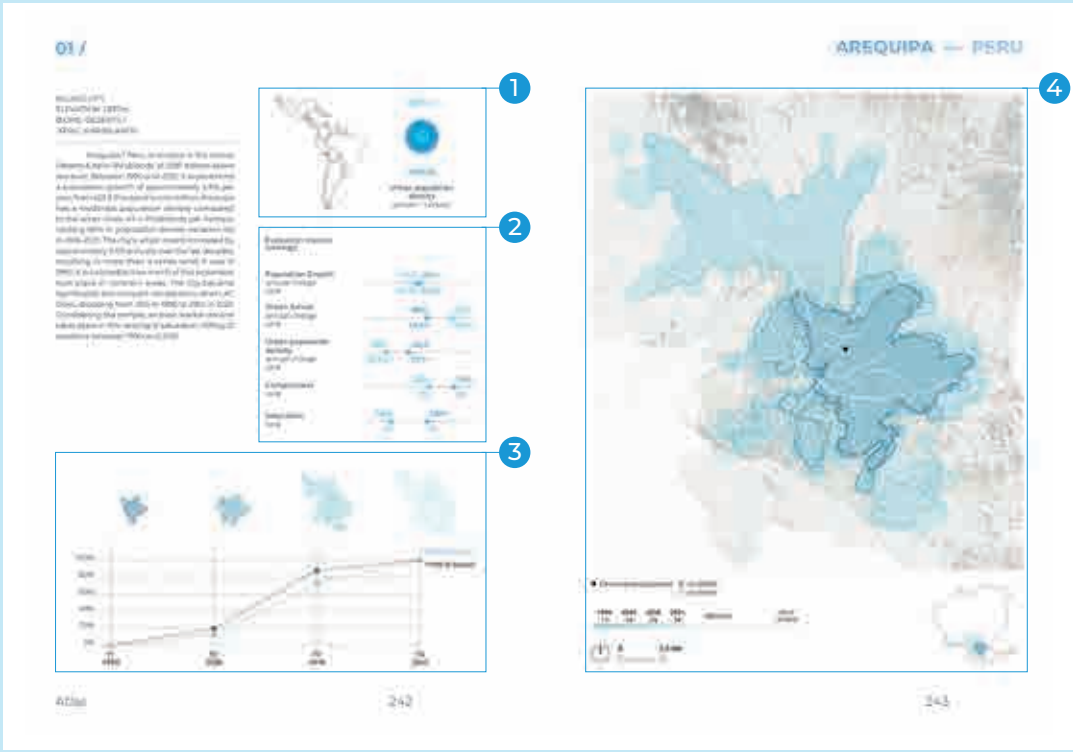
68 / Villavicencio
Colombia
p.506

How to Read the Atlas

This guide provides a short description of how to read the graphics and maps displayed for each of the 68 cities in the Atlas. Each city is represented in two spreads. The first spread presents the city's location and geographic context, its ranking in comparison to other cities, and its population growth and urban expansion over the three decades under analysis. The second spread shows the assessment of the processes of expansion and densification. There are also diagrams of these factors for the 30 cities assessed in the Anatomy of Density.

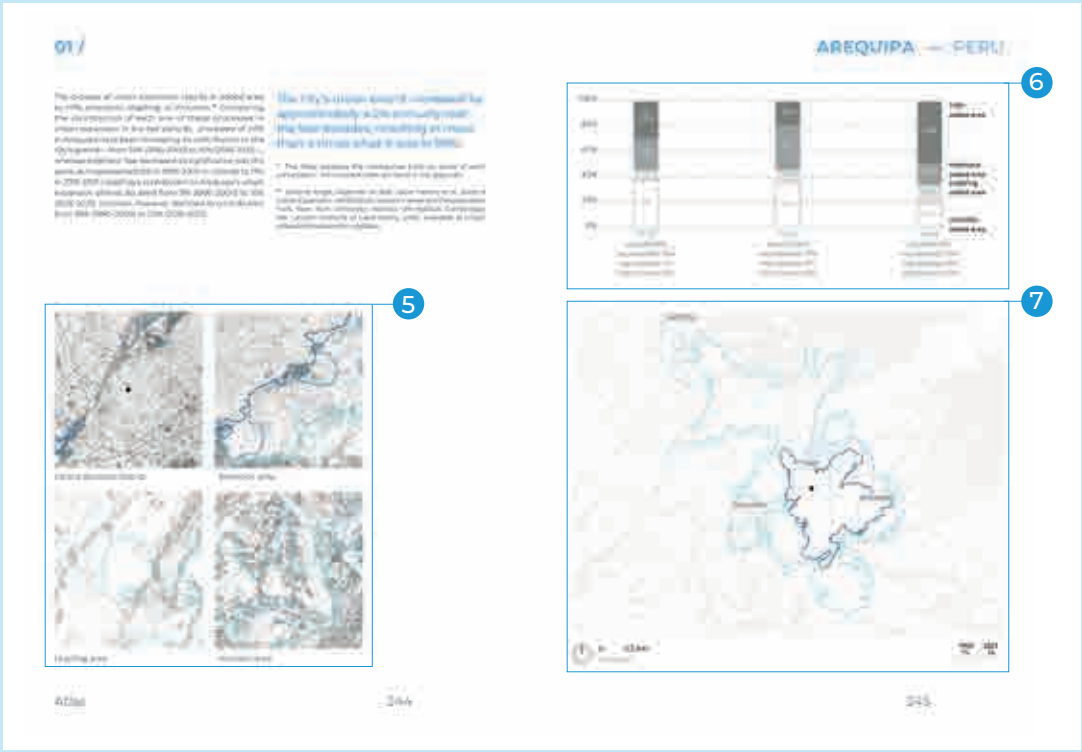
1 The graphic compares the city's Urban Extent Density over two periods: T1—approximately 1990, in dark blue— and T4— approximately 2020, in light blue. For the specific years in which each city was assessed and notes on the methodology see the introduction to this Atlas (Part 2) and Shlomo Angel's Chapter 3 (Part 1) in this book.

2 The graphic compares how the city ranks in comparison to the other 67 cities in the database. Each metric is indicated on the left and, while the way it was obtained is shown below. Rankings are assessed by comparing changes in value that took place from T1 to T2 to those that happened from T3 to T4. Thus, what is displayed is a ranking of changes within a common period. At the left, a dashed line represents the spectrum of 68 cities. On this line, the city's position in the ranking is indicated by two dots: dark blue indicates ranking between T1 and T2; while lighter blue shows the same going from T3 to T4. Metrics displaying the 'annual change rank' consider the average change in the metric within the period. Those that say 'Rank' consider the total change from T3 to T4.



3 This graphic provides a synthetic view of city growth for each of the 4 periods (T1, T2, T3, T4), considering both population and area. The growth that took place over the past four decades is shown by percentages: one can assess the cumulative percentage of growth in terms of population and urban extent on each vertical line. A figure along this line presents the urban extent's layout at each period. Each color matches the one shown in the map presented on the following page.

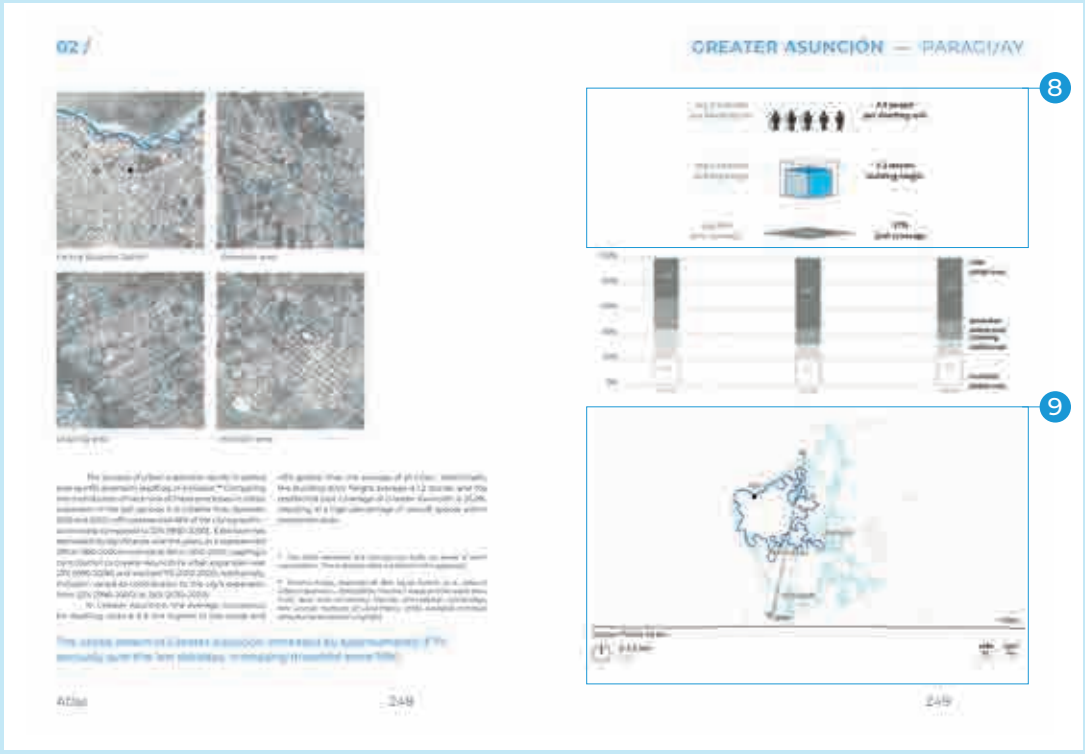
4 The map overlaps the city's urban extent for each one of the four periods showing the progression of its expansion. The urban extent layout is indicated in blue polygons shading from darker to lighter and from oldest to most recent, respectively. A black dot indicates the location of the city hall. White lines represent the main roads. The map is plotted on top of a shaded relief background and aerial image, providing an insight into the city's surrounding landscape; the study area considered in the data collection is represented in full resolution while the area outside of it is masked by a white layer. Down to the right, a smaller map compares the whole study area—black line— to the city's expanding urban extent—in shades of blue.



5 The mosaic provides four satellite images: one focusing on the city center and the other three with a sample of three types of urban expansion processes. To describe the city's expansion morphology, the frames are in a scale of 1:71.000. The city's urban extent for each period is indicated in blue lines following the other maps' colors.

6 The graphic describes how the city grew from T1-T2, T2-T3, and T3-T4, attributing the added area to a type of urban expansion: infill, extension, leapfrog, and inclusion. The percentage for each type of urban expansion is indicated as a bar, adding up to 100% within each period. Each period is indicated under each bar, in light grey, the period is indicated, as well as the average value for each type of urban expansion that took place over the same period for all 68 LAC cities.

7 The map locates the four-image satellite mosaic in scale. The city's urban extent is shown in two periods (T1 is the darkest and T4 the lightest). In the background, a hill shade image of the terrain's relief provides insight into the city's topography.



* The following map and diagrams are included only for the 30 cities that were assessed for the Anatomy of Density.

8 These graphics compare three measures of Anatomy of Density, comparing the city's built environment (on the right) to the average of the 30 LAC cities (on the left). From top to bottom: (i) for the city, the amount of people inhabiting the same dwelling unit is shown in full-black figures, whereas the LAC average is displayed as ones with a black outline; (ii) the cube compares the average building height in the city—in a black outline with a blue filling— to the LAC cities' average—dashed black contour; and (iii) the plot coverage is compared by laying the LAC cities' average as a rectangle with a black outline on top of a grey rectangle for the city average.

9 As for map 7, this map locates the four-image satellite mosaic in scale. The city's urban extent is shown in four periods (T1 is the darkest and T4 the lightest). In the background, a hill shade image of the terrain's relief provides insight into the city's topography. In this map, the topography is also represented by a section—indicated with a black line on the map. The section is plotted on the bottom of the map showing the city's profile marked as a black line. The section's height compared to sea level at the beginning and end is shown right above the line, providing an additional insight on the factors that are driving urban expansion and densification.

01 /

INLAND CITY
ELEVATION: 2397m
BIOME: DESERTS / XERIC SHRUBLANDS

Arequipa,* Peru, is located in the biome Deserts & Xeric Shrublands, at 2397 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 2.8% per year, from 423.8 thousand to one million. Arequipa has a moderate population density compared to the other cities: 47.4 inhabitants per hectare, ranking 56th in population density variation (%) in 2016-2021. The city's urban extent increased by approximately 4.5% annually over the last decades, resulting in more than 4 times what it was in 1990. It is noticeable how much of this expansion took place in northern areas. The city became significantly less compact compared to other LAC cities, dropping from 13th in 1990 to 29th in 2021. Considering the sample, an even starker decline takes place in the ranking of saturation, falling 23 positions between 1990 and 2021.





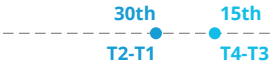
Urban population density
person / hectare

Evaluation metrics rankings:

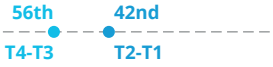
Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

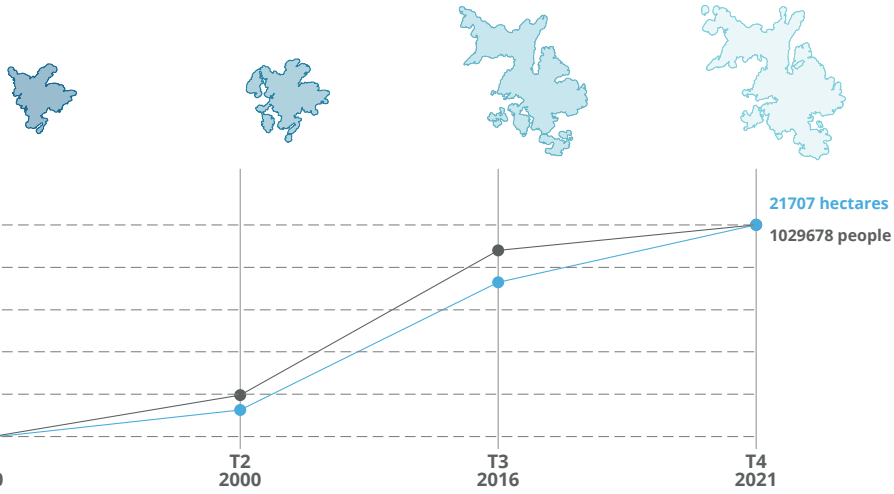


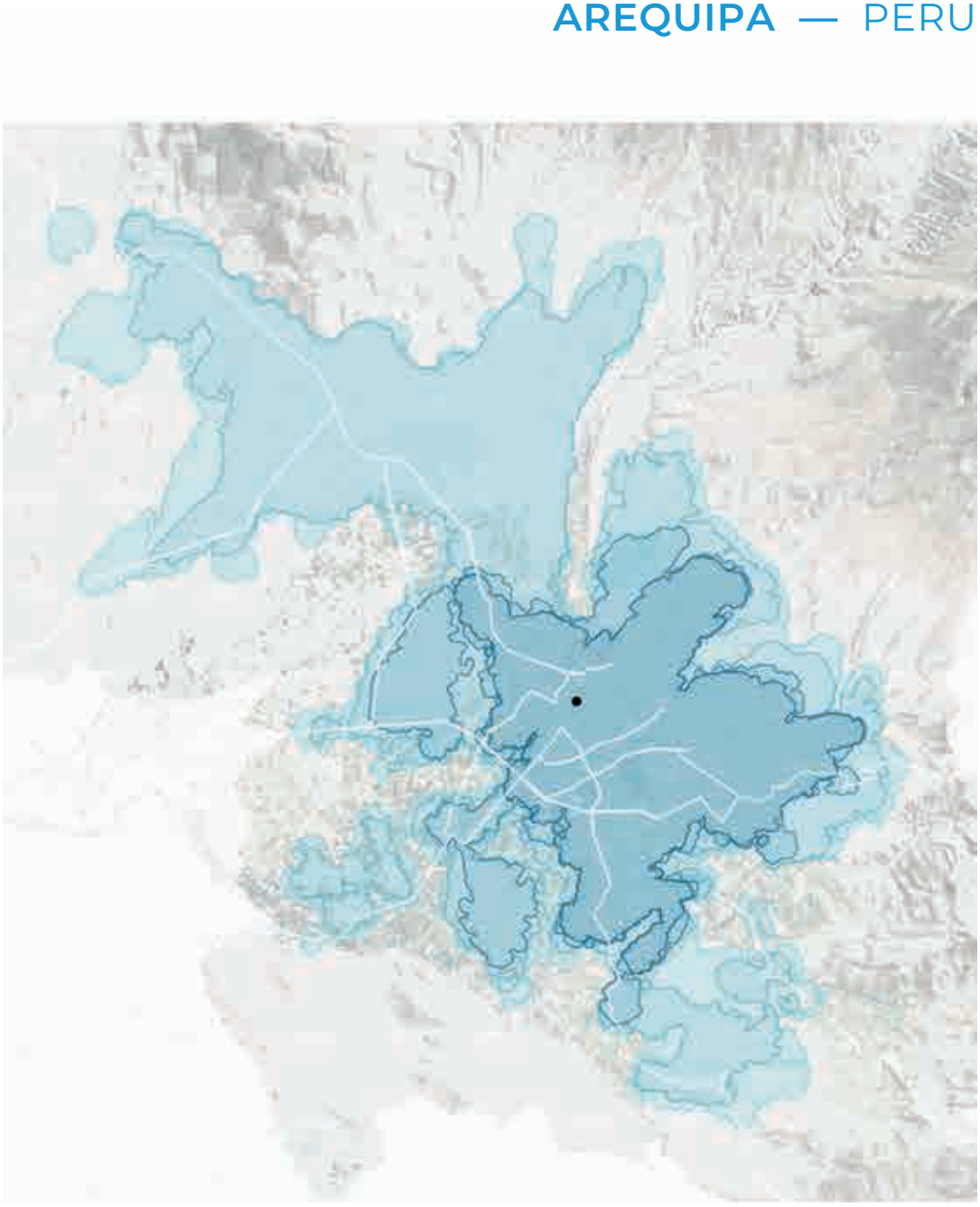
Compactness
rank



Saturation
rank







● Central Business District N -16.399568
E -71.536761

01 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Arequipa have been increasing its contribution to the city's growth—from 30% (1990-2000) to 50% (2016-2021)—, whereas extension has decreased its significance over the years, as it represented 25% in 1990-2000 in contrast to 17% in 2016-2021. Leapfrog's contribution to Arequipa's urban expansion almost doubled from 8% (1990-2000) to 15% (2016-2021). Inclusion, however, declined its contribution from 39% (1990-2000) to 20% (2016-2021).

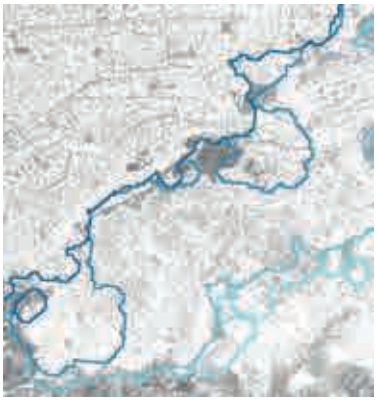
The city's urban extent increased by approximately 4.5% annually over the last decades, resulting in more than 4 times what it was in 1990.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

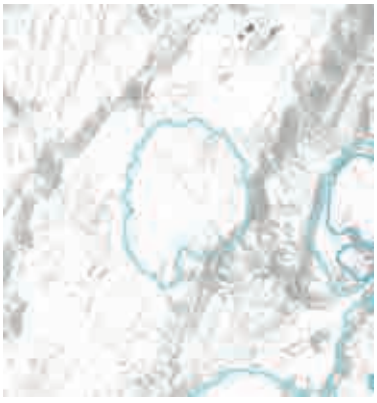
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



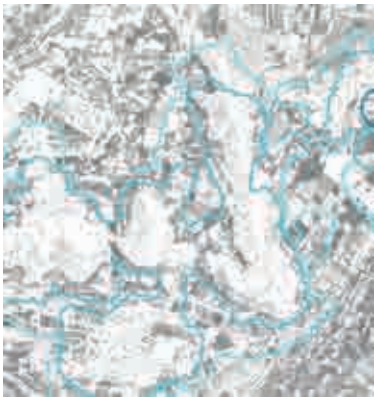
Central Business District



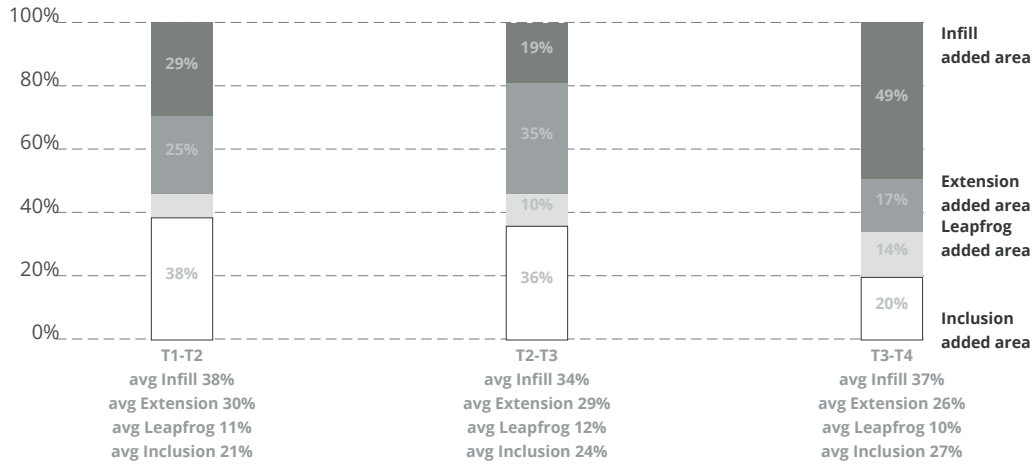
Extension area

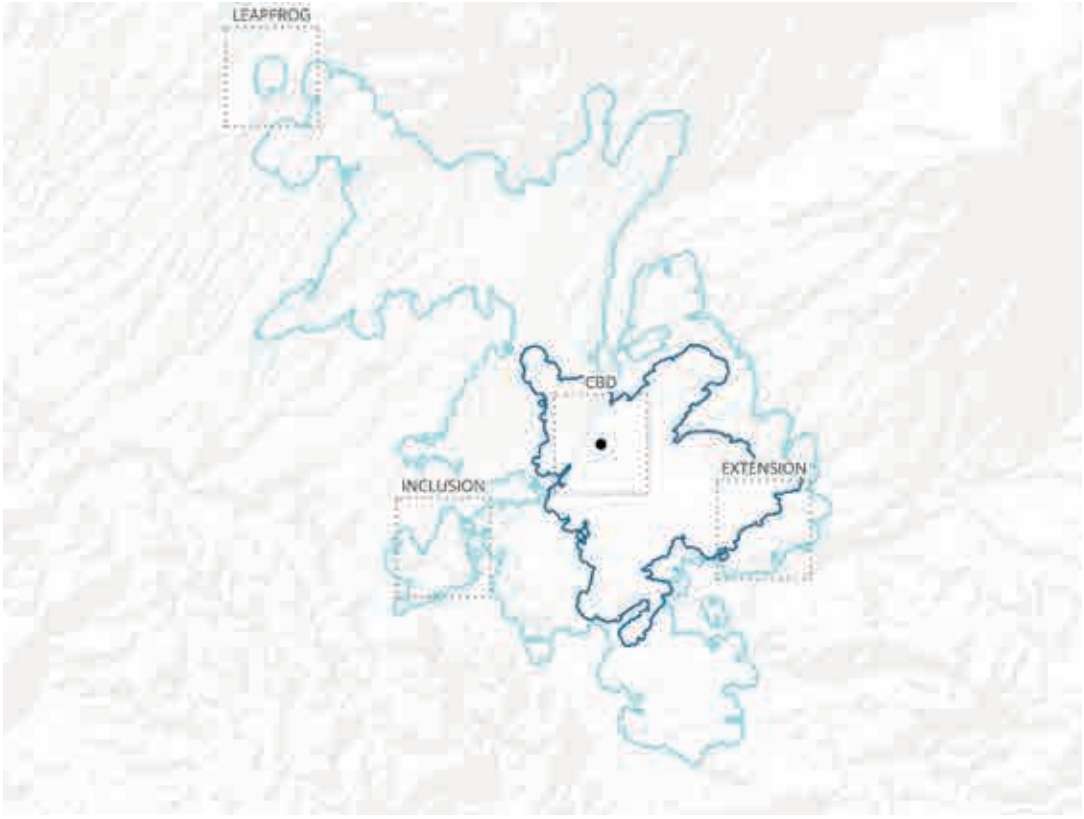


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
29%
25%
38%
19%
35%
10%
36%
49%
17%
14%
20%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
CBD
INCLUSION
EXTENSION
0
2.5 km
1990 T1
2021 T4

02 /

INLAND CITY
ELEVATION: 76m
BIOME: FLOODED GRASSLANDS / SAVANNAS

Greater Asunción,* Paraguay, is located in the biome Flooded Grasslands & Savannas, at 76 meters above sea level. Between 1990 and 2020, it experienced an intense population growth of approximately 3.3% per year, from 946.6 thousand to 2.5 million. Greater Asunción has a low population density compared to the other cities: 38.7 inhabitants per hectare, yet its rank as 11th in population density variation (%) in 2010-2020 contrasts with its former position as 54th (1990-2000). The urban extent of Greater Asunción increased by approximately 3.7% annually over the last decades, increasing threefold since 1990. The city became more compact compared to other LAC cities, and such an increase was accompanied by a rise in saturation, gaining 12 positions, from 60st to 48th between 1990 to 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

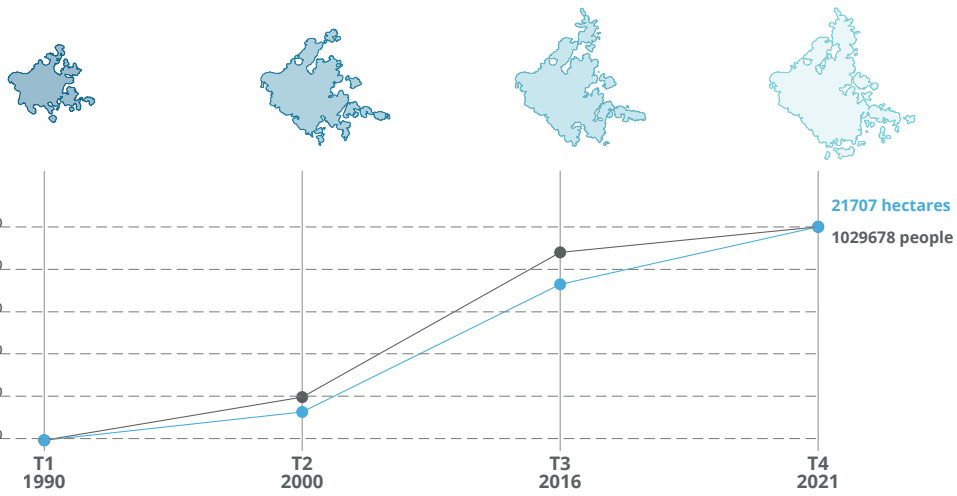
Population Growth
annual change
rank
24th (T4-T3) 9th (T2-T1)

Urban Extent
annual change
rank
52nd (T4-T3) 4th (T2-T1)

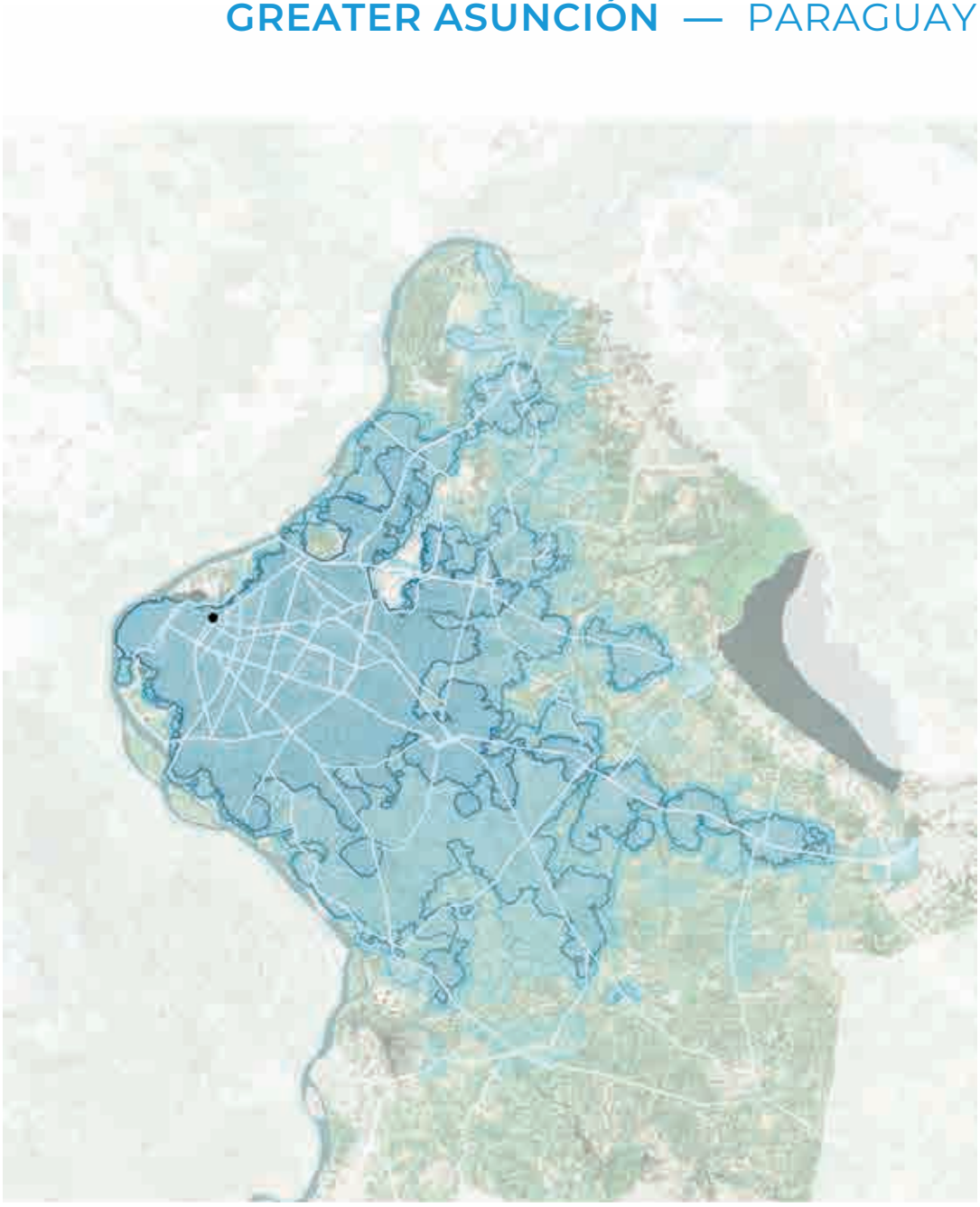
Urban population density
annual change
rank
54th (T2-T1) 11th (T4-T3)

Compactness
rank
19th (T1) 14th (T4)

Saturation
rank
63rd (T4) 56th (T1)



GREATER ASUNCIÓN — PARAGUAY



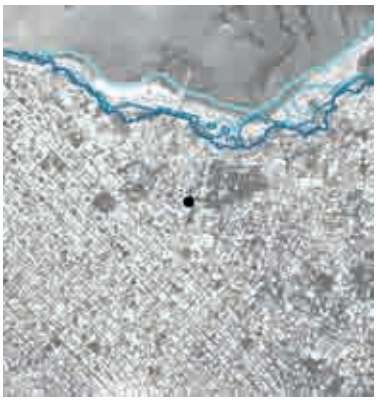
● Central Business District N -25.283266
E -57.623281

1990 T1 | 2000 T2 | 2016 T3 | 2021 T4

highways

local streets

0 2.5 km



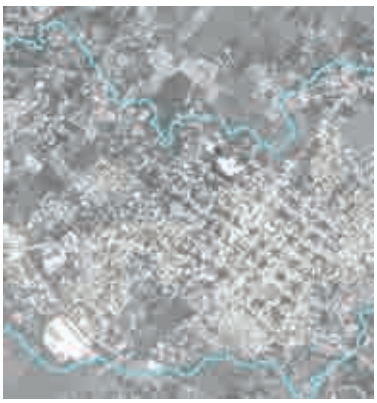
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, it is notable how, between 2010 and 2020, infill represented 48% of the city's growth—an increase compared to 32% (1990-2000). Extension has decreased its significance over the years, as it represented 25% in 1990-2000 in contrast to 16% in 2010-2020. Leapfrog's contribution to Greater Asunción's urban expansion was 23% (1990-2000) and reached 11% (2010-2020). Additionally, inclusion varied its contribution to the city's expansion from 22% (1990-2000) to 26% (2010-2020).

In Greater Asunción, the average occupancy for dwelling units is 4.9, the highest in this study and 45% greater than the average of all cities. Additionally, the building story height average is 1.2 stories, and the residential plot coverage of Greater Asunción is 26.9%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

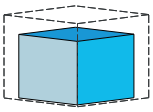
The urban extent of Greater Asunción increased by approximately 3.7% annually over the last decades, increasing threefold since 1990.

avg 3.4 people per dwelling unit



4.9 people per dwelling unit

avg 1.6 stories building height

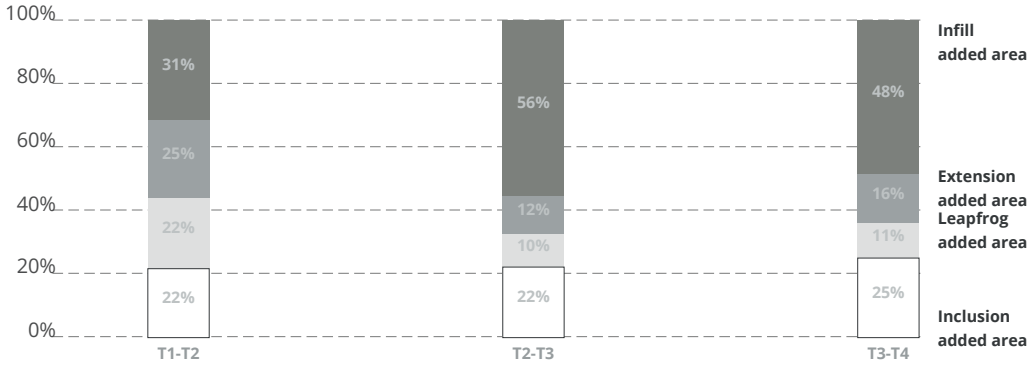


1.2 stories building height

avg 44% plot coverage

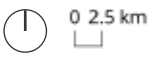


27% plot coverage





Section Profile 44 km





03 /

INLAND CITY
ELEVATION: 2862m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

Ayacucho,* Peru, is located in the biome Tropical & Subtropical Moist Broadleaf Forests, at 2862 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 3.2% per year, from 86.7 thousand to 228.1 thousand. Ayacucho has a moderate population density compared to the other cities: 61.3 inhabitants per hectare, and ranks 18th in population density variation (%) in 2010-2020. Its urban extent increased by approximately 3.2% annually over the last decades and reached an extent of 2.6 times what it was in 1990. The fast increase in urban extent is also noticeable in comparison to the sample, as the city went from 48th (1990-2000) to 22st (2010-2020) place. The city became more compact compared to other LAC cities and had an increase in saturation, rising from 45th to 39th between 1990 and 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

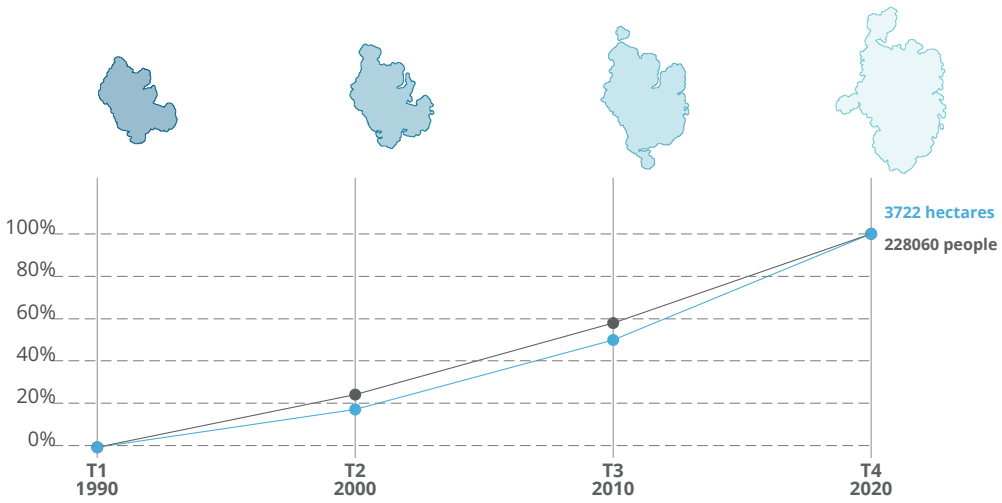


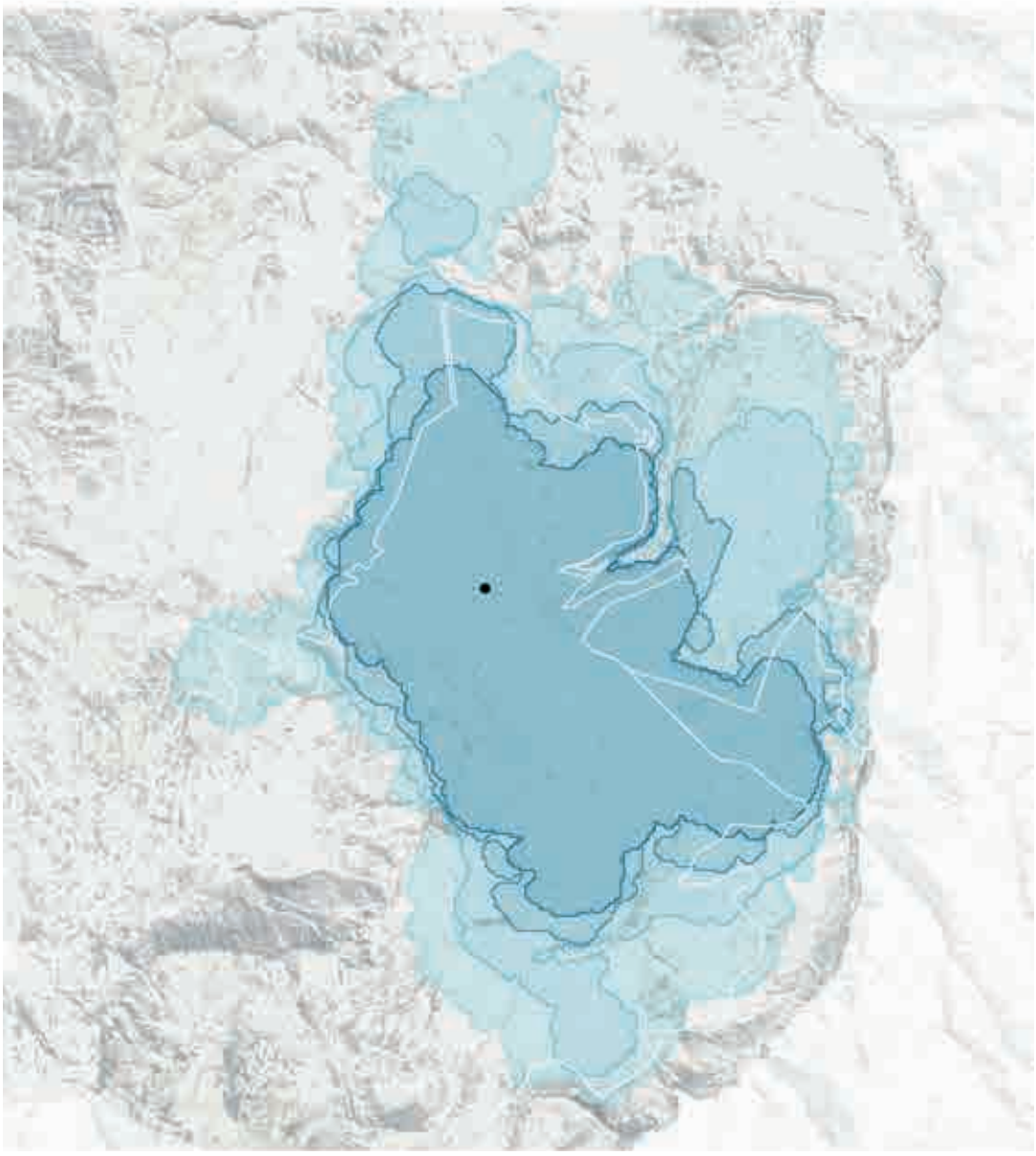
Compactness
rank



Saturation
rank







● Central Business District N -13.160275
E -74.225603

1990 T1 | 2000 T2 | 2016 T3 | 2021 T4

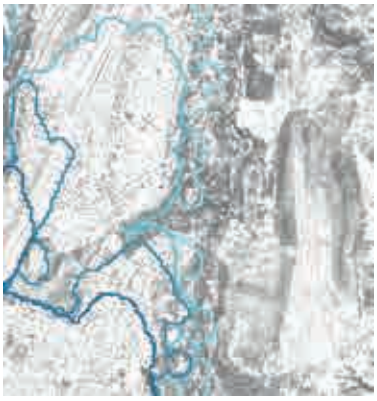
highways

local streets

0 2.5 km



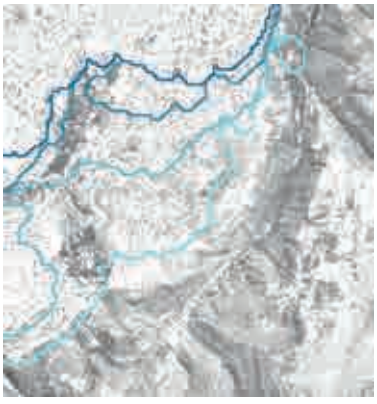
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Ayacucho have been decreasing its contribution to the city's growth: from 52% (1990-2000) to 36% (2010-2020). Extension's predominance is noticeable over the years, as it represented 38% in 1990-2000 and 42% in 2010-2020. Leapfrog's contribution to Ayacucho's urban expansion more than doubled, and inclusion also had a meaningful increase in its contribution to the city's expansion from 7% (1990-2000) to 12% (2010-2020).

The dwelling unit occupancy in Ayacucho is 3.1 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.5 stories. The residential plot coverage of Ayacucho is 48%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

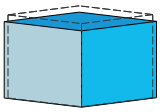
Its urban extent increased by approximately 3.2% annually over the last decades and reached an extent of 2.6 times what it was in 1990.

avg 3.4 people per dwelling unit



3.1 people per dwelling unit

avg 1.6 stories building height

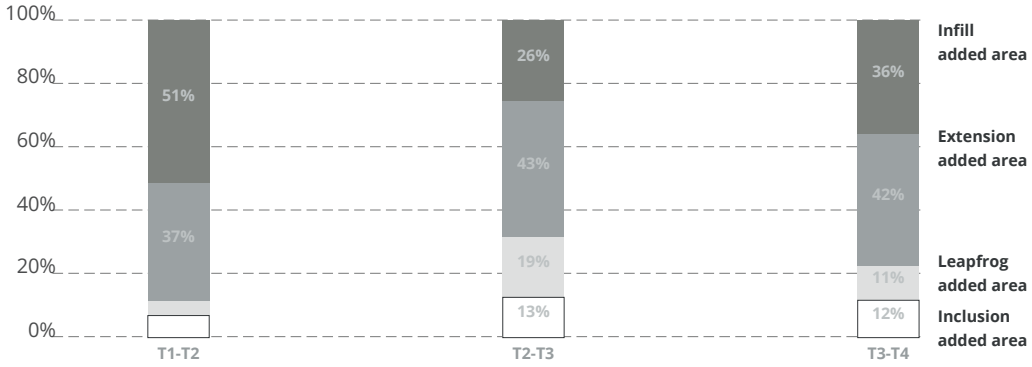


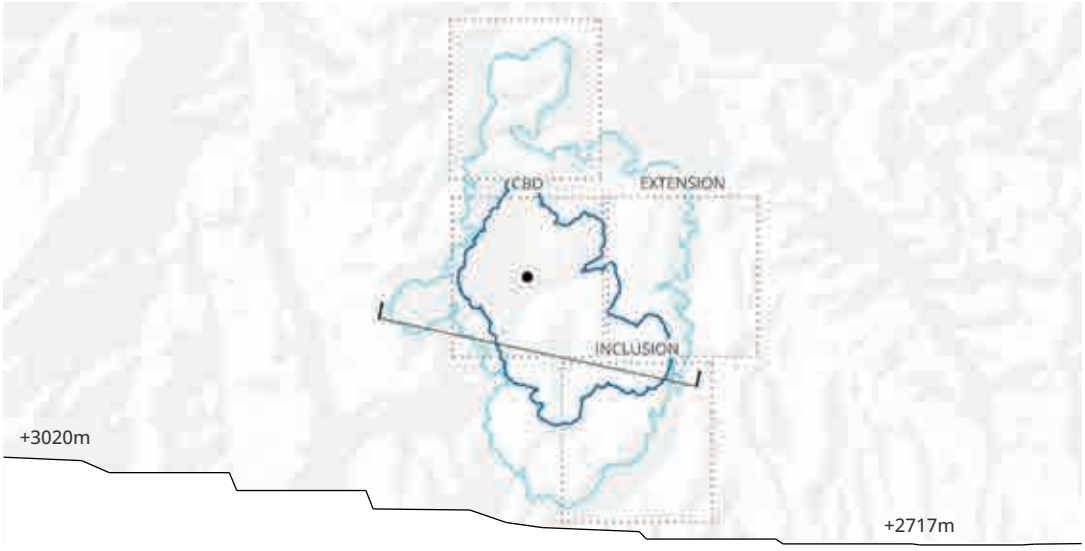
1.5 stories building height

avg 44% plot coverage



48% plot coverage





Section Profile 7 km





04 /

COASTAL CITY
ELEVATION: 7m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

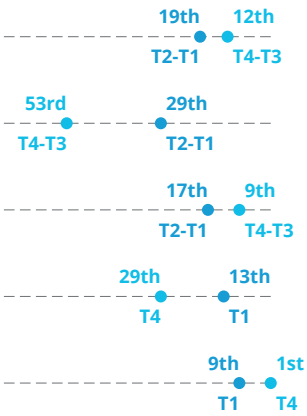
Greater Barranquilla,**Colombia, is located in the biome Deserts & Xeric Shrublands, at 7 meters above sea level. Between 1991 and 2019, it experienced a population growth of approximately 2.2% per year, from 1.1 million to 2.1 million. Greater Barranquilla has a high population density compared to the other cities: 126.1 inhabitants per hectare, rising from 17th (1991-1999) to 9th in population density variation (%) in 2011-2019. Additionally, urban extent increased by approximately 2.1% annually over the last decades, resulting in an area 1.8 times larger than what it was in 1991. The city became less compact compared to other LAC cities, dropping from 15th in 1991 to 25th in 2019. Saturation increased over the decades, resulting in Greater Barranquilla being the most saturated city in the sample for the 2011-2019 period.

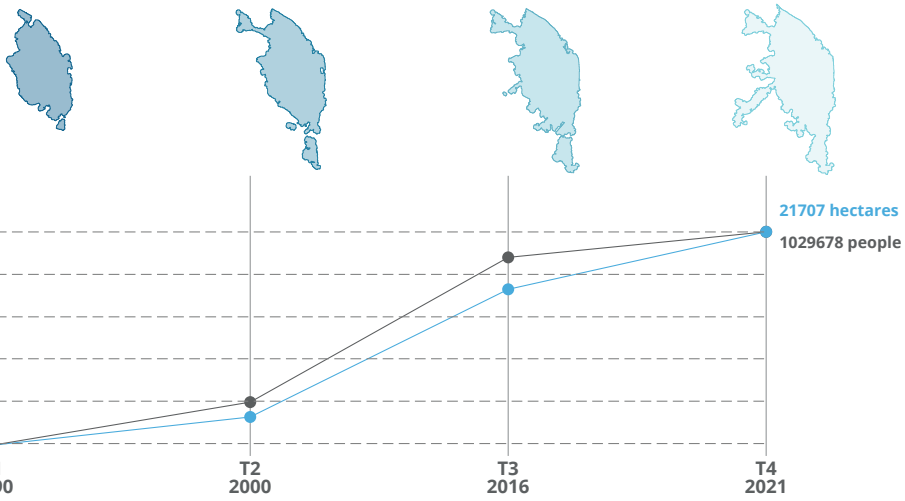




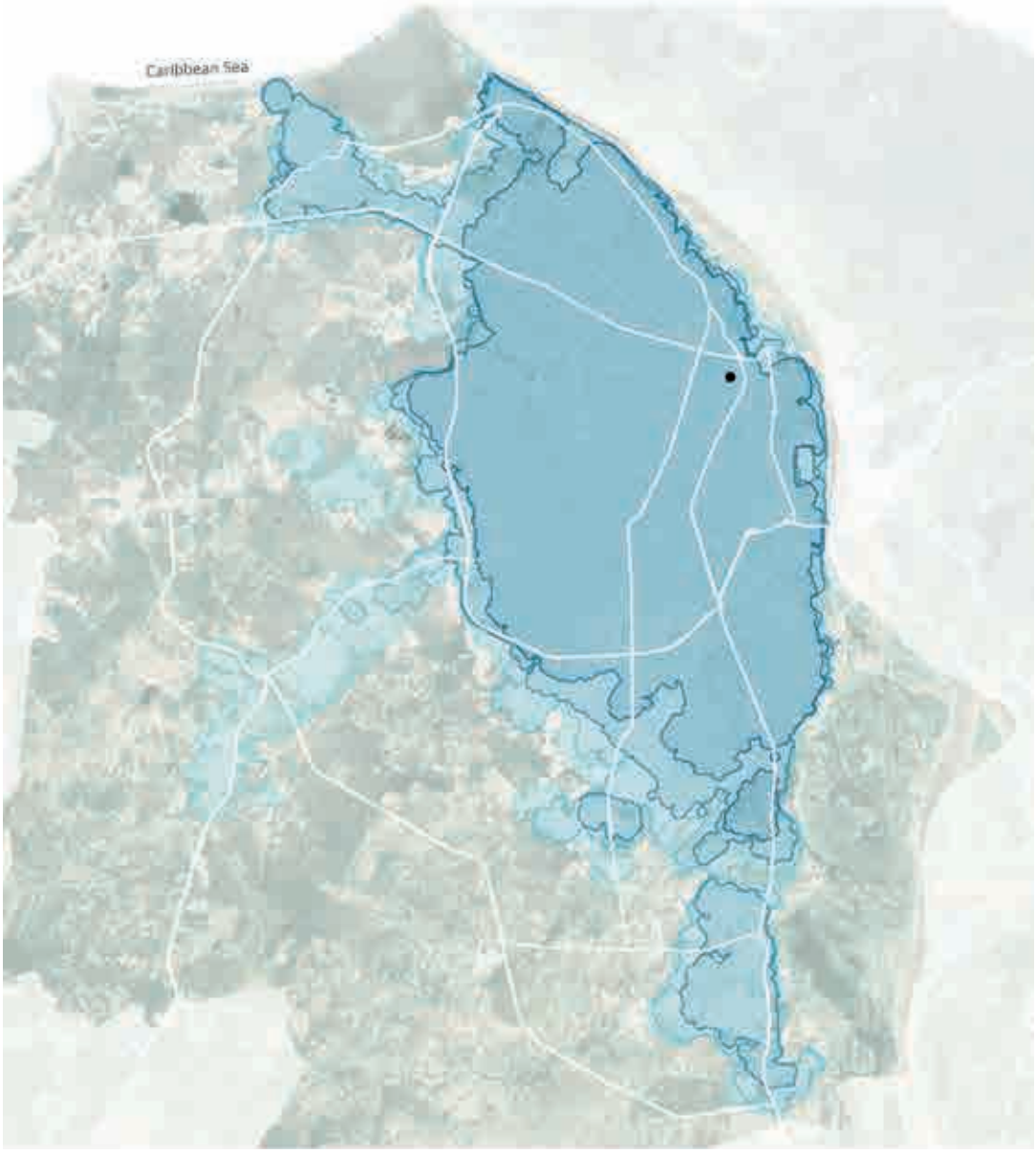
Urban population density
person / hectare

Evaluation metrics rankings:





GREATER BARRANQUILLA — COLOMBIA



● Central Business District N 10.9817204
E -74.778426

1990 T1 | 2000 T2 | 2016 T3 | 2021 T4

highways

local streets

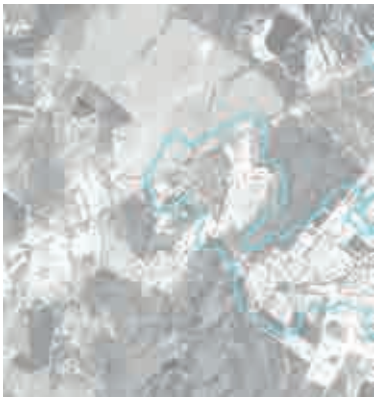
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, the processes of infill in Greater Barranquilla have been decreasing its contribution to the city's growth: from 48% (1991-1999) to 27% (2011-2019). On the other hand, extension doubled its significance over the years, as it represented 21% in 1991-1999 in contrast to 42% in 2011-2019. Leapfrog's contribution decreased to a third, from 14% (1991-1999) to 5% (2011-2019). Additionally, inclusion varied its contribution to the city's expansion from 19% (1991-1999) to 27% (2011-2019).

The dwelling unit occupancy in Greater Barranquilla is 3.7 people per unit, high in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.5 stories. The residential plot coverage of Greater Barranquilla is 69.6%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Saturation increased over the decades, resulting in Greater Barranquilla being the most saturated city in the sample for the 2011-2019 period.

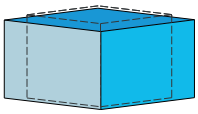
GREATER BARRANQUILLA — COLOMBIA

avg 3.4 people per dwelling unit



3.7 people per dwelling unit

avg 1.6 stories building height

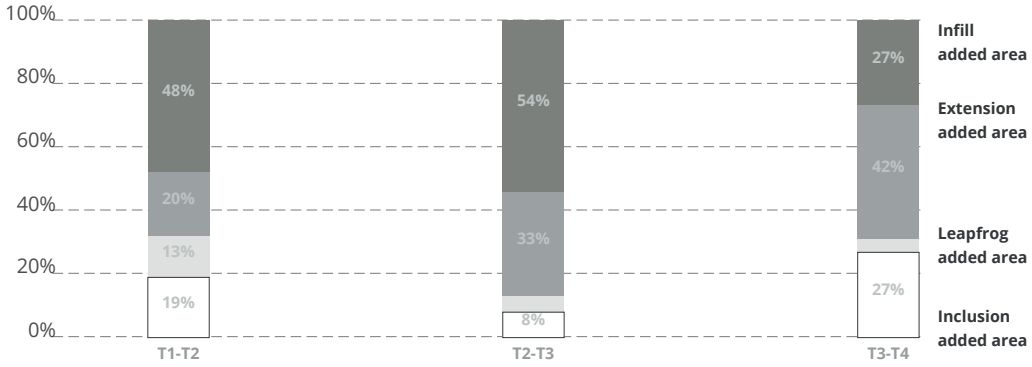


1.5 stories building height

avg 44% plot coverage



70% plot coverage





Section Profile 25 km



1990 T1 — 2021 T4

05 /

COASTAL CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

Belize City,* Belize, is located in the biome Tropical & Subtropical Coniferous Forests, at one meter above sea level. Between 1990 and 2021, it experienced a population growth of approximately 1.5% per year, from 38.6 thousand to 61.8 thousand. Belize City has a moderate population density compared to the other cities: 43.6 inhabitants per hectare. However, over the past decade, Belize City has densified its urban extension, ranking 2nd in variation in the sample (2010-2021). Even more remarkable is that the city previously ranked at the bottom of the list. Additionally, urban extent increased by approximately 2.7% annually over the last decades, however, considering the variation in the ranking, Belize City plummeted from 5th to 68th. The city became less compact compared to other LAC cities, and such a decrease was accompanied by a spike in saturation, rising 44 positions from 49th to 5th.

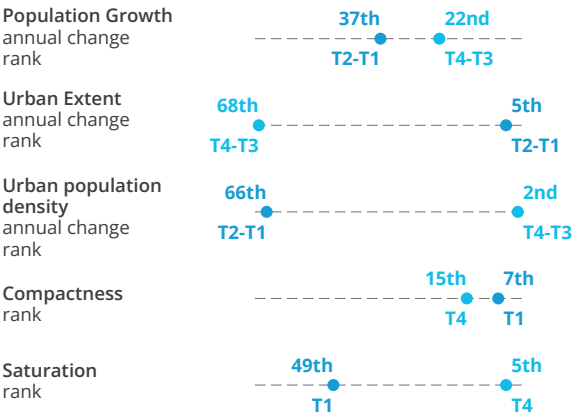


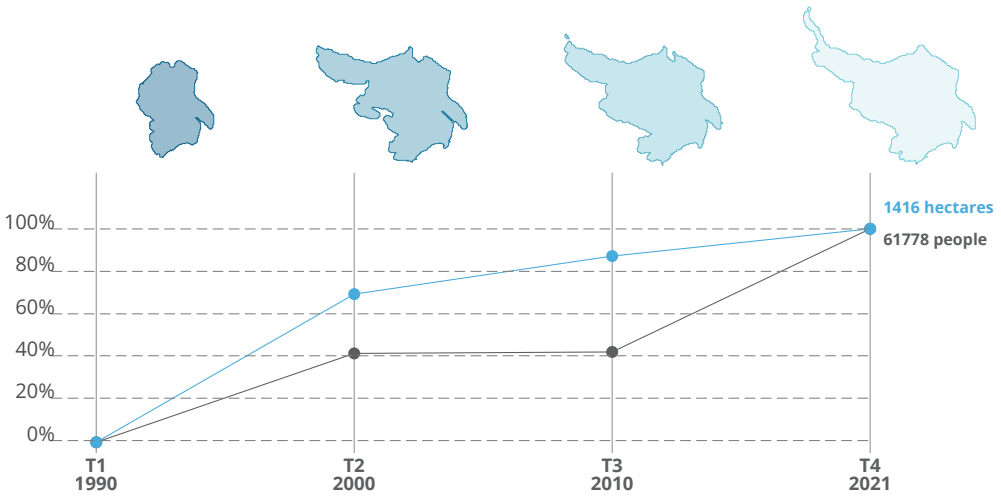
2021=44

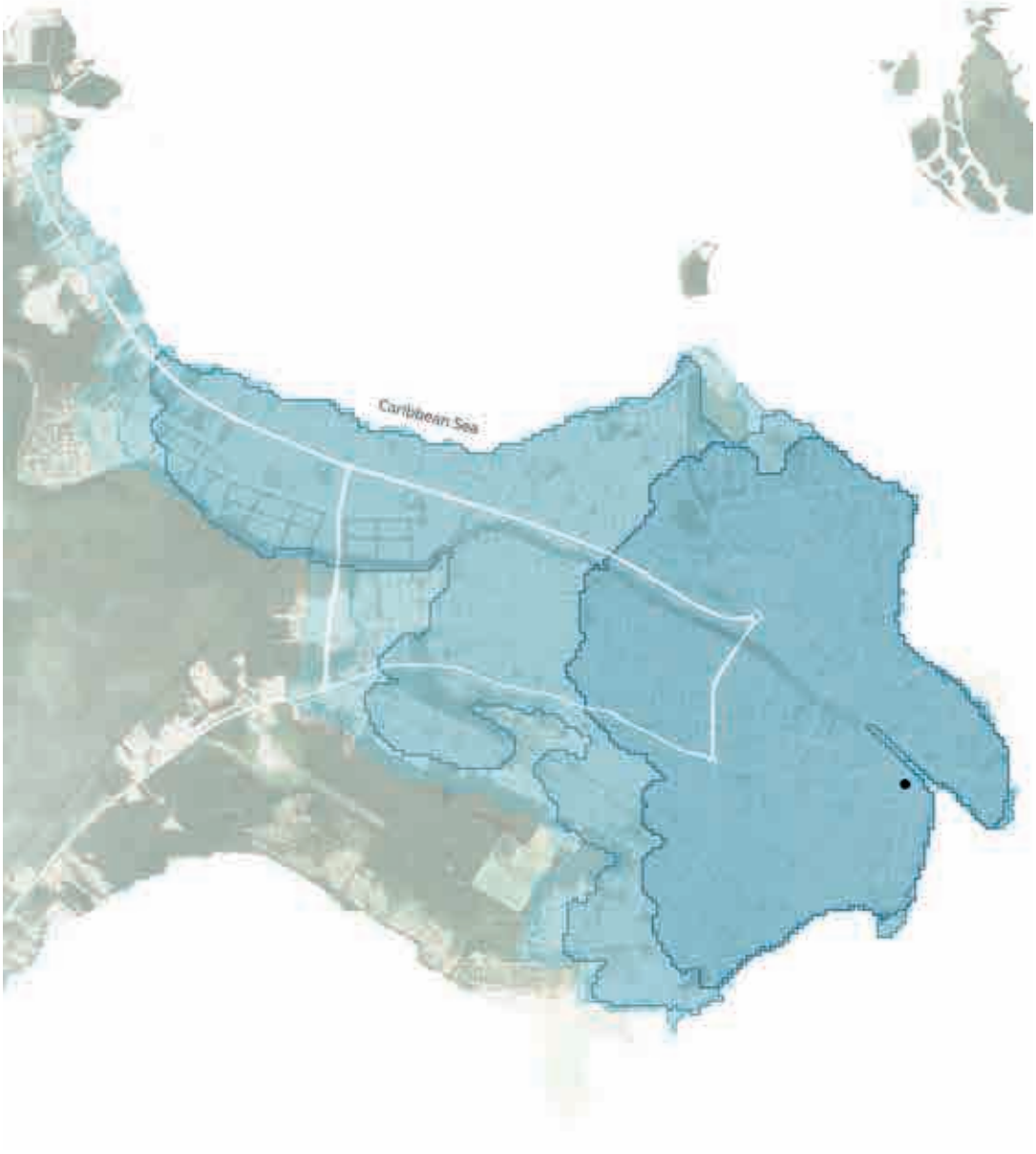
1990=62

Urban population density
person / hectare

Evaluation metrics rankings:







● Central Business District N 17.4942160
E -88.187421

1990 T1 | 2000 T2 | 2016 T3 | 2021 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Belize City have been increasing its contribution to the city's growth: from 29% (1990-2000) to 43% (2010-2021). Extension has decreased its significance over the years, as it represented 37% in 1990-2000 in contrast to 29% in 2010-2021. Leapfrog processes in Belize City dropped from 21% (1990-2000) to 1% (2010-2021), whereas inclusion almost doubled its contribution to the city's expansion from 15% (1990-2000) to 29% (2010-2021).

Leapfrog processes in Belize City dropped from 21% (1990-2000) to 1% (2010-2021), whereas inclusion almost doubled its contribution to the city's expansion.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



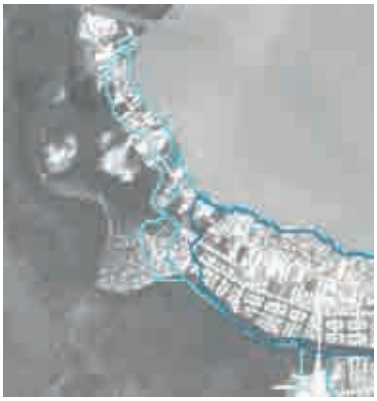
Central Business District



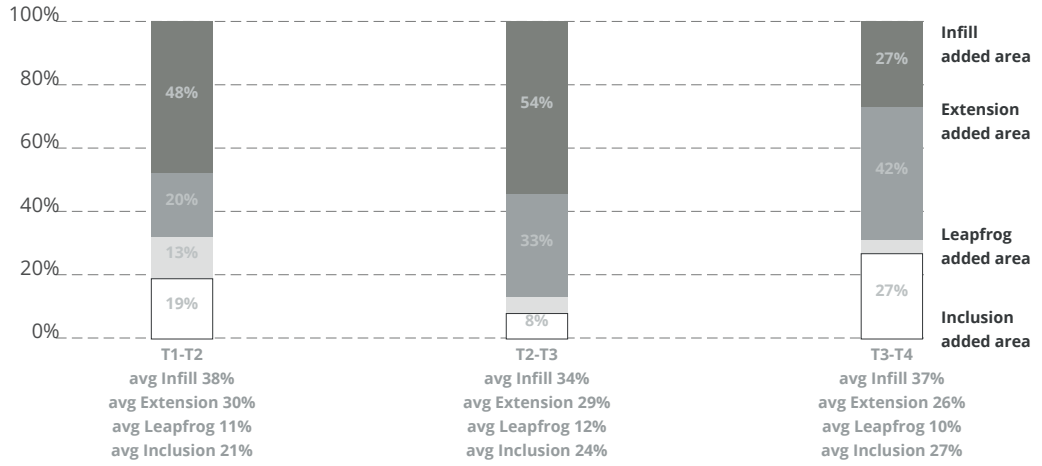
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
48%
20%
13%
19%
54%
33%
8%
27%
42%
27%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
INCLUSION
EXTENSION
CBD
0
2.5 km
1990 T1
2021 T4

06 /

INLAND CITY
ELEVATION: 51m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS, SAVANNAS / SHRUBLANDS

Greater Belo Horizonte,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at 877 meters above sea level. Between 1989 and 2020, it experienced a population growth of approximately 1.5% per year, from 2.7 million to 4.3 million. Greater Belo Horizonte has a moderate population density compared to the other cities: 57.4 inhabitants per hectare. Considering population density annual change (%), Greater Belo Horizonte ranked 8th in 1989-2000 in comparison to other LAC cities, but in 2013-2020 it lowered to 38th. The city's urban extent increased by approximately 1.4% annually over the last decades, resulting in 1.6 times what it was in 1989. In this process, Greater Belo Horizonte became more compact compared to other LAC cities, rising from 38th in the period 1989 to 32nd in 2020. Such an increase is accompanied by a slight rise in saturation, from 19th to 17th place.





Urban population density
person / hectare

Evaluation metrics rankings:

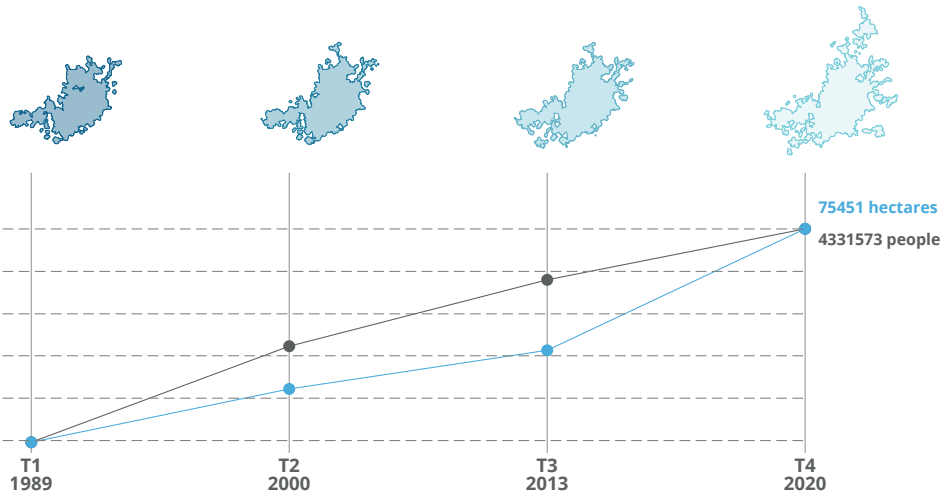
Population Growth
annual change rank
44th (T4-T3) 40th (T2-T1)

Urban Extent
annual change rank
65th (T2-T1) 32nd (T4-T3)

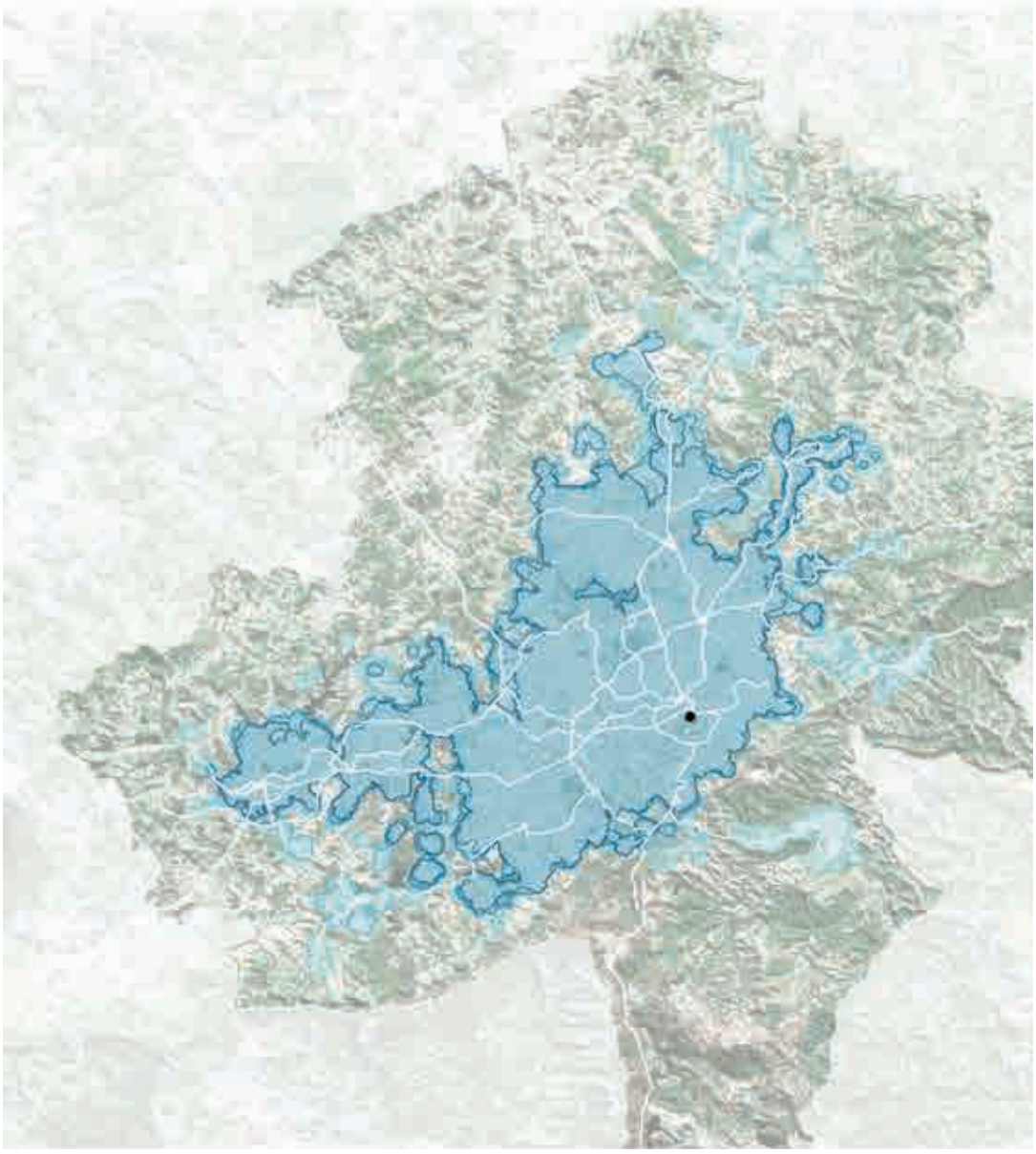
Urban population density
annual change rank
38th (T4-T3) 8th (T2-T1)

Compactness
rank
38th (T1) 32nd (T4)

Saturation
rank
19th (T1) 17th (T4)



GREATER BELO HORIZONTE — BRAZIL



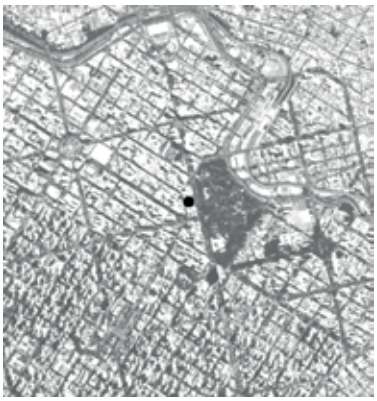
● Central Business District N -19.923763
E -43.936423

1990 T1 | 2000 T2 | 2016 T3 | 2021 T4

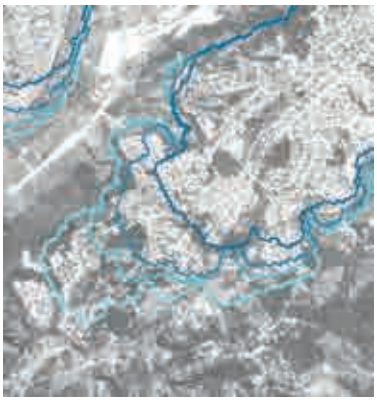
highways

local streets

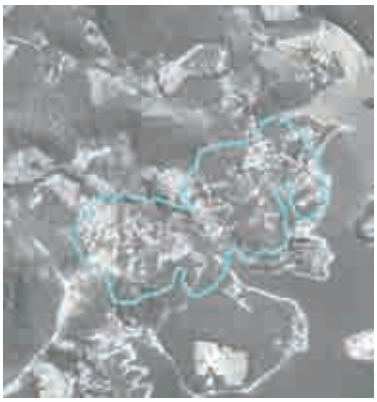
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Belo Horizonte have been decreasing its contribution to the city's growth: from 57% (1989-2000) to 39% (2013-2020). Extension has also decreased its significance over the years, as it represented 23% in 1989-2000 in contrast to 15% in 2013-2020, whereas Leapfrogslightly increased. Additionally, inclusion's contribution to Greater Belo Horizonte's urban expansion more than doubled its contribution to the city's expansion, from 16% (1989-2000) to 39% (2013-2020).

The average dwelling unit occupancy in Greater Belo Horizonte is 3.2 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.9 stories. The residential plot coverage of Greater Belo Horizonte is 41.9%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Inclusion's contribution to Greater Belo Horizonte's urban expansion more than doubled its contribution to the city's expansion, from 16% (1989-2000) to 39% (2013-2020).

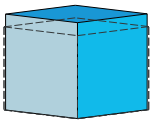
GREATER BELO HORIZONTE — BRAZIL

avg 3.4 people per dwelling unit



3.2 people per dwelling unit

avg 1.6 stories building height

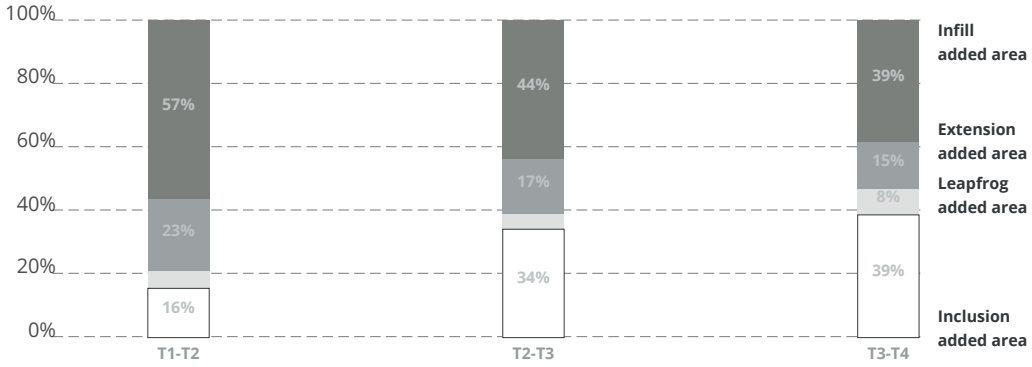


1.9 stories building height

avg 44% plot coverage



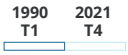
42% plot coverage





Section Profile 77 km



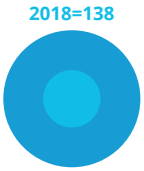


07 /

INLAND CITY
ELEVATION: 2620m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Greater Bogotá,* Colombia, is located in the biome Montane Grasslands & Shrublands, at 2620 meters above sea level. Between 1991 and 2018, it experienced a population growth of approximately 2.2% per year, from 4.9 million to 8.8 million. Bogota's population density is high compared to the other cities—137.7 inhabitants per hectare—however, in recent years, the city has not been densifying at a fast rate in comparison to the region, ranking 60th in population density annual variation (%) in 2015-2018. Its urban extent increased by approximately 2.5% annually over the last decades, reaching an area two times what it was in 1991. This expansion was more significant along plains to the north and west of the city's center. Greater Bogotá became less compact compared to other LAC cities, lowering from 35th in 1991 to 39th in 2018, but its saturation barely changed in relation to the sample (14th to 13th).





Urban population density
person / hectare

Evaluation metrics rankings:

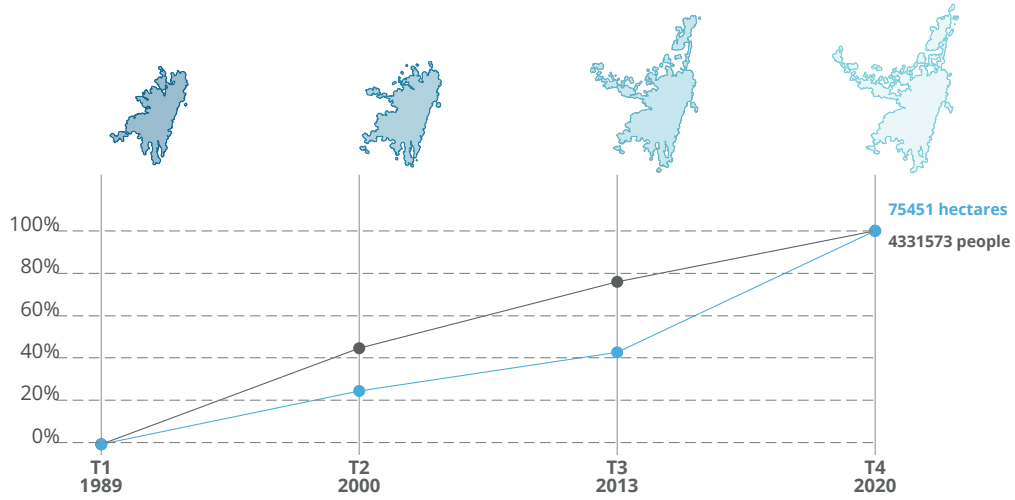
Population Growth
annual change rank
30th 29th
T2-T1 T4-T3

Urban Extent
annual change rank
60th 11th
T2-T1 T4-T3

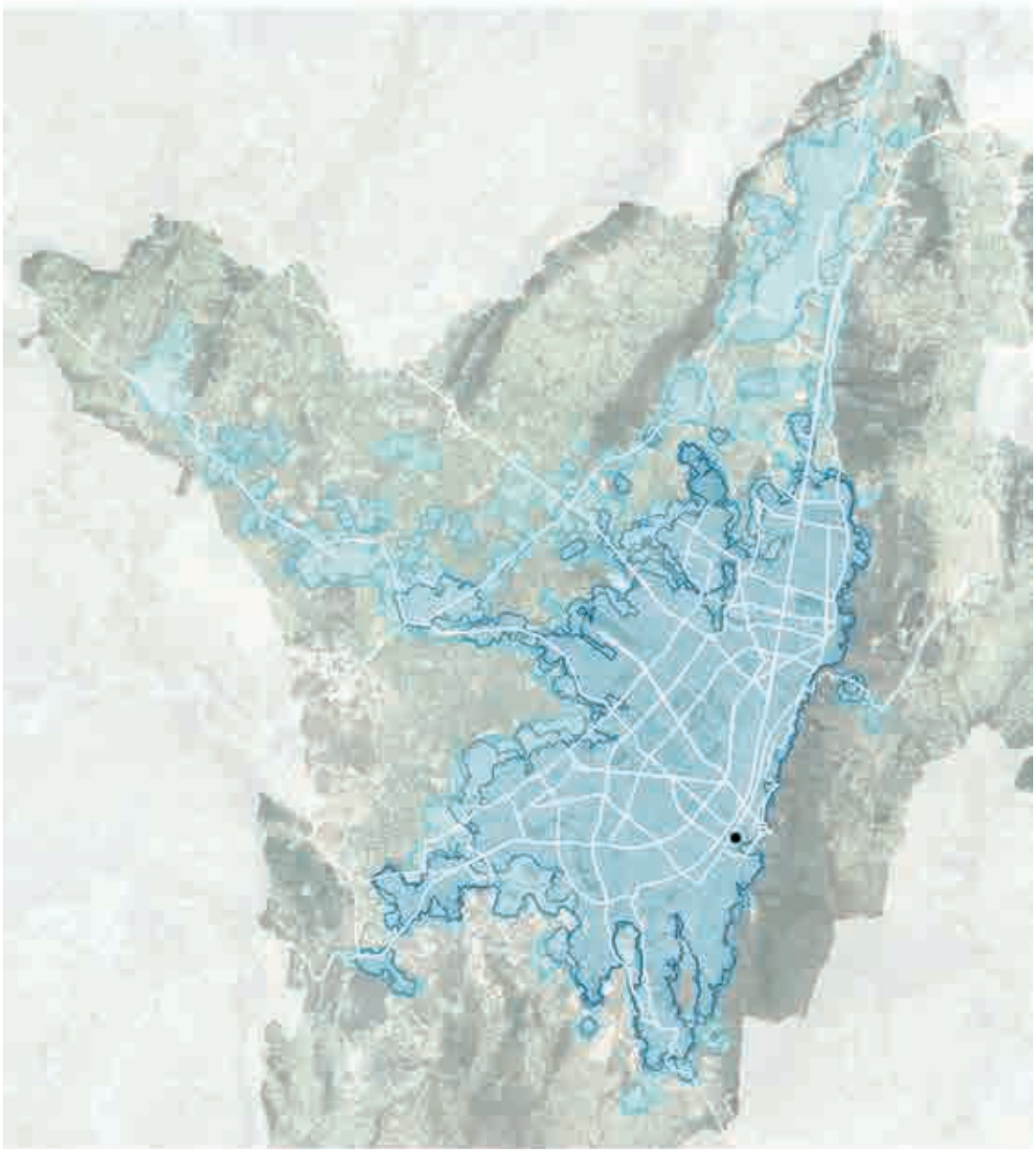
Urban population density
annual change rank
60th 9th
T4-T3 T2-T1

Compactness
rank
39th 35th
T4 T1

Saturation
rank
14th 13th
T1 T4



GREATER BOGOTÁ — COLOMBIA



● Central Business District N 4.59842799
E -74.076515

1990 T1 | 2000 T2 | 2016 T3 | 2021 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

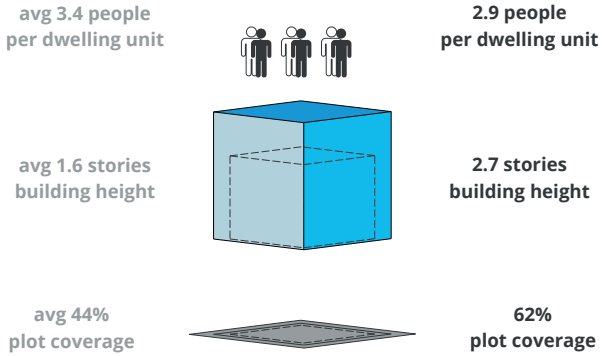
The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing each one of these processes in urban expansion in the last periods, processes of infill in Greater Bogotá have been decreasing its contribution to the city's growth: from 49% (1991-2003) to 36% (2015-2018). Moreover, inclusion increased from 13% (1991-2003) to 31% (2015-2018). In the meantime, extension slightly decreased its significance, as it represented 33% in 1991-2003 in contrast to 28% in 2015-2018, while leapfrog maintained its contribution to urban expansion.

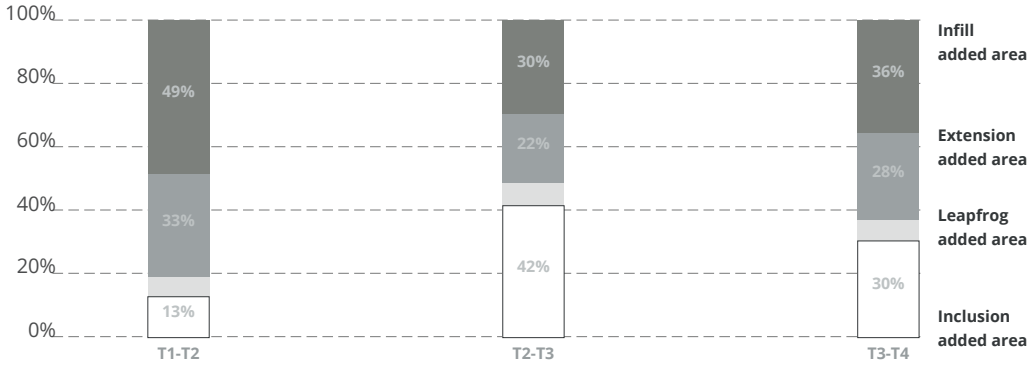
In Greater Bogotá, the average dwelling unit occupancy is 2.9 people per unit. The building story height average is 2.7 stories, high in comparison to the average of the cities in this Atlas, and the residential plot coverage is 62.4%.

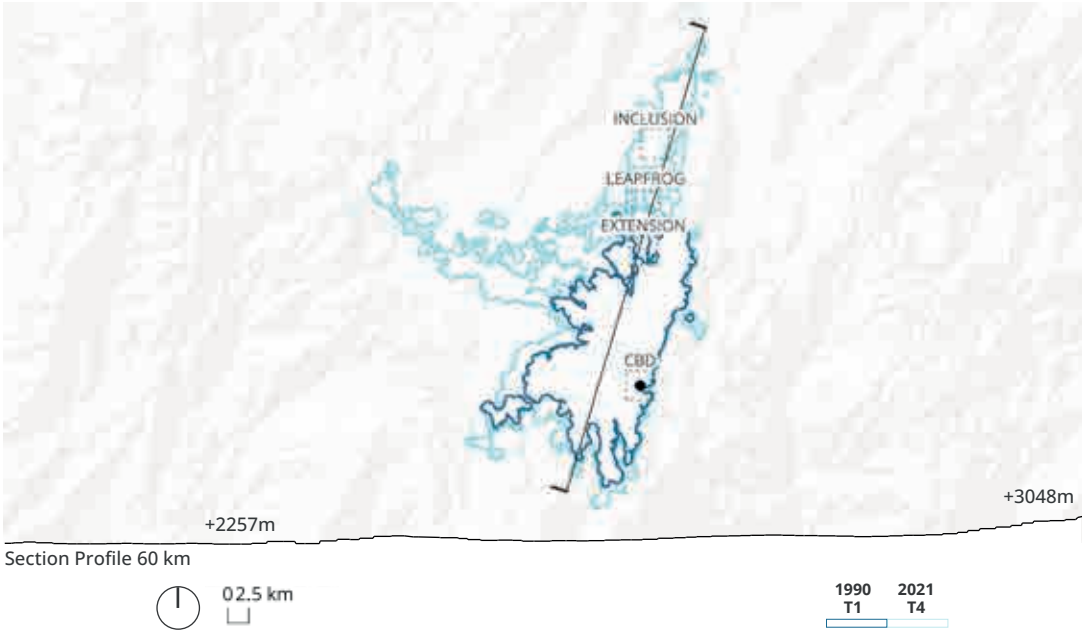
* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Bogota's population density is high compared to the other cities—137.7 inhabitants per hectare—however, in recent years, the city has not been densifying at a fast rate in comparison to the region, ranking 61st in population density annual variation (%) in 2015-2018.


avg 3.4 people
per dwelling unit
2.9 people
per dwelling unit
avg 1.6 stories
building height
2.7 stories
building height
avg 44%
plot coverage
62%
plot coverage


100%
80%
60%
40%
20%
0%
49%
33%
13%
30%
22%
42%
36%
28%
30%
T1-T2
T2-T3
T3-T4
Infill
added area
Extension
added area
Leapfrog
added area
Inclusion
added area


INCLUSION
LEAPFROG
EXTENSION
CBD
+3048m
+2257m
Section Profile 60 km
0 2.5 km
1990
T1
2021
T4

08 /

COASTAL CITY
ELEVATION: 1m
BIOME: DESERTS / XERIC SHRUBLANDS

Bridgetown,* Barbados, is located in the biome Deserts & Xeric Shrublands, at one meter above sea level. From 1991 to 2021, it experienced a population growth of approximately 1.6% per year, from 139.5 thousand to 225.2 thousand. Bridgetown has a low population density compared to the other cities: 16.7 inhabitants per hectare, and ranks 34th in population density variation (%) in 2010-2021—though it represents an increase from the previous mark of 61nd (1991-2000). Its urban extent increased by approximately 3.2% annually in the last forty years, resulting in 2.6 times what it was in 1991. The city became even less compact compared to other LAC cities, lowering from 64th in 1991 to 66th in 2021. Such a decrease is accompanied by an increase in the ranking of saturation, rising 12 positions between 1991 and 2021.





2021=17

1991=27

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank

55th T2-T1 — 20th T4-T3

Urban Extent
annual change
rank

53rd T4-T3 — 29th T2-T1

Urban population density
annual change
rank

56th T4-T3 — 42nd T2-T1

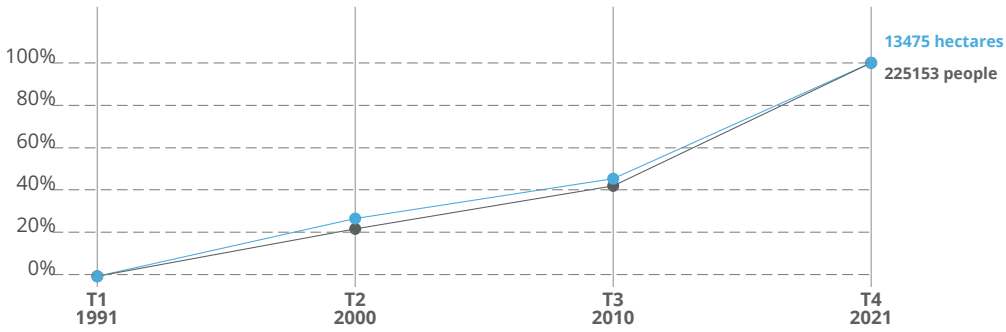
Compactness
rank

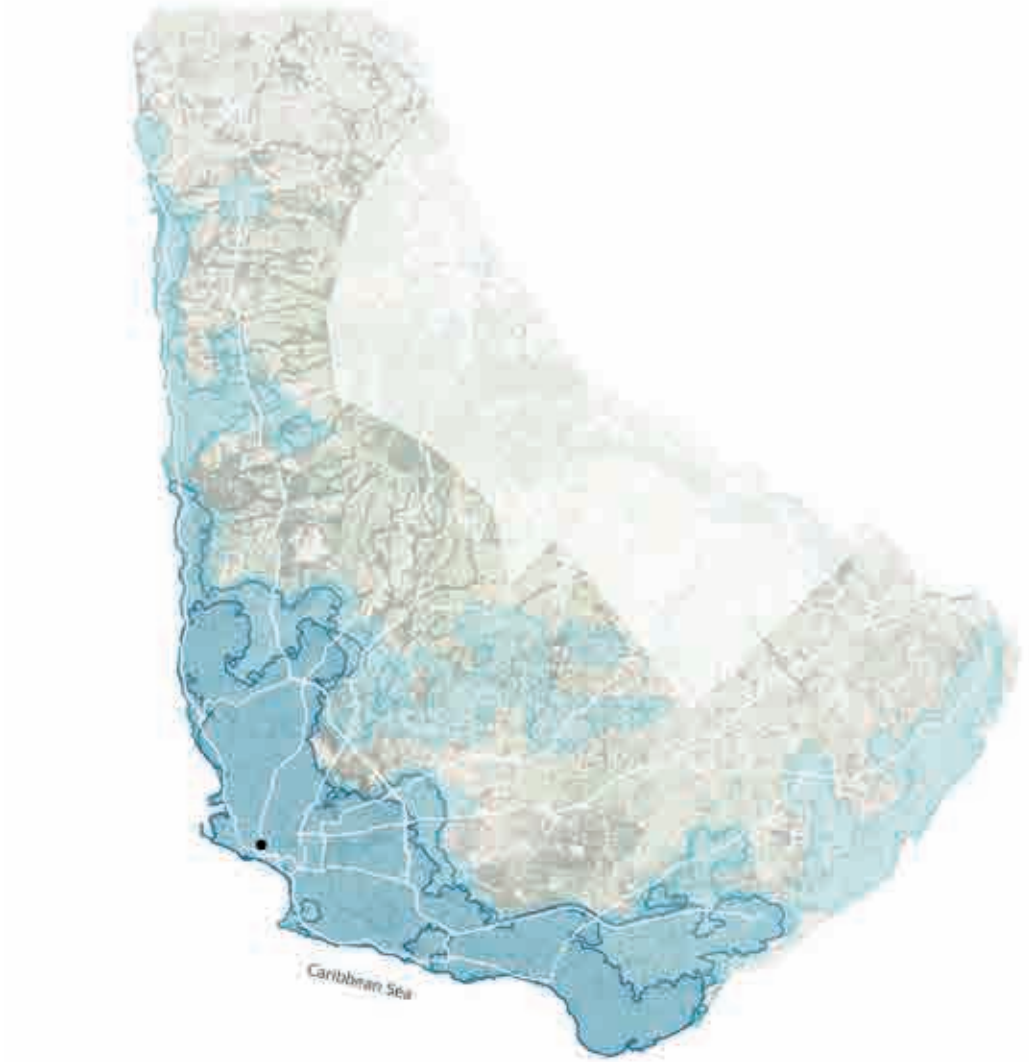
66th T4 — 64th T1

Saturation
rank

53rd T4 — 30th T1







● Central Business District N 13.0994685
E -59.617304

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km



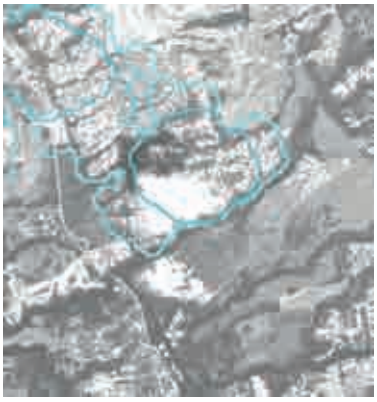
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Bridgetown have been decreasing its contribution to the city's growth: from 51% (1991-2000) to 38% (2010-2021). Extension has halved its significance over the years, as it represented 20% in 1991-2000 in contrast to 11% in 2010-2021, whereas Leapfrog's contribution barely decreased from 9% (1991-2000) to 7% (2010-2021). Additionally, most of the new urban expansion in Bridgetown (45%) was through inclusion, double the sample average.

The average dwelling unit occupancy in Bridgetown is 2.8 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.3 stories. The residential plot coverage of Bridgetown is 25.8%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

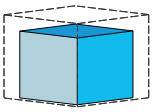
Most of the new urban expansion in Bridgetown (45%) was through inclusion, double the sample average.

avg 3.4 people per dwelling unit



2.8 people per dwelling unit

avg 1.6 stories building height

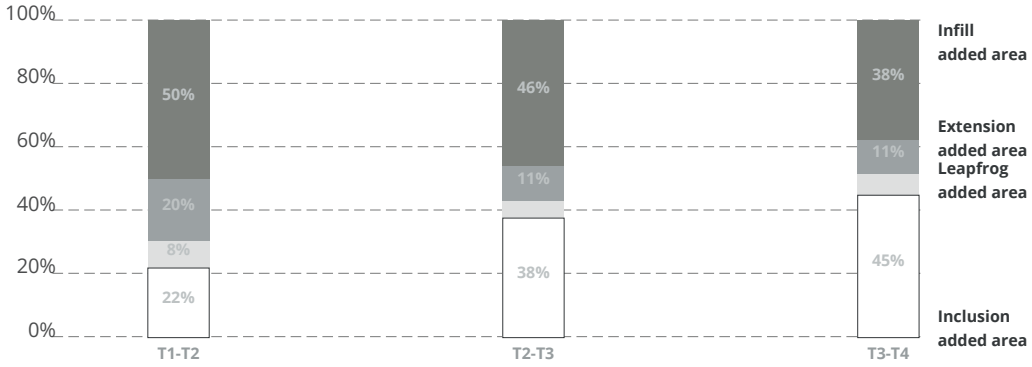


1.3 stories building height

avg 44% plot coverage



26% plot coverage





Section Profile 30 km



1991 T1 2021 T4

09 /

COASTAL CITY
ELEVATION: 18m
BIOME: TEMPERATE GRASSLANDS / SAVANNAS / SHRUBLANDS

Greater Buenos Aires,* Argentina, is located in the biome Temperate Grasslands, Savannas & Shrublands, at 18 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 1.2% per year, from 10.9 million to 15.7 million inhabitants. Greater Buenos Aires has a moderate population density compared to the other cities: 61.1 inhabitants per hectare, ranking 31st in population density variation (%) in 2014-2021. Additionally, urban extent increased by approximately 1.3% annually in the last forty years, expanding 1.5 times what it was in 1990. In this process, Buenos Aires developed the second-largest urban extent in the sample. Such an increase is accompanied by a significant rise in saturation, gaining 19 positions, from 26th to 7th, between 1990 and 2021.





2021=61

1990=63

Urban population density
person / hectare

Evaluation metrics rankings:

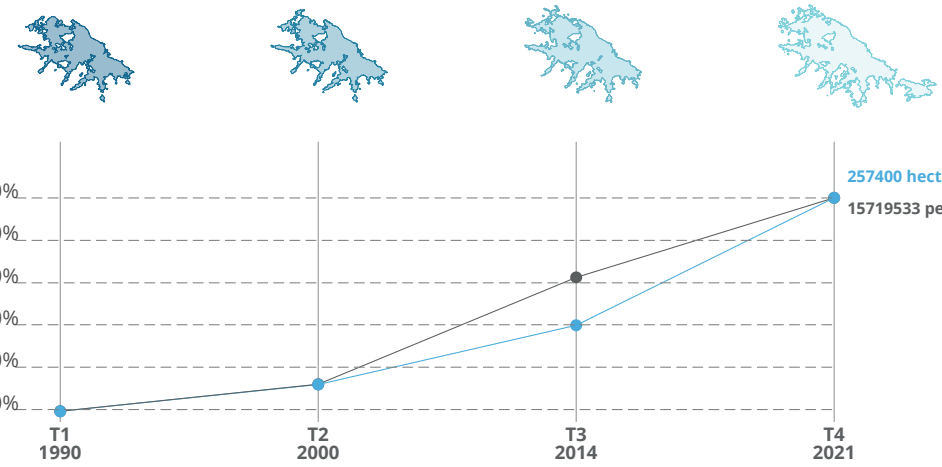
Population Growth
annual change rank
64th T2-T1 — 32nd T4-T3

Urban Extent
annual change rank
65th T2-T1 — 32nd T4-T3

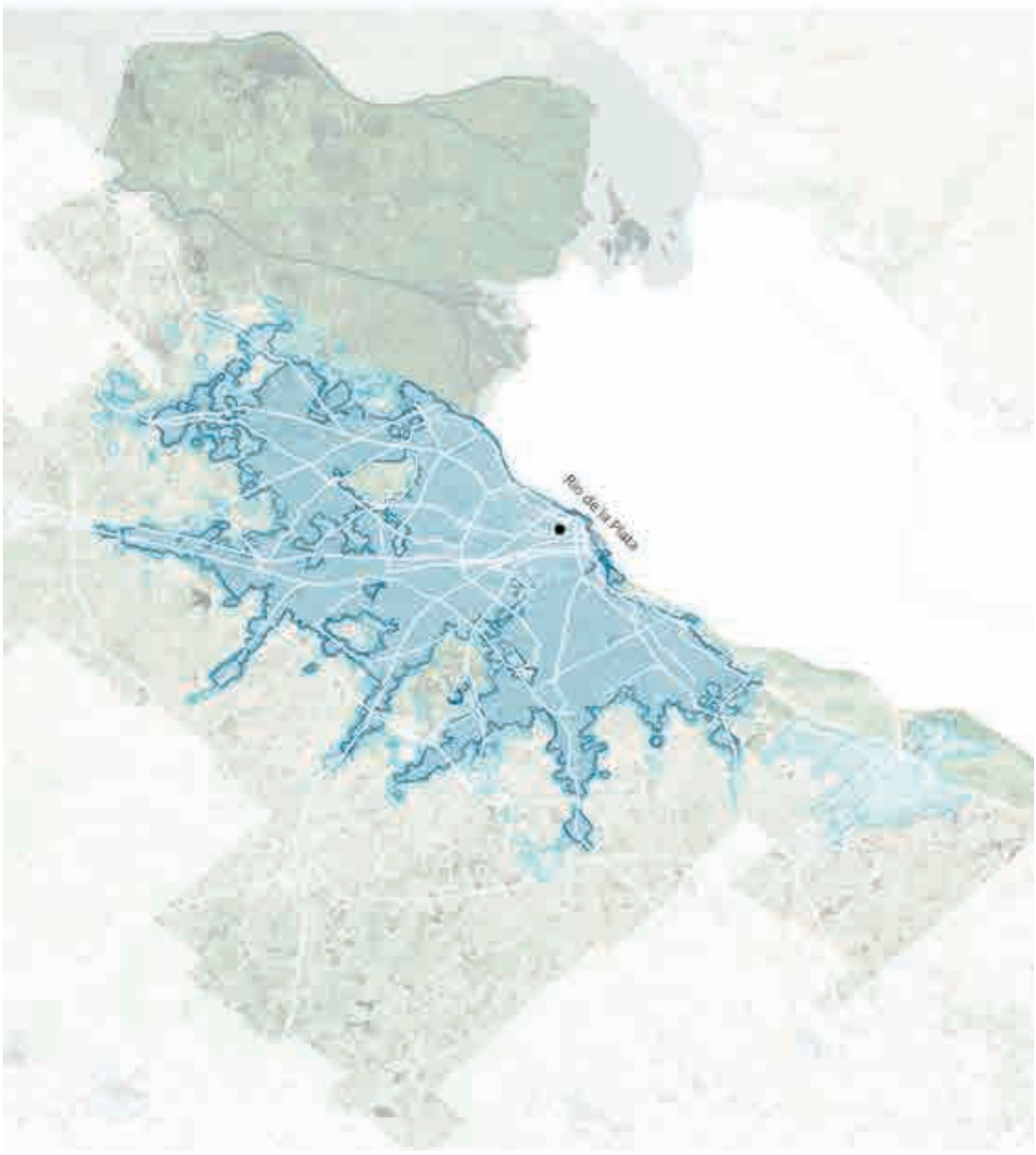
Urban population density
annual change rank
31st T4-T3 — 19th T2-T1

Compactness
rank
38th T1 — 32nd T4

Saturation
rank
26th T1 — 7th T4



GREATER BUENOS AIRES — ARGENTINA



● Central Business District N -34.594719
E -58.402261

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, over the past decade, 57% of Greater Buenos Aires's urban growth was through infill, while the average infill growth for the sample was only 37%. Extension has increased its significance, as it represented 14% in 1990-2000 in contrast to 19% in 2014-2021. Leapfrog's contribution to Greater Buenos Aires's urban expansion was 3% (1990-2000) and reached 11% (2014-2021), while inclusion varied little. Greater Buenos Aires latest decade's increase in urban density regarding the sample and its predominance of infill in urban expansion suggest it as case of well management of urban growth in the region.

The average dwelling unit occupancy in Greater Buenos Aires is 3.4 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.8 stories. The residential plot coverage of Greater Buenos Aires is 36.4%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Over the past decade, 57% of Greater Buenos Aires's urban growth was through infill, while the average infill growth for the sample was only 37%.

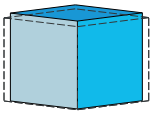
GREATER BUENOS AIRES — ARGENTINA

avg 3.4 people per dwelling unit



3.4 people per dwelling unit

avg 1.6 stories building height

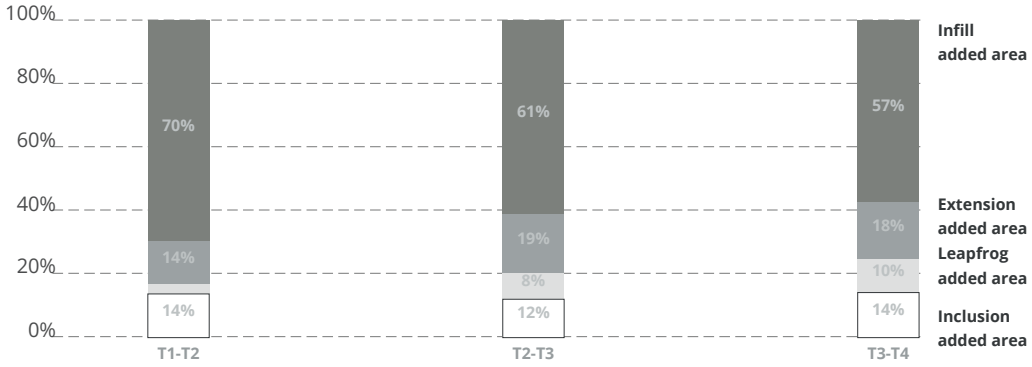


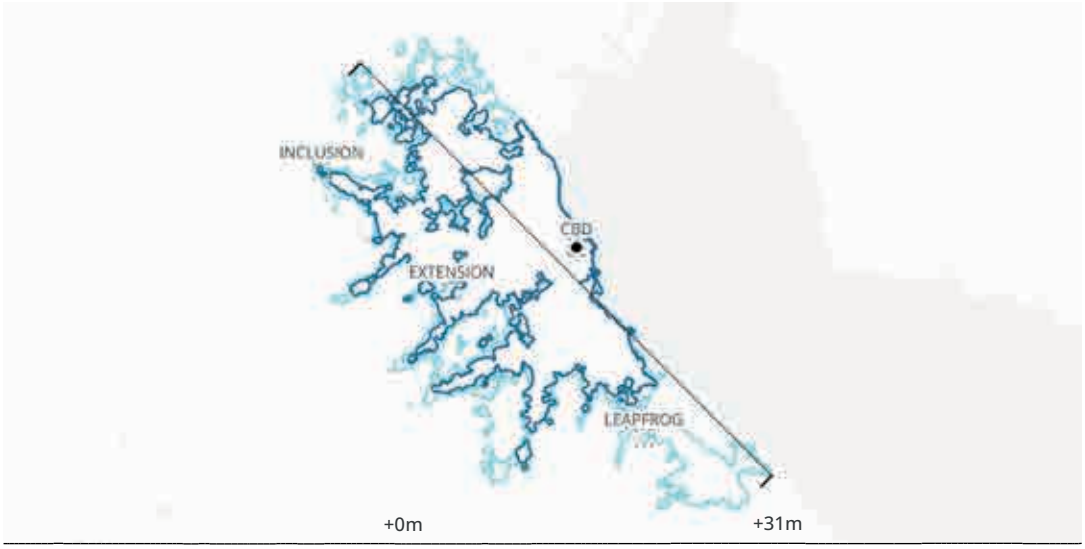
1.8 stories building height

avg 44% plot coverage



36% plot coverage





Section Profile 129 km

2.5 km

1991 T1 2021 T4

10 /

INLAND CITY
ELEVATION: 848m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Cali,* Colombia, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 848 meters above sea level. Between 1989 and 2019, it experienced a population growth of approximately 1.1% per year, from 1.7 million to 2.3 million. Greater Cali has a high population density compared to the other cities: 124.9 inhabitants per hectare, though regarding population density variation (%), it fell 15 positions, reaching 43rd in 2015-2019. Additionally, urban extent increased by approximately 2.2% annually over the last decades, resulting in 1.9 times what it was in 1989. The city became less compact compared to other LAC cities, falling from 16th in 1989 to 31st in 2019. Such a decrease is accompanied by an increase in saturation, rising from 21st to 10th between 1989 and 2019.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

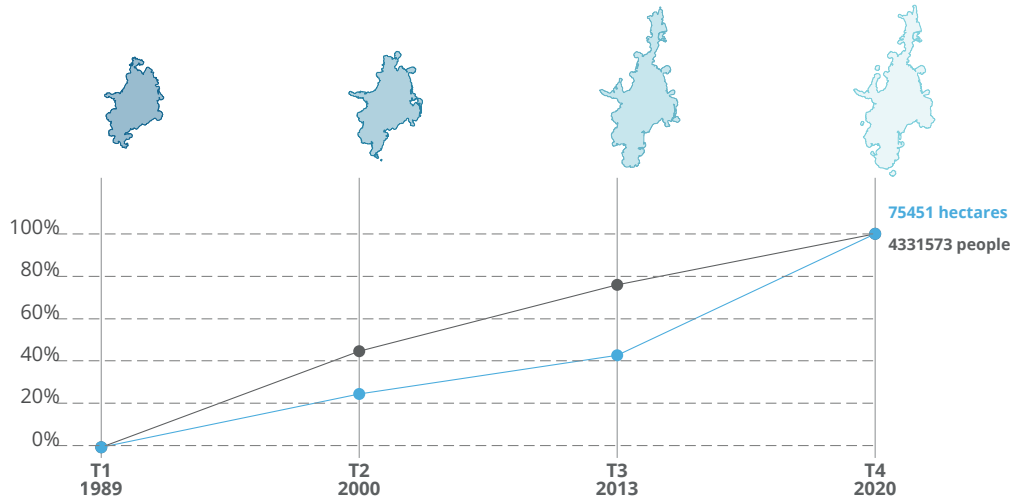


Compactness
rank

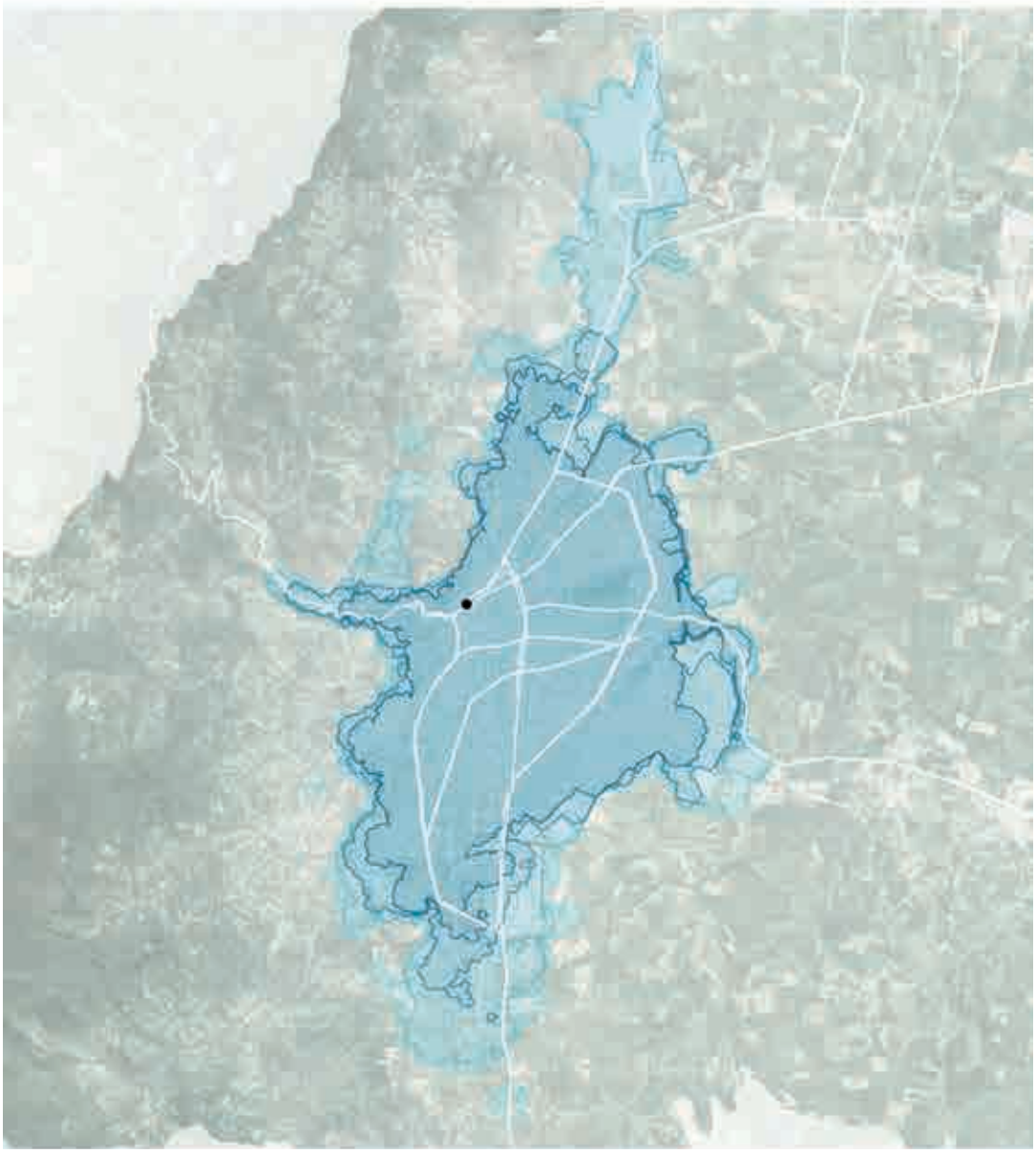


Saturation
rank





GREATER CALI — COLOMBIA



● Central Business District N 3.45411221
E -76.534275

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Cali have not been changing significantly its contribution to the city's growth, just as extension has barely decreased its significance over the years, as it represented 32% in 1989-2003 in contrast to 30% in 2015-2019. Leapfrog followed the trend of the previous processes. Aside from an increase in inclusion's contribution to the city's expansion from 2003-2015 (32%), each process has maintained its relevance over the last decades.

Aside from an increase in inclusion's contribution to the city's expansion from 2003-2015 (32%), each process has maintained its relevance over the last decades.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

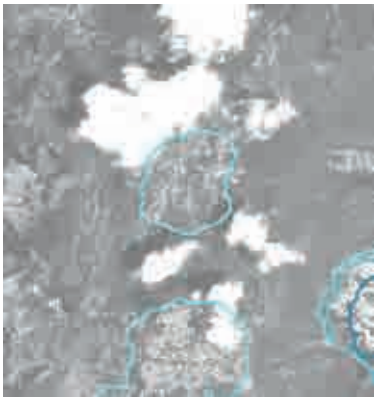
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



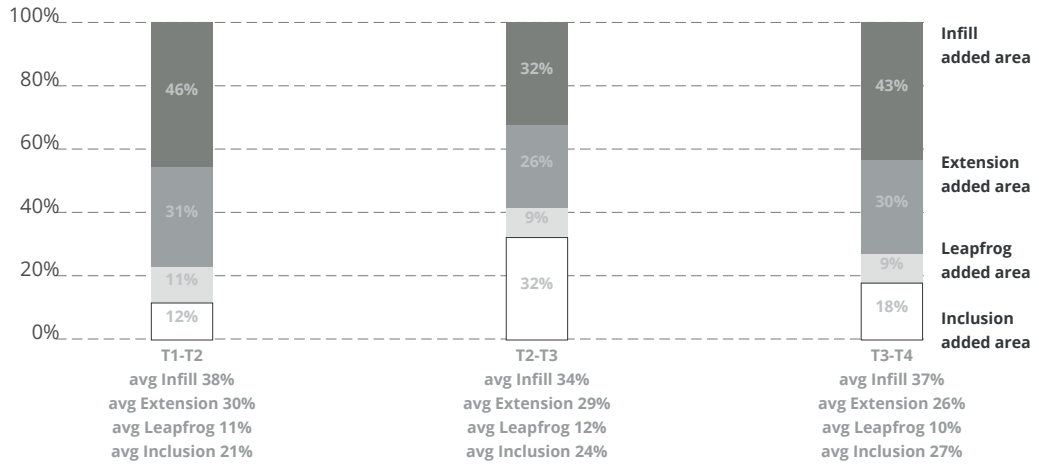
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
46%
31%
11%
12%
32%
26%
9%
32%
43%
30%
9%
18%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
LEAPFROG
CBD
EXTENSION
0
2.5 km
1991
T1
2021
T4

11 /

INLAND CITY
ELEVATION: 568m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS / SAVANNAS / SHRUBLANDS

Campo Grande,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at 568 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 2.2% per year, from 428.1 thousand to 839.4 thousand. Campo Grande has a low population density compared to the other cities: 33.9 inhabitants per hectare. In the last decades, its population density has increased at a fast rate in comparison to the region, and the city rose 34 positions in population density variation (%), reaching 5th in 2010-2020. Additionally, urban extent increased by approximately 2.5% annually over the last decades, resulting in 2.1 times what it was in 1990. The city became much more compact compared to other LAC cities, as Campo Grande became the 2nd most compact city in the sample, in contrast to its former position as 42nd (1990-2000). Such an increase is accompanied by a rise in saturation, gaining 9 positions from 1990 to 2020.



2021=17

1991=27

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change rank
42nd (T4-T3) — 16th (T2-T1)

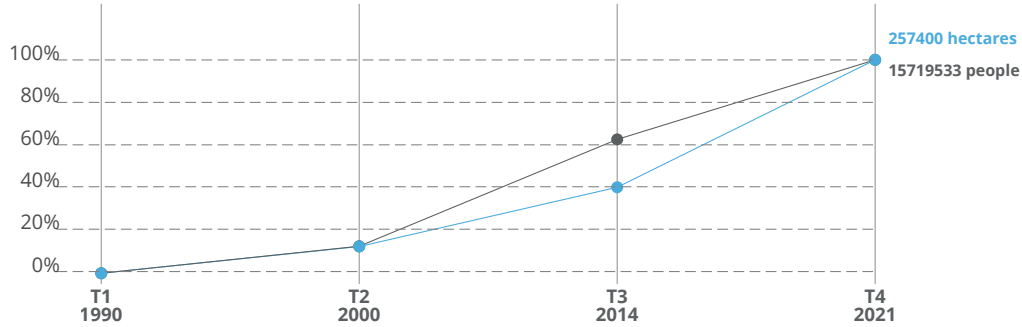
Urban Extent
annual change rank
66th (T4-T3) — 17th (T2-T1)

Urban population density
annual change rank
39th (T2-T1) — 5th (T4-T3)

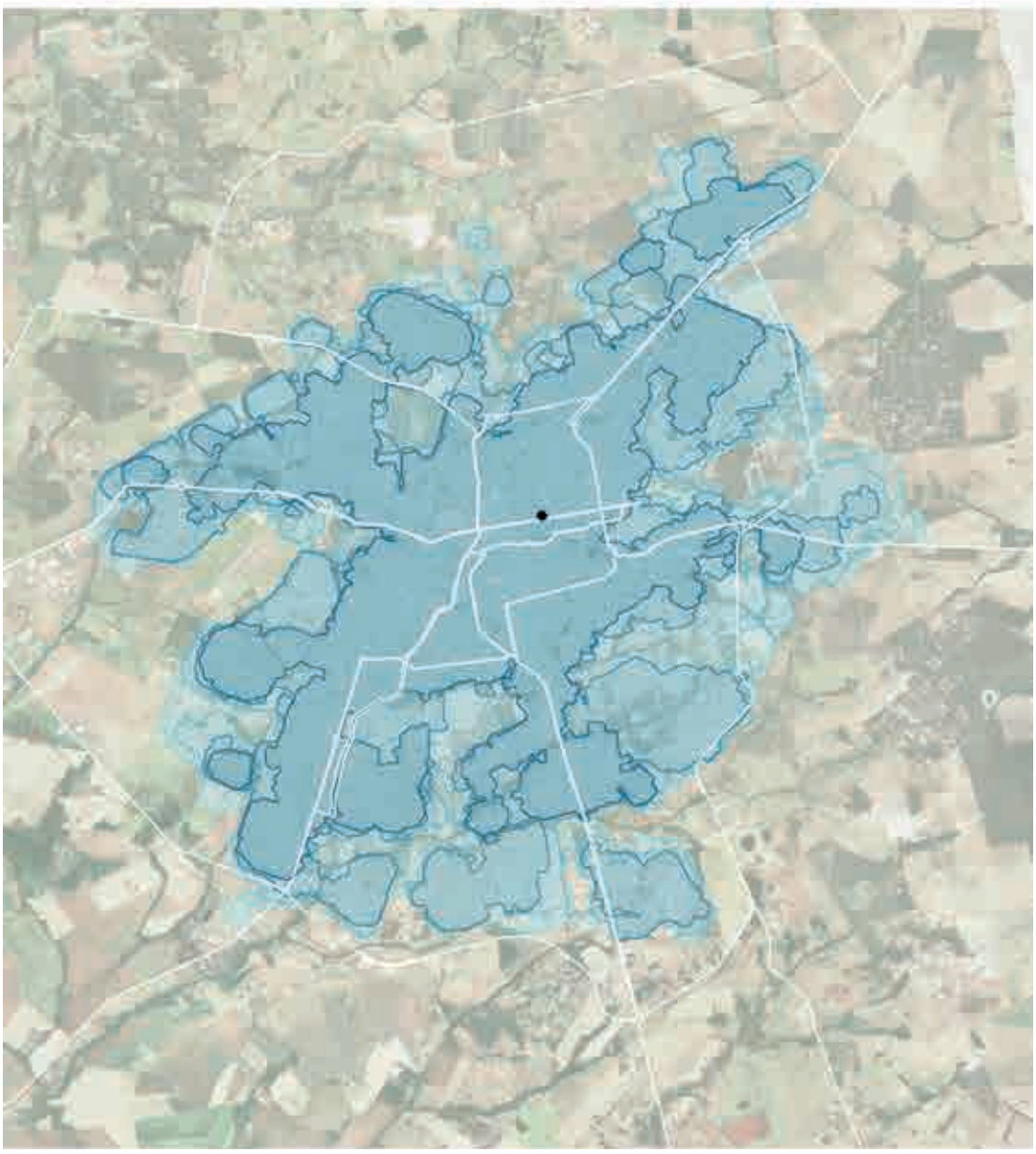
Compactness
rank
42nd (T1) — 2nd (T4)

Saturation
rank
50th (T1) — 41st (T4)





CAMPO GRANDE — BRAZIL



● Central Business District N -20.461431
E -54.606555

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km

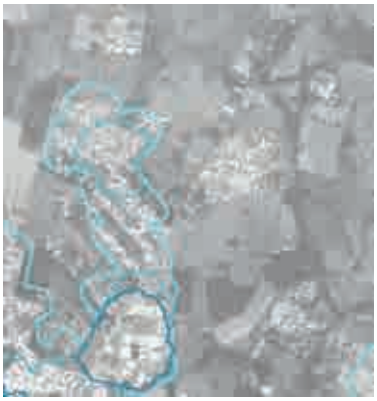
11 /



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that more than half of the urban growth over the past decade was through Infill, increasing its relevance for the city's expansion. Extension has decreased its significance over the years, as it represented 42% in 1990-2000 in contrast to 35% in 2010-2020. Leapfrog's contribution was 9% (1990-2000) and reached a third, 3% (2010-2020). Additionally, inclusion decreased its contribution to the city's expansion from 19% (1990-2000) to 11% (2010-2020).

The average dwelling unit occupancy in Campo Grande is 3.1 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.4 stories. The residential plot coverage of Campo Grande is 36.5%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

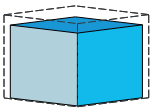
The city became much more compact compared to other LAC cities, as Campo Grande became the 2nd most compact city in the sample, in contrast to its former position as 42nd (1990-2000).

avg 3.4 people per dwelling unit



3.1 people per dwelling unit

avg 1.6 stories building height

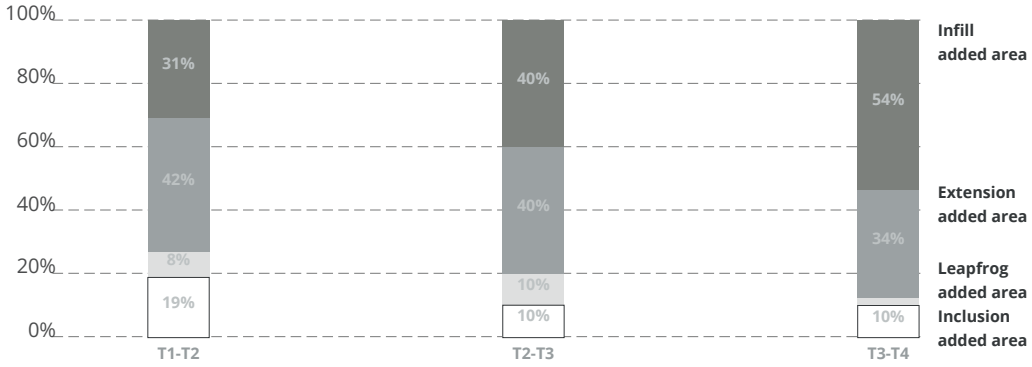


1.4 stories building height

avg 44% plot coverage



37% plot coverage





Section Profile 29 km



1991 T1 2021 T4

12 /

COASTAL CITY
ELEVATION: 5m
BIOME: DESERTS / XERIC SHRUBLANDS

Greater Cartagena de Indias,* Colombia, is located in the biome Deserts & Xeric Shrublands, at 5 meters above sea level. Between 1991 and 2020, it experienced a population growth of approximately 1.9% per year, from 556.4 thousand to 955 thousand. Greater Cartagena de Indias has a high population density compared to the other cities: 106.2 inhabitants per hectare. Its rank as 7th in population density variation (%) in 2015-2020 results in a 33-position ascent compared to 1991-2001. Additionally, urban extent increased by approximately 2.3% annually over the last decades, reaching 1.9 times what it was in 1991. The city almost maintained its compactness compared to other LAC cities, increasing one position in 2015-2020. Cartagena de India's urban extent is characterized by high saturation, ranking 1st or 2nd in the sample through the three analyzed decades.





Urban population density
person / hectare

Evaluation metrics rankings:

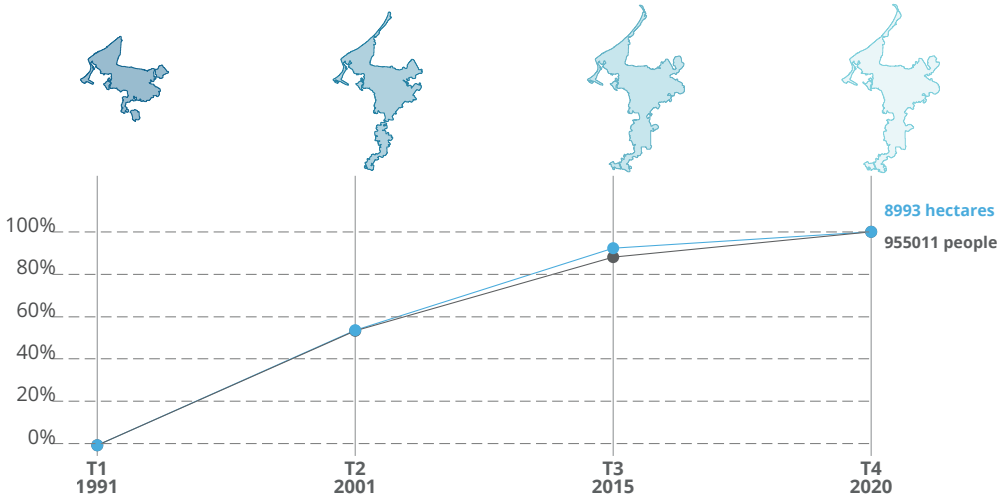
Population Growth
annual change
rank
55th T4-T3
21st T2-T1

Urban Extent
annual change
rank
67th T4-T3
20th T2-T1

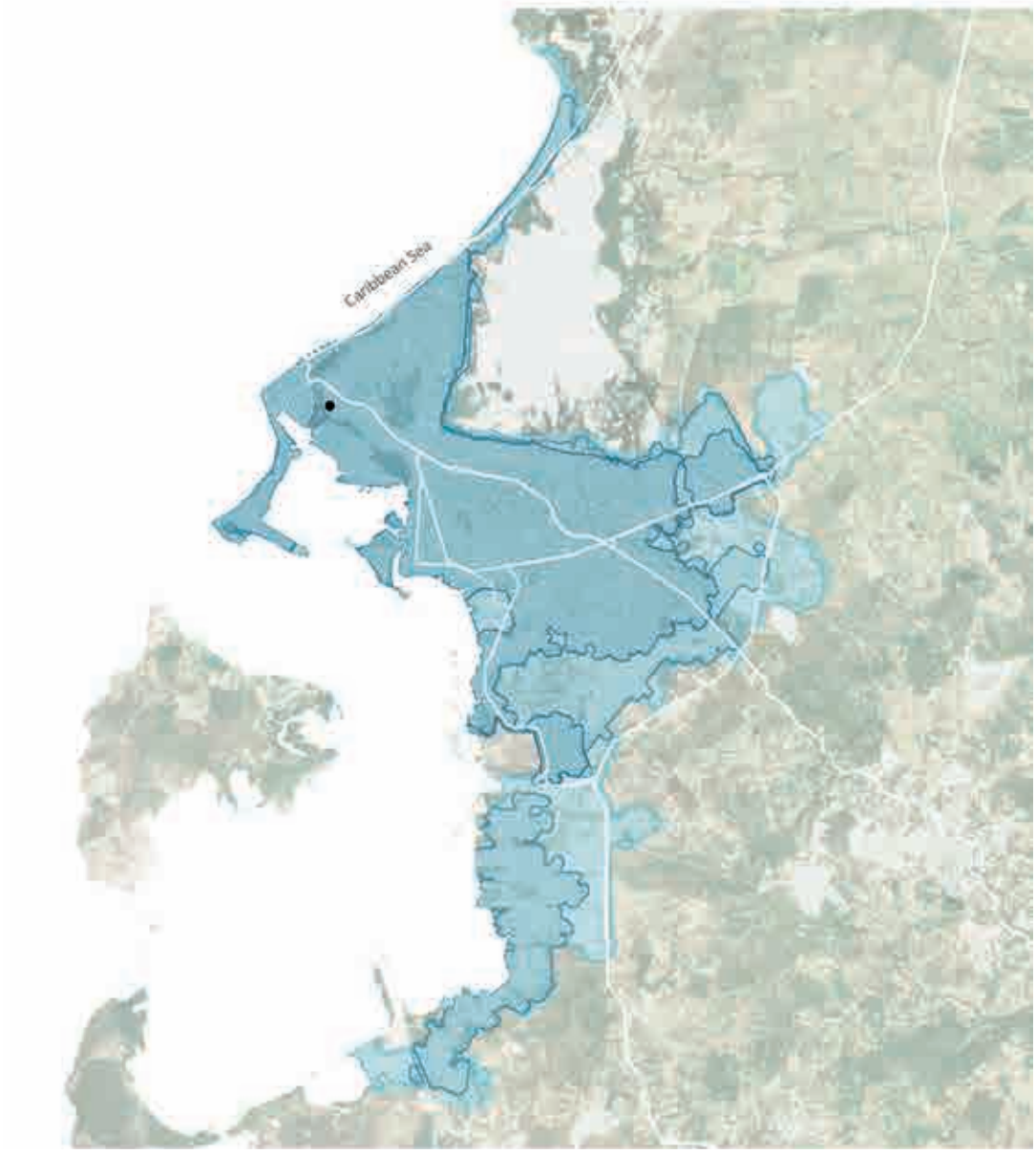
Urban population density
annual change
rank
39th T2-T1
5th T4-T3

Compactness
rank
66th T4
64th T1

Saturation
rank
2nd T4
1st T1



GREATER CARTAGENA DE INDIAS — COLOMBIA



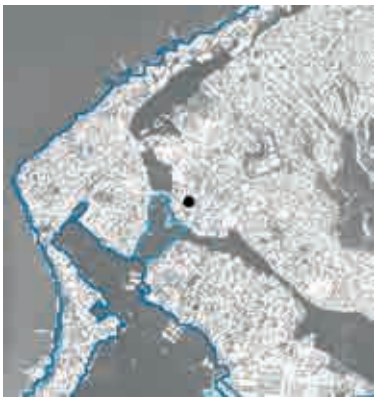
● Central Business District N 10.4218823
E -75.540313

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Cartagena de Indias have been greatly increasing its contribution to the city's growth: from 18% (1991-2001) to 57% (2015-2020). Extension has decreased its significance over the years, as it represented 45% in 1991-2001 in contrast to 30% in 2015-2020. Leapfrog's contribution continued with low relevance as inclusion decreased its contribution to the city's expansion to almost a third, from 36% (1991-2001) to 13% (2015-2020).

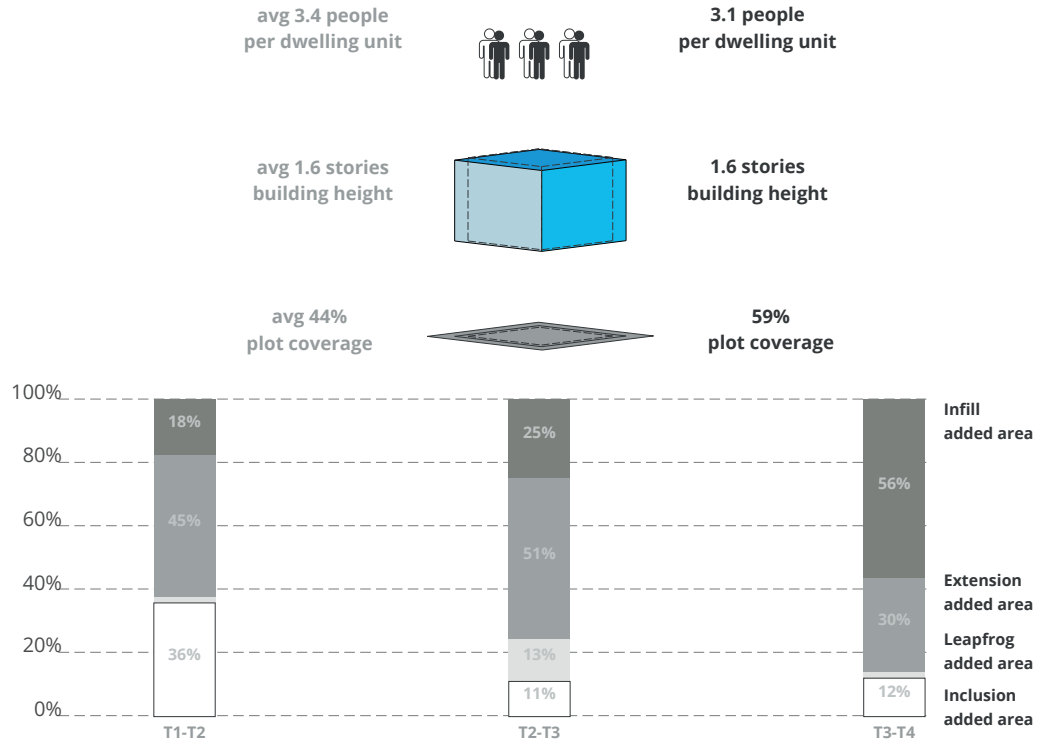
The average dwelling unit occupancy in Greater Cartagena de Indias is 3.1 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is the same as the average for the sample,1.6 stories. The residential plot coverage of Greater Cartagena de Indias is 58.9%, resulting in a low percentage of unbuilt spaces within residential plots.

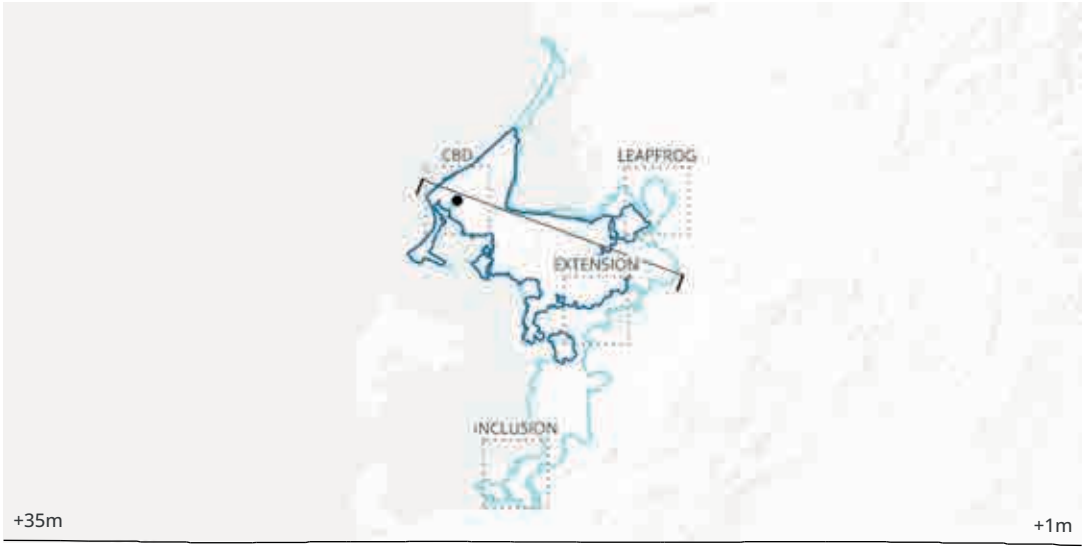
* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

High saturation of the urban extent characterizes Cartagena de India's urban extent, ranking 1st or 2nd in the sample through the three analyzed decades.

GREATER CARTAGENA DE INDIAS — COLOMBIA





Section Profile 14 km





13 /

INLAND CITY
ELEVATION: 2553m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Cochabamba,* Bolivia, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 2553 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 3% per year, from 501.3 thousand to 1.2 million. Accompanying this fast population growth, urban extent soared by approximately 5.1% annually over the last decades, resulting in 4.6 times what it was in 1990. As a result, Greater Cochabamba has a low population density compared to the other cities: 32.6 inhabitants per hectare and ranks 64th in population density variation (%) in 2013-2020. The city became more compact compared to other LAC cities, rising from 59th in 1991 to 38th in 2020. Considering the region, the ranking of saturation declined, dropping 7 positions, from 56th to 63th between 1990 to 2020.





2021=61

1990=63

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank

13th 8th
T2-T1 T4-T3

Urban Extent
annual change
rank

8th 6th
T2-T1 T4-T3

Urban population density
annual change
rank

64th 49th
T4-T3 T2-T1

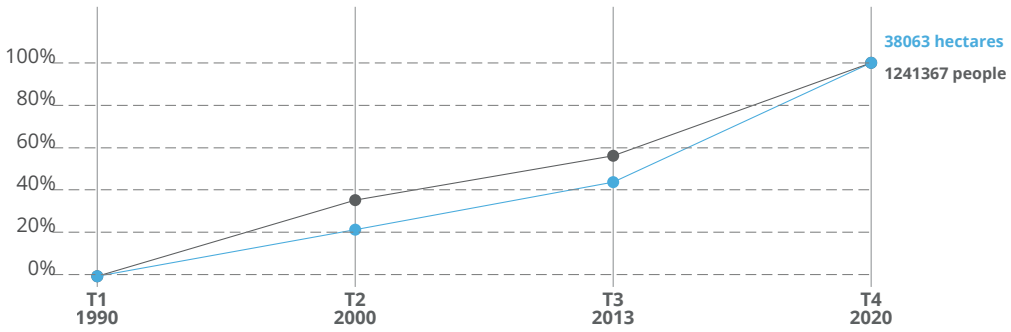
Compactness
rank

59th 38th
T1 T4

Saturation
rank

63rd 56th
T4 T1





GREATER COCHABAMBA — BOLIVIA



● Central Business District N -17.387770
E -66.154010

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

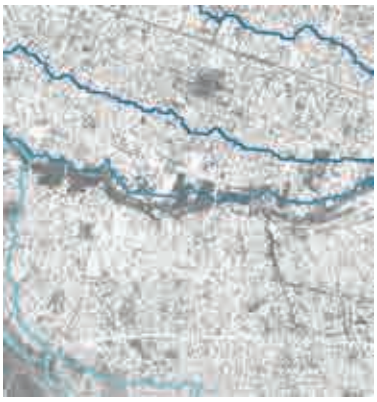
highways

local streets

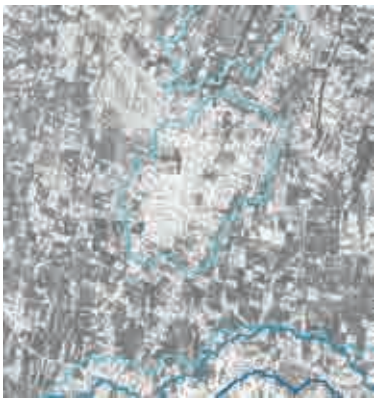
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Cochabamba have not been significantly changing its contribution to the city's growth, maintaining 37% (2013-2020). Extension, on the other hand, has decreased its significance over the years, as it represented 34% in 1990-2000 in contrast to 19% in 2013-2020. Leapfrog's contribution to Greater Cochabamba's urban expansion almost doubled, from 14% (1990-2000) to 23% (2013-2020). Additionally, inclusion increased its contribution to the city's expansion from 17% (1990-2000) to 23% (2013-2020).

The average dwelling unit occupancy in Cochabamba is 3.6 people per unit, high in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.7 stories. The residential plot coverage of Cochabamba is 26.4%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

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Accompanying this fast population growth, urban extent soared by approximately 5.1% annually over the last decades, resulting in 4.6 times what it was in 1990.

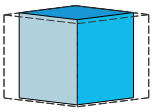
GREATER COCHABAMBA — BOLIVIA

avg 3.4 people per dwelling unit



3.6 people per dwelling unit

avg 1.6 stories building height

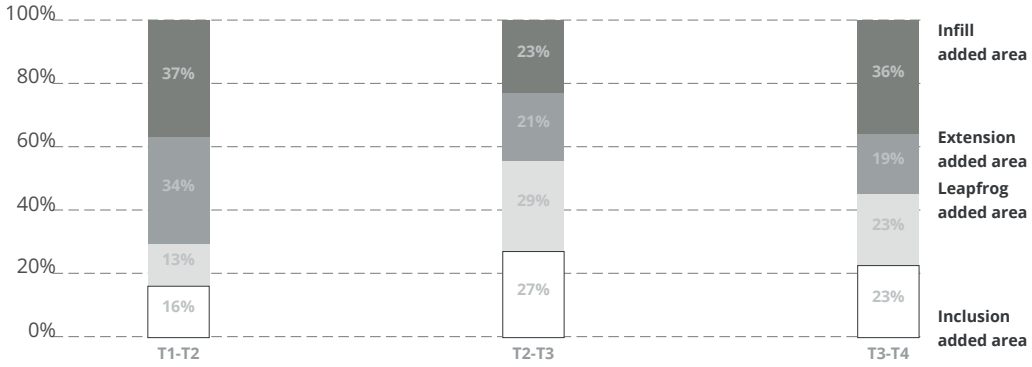


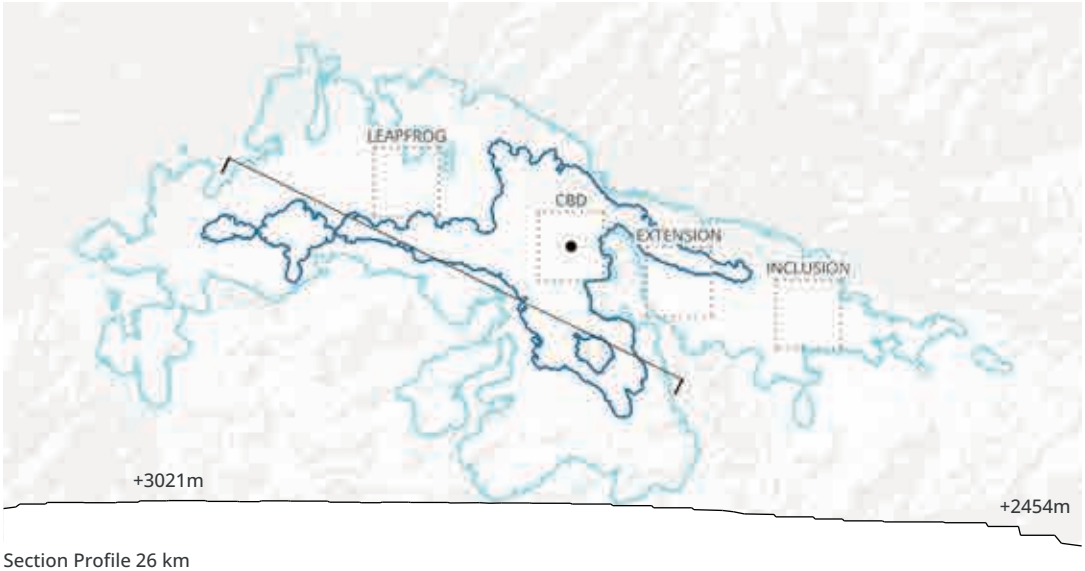
1.7 stories building height

avg 44% plot coverage



26% plot coverage





Section Profile 26 km



1991 T1 2021 T4

14 /

INLAND CITY
ELEVATION:383m
BIOME: TEMPERATE GRASSLANDS / SAVANNAS / SHRUBLANDS

Greater Córdoba,* Argentina, is located in the biome Temperate Grasslands, Savannas & Shrublands, at 383 meters above sea level. Across the analyzed period, 1991 to 2021, it experienced a population growth of approximately 1.2% per year, from 1.1 million to 1.6 million. However, in the last decades, the growth rate was more expressive, and Greater Córdoba rose from 61st to 33rd in terms of annual population growth (%). Even so, Greater Córdoba has a low population density compared to the other cities: 37.6 inhabitants per hectare. Additionally, urban extent increased by approximately 2.4% annually over the last decades, reaching 2 times what it was in 1991. The city became less compact compared to other LAC cities, falling from 27th in the period 1991 to 40th in 2021. Saturation has declines compared to the sample, dropping 13 positions, from 12th to 25th between 1991 to 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

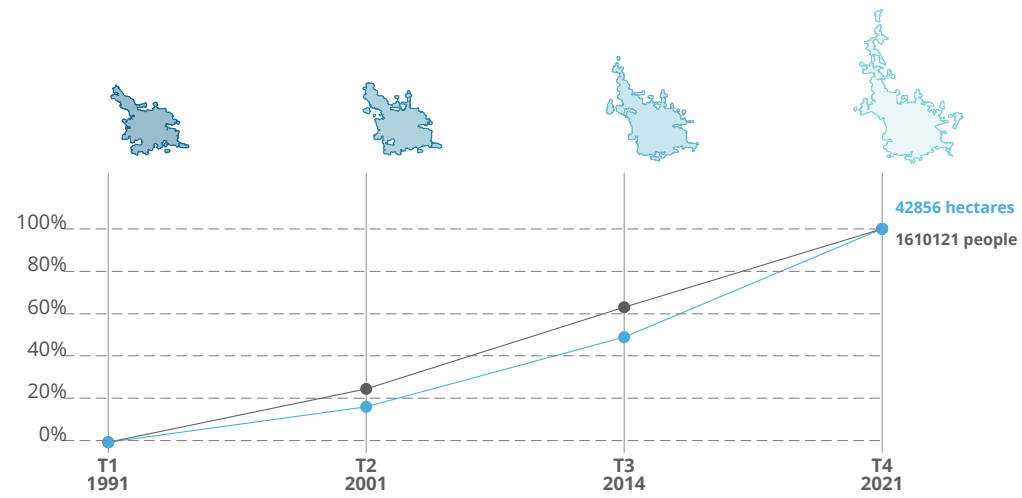
Population Growth
annual change rank
44th (T4-T3) 40th (T2-T1)

Urban Extent
annual change rank
60th (T2-T1) 11th (T4-T3)

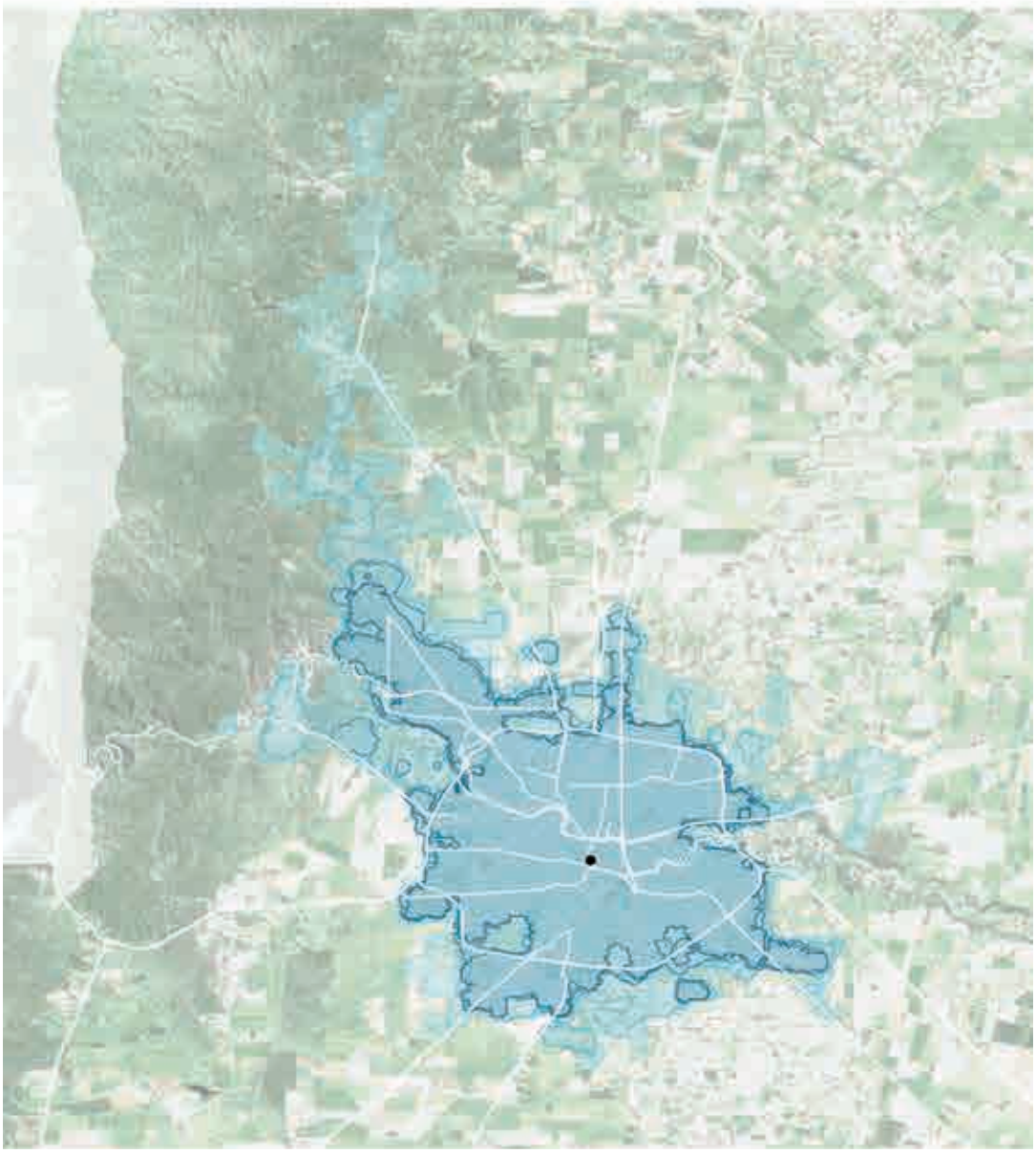
Urban population density
annual change rank
31st (T4-T3) 19th (T2-T1)

Compactness
rank
38th (T1) 32nd (T4)

Saturation
rank
25th (T4) 12th (T1)



GREATER CÓRDOBA — ARGENTINA



● Central Business District N -31.416466
E -64.190822

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km

14 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Greater Córdoba expanded mostly towards the North, with a greater contribution of infill, even though it decreased contribution from 50% (1991-2001) to 40% (2014-2021). Extension has slightly increased its significance over the years, as it represented 21% in 1991-2001 in contrast to 24% in 2014-2021. Leapfrog's contribution to Greater Córdoba's urban expansion was 13% (1991-2001) and reached 10% (2014-2021). Additionally, inclusion varied its contribution to the city's expansion by more than 50%, from 18% (1991-2001) to 29% (2014-2021).

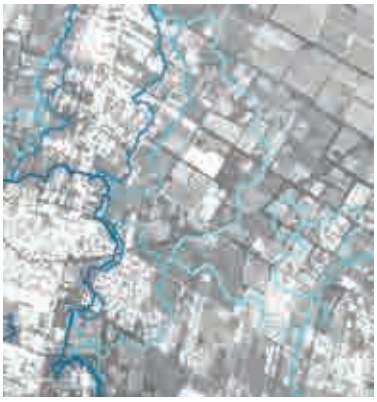
Greater Córdoba expanded mostly towards the North, with a greater contribution of infill.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

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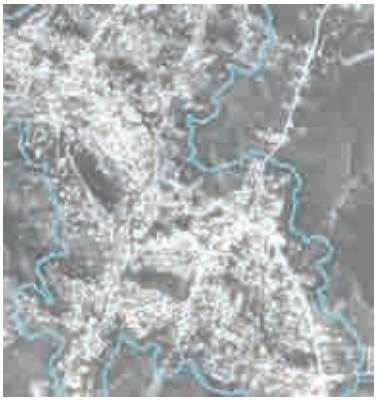
Central Business District



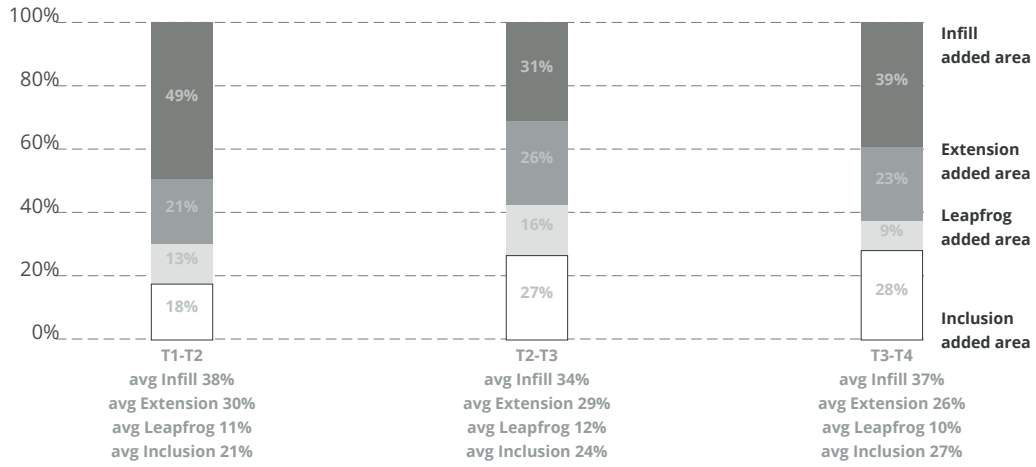
Extension area

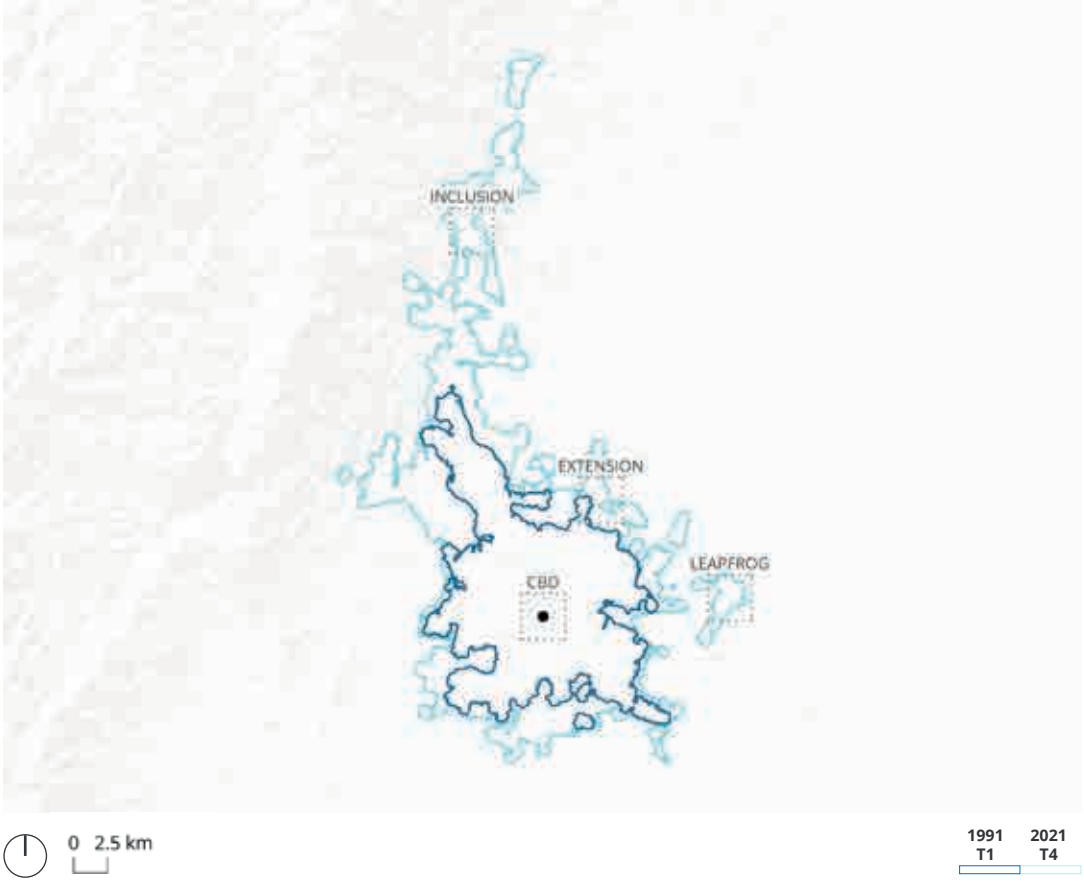


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
49%
21%
13%
18%
31%
26%
16%
27%
39%
23%
9%
28%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
EXTENSION
LEAPFROG
CBD
0 2.5 km
1991 T1
2021 T4

15 /

INLAND CITY
ELEVATION: 2499m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Cuenca,* Ecuador, is located in the biome Montane Grasslands & Shrublands, at 2499 meters above sea level. Between 1989 and 2021, it experienced an expressive population growth of approximately 2.7% per year, from 218.2 thousand to 519.6 thousand, thus ranking 5th in comparison to the other cities on the Atlas. This population growth was accompanied by an equally important and fast increase in urban extent: its area is now 5.5 times what it was in 1989. Hence, Cuenca has a low population density compared to the other cities: 28.2 inhabitants per hectare, ranking 67th in population density variation (%) in 2016-2021. The city became more compact compared to other LAC cities, rising from 26th in 1989 to 7th in 2021. Such an increase is accompanied by a decline in saturation and its saturation ranking dropped 15 places, from 52nd to 67th, from 1989 to 2021.



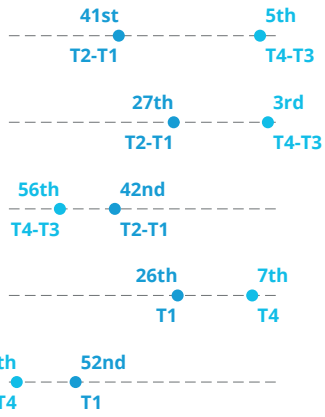
2021=28

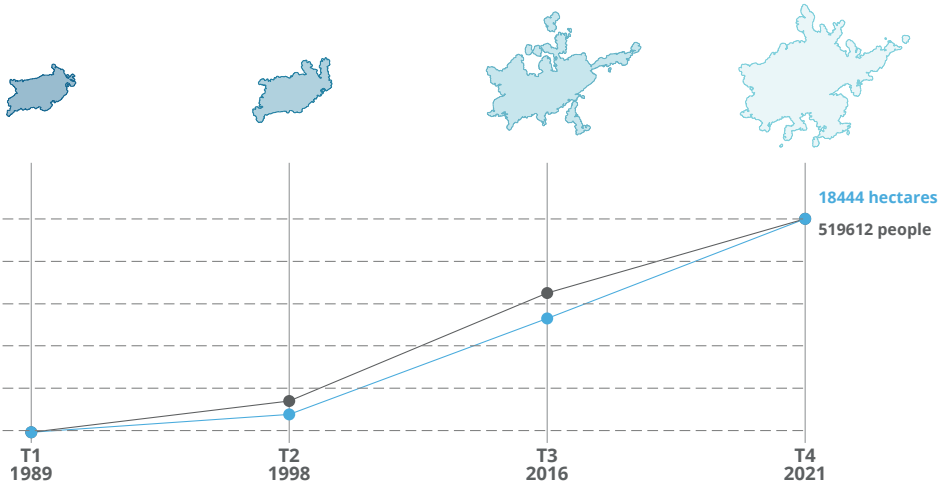


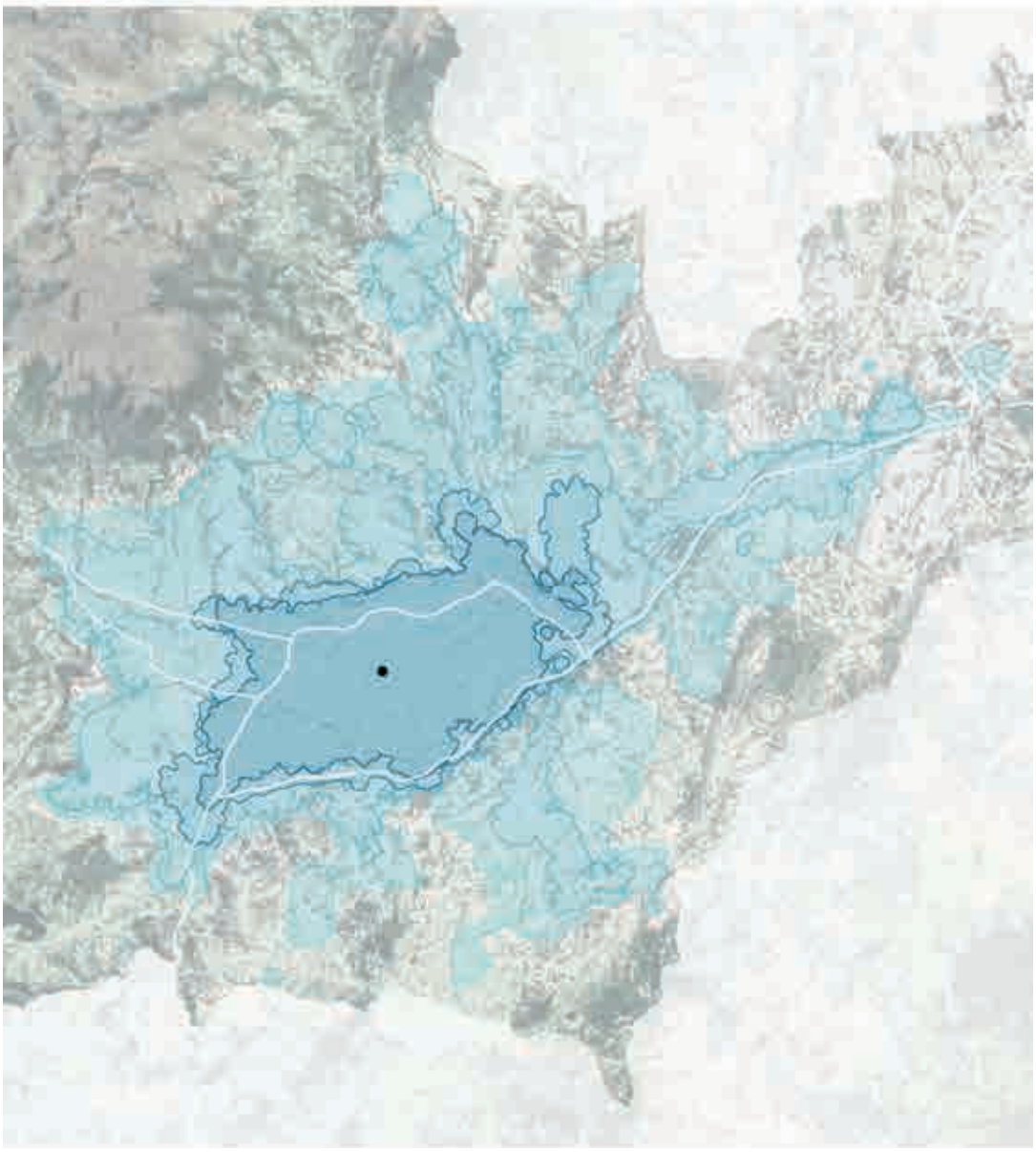
1989=65

Urban population density
person / hectare

Evaluation metrics rankings:







● Central Business District N -2.8979462
E -79.004699

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways

local streets

0 2.5 km

15 /

The process of Urban Expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Cuenca have decreased its contribution to the city's growth to almost half: from 46% (1989-1998) to 25% (2016-2021), what can be related to the low population density. Extension has decreased its significance over the years, as it represented 25% in 1989-1998 in contrast to 15% in 2016-2021. Leapfrog's and inclusion's contribution to Cuenca's urban expansion has increased from 9% (1989-1998) to 26% (2016-2021) and from 22% (1989-1998) to 36% (2016-2021), respectively. From 1989 to 2021, Cuenca presents the highest share of Leapfrog contribution amongst the sample.

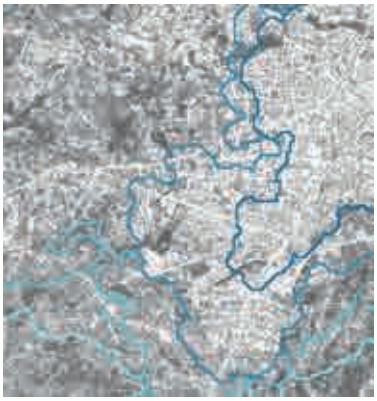
From 1989 to 2021, Cuenca presents the highest share of Leapfrog contribution amongst the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

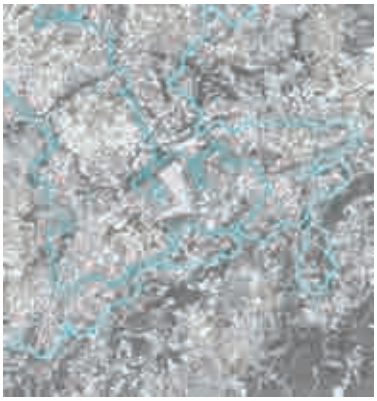
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



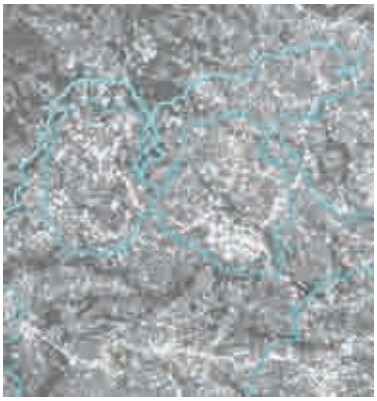
Central Business District



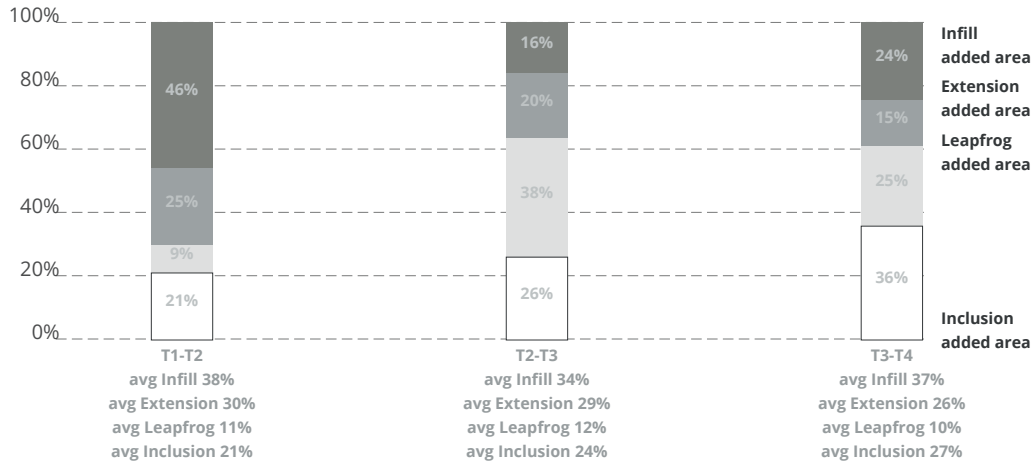
Extension area

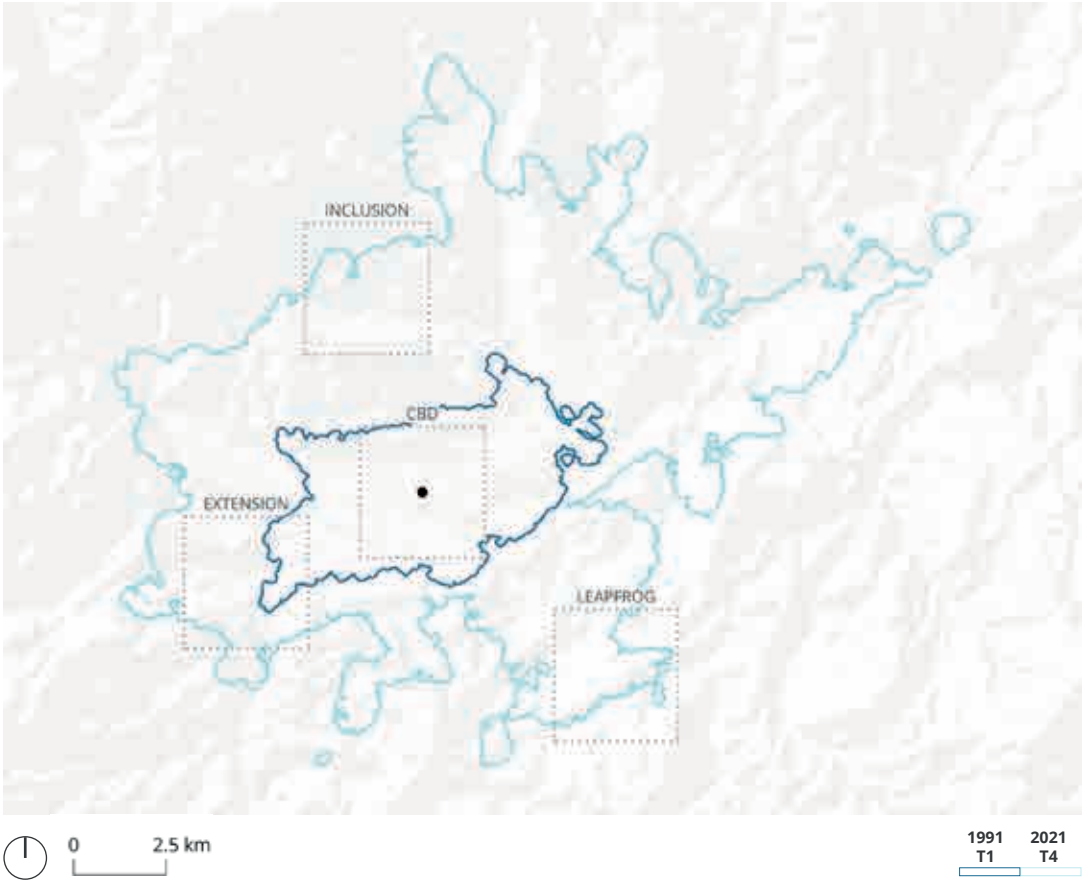


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
46%
25%
9%
21%
16%
20%
38%
26%
24%
15%
25%
36%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
CBD
EXTENSION
LEAPFROG
0
2.5 km
1991 T1
2021 T4

16 /

INLAND CITY
ELEVATION: 47m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Culiacán,* Mexico, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 47 meters above sea level. Between 1990 and 2021, the population grew at an average annual rate of 1.5%, increasing from 393,200 to 629,200. In recent decades, this growth rate plummeted Greater Culiacán from 27th place to where it now stands in last place. Greater Culiacán has a low population density compared to the other cities: 37.5 inhabitants per hectare, ranking 55th in population density variation (%) in 2014-2021. Additionally, urban extent increased by approximately 3.4% annually over the last decades, reaching an area 2.8 times what it was in 1990. The city became much more compact compared to other LAC cities, rising from 32nd in 1990 to 3rd in 2021. A decline in the ranking of saturation is perceived in relation to the sample, dropping 10 positions, from 8th to 18th between 1990 to 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change rank
67th T4-T3 — 28th T2-T1

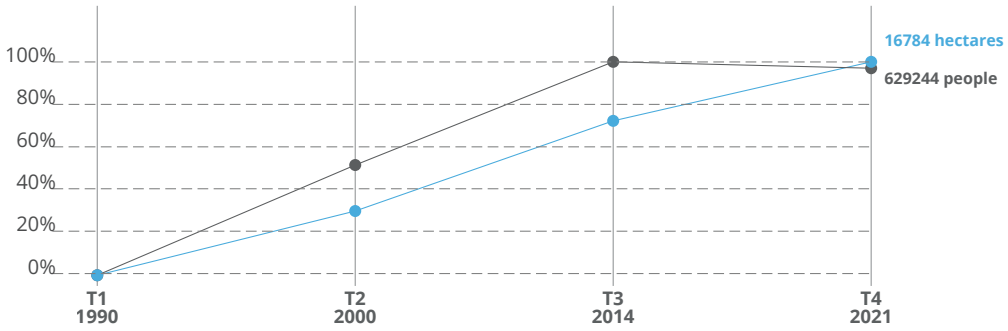
Urban Extent
annual change rank
37th T4-T3 — 16th T2-T1

Urban population density
annual change rank
55th T4-T3 — 51st T2-T1

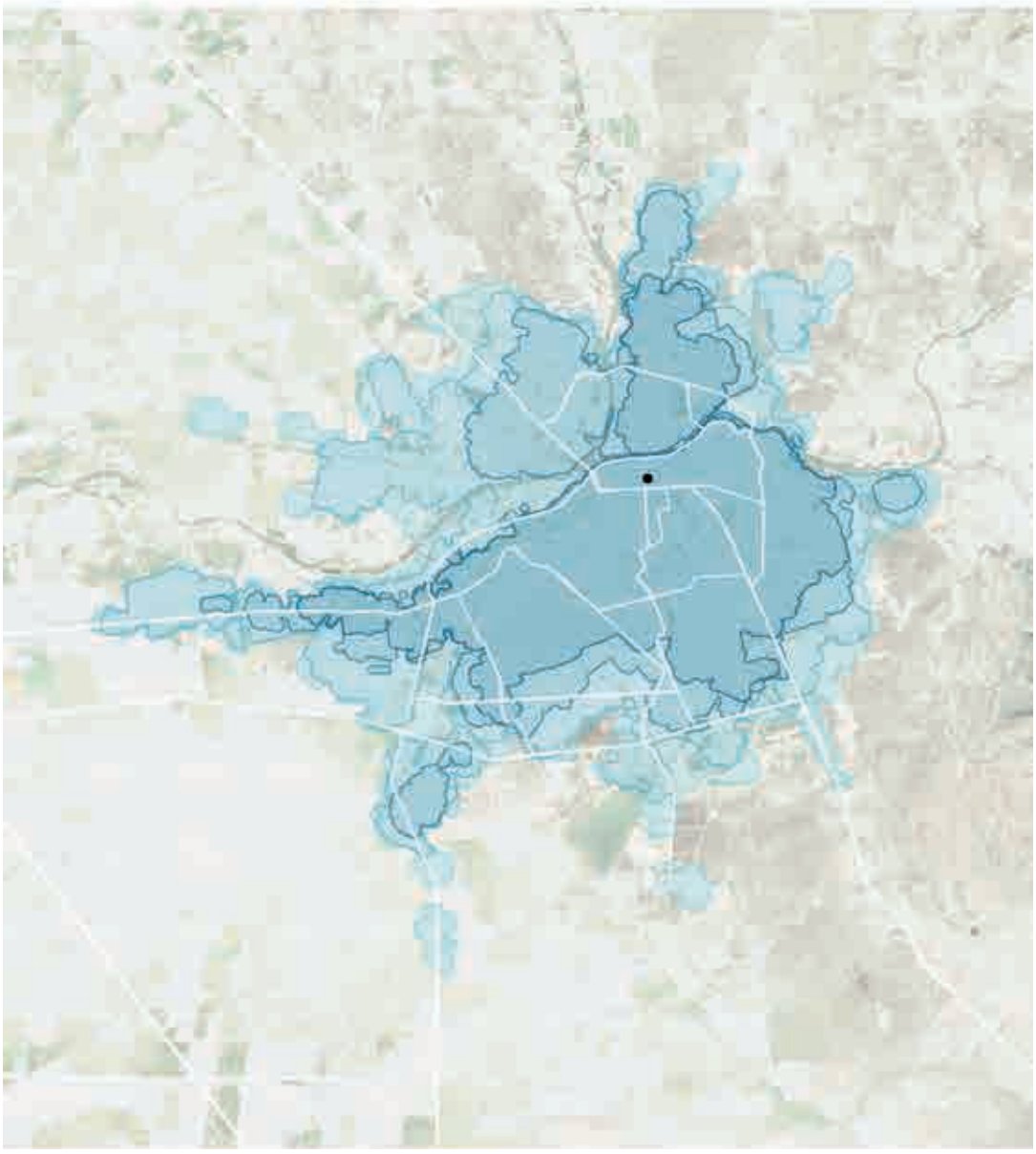
Compactness
rank
26th T1 — 7th T4

Saturation
rank
18th T4 — 8th T1





GREATER CULIACÁN — MEXICO



● Central Business District N 24.8070428
E -107.39370

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

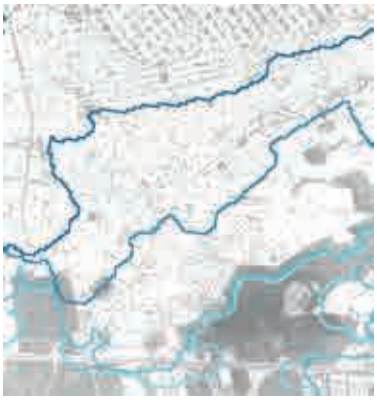
highways

local streets

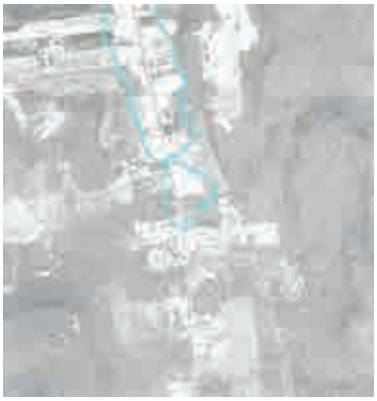
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Culiacán have been increasing significantly its contribution to the city's growth: from 12% (1990-2000) to 47% (2014-2021). Thus, almost half of recent urban growth in Greater Culiacán was through infill, which can help explain its increase in compactness. Extension has decreased its significance over the years, as it represented 58% in 1990-2000 in contrast to 28% in 2014-2021. Leapfrog's contribution to Greater Culiacán's urban expansion was 7% (1990-2000) and reached 11% (2014-2021). Additionally, inclusion varied its contribution to the city's expansion from 25% (1990-2000) to 16% (2014-2021).

The average dwelling unit occupancy in Greater Culiacán is 3.5 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.6 stories. The residential plot coverage of Greater Culiacán is 48.8%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

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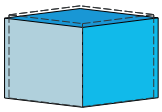
Almost half of recent urban growth in Greater Culiacán was through infill.

avg 3.4 people per dwelling unit



3.5 people per dwelling unit

avg 1.6 stories building height

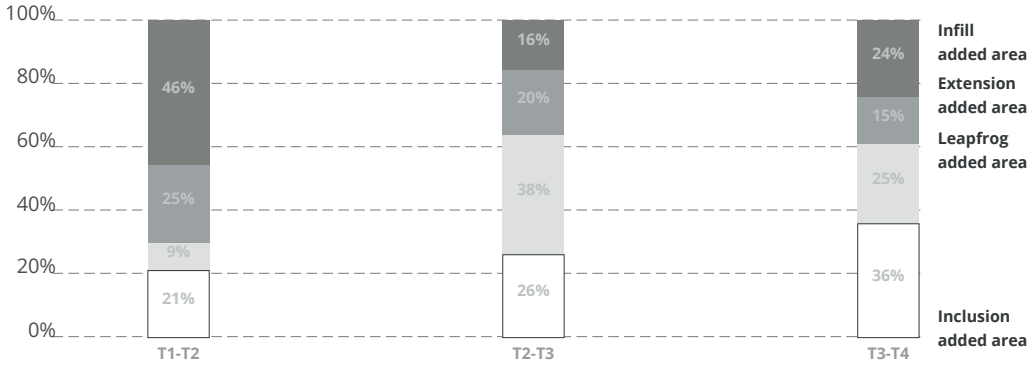


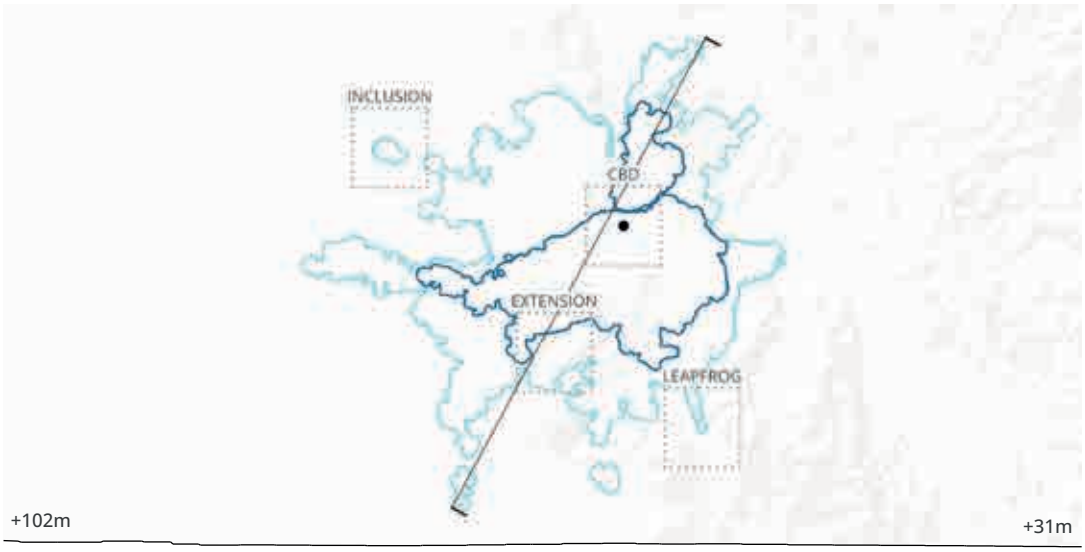
1.6 stories building height

avg 44% plot coverage



49% plot coverage





Section Profile 24 km



1991 T1 — 2021 T4

17 /

INLAND CITY
ELEVATION: 914m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

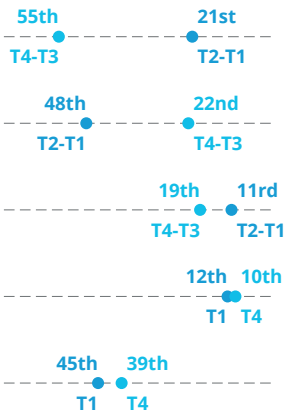
Greater Curitiba,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at 914 meters above sea level. Between 1990 and 2021, the city's population grew at a rate of approximately 2.1% annually, from 1.5 million to 2.9 million. Greater Curitiba has a low population density compared to the other cities: 39.6 inhabitants per hectare, ranking 19th in population density variation (%) in 2014-2021. Additionally, urban extent increased by approximately 2.2% annually over the last decades, reaching an area two times what it was in 1990. In this process, the city slightly increased in compactness compared to other LAC cities, rising 2 positions from 1990 to 2021. Within the same period, this increase in compactness is accompanied by a slight ascent in saturation, from 33rd to 31st between 1990 and 2021.

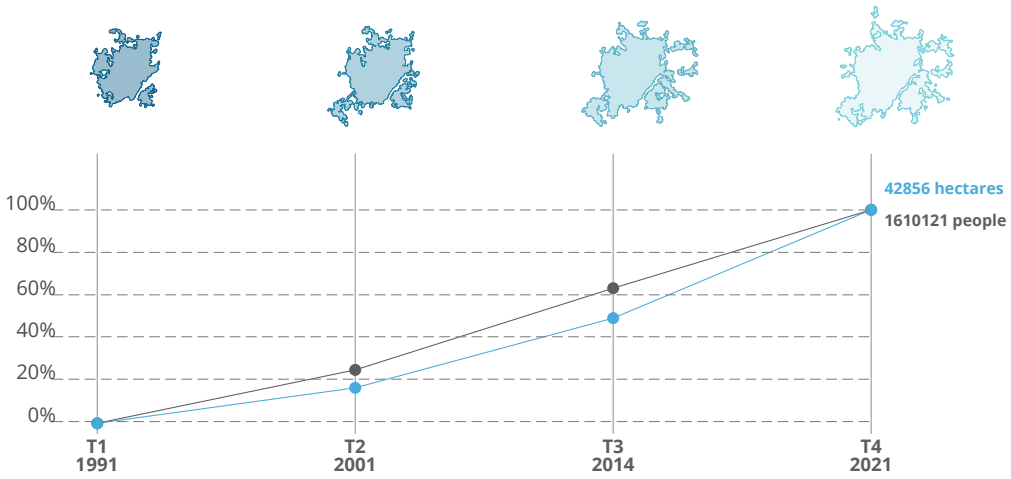




Urban population density
person / hectare

Evaluation metrics rankings:





GREATER CURITIBA — BRAZIL



● Central Business District N -25.417550
E -49.268680

1991 T1 | 2000 T2 | 2010 T3 | 2021 T4

highways — local streets

0 2.5 km

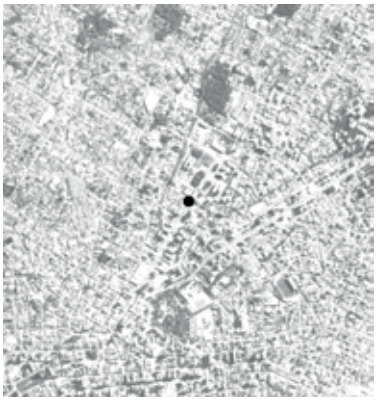
17 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in the last periods, one can conclude that in Greater Curitiba, over the past decade, 56% of the added urban area was through infill development—almost double the average of the sample. Extension has decreased its significance over the years, as it represented 22% in 1990-2000 in contrast to 16% in 2014-2021. Leapfrog's contribution to the city's urban expansion was 15% (1990-2000) and reached 8% (2014-2021). Additionally, inclusion decreased its contribution to the city's expansion from 30% (1990-2000) to 21% (2014-2021).

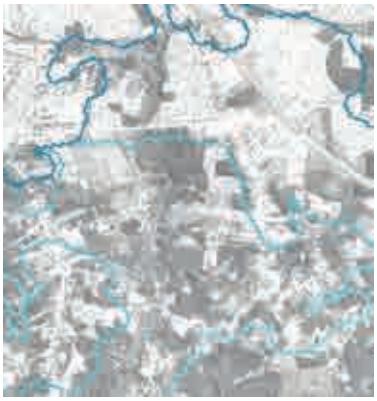
Over the past decade, 56% of the added urban area was through infill development—almost double the average of the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



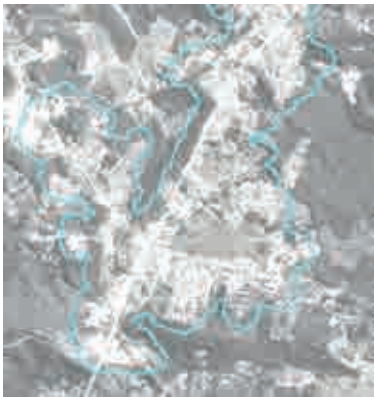
Central Business District



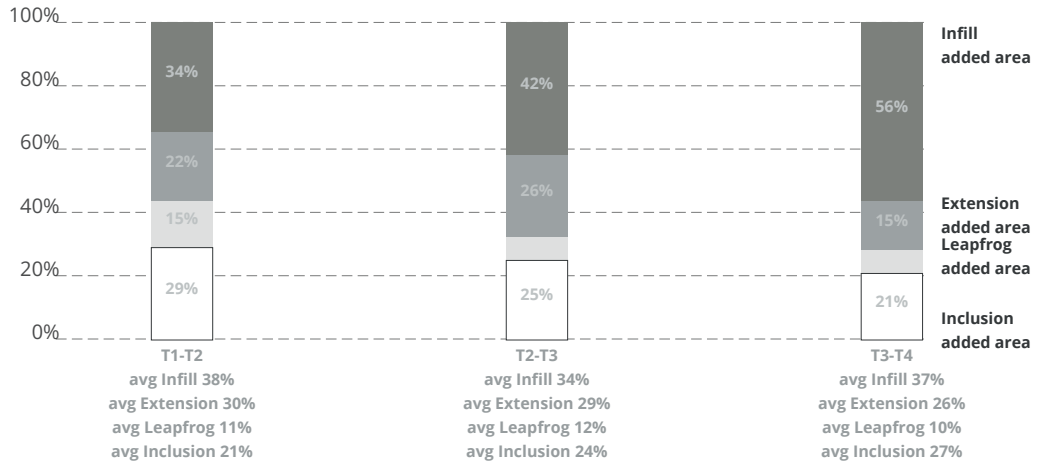
Extension area

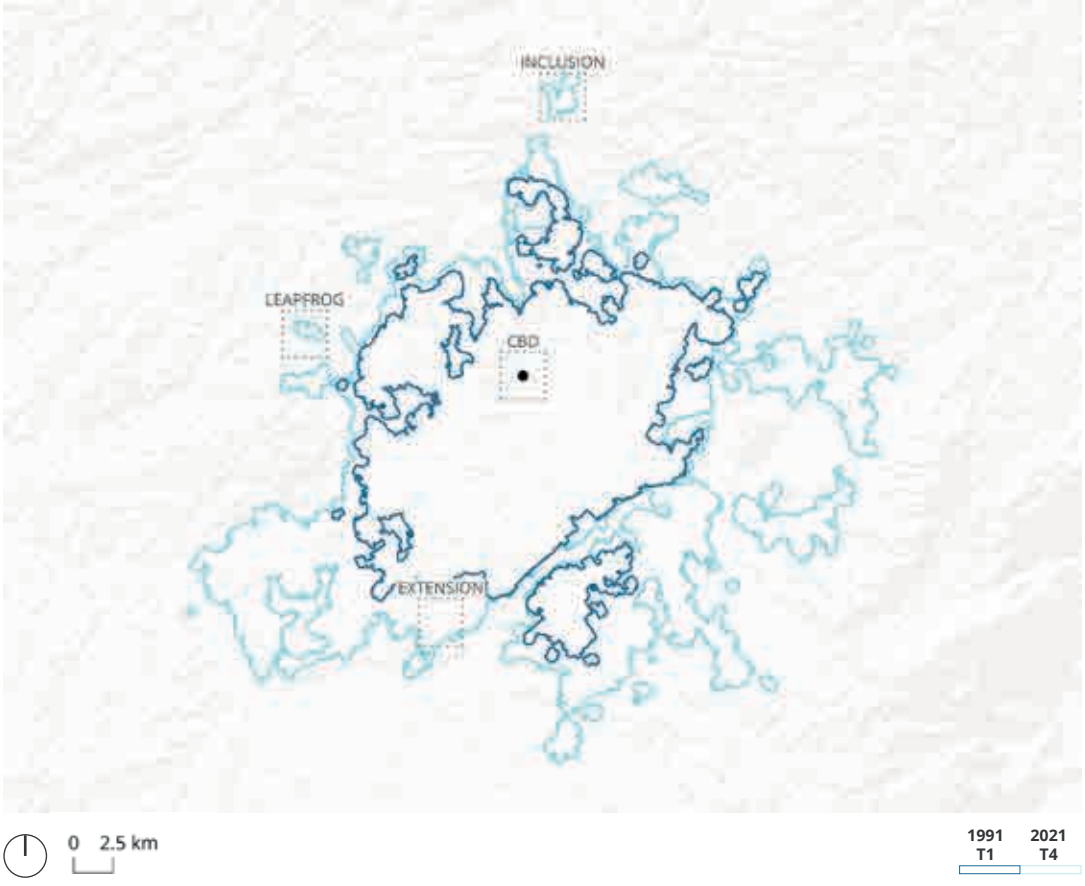


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
34%
22%
15%
29%
42%
26%
25%
56%
15%
21%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
LEAPFROG
CBD
EXTENSION
0 2.5 km
1991 T1
2021 T4

18 /

INLAND CITY
ELEVATION: 3330m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Cusco,* Peru, is located in the biome Montane Grasslands & Shrublands, at 3330 meters above sea level. Between 1990 and 2020, it experienced a significant population growth of approximately 2.5% per year, from 211 thousand to 441.7 thousand. Cusco has a high population density compared to the other cities: 81.6 inhabitants per hectare. Its rank as 21st in population density variation (%) in 2010-2020 presents a 23-position ascent in the ranking compared to 1990-2000. Additionally, urban extent increased by approximately 2.5% annually over the last decades, expanding 2.1 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 60th in 1990 to 51st in 2020. This process was accompanied by a spike in saturation, rising 25 positions from 1990 to 2020.



2021=28



1989=65

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



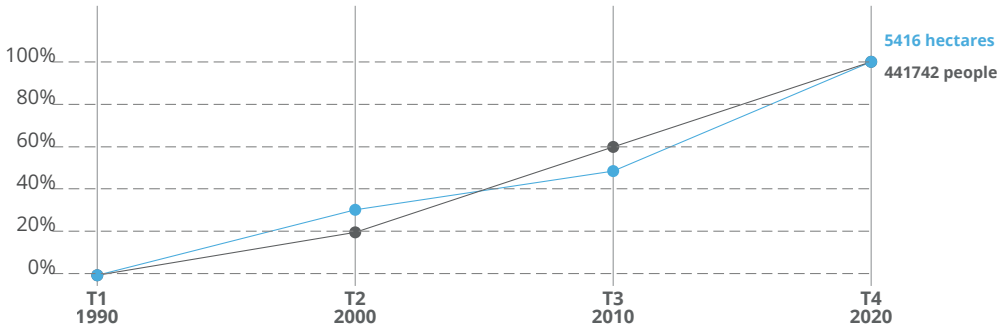
Compactness
rank

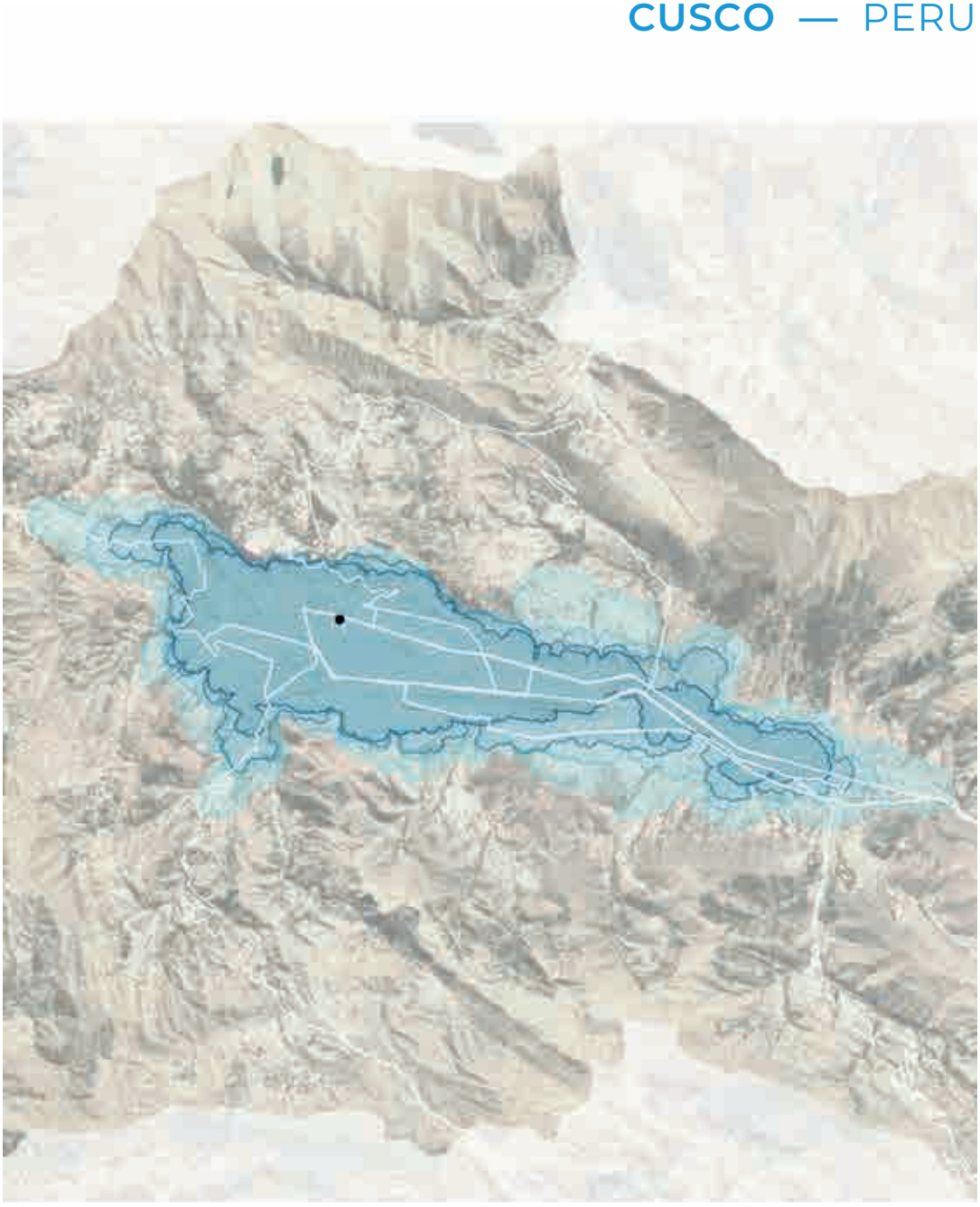


Saturation
rank









● Central Business District N -13.521492
E -71.967269

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

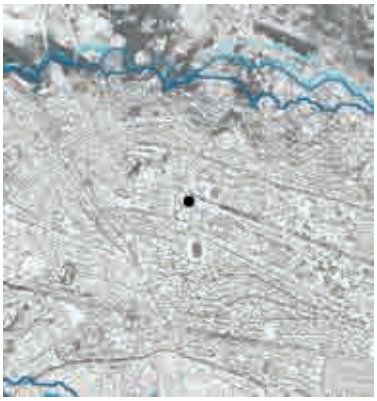
18 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Cusco have been decreasing its contribution to the city's growth: from 50% (1990-2000) to 33% (2010-2020). Urban extension has increased its significance over the years, from 27% in 1990-2000 to 51% in 2010-2020. Leapfrog's contribution to Cusco's urban expansion barely decreased, whereas inclusion's decreased from 17% (1990-2000) to 10% (2010-2020).

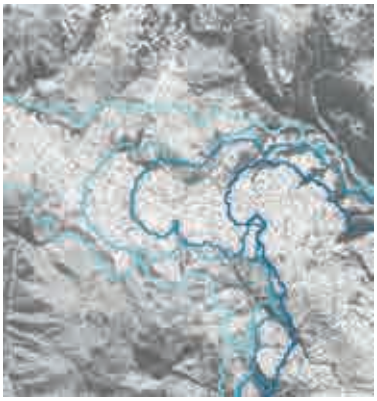
Urban extension has increased its significance over the years, from 27% in 1990-2000 to 51% in 2010-2020.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



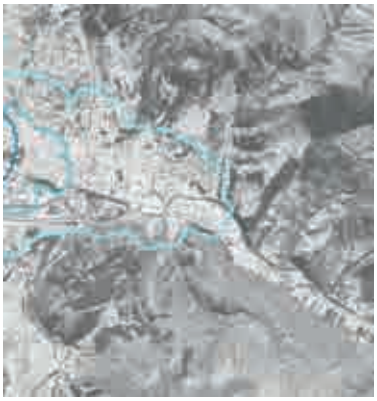
Central Business District



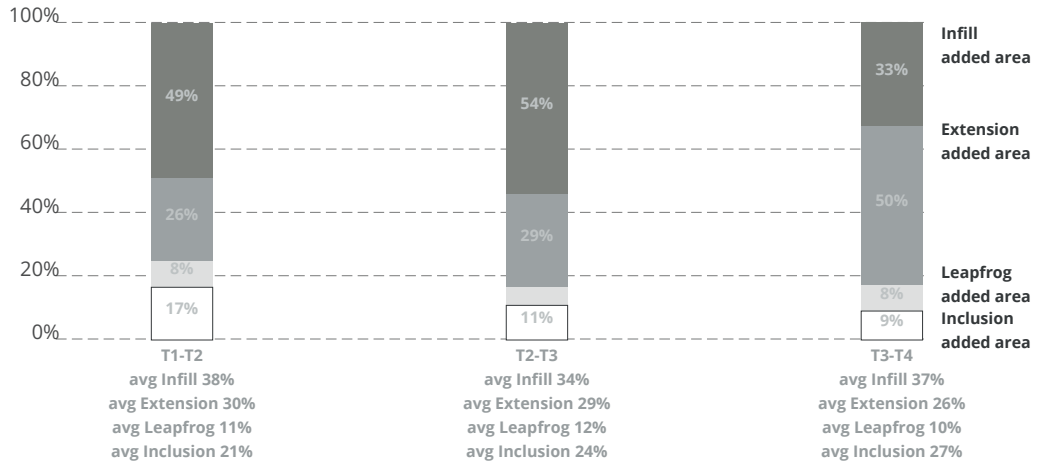
Extension area

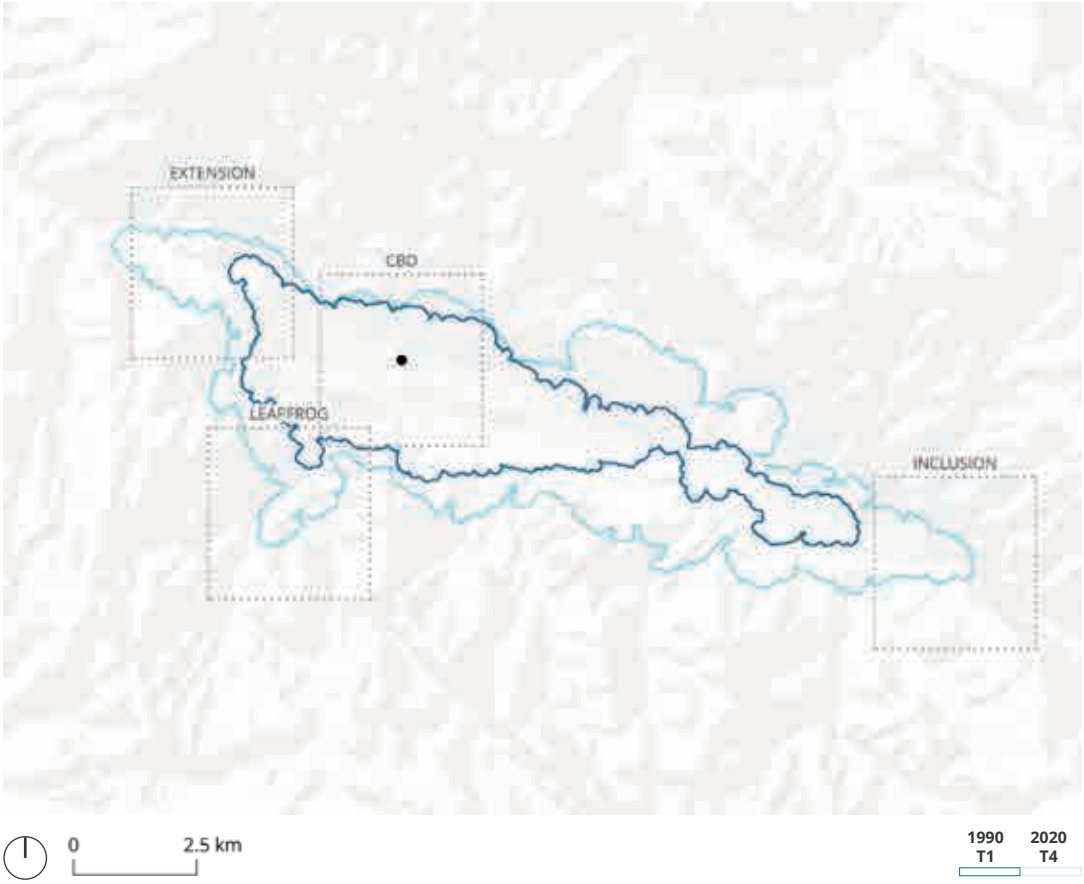


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
49%
26%
8%
17%
54%
29%
11%
33%
50%
8%
9%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


EXTENSION
CBD
LEAPFROG
INCLUSION
0
2.5 km
1990
T1
2020
T4

19 /

INLAND CITY
ELEVATION: 110m
BIOME: MANGROVES

Greater Florianópolis,* Brazil, is located in the biome Mangroves, at 110 meters above sea level. Between 1990 and 2021, the population grew at an average annual rate of 2.1%, from 300.1 thousand to 580.4 thousand. Greater Florianópolis has a low population density compared to the other cities: 33.4 inhabitants per hectare, ranking 36th in population density variation (%) in the last decade. Additionally, urban extent increased by approximately 3% annually over the last decades, reaching an area 2.5 times what it was in 1990. Florianópolis became more compact compared to other Latin American and Caribbean cities, rising from the bottom of the ranking to 56th in 2021. Considering the sample, there is a decline in the ranking of saturation, from 48th to 55th, between 1990 and 2021.





2021=28

1989=65

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



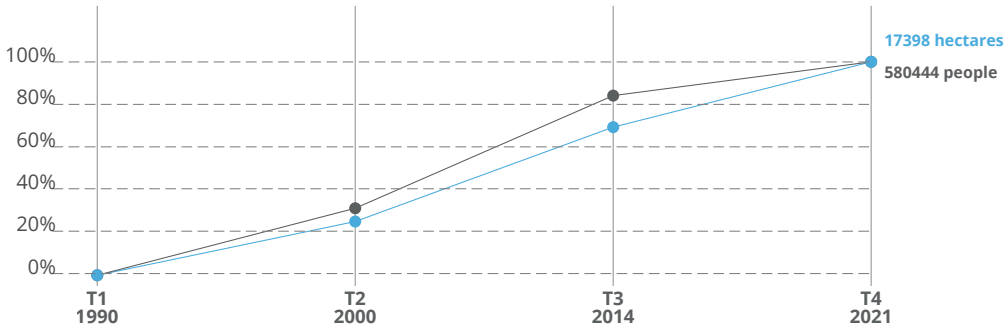
Compactness
rank



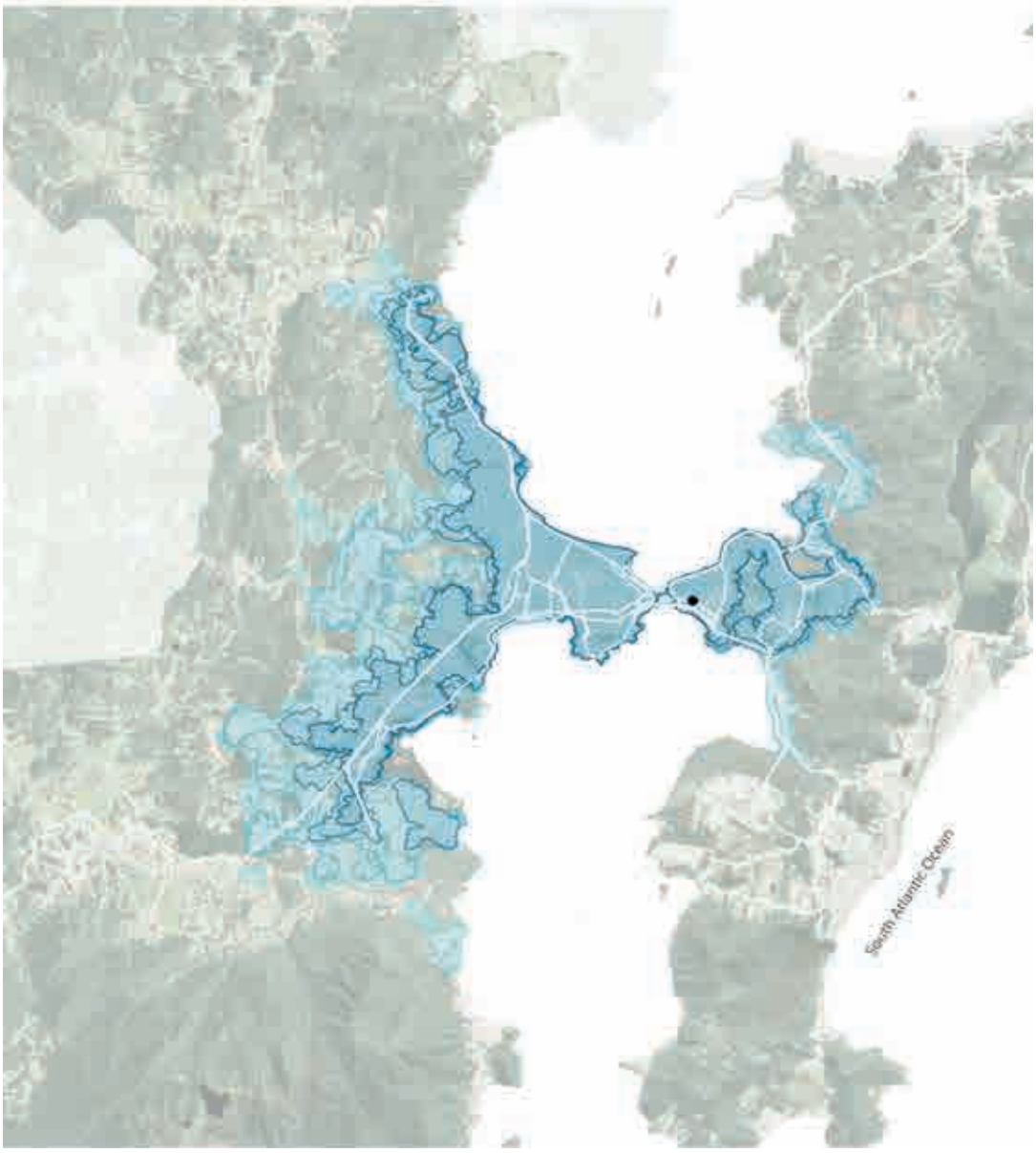
Saturation
rank







GREATER FLORIANÓPOLIS — BRAZIL



● Central Business District N -27.596370
E -48.554918

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

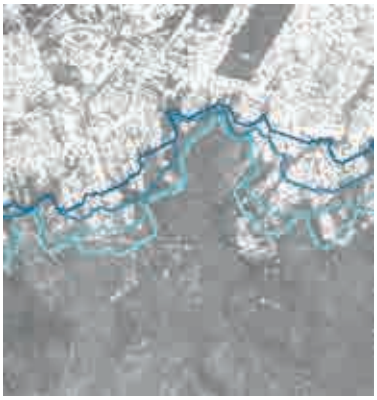
highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Florianópolis have sustained its significance to the city's growth: from 42% (1990-2000) to 46% (2014-2021)—still above the 37% average for the sample. Extension slightly decreased its contribution over the years, as it represented 23% in 1990-2000 in contrast to 19% in 2014-2021. Following this trend, leapfrog's share declined from 16% (1990-2000) and reached 11% (2014-2021). Additionally, inclusion increased its contribution to the city's expansion from 22% (1990-2000) to 26% (2014-2021).

The average dwelling unit occupancy in Greater Florianópolis is 3.0 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.8 stories. The residential plot coverage of Greater Florianópolis is 41.2%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Greater Florianópolis became more compact compared to other Latin American and Caribbean cities.

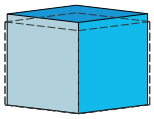
GREATER FLORIANÓPOLIS — BRAZIL

avg 3.4 people per dwelling unit



3 people per dwelling unit

avg 1.6 stories building height

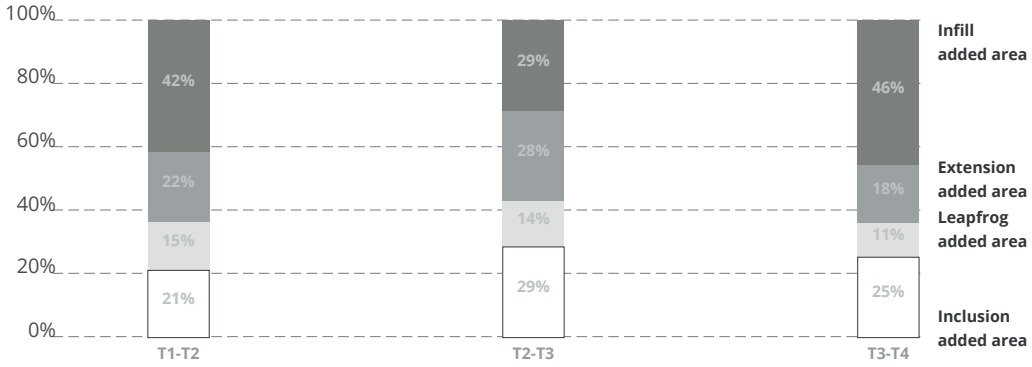


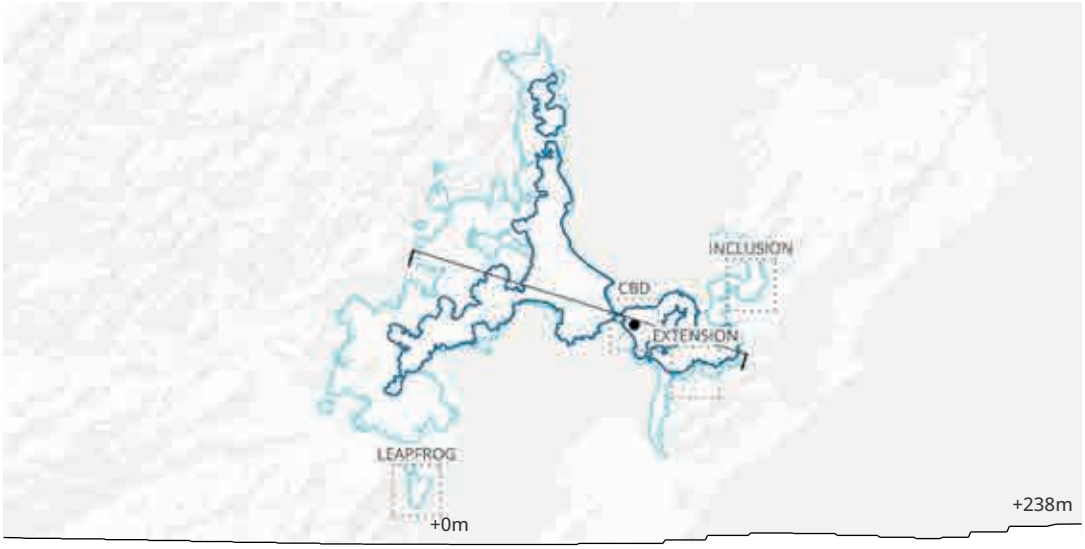
1.8 stories building height

avg 44% plot coverage



41% plot coverage





Section Profile 25 km



1990 T1 2020 T4

20 /

INLAND CITY
ELEVATION: 35m
BIOME: DESERTS / XERIC SHRUBLANDS

Greater Fortaleza,* Brazil, is located in the biome Deserts & Xeric Shrublands, at 35 meters above sea level. Between 1988 and 2020, it experienced a population growth of approximately 2.1% per year, from 1.7 million to 3.3 million. Greater Fortaleza has a high population density compared to the other cities: 69.9 inhabitants per hectare, ranking 40th in population density variation (%) in 2015-2020. Additionally, urban extent increased by approximately 2.7% annually over the last decades, resulting in twice its area of 1988. Throughout this process, the city became significantly more compact compared to other LAC cities, rising from 40th in 1988 to 19th in 2020. Such an increase is accompanied by a rise in saturation, from 43rd to 37th, between 1988 and 2020.



2021=28

1989=65

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank

46th (T4-T3) — 23rd (T2-T1)

Urban Extent
annual change
rank

31st (T4-T3) — 21st (T2-T1)

Urban population density
annual change
rank

55th (T4-T3) — 51st (T2-T1)

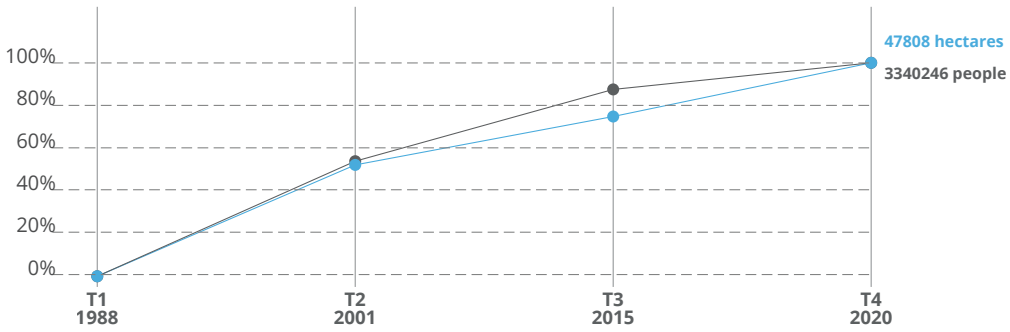
Compactness
rank

40th (T1) — 19th (T4)

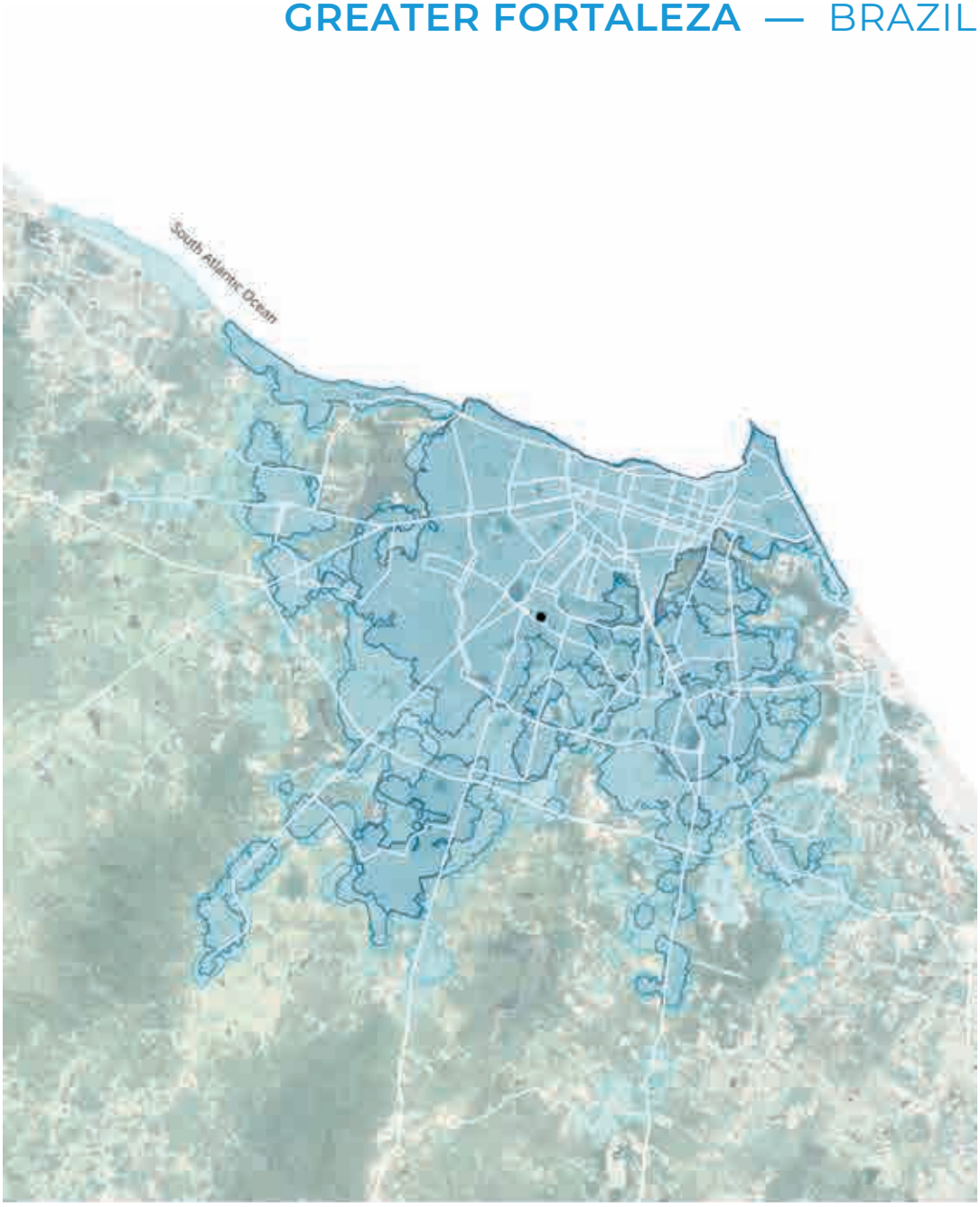
Saturation
rank

53rd (T4) — 30th (T1)





GREATER FORTALEZA — BRAZIL



● Central Business District N -3.7794993
E -38.556650

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

20 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Fortaleza have been increasing its contribution to the city's growth: from 33% (1988-2001) to 47% (2015-2020). In contrast, extension has halved its significance over the years, as it represented 31% in 1988-2001 in contrast to 12% in 2015-2020—less than half the sample average. Whereas leapfrog's contribution to Greater Fortaleza's urban expansion decreased from 16% (1988-2001) to 12% (2015-2020), inclusion's varied from 21% (1988-2001) to 30% (2015-2020).

Greater Fortaleza has a high population density compared to the other cities: 69.9 inhabitants per hectare.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



Extension area

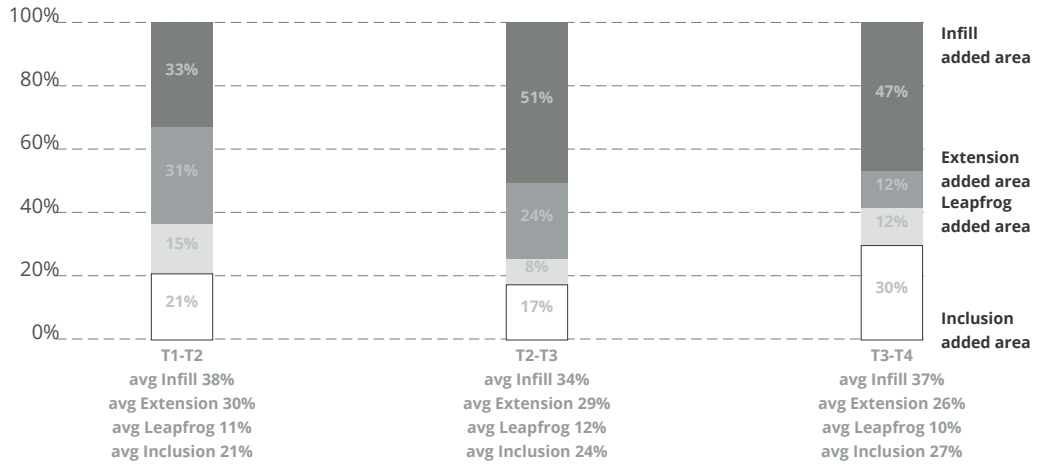


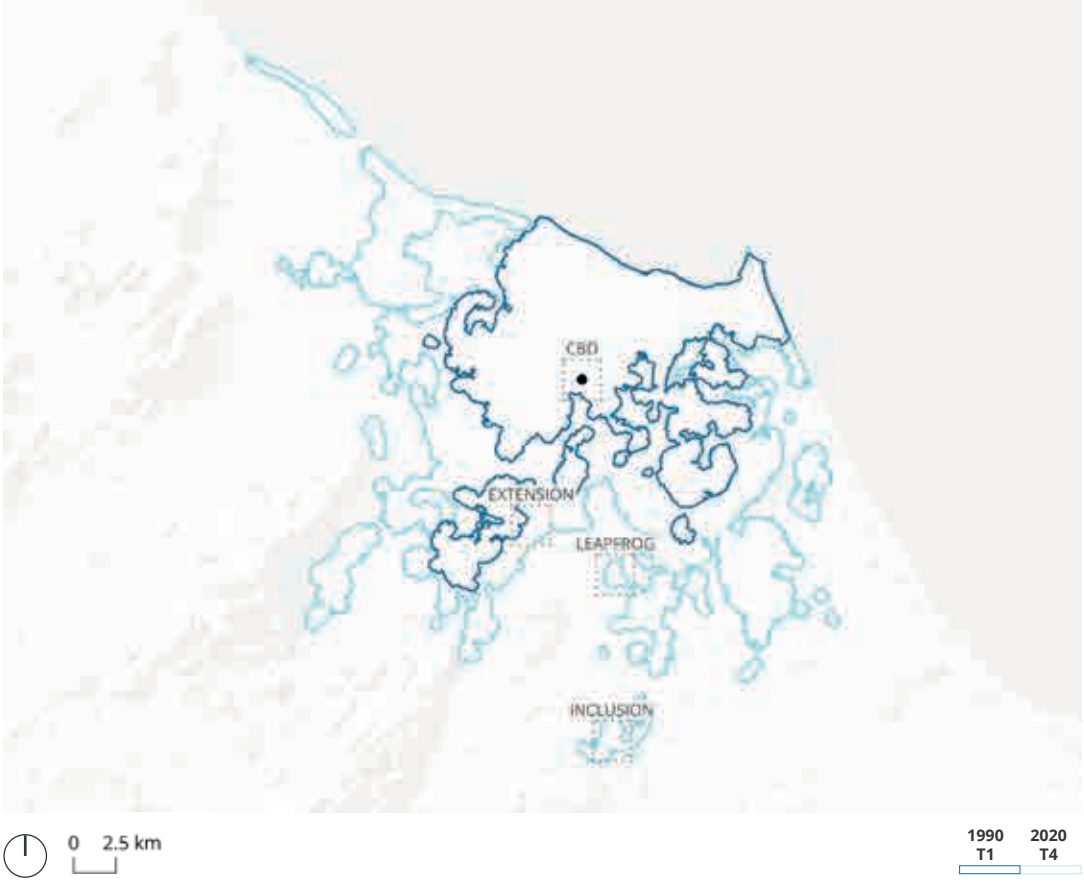
Leapfrog area



Inclusion area

GREATER FORTALEZA — BRAZIL





21 /

COASTAL CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

Georgetown,* Guyana, is located in the biome Tropical & Subtropical Moist Broadleaf Forests, at one meter above sea level. Between 1990 and 2020, its population grew at an average annual rate of 2.7%, from 111.2 thousand to 246.4 thousand. The city has a low population density compared to the other cities: 25.2 inhabitants per hectare, ranking 44th in population density variation (%) in 2010-2020. Additionally, Georgetown's urban extent increased 4.2 times since 1990, a process in which the city became one of the least compact in the sample— dropping from 29th in 1990 to 68th in 2020. Compared to other LAC cities, there is a decline in the ranking of saturation, falling 12 positions, from 32nd to 44th between 1990 and 2020.



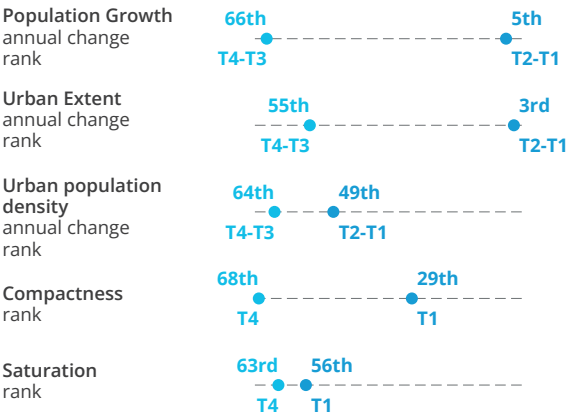
2021=37



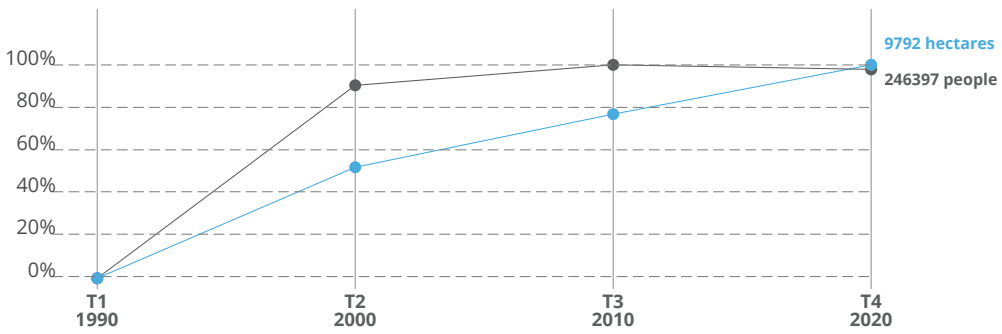
1990=66

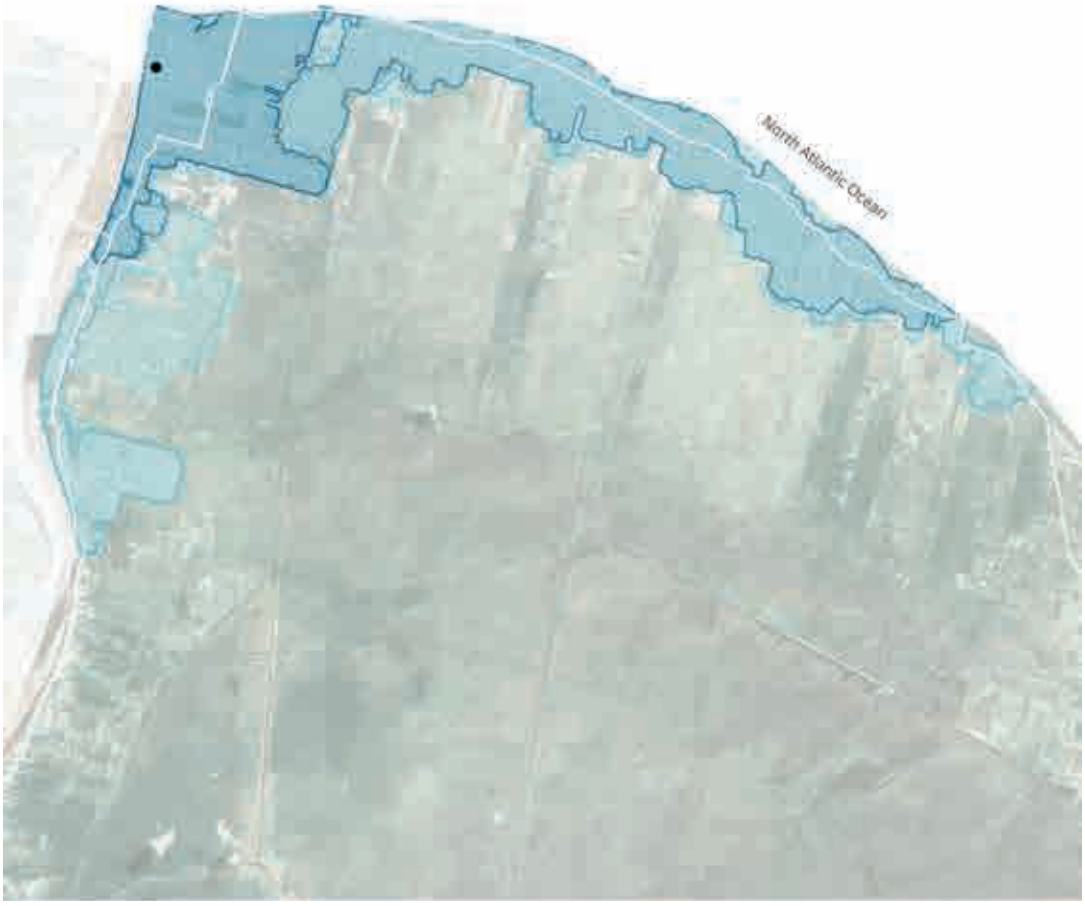
Urban population density
person / hectare

Evaluation metrics rankings:









● Central Business District N 6.81102534
E -58.165334

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

21 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Georgetown have expressively increased its contribution to the city's growth: from 8% (1990-2000) to 46% (2010-2020). Extension has also increased its significance over the years, as it represented 21% in 1990-2000 in contrast to 33% in 2010-2020. Leapfrog's contribution threefolded from 3% (1990-2000) to 16% (2010-2020). Conversely, inclusion varied its previous predominance of 70% (1990-2000) of the city's expansion to 8% (2010-2020).

Georgetown's urban extent increased 4.2 times since 1990, a process in which the city became one of the least compact in the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



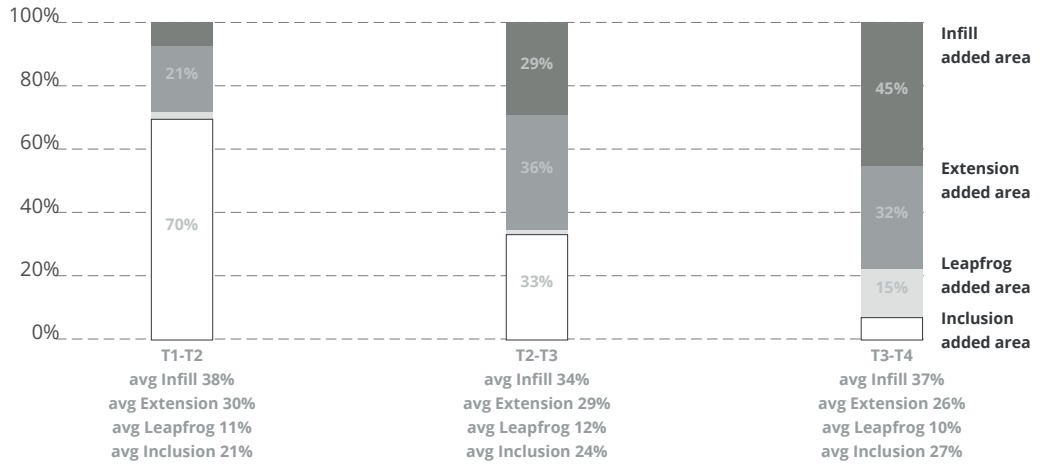
Extension area

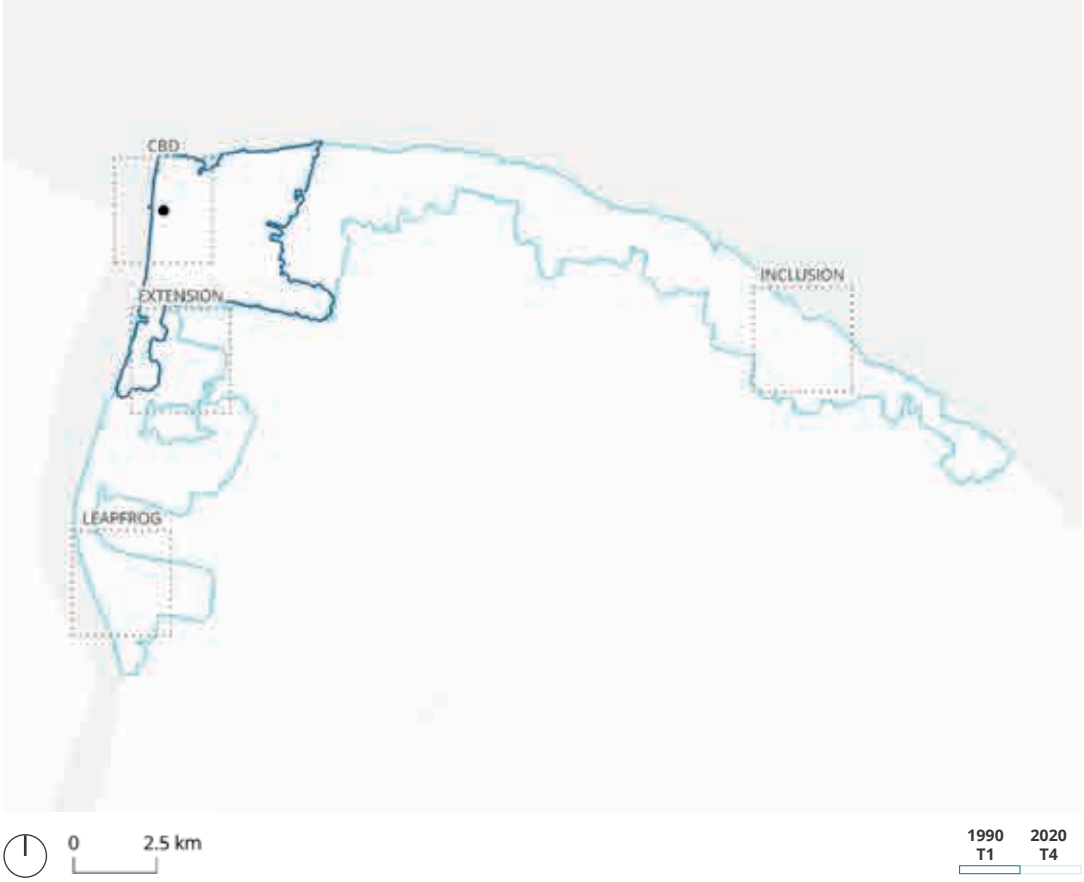


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
21%
70%
29%
36%
33%
45%
32%
15%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


CBD
EXTENSION
INCLUSION
LEAPFROG
0
2.5 km
1990 T1
2020 T4

22 /

INLAND CITY
ELEVATION: 1546m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

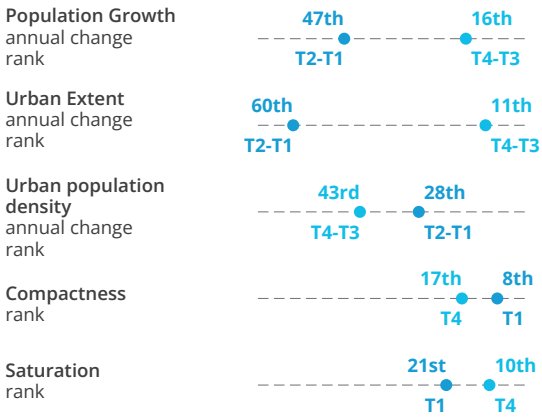
Greater Guadalajara,* Mexico, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 1546 meters above sea level. Between 1990 and 2018, it experienced a population growth of approximately 1.9% per year, from 2.7 million to 4.6 million. Greater Guadalajara has a moderate population density compared to the other cities: 64.4 inhabitants per hectare, ranking 48th in population density variation (%) in 2014-2018. Its urban extent increased by approximately 2.6% annually over the last decades, reaching an area 2.1 times what it was in 1990. The city became remarkably less compact compared to other LAC cities, falling from 8th in 1990 to 17th in 2018 and saturation remained close to 72%.

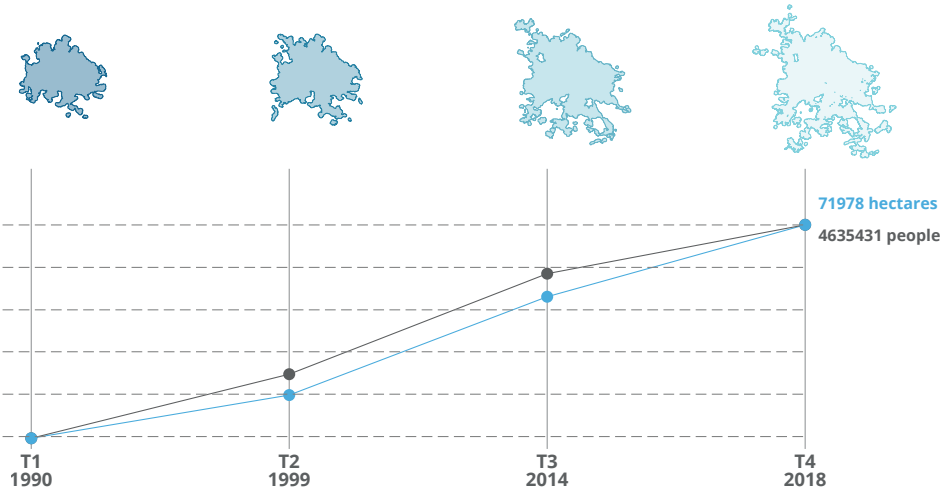




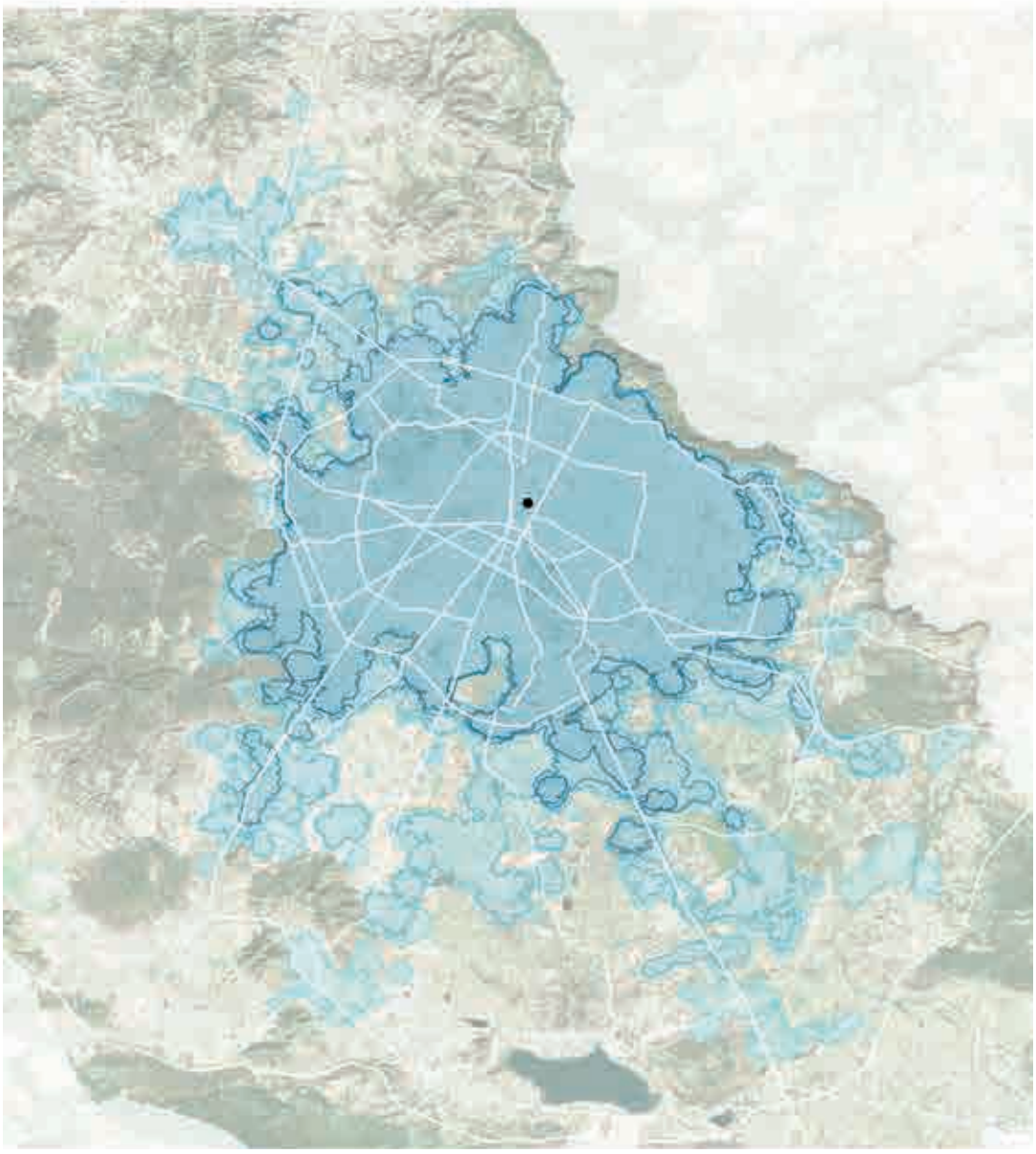
Urban population density
person / hectare

Evaluation metrics rankings:





GREATER GUADALAJARA — MEXICO



● Central Business District N 20.6762660
E -103.34693

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways | local streets

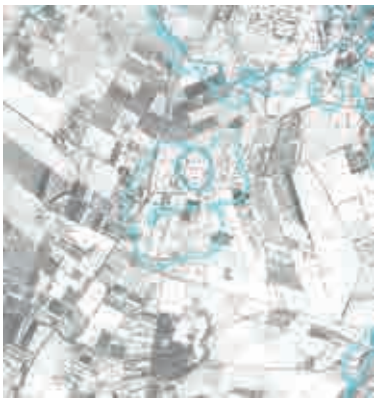
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that 74% of most recent Greater Guadalajara's urban expansion occurred through Infill and Inclusion. The first has decreased its contribution to the city's growth, from 50% (1990-1999) to 36% (2014-2018), whereas the second increased from 20% (1990-1999) to 38% (2014-2018). Extension has slightly decreased its significance over the years, as it represented 21% in 1990-1999 in contrast to 18% in 2014-2018. Leapfrog's contribution to Greater Guadalajara's urban expansion barely changed.

The average dwelling unit occupancy in Guadalajara is 3.5 people per unit, high in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.7 stories. The residential plot coverage of Guadalajara is 46.7%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

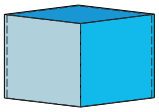
74% of most recent Greater Guadalajara's urban expansion occurred through Infill and Inclusion.

avg 3.4 people per dwelling unit



3.5 people per dwelling unit

avg 1.6 stories building height

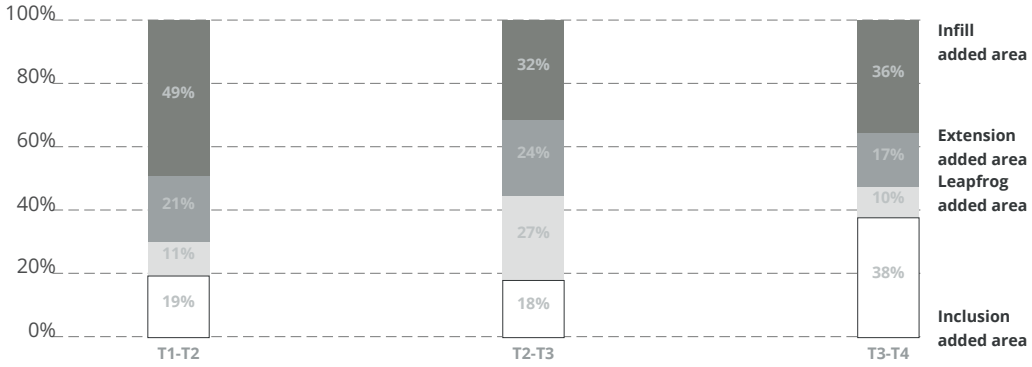


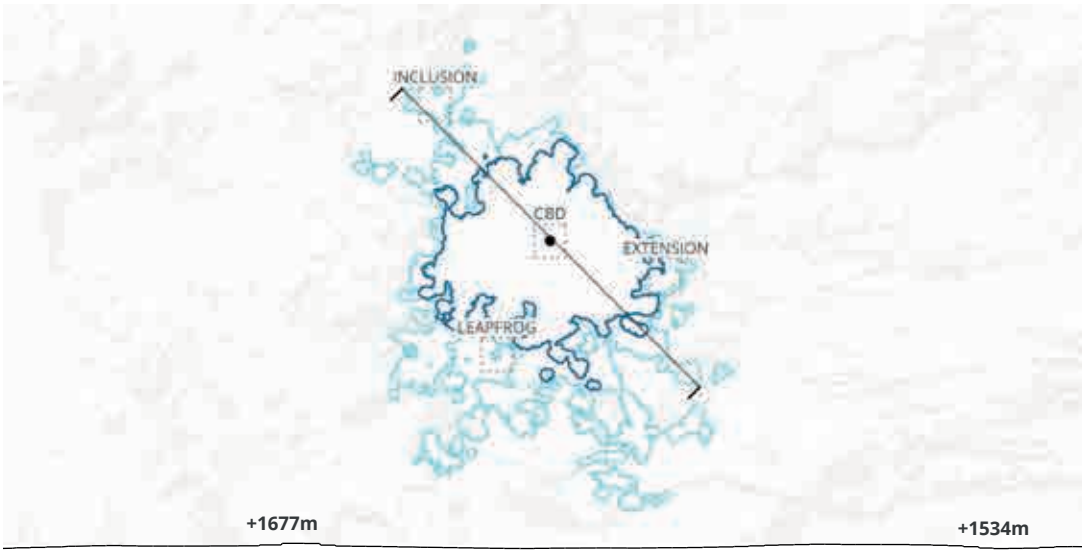
1.7 stories building height

avg 44% plot coverage



47% plot coverage





Section Profile 46 km





23 /

INLAND CITY
ELEVATION: 1542m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

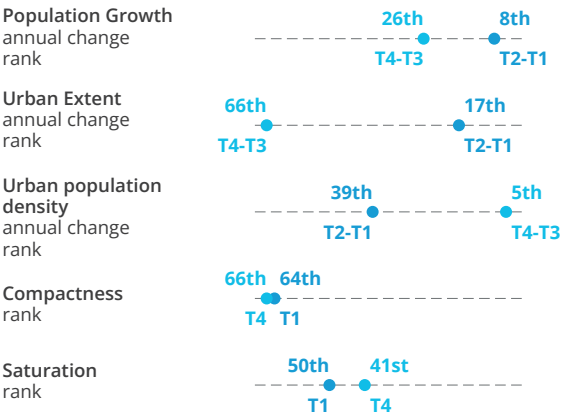
Greater Guatemala City,* Guatemala, is located in the biome Tropical & Subtropical Coniferous Forests, at 1542 meters above sea level. From 1990 to 2020, it experienced a high population growth of approximately 3.4% per year, from 1.1 million to 2.9 million. Greater Guatemala City has a high population density compared to the other cities: 65.4 inhabitants per hectare, and regarding population density variation (%), its position as 6th in 1990-2001 plummeted to 53rd in 2013-2020. Additionally, urban extent increased by approximately 3.4% annually over the last decades, reaching an area 2.8 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 33rd in 1990 to 26th in 2020. Such an increase is accompanied by a decline in the ranking of saturation regarding the sample, dropping 8 positions from 1990 to 2020.

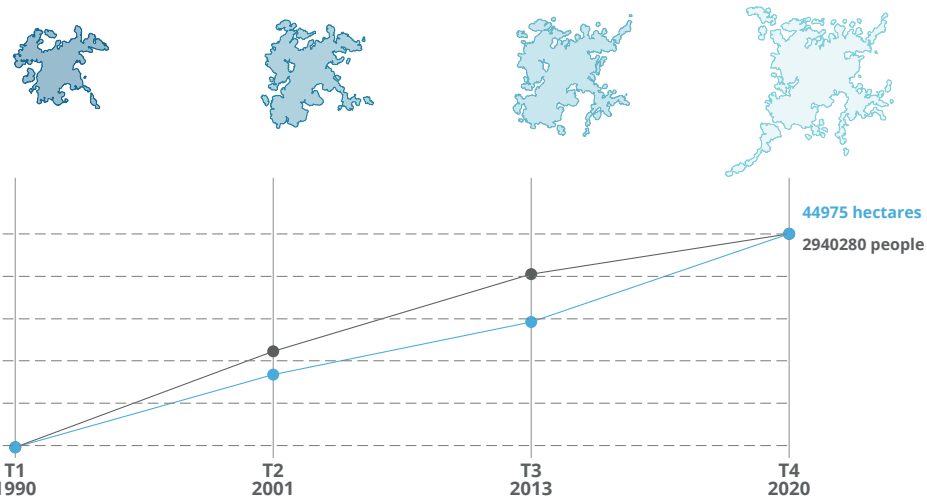




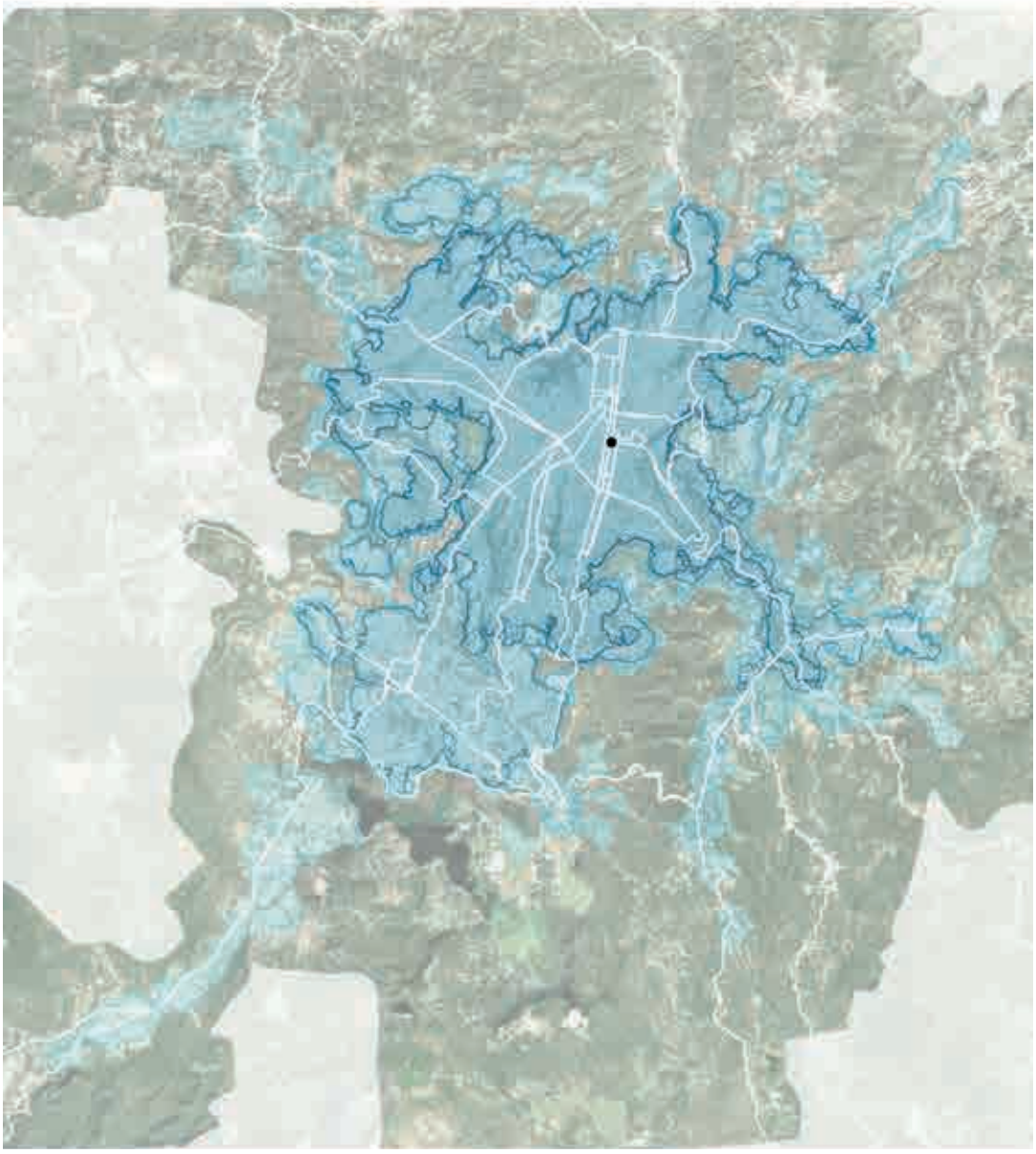
Urban population density
person / hectare

Evaluation metrics rankings:





GREATER GUATEMALA CITY — GUATEMALA



● Central Business District N 14.6126172
E -90.516462

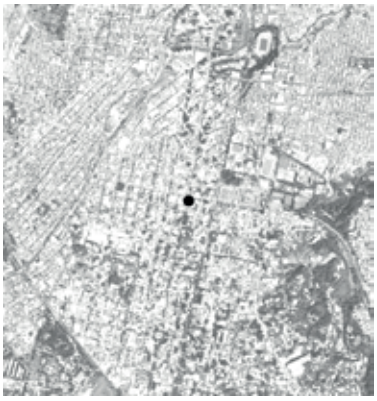
1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

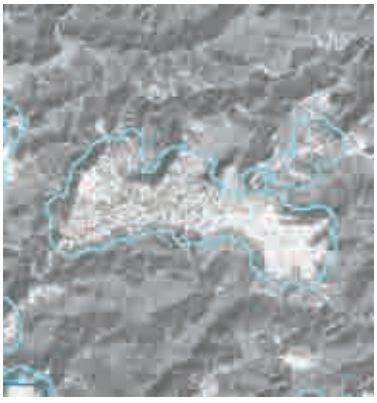
23 /



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Guatemala City have not been changing significantly its contribution to the city's growth: from 28% (1990-2001) to 34% (2013-2020). Extension has decreased its significance over the years, as it represented 28% in 1990-2001 in contrast to 19% in 2013-2020. Leapfrog's share of the city's expansion has remained almost unchanged. Additionally, inclusion varied its contribution to the city's expansion from 34% (1990-2001) to 37% (2013-2020).

Greater Guatemala City has a high plot coverage and a high density of people per dwelling unit compared to the sample. That is a 54.5% plot coverage and 3.9 dwelling unit occupancy, in contrast to the sample's average of 44% plot coverage and 3.4 people per dwelling unit. Additionally, the building story height average is 1.6 stories.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Greater Guatemala City has a high plot coverage and a high density of people per dwelling unit compared to the sample.

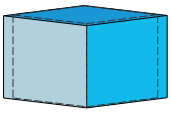
GREATER GUATEMALA CITY — GUATEMALA

avg 3.4 people per dwelling unit



4 people per dwelling unit

avg 1.6 stories building height

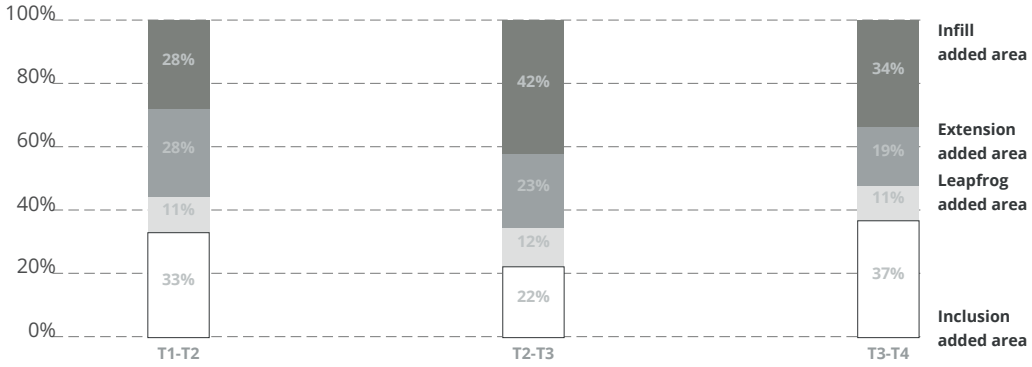


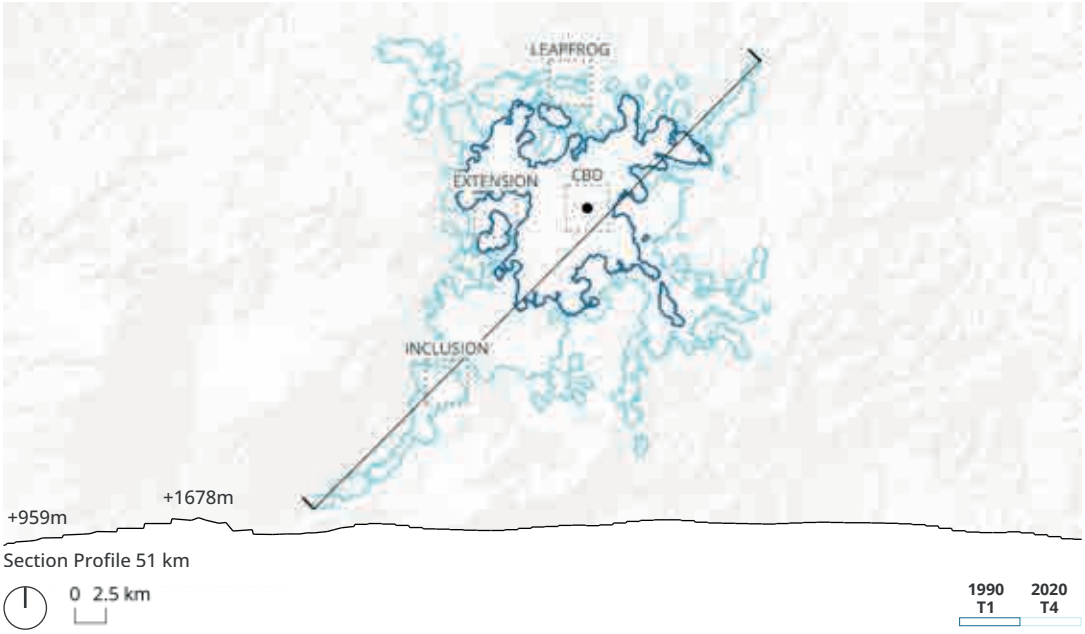
1.6 stories building height

avg 44% plot coverage



54% plot coverage





24 /

INLAND CITY
ELEVATION: 1m
BIOME: FLOODED GRASSLANDS / SAVANNAS

Greater Guayaquil,* Ecuador, is located in the biome Flooded Grasslands & Savannas, at one meter above sea level. Between 1990 and 2021, the population grew at an average annual rate of 1.7%, from 1.5 million to 2.4 million. Greater Guayaquil has a high population density compared to the other cities: 98.1 inhabitants per hectare, ranking 42nd in population density variation (%) in 2016-2021. Additionally, urban extent increased by approximately 2.2% annually over the last decades, resulting in an area two times what it was in 1990. The city became much more compact compared to other LAC cities, rising from 53rd in 1990 to 33rd in 2021. Over the past three decades, Greater Guayaquil's saturation was among the highest in the sample. Still, it rose from 4th to 3rd between 1990 and 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



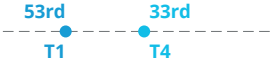
Urban Extent
annual change
rank



Urban population density
annual change
rank

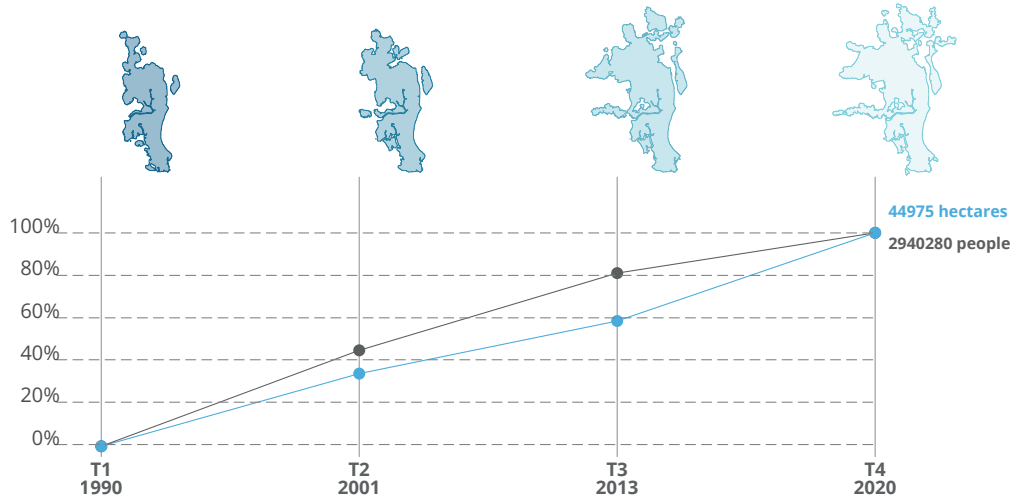


Compactness
rank

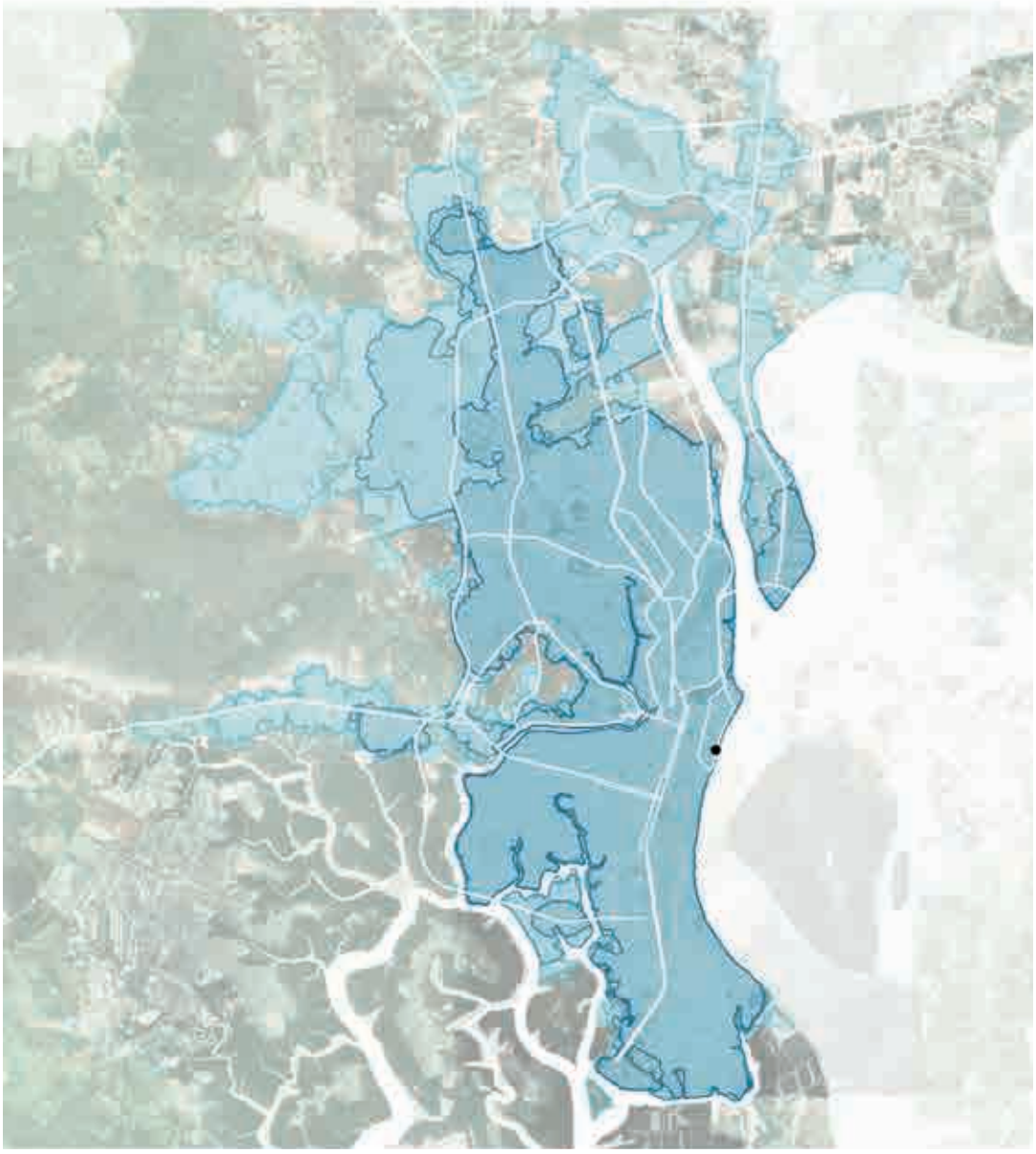


Saturation
rank





GREATER GUAYAQUIL — ECUADOR



● Central Business District N -2.1953889
E -79.880755

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Guayaquil have not been changing significantly its contribution to the city's growth: from 36% (1990-2000) to 42% (2016-2021). Leapfrog's contribution to Greater Guayaquil's urban expansion was 11% (1990-2000) and reached 17% (2016-2021). Additionally, inclusion increased its contribution to the city's expansion from 9% (1990-2000) to 24% (2016-2021). Extension, on the other hand, has significantly decreased its significance over the years, as it represented 46% in 1990-2000 in contrast to 19% in 2016-2021.

The average dwelling unit occupancy in Greater Guayaquil is 3.4 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.7 stories. The residential plot coverage of Greater Guayaquil is 60.7%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

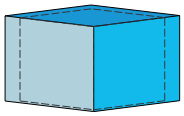
Over the past three decades, Greater Guayaquil's saturation was among the highest in the sample.

avg 3.4 people per dwelling unit



3.4 people per dwelling unit

avg 1.6 stories building height

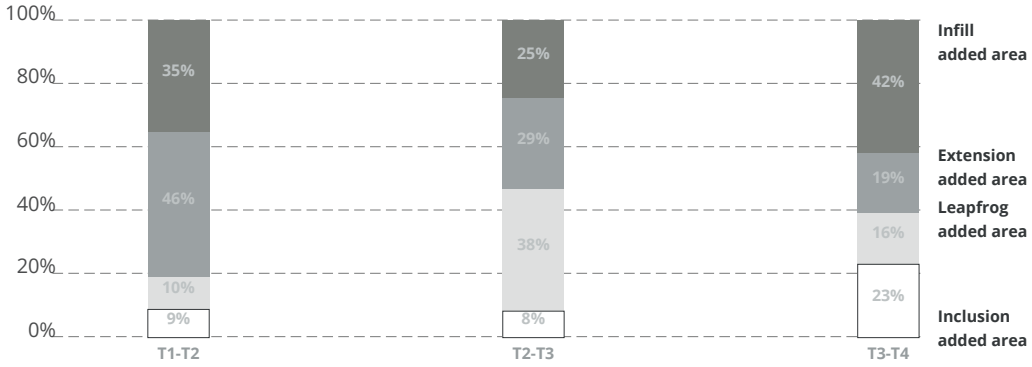


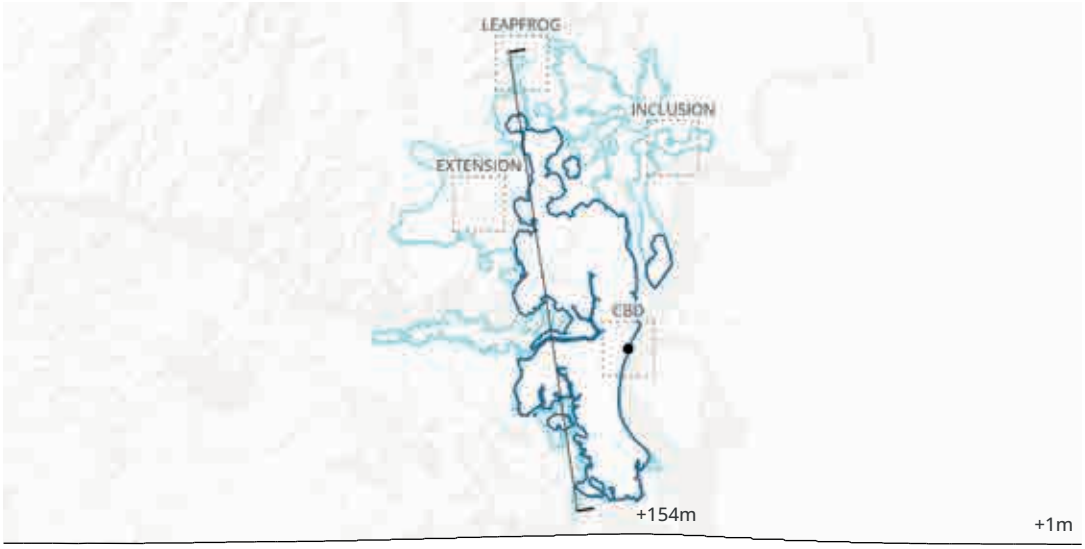
1.7 stories building height

avg 44% plot coverage



61% plot coverage





Section Profile 31 km

0 2.5 km

1990 T1 2020 T4

25 /

INLAND CITY
ELEVATION: 207m
BIOME: DESERTS / XERIC SHRUBLANDS

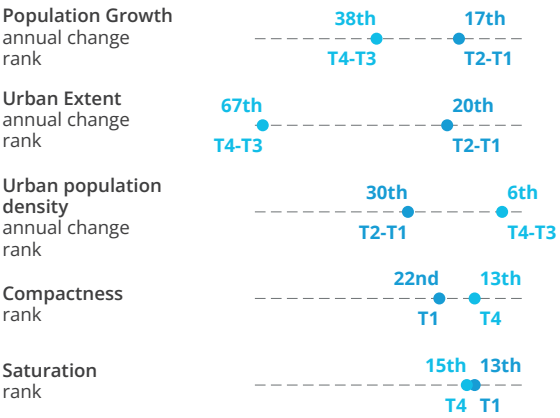
Hermosillo,* Mexico, is located in the biome Deserts & Xeric Shrublands, at 207 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 2.6% per year, from 320.5 thousand to 710.3 thousand. Hermosillo has a moderate population density compared to the other cities: 42.1 inhabitants per hectare, ranking 6th in population density variation (%) in 2010-2020. This position is a meaningful ascent in comparison to its previous place as 30th (1990—2000). Additionally, urban extent increased by approximately 3% annually in the last years, reaching an area 2.5 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 22nd in 1990 to 13th in 2020. Regarding the sample, a minor decline in the ranking of saturation is observed.

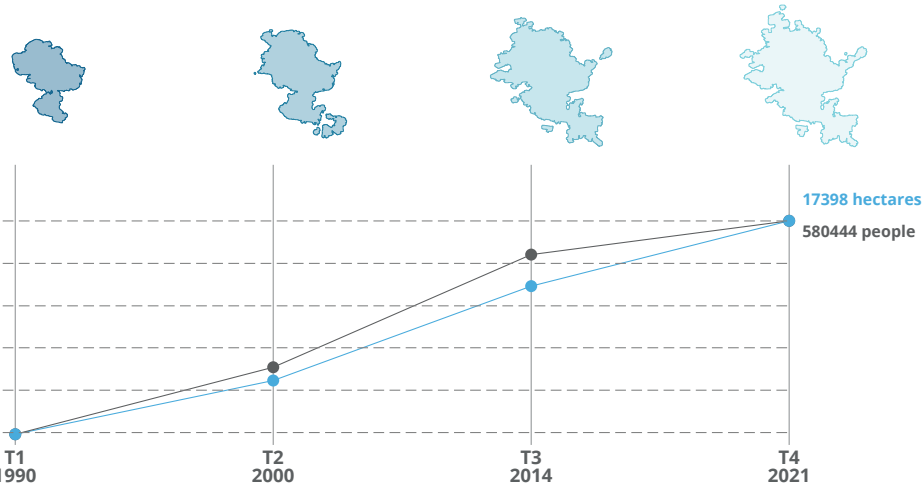




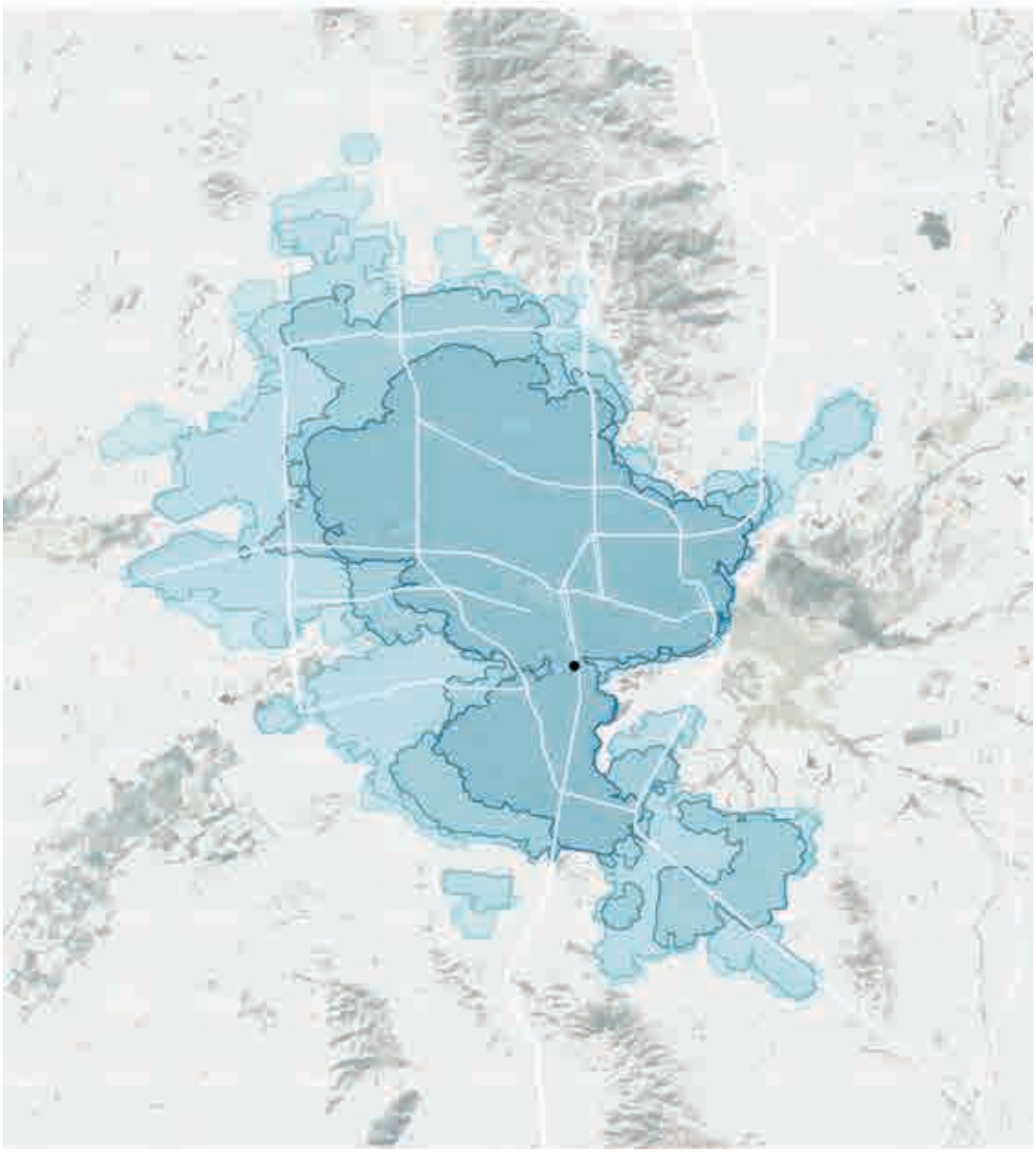
Urban population density
person / hectare

Evaluation metrics rankings:





HERMOSILLO — MEXICO



● Central Business District N 29.0670526
E -110.95579

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

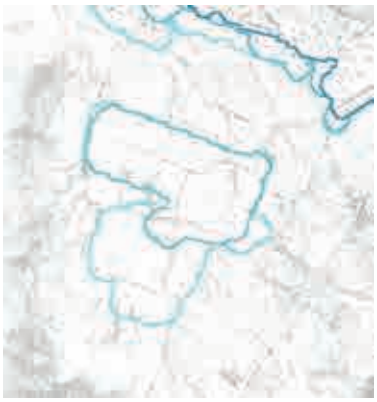
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Hermosillo have been increasing its contribution to the city's growth: from 30% (1990-2000) to 44% (2010-2020). Extension has slightly decreased its significance over the years, as it represented 49% in 1990-2000 in contrast to 42% in 2010-2020. Leapfrog's contribution to Hermosillo's urban expansion was 9% (1990-2000) and reached 7% (2010-2020). Additionally, inclusion varied its contribution to the city's expansion from 14% (1990-2000) to 10% (2010-2020).

The average dwelling unit occupancy in Hermosillo is 3.2 people per unit, low in comparison to the average of the cities in this Atlas. Hermosillo's average building height is 1.2 stories for the city, 25% lower than the average for the analyzed cities. The residential plot coverage of Hermosillo is 45.8%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

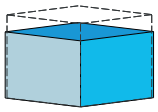
Hermosillo's average building height is 1.2 stories for the city, 25% lower than the average for the analyzed cities.

avg 3.4 people per dwelling unit



3.2 people per dwelling unit

avg 1.6 stories building height

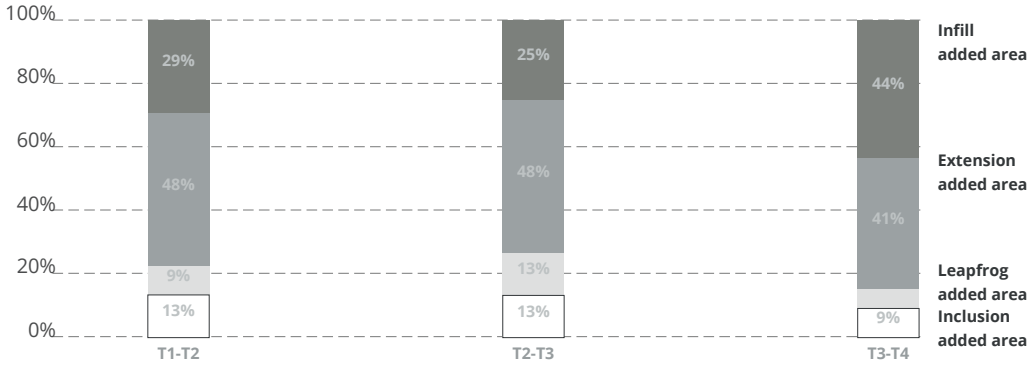


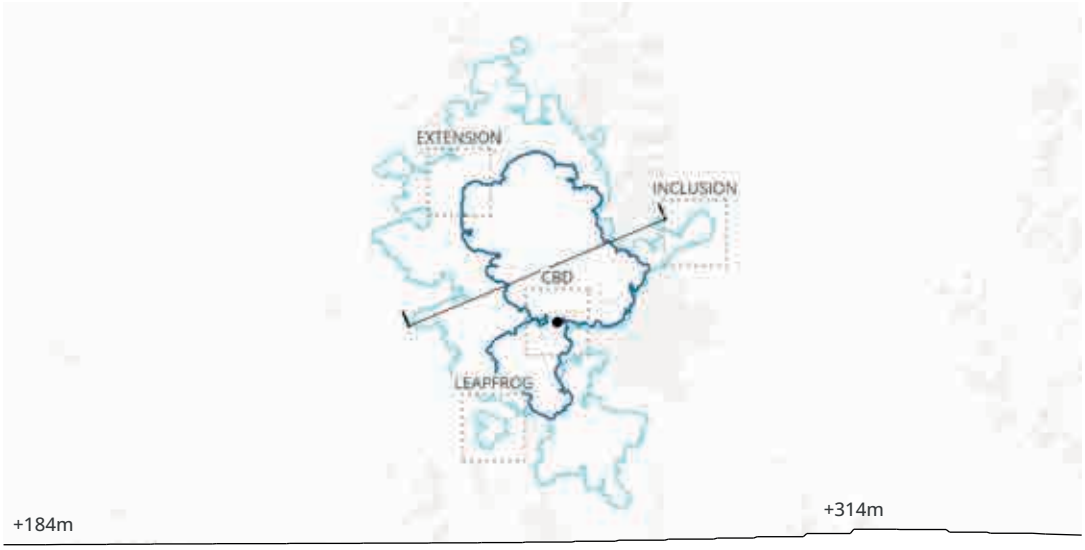
1.2 stories building height

avg 44% plot coverage

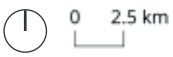


46% plot coverage





Section Profile 15 km





26 /

COASTAL CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

Ilhéus,* Brazil, is located in the biome Tropical & Subtropical Moist Broadleaf Forests, at one meter above sea level. Between 1993 and 2020, it experienced a population growth of approximately 1% per year, from 78.9 thousand to 104.5 thousand. Ilhéus has a moderate population density compared to the other cities: 51.6 inhabitants per hectare, ranking 62nd in population density variation (%) in 2013-2020. Additionally, urban extent increased by approximately 4.4% annually over the last decades, reaching an area 3.3 times what it was in 1993. Despite such growth, in 2020, Ilhéus presents the second smallest urban extent area in the sample. The city became much less compact compared to other LAC cities, plummeting from 21st in 1993 to 67th in 2020. Such a decrease is accompanied by an increase in saturation, rising 8 positions from 1993 to 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

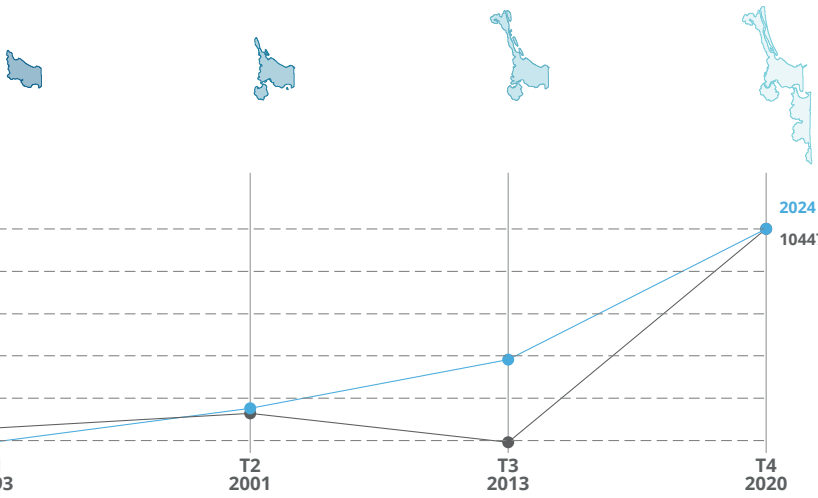


Compactness
rank



Saturation
rank







● Central Business District N -14.798029
E -39.036599

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Ilhéus decreased its contribution to the city's growth from 36% (1993-2001) to 16% (2013-2020). Extension has decreased its significance, as it represented 13% in 1993-2001 in contrast to 9% in 2013-2020. Leapfrog's share of Ilhéus' urban expansion has remained almost unchanged. In contrast, inclusion represented 74% of Ilhéus' urban expansion between 2013 and 2020, almost three times the average sample. This is an increase in comparison to its share of 46% from 1993 to 2001.t

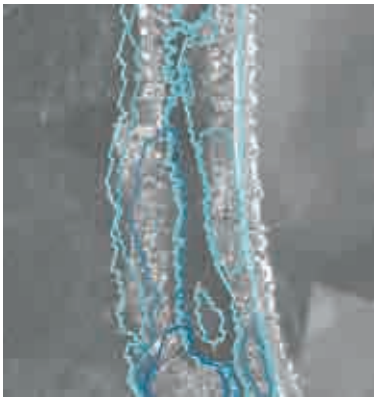
Inclusion represented 74% of Ilhéus' urban expansion between 2013 and 2020, almost three times the average sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

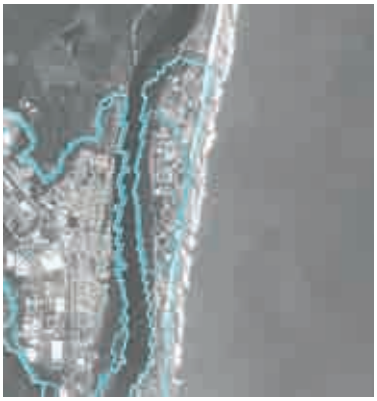
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



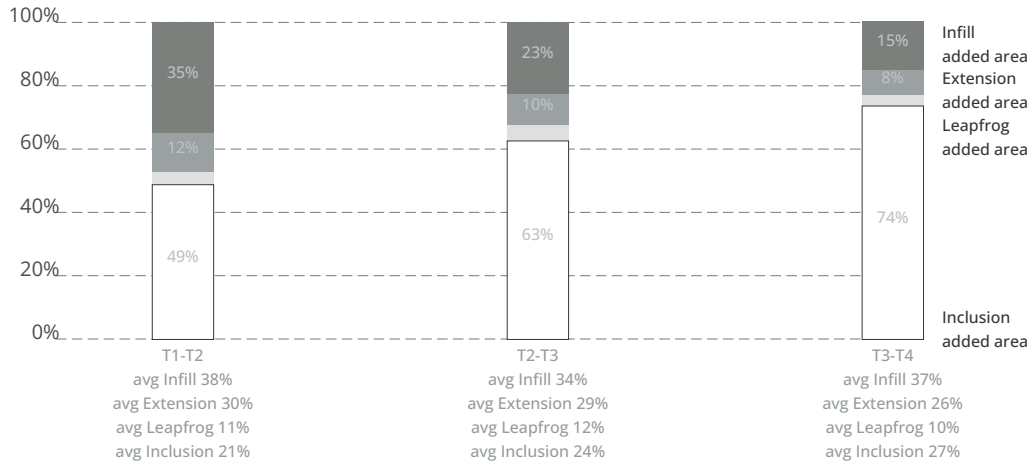
Extension area

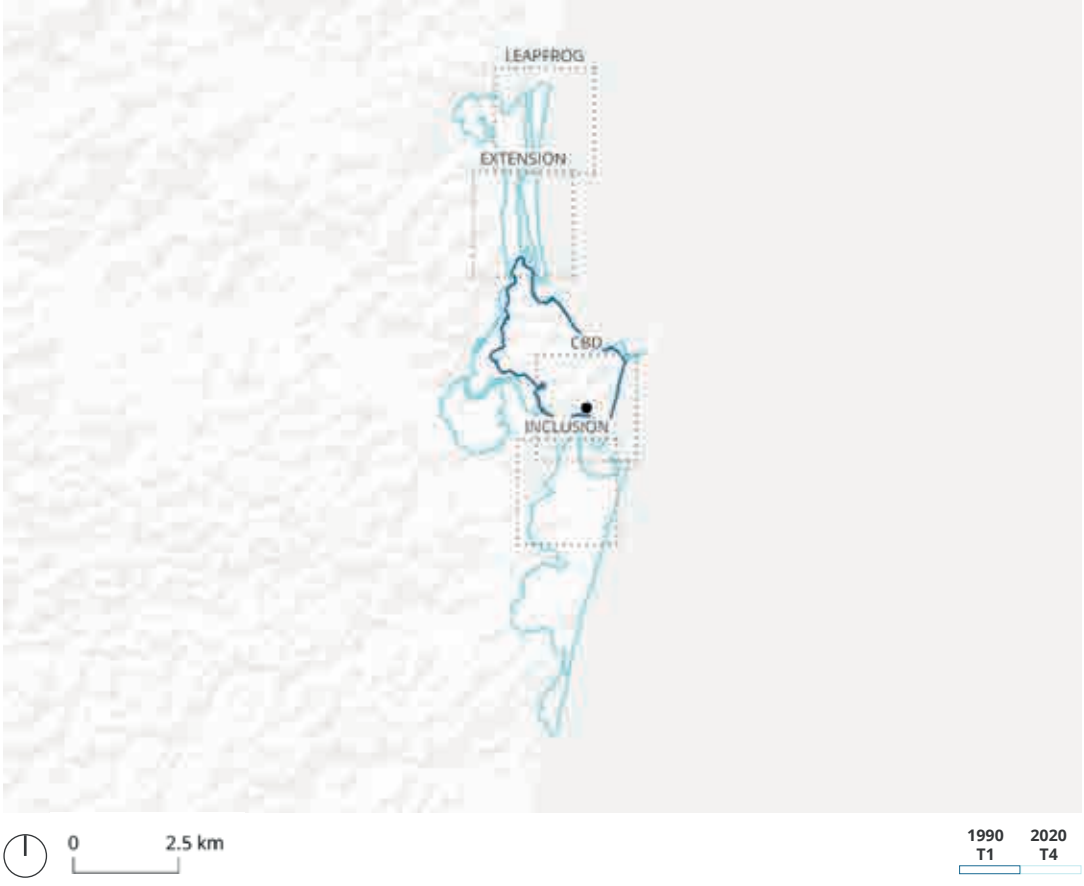


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
35%
12%
49%
23%
10%
63%
15%
8%
74%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1990 T1
2020 T4

27 /

INLAND CITY
ELEVATION: 194m
BIOME: DESERTS / XERIC SHRUBLANDS

Jequié,* Brazil, is located in the biome Deserts & Xeric Shrublands, at 194 meters above sea level. Between 1992 and 2021, it experienced a population growth of approximately 0.6% per year, from 116.9 thousand to 137.4 thousand. Jequié is characterized by its low population growth, remaining at the end of the ranking. The city has a moderate population density compared to the other cities: 45.1 inhabitants per hectare, ranking 37th in population density variation (%) in 2014-2021. This position presents an expressive increase, considering that the city previously occupied last place in the ranking. Additionally, urban extent increased by approximately 3.4% annually over the last decades, meaning the area is now 2.7 times what it was in 1992. The city became much more compact compared to other Latin American and Caribbean cities, rising from 43rd in 1992 to 16th in 2021. Such an increase is accompanied by a minor rise in saturation, gaining one position, from 65th to 64th between 1992 and 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



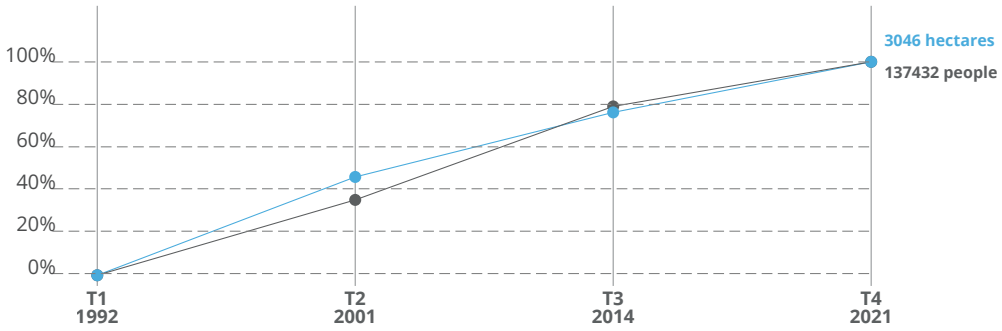
Compactness
rank

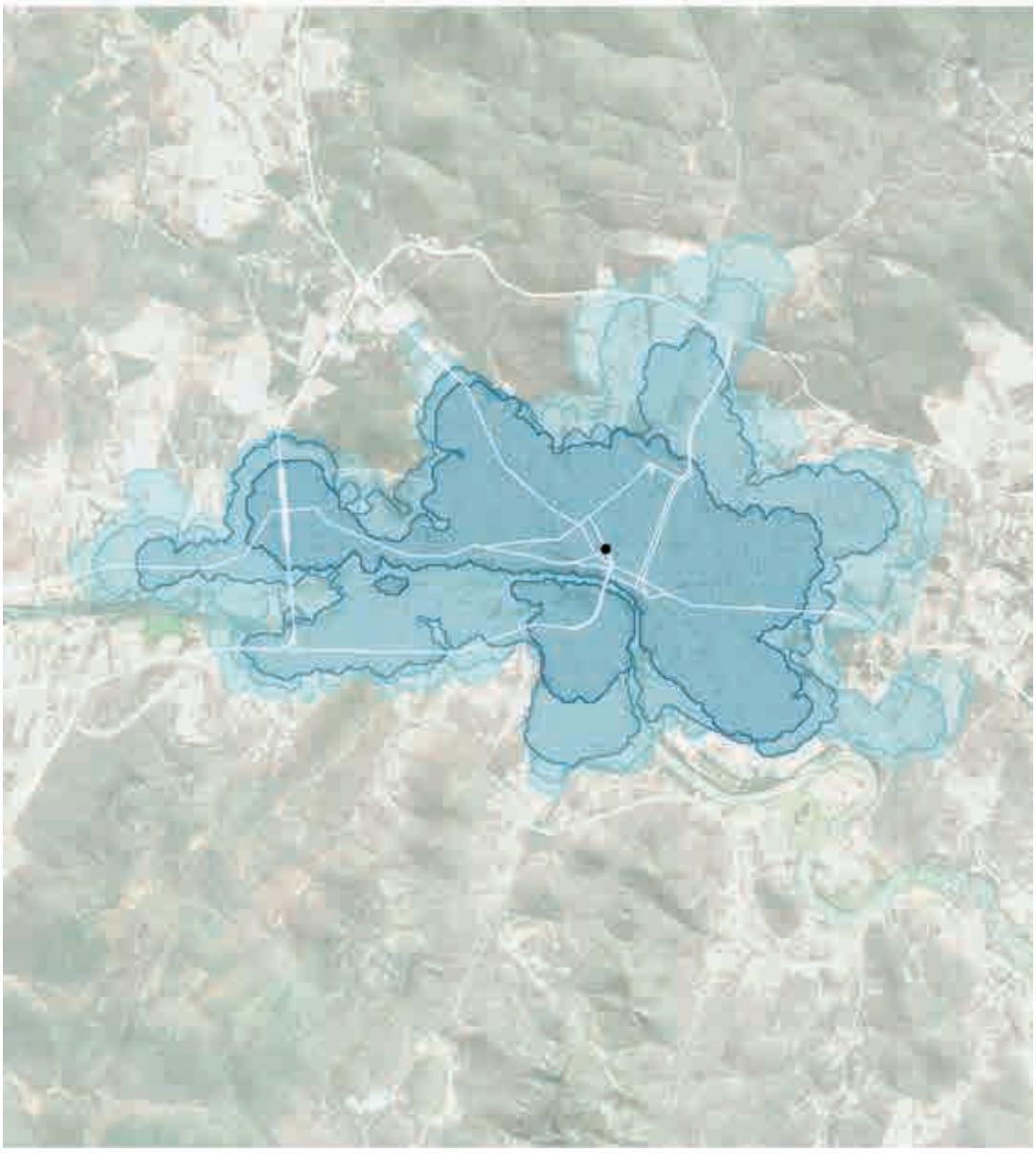


Saturation
rank

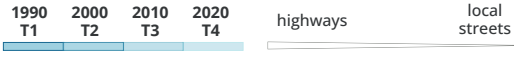








● Central Business District N -13.861519
E -40.080989





27 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that the contribution of infill to Jequié's urban expansion almost doubled: from 26% (1992-2001) to 45% (2014-2021). On the contrary, extension has decreased its significance over the years, as it represented 38% in 1992-2001 in contrast to 29% in 2014-2021. Leapfrog's contribution to Jequié's urban expansion was 15% (1992-2001) and reached 11% (2014-2021). Additionally, inclusion varied its contribution to the city's expansion from 23% (1992-2001) to 18% (2014-2021).

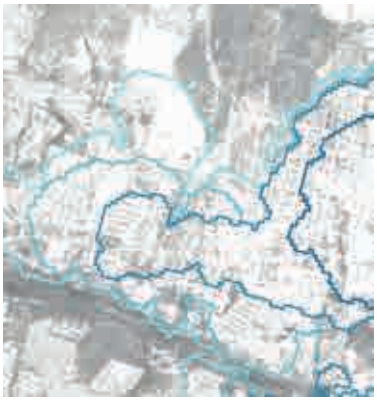
Jequié is characterized by its low population growth. The city became much more compact compared to other Latin American and Caribbean cities.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

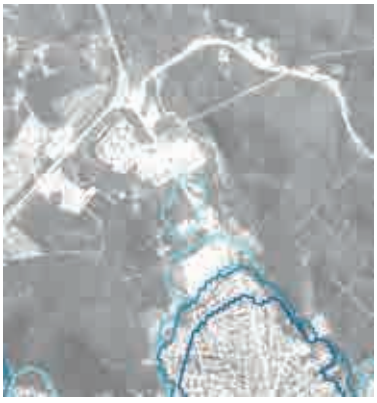
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



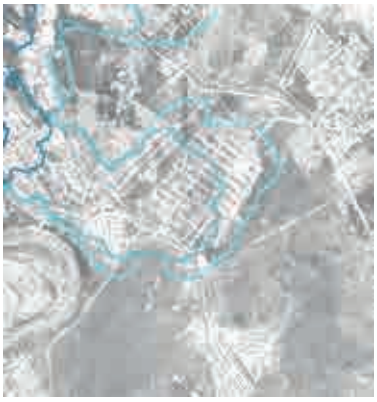
Central Business District



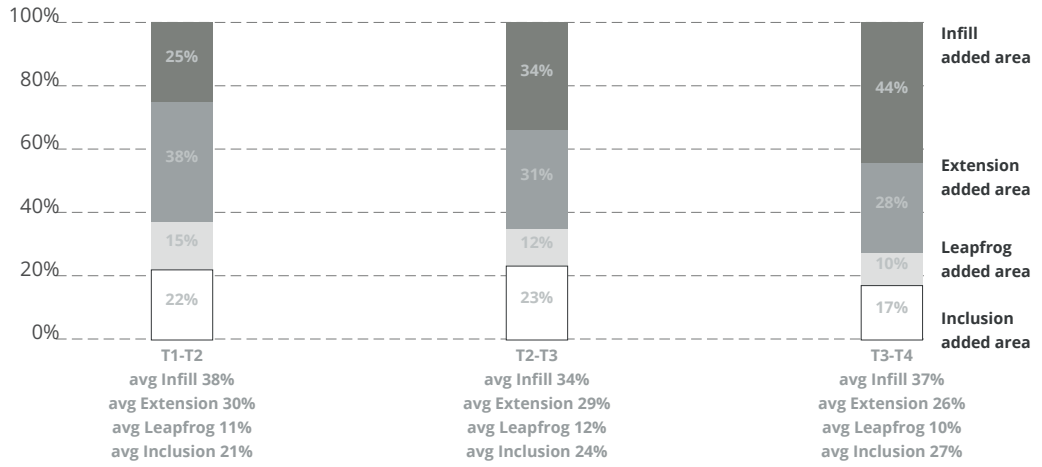
Extension area

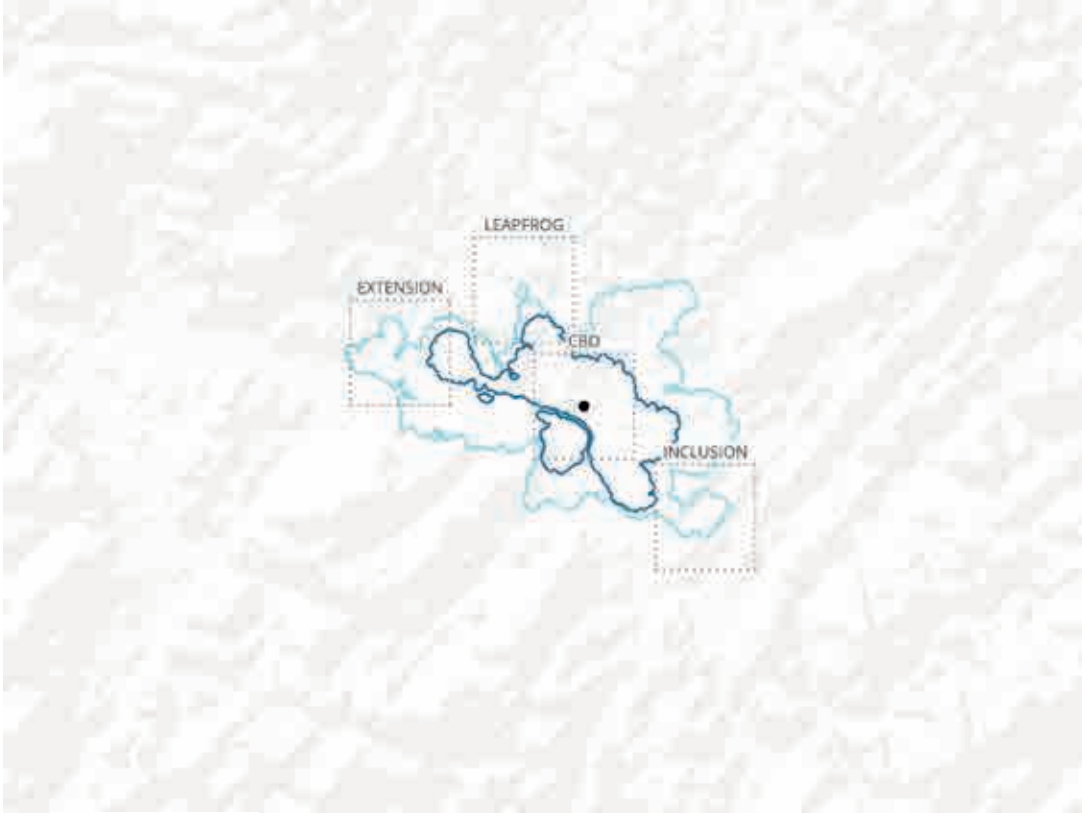


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
25%
38%
15%
22%
34%
31%
12%
23%
44%
28%
10%
17%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1990 T1
2020 T4

28 /

COASTAL CITY
ELEVATION: 14m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Kingston,* Jamaica, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 14 meters above sea level. Between 1990 and 2020, it experienced a slow population growth of approximately 0.1% per year, from 574.9 thousand to 594.3 thousand. Moreover, urban extent had a low increase, approximately 0.9% annually in the last decades. As a result, the area extended 32% beyond what it was in 1990. Both the cities' population growth and urban extent growth are ranked in the very end compared with other LAC cities. Kingston has a moderate population density compared to the other cities: 45.9 inhabitants per hectare, ranking 29th in population density variation (%) in 2010-2020. Further on, the city became much less compact compared to other LAC cities, lowering from 2nd in 1990 to 20th in 2020. Such a decrease is accompanied by an increase in saturation, rising 6 positions, from 10th to 4th between 1990 and 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank
64th (T2-T1) — 32nd (T4-T3)

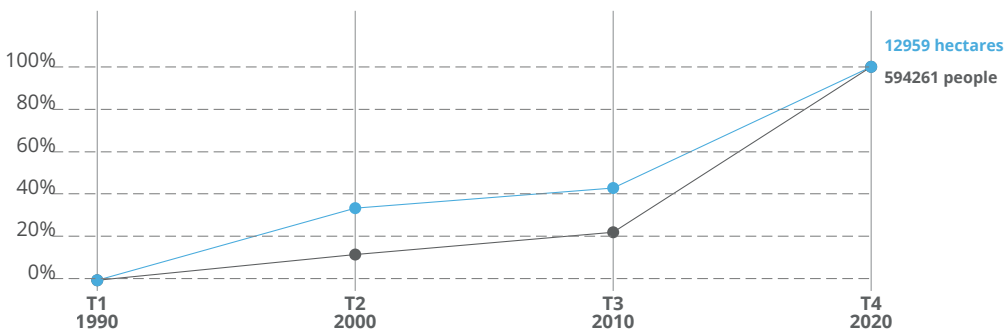
Urban Extent
annual change
rank
65th (T2-T1) — 32nd (T4-T3)

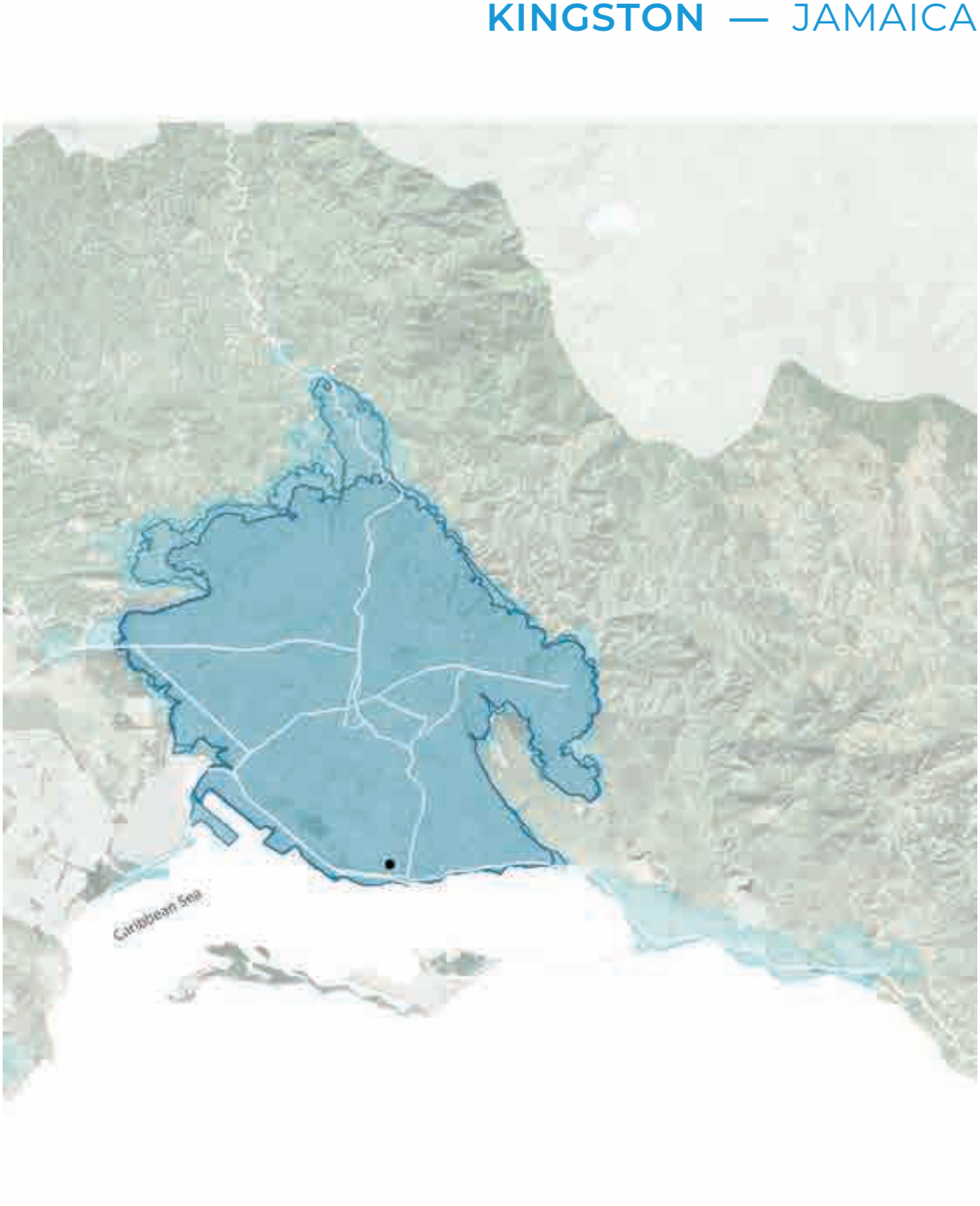
Urban population density
annual change
rank
31st (T4-T3) — 19th (T2-T1)

Compactness
rank
20th (T4) — 2nd (T1)

Saturation
rank
10th (T1) — 4th (T4)







● Central Business District N 17.9687249
E -76.788471

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that most of Kingston's expansion, approximately 80%, has occurred through processes of infill and inclusion. Regarding extension and leapfrog, the first has increased its significance over the years, from 7% in 1990-2000 to 15% in 2010-2020, while the second slightly lowered from 8% (1990-2000) to 6% (2010-2020).

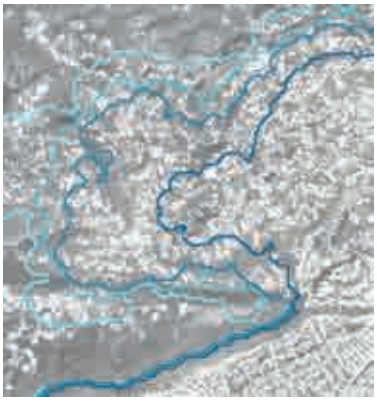
Most of Kingston's expansion, approximately 80%, has occurred through processes of infill and inclusion.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

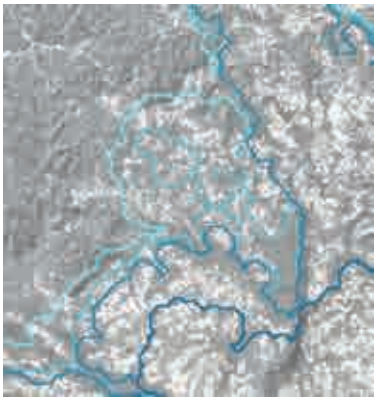
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



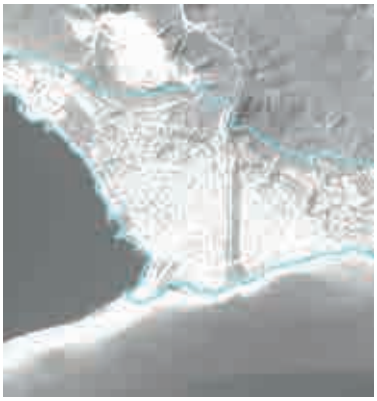
Central Business District



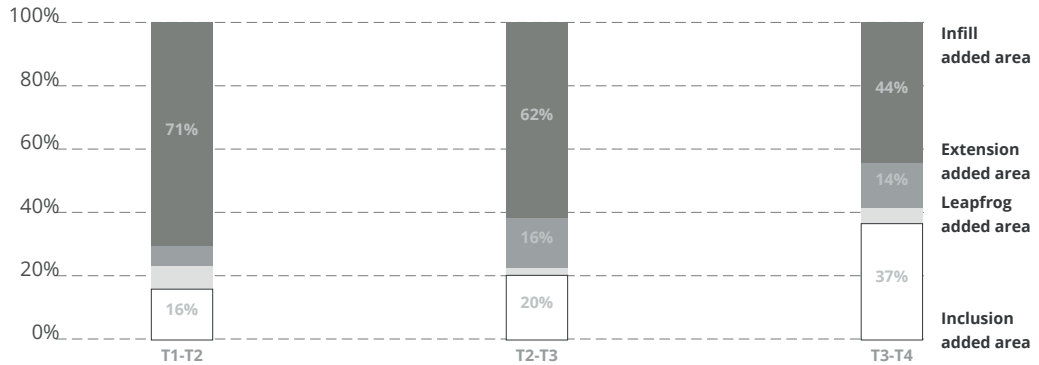
Extension area

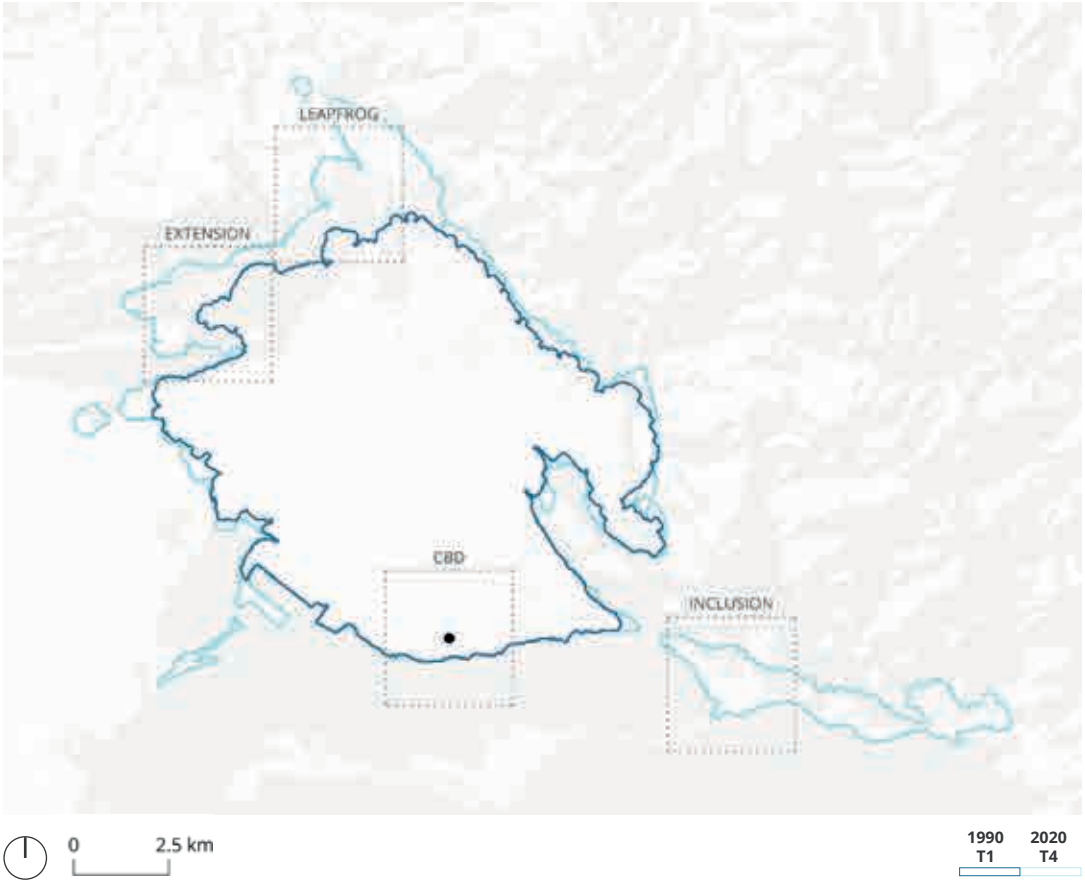


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
71%
16%
62%
16%
20%
44%
14%
37%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1990 T1
2020 T4

29 /

INLAND CITY
ELEVATION: 4606m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Greater La Paz,* Bolivia, is located in the biome Montane Grasslands & Shrublands, at 3967 meters above sea level. Between 1989 and 2020, it experienced a population growth of approximately 1.88% per year, from 981 thousand to 1.757 million. Greater La Paz has a moderate population density compared to the other cities: 60.7 inhabitants per hectare, ranking 45th in population density variation (%) in 2010-2020. Additionally, urban extent had a moderate increase, approximately 3.6% annually over the last decades, which resulted in an area more than 3 times what it was in 1990. The city increased significantly its compactness compared to other LAC cities, changing its ranking from 48th in 1989 to 22nd in 2020. Such an increase is also observed in saturation, which rose 16 positions, from 40th to 24th between 1989 and 2020.

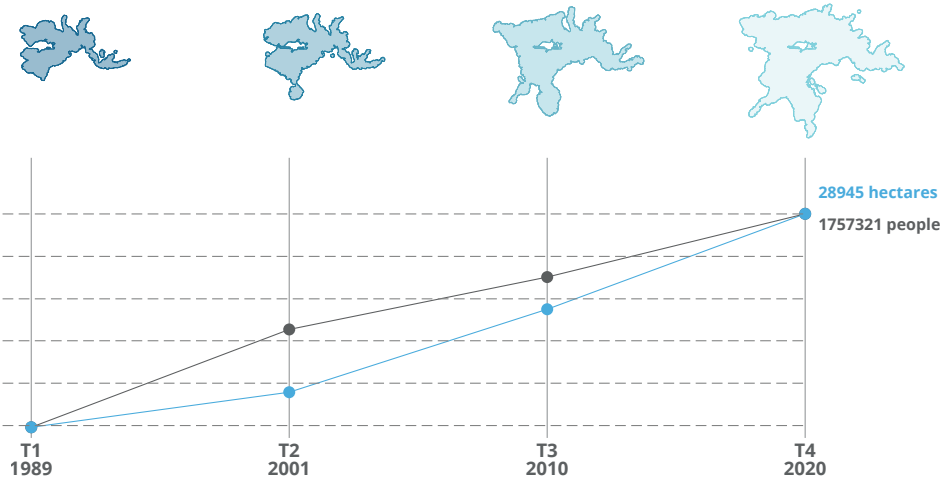


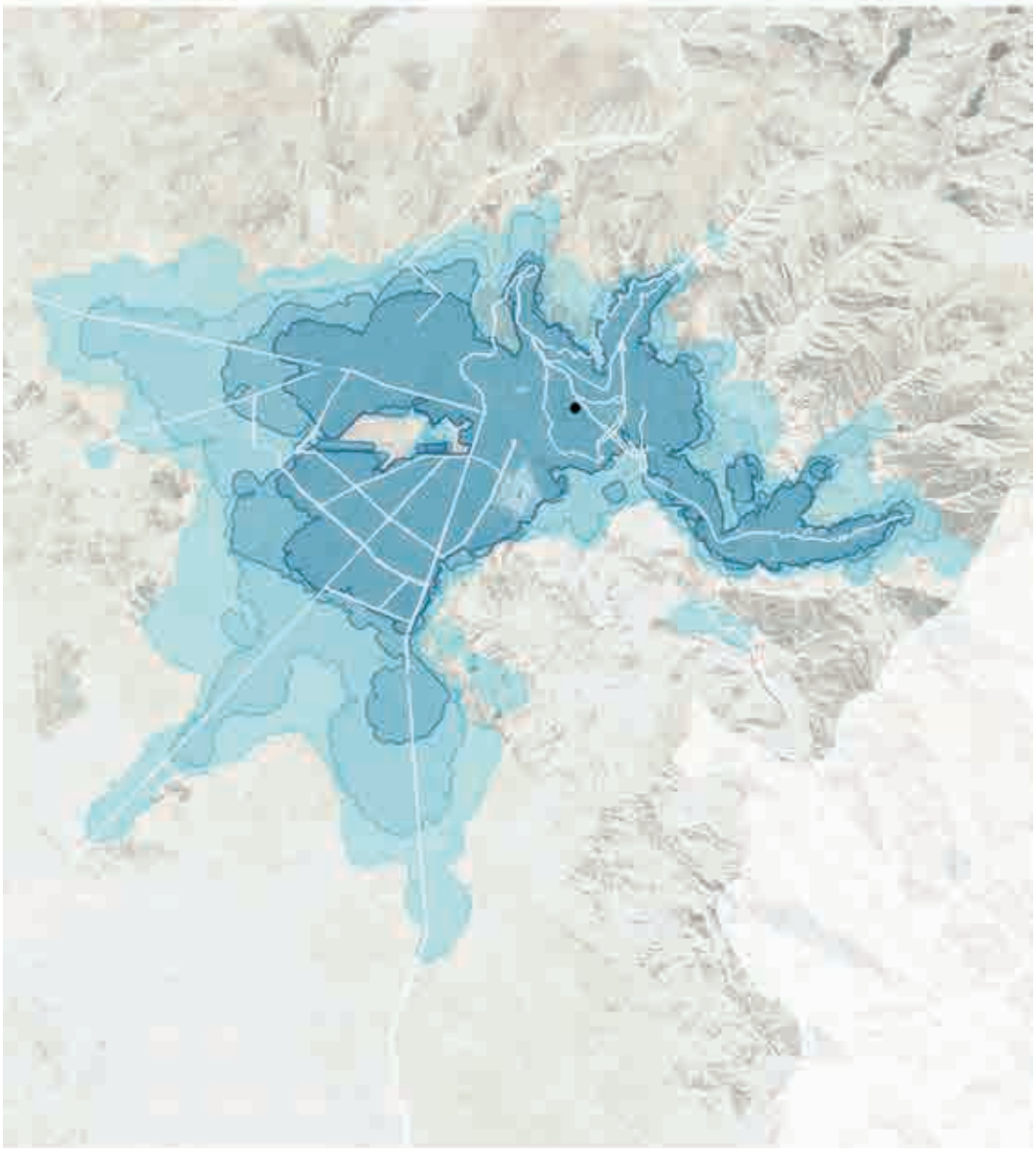


Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth annual change rank	61st (T4-T3)	29th (T2-T1)
Urban Extent annual change rank	48th (T2-T1)	22nd (T4-T3)
Urban population density annual change rank	45th (T4-T3)	14th (T2-T1)
Compactness rank	53rd (T1)	33rd (T4)
Saturation rank	40th (T1)	24th (T4)





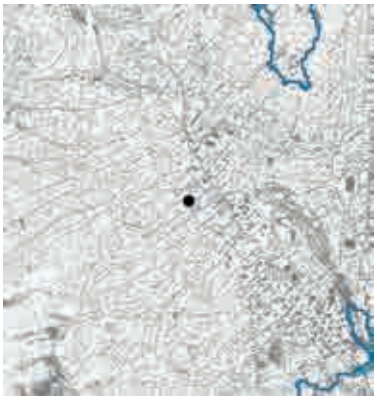
● Central Business District N -16.502000
E -68.135734

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

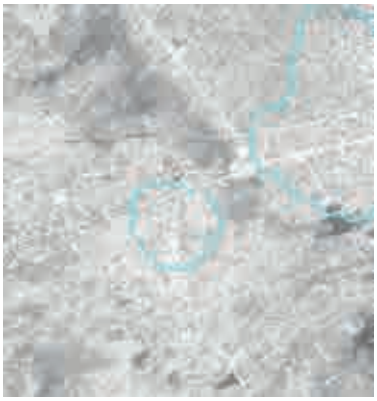
0 2.5 km



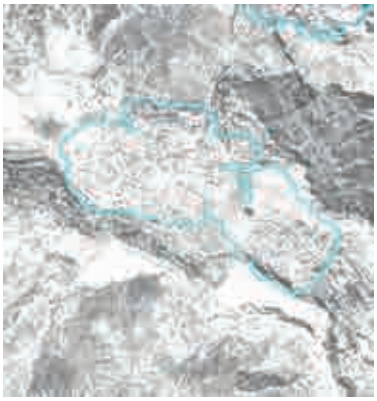
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater La Paz have been decreasing its contribution to the city's growth: from 46% (1989-2001) to 35% (2010-2020). In the same direction, extension has increased its significance over the years, from 33% in 1989-2001 to 46% in 2010-2020. Leapfrog's contribution to Greater La Paz's urban Expansion was 13% (1989-2001) and reached 9% (2010-2020). Additionally, Inclusion slightly varied its contribution to the city's expansion from 8% (1989-2001) to 10% (2010-2020).

The average dwelling unit occupancy in Greater La Paz is 3.2 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.8 stories. The residential plot coverage of Greater La Paz is 31.5%, which means there is a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Extension has increased its significance over the years, from 33% in 1989-2001 to 46% in 2010-2020.

avg 3.4 people per dwelling unit

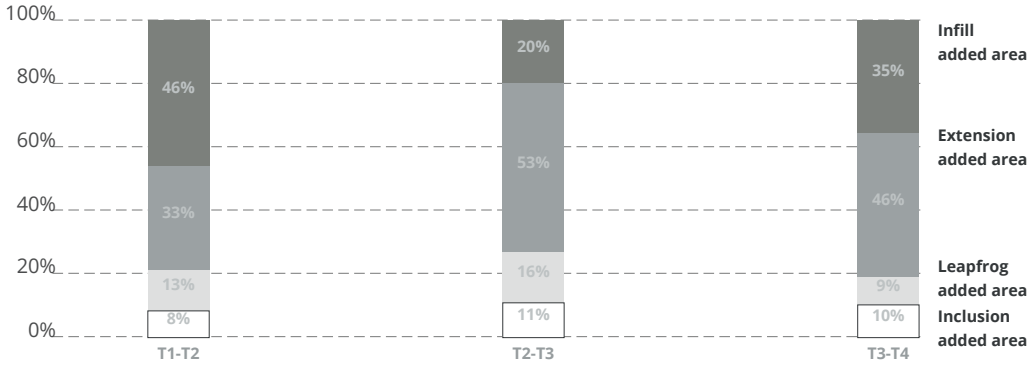
3.2 people per dwelling unit

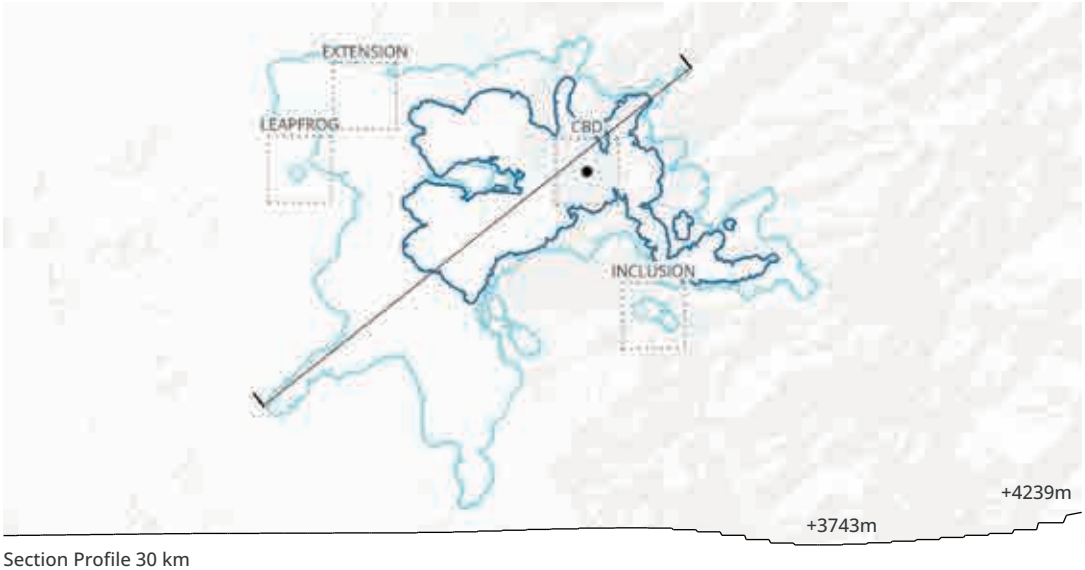
avg 1.6 stories building height

1.8 stories building height

avg 44% plot coverage

31% plot coverage





Section Profile 30 km

0 2.5 km

1991 T1 2019 T4

30 /

COASTAL CITY
ELEVATION: 30m
BIOME: MEDITERRANEAN FORESTS / WOODLANDS / SCRUB

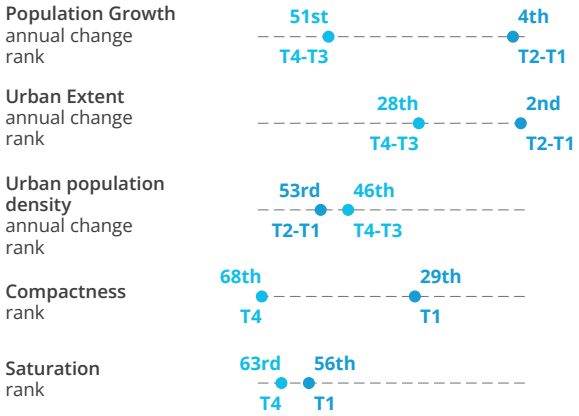
La Serena,* Chile, is located in the biome Mediterranean Forests, Woodlands & Scrub, at 30 meters above sea level. Between 1990 and 2000, it experienced a steady population growth, ranked as 4th, but it lowered its annual rate considerably to reach the 51st position between 2010-2020. The annual population growth across the periods is still high, averaging 4.7% per year. As a result, the population of La Serena quadrupled, from 85.9 thousand to 351.1 thousand. Nevertheless, La Serena has a low population density compared to the other cities: 36.6 inhabitants per hectare, ranking 46th in population density variation (%) in 2010-2020. This can be explained by a greater increase in urban areas than in population: the area is now 6 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 61st in 1990 to 54th in 2020. Such an increase is accompanied by a rise in saturation, gaining 21 positions, from 55th to 34th between 1990 and 2020.



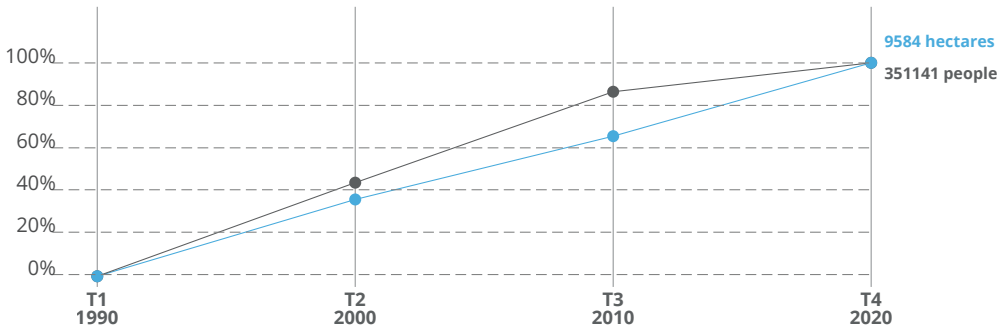


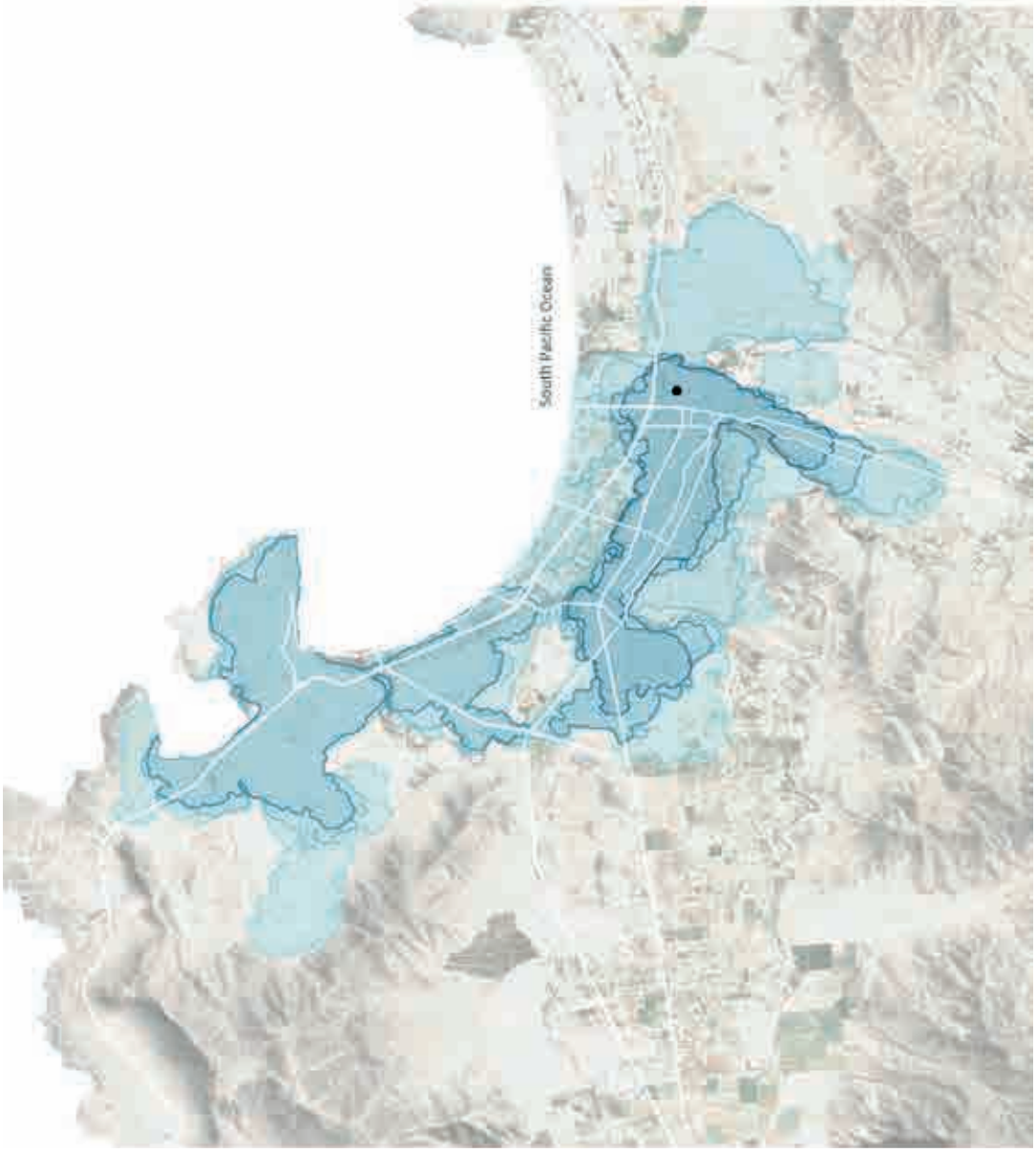
Urban population density
person / hectare

Evaluation metrics rankings:









● Central Business District N -29.902205
E -71.251221

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that the city grew mostly through extension in the past decade (61%)—the highest share in the sample for the period—and infill (25%). The contribution of each one of these processes to the urban extent growth has varied significantly, especially extension—which more than doubled—and inclusion—which reduced to its fifth comparing 1990-2000 to 2010-2020.

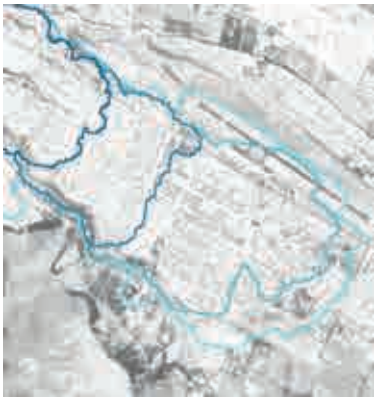
The annual population growth across the periods is still high, averaging 4.7% per year. As a result, the population of La Serena quadrupled, from 85.9 thousand to 351.1 thousand.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



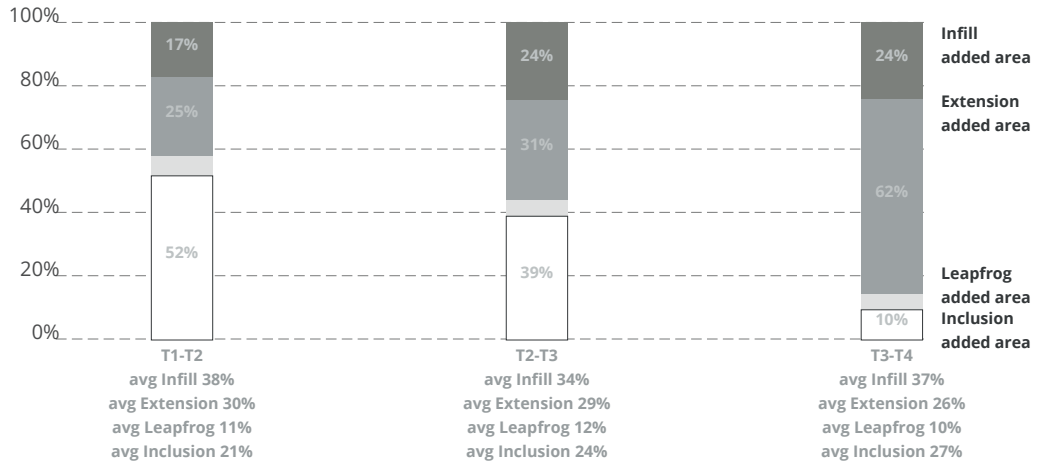
Extension area

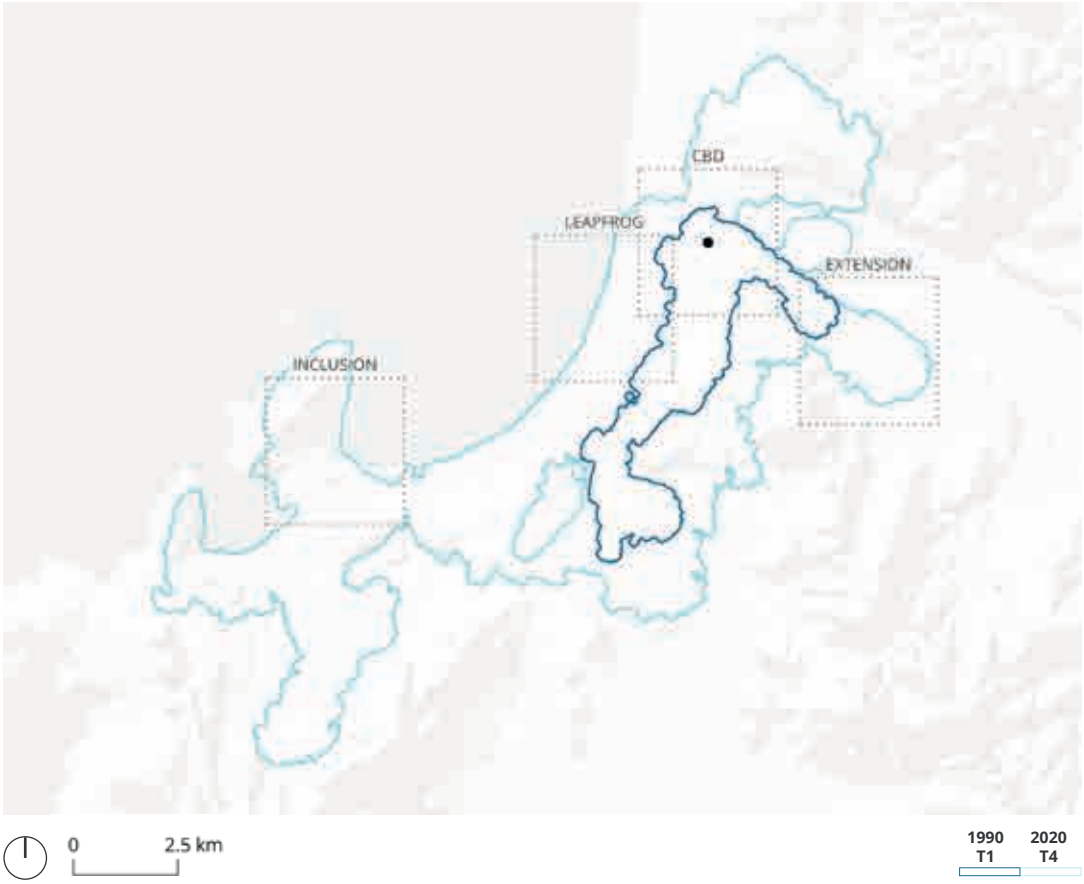


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
17%
25%
52%
24%
31%
39%
24%
62%
10%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


CBD
LEAPFROG
EXTENSION
INCLUSION
0
2.5 km
1990 T1
2020 T4

31 /

INLAND CITY
ELEVATION: 102m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Léon,* Nicaragua, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 102 meters above sea level. The city has been expanding in a compact shape, ranking 11th in comparison to other LAC cities. However, Greater Léon is not as saturated as most cities assessed. Between 1991 and 2021, it experienced a low population growth of approximately 0.5% per year, from 121.3 thousand to 140.1 thousand. Greater Léon has a moderate population density compared to the other cities: 49 inhabitants per hectare, ranking 61st in population density variation (%) in 2010-2021. Additionally, urban extent increased by approximately 3% annually in the last forty years, resulting in an area 2.5 times what it was in 1991.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



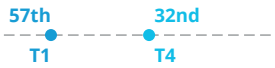
Urban population density
annual change
rank

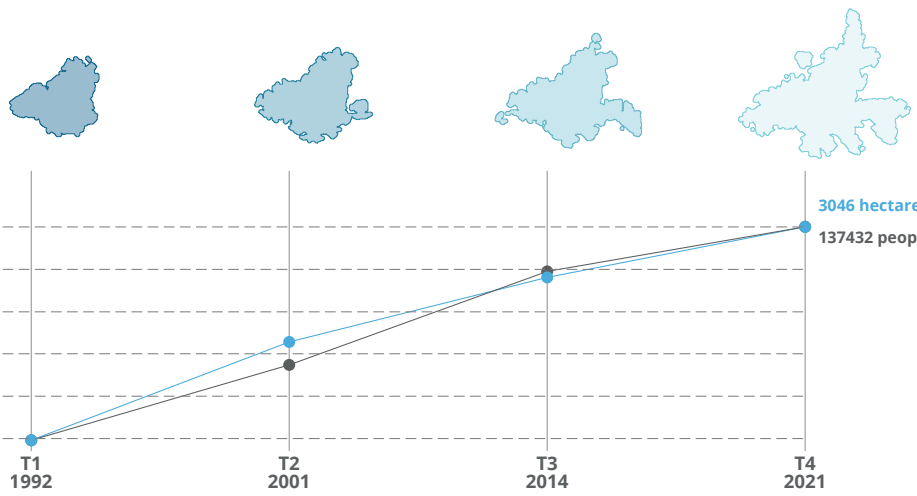


Compactness
rank

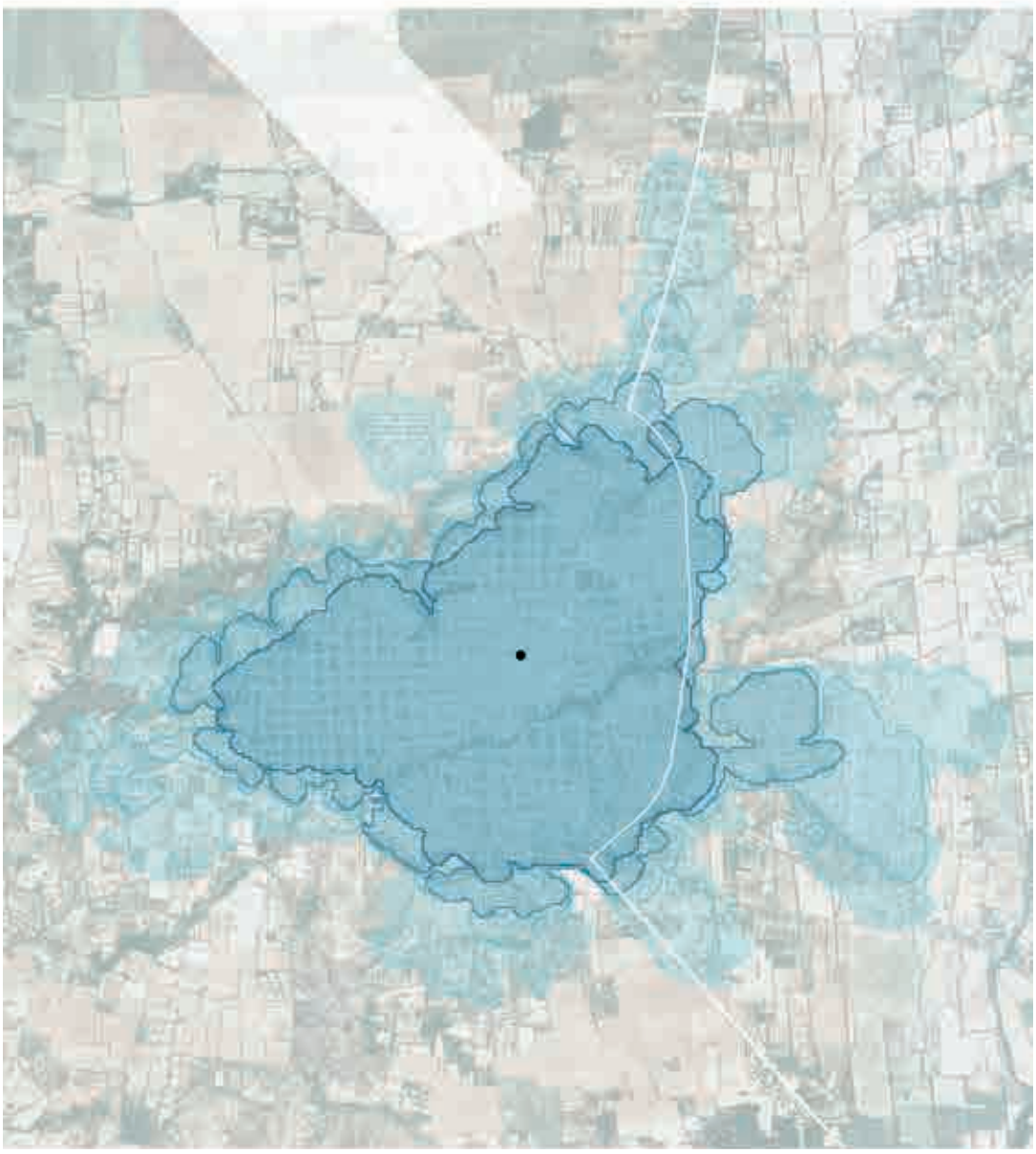


Saturation
rank





GREATER LEÓN — NICARAGUA



● Central Business District N 12.4374259
E -86.877329

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

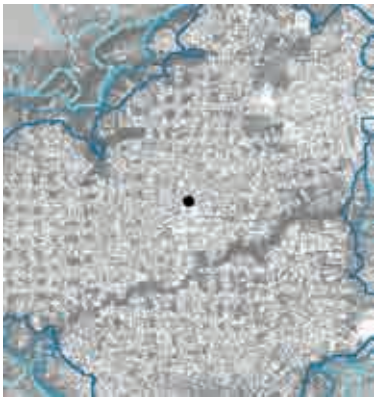
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Léon have been decreasing its contribution to the city's growth: from 49% (1991-2000) to 31% (2010-2021). Extension has increased its significance over the years, as it represented 28% in 1991-2000 in contrast to 37% in 2010-2021. Leapfrog's contribution to Greater Léon's urban expansion was 13% (1991-2000) and increased to 14% (2010-2021). Additionally, inclusion varied its contribution to the city's expansion from 13% (1991-2000) to 20% (2010-2021).

Processes of infill in Greater Léon have been decreasing its contribution to the city's growth: from 49% (1991-2000) to 31% (2010-2021).

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

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Central Business District



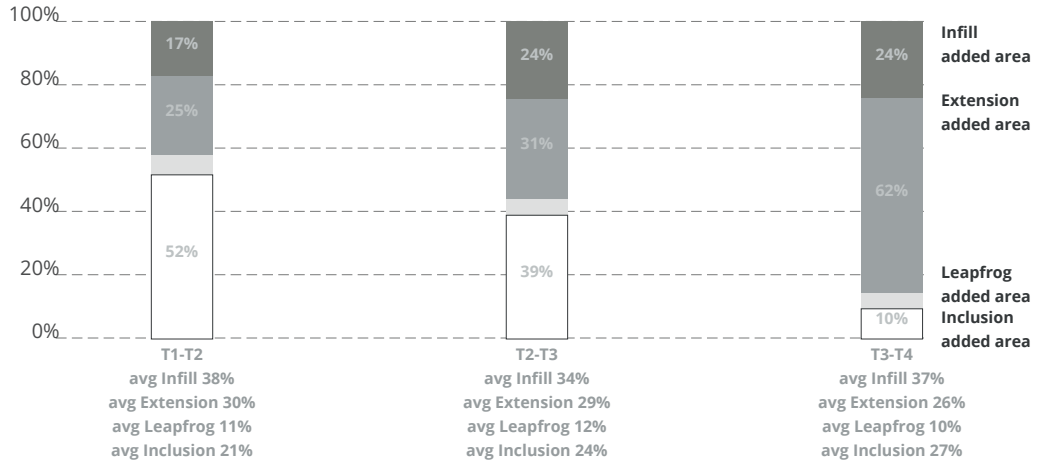
Extension area

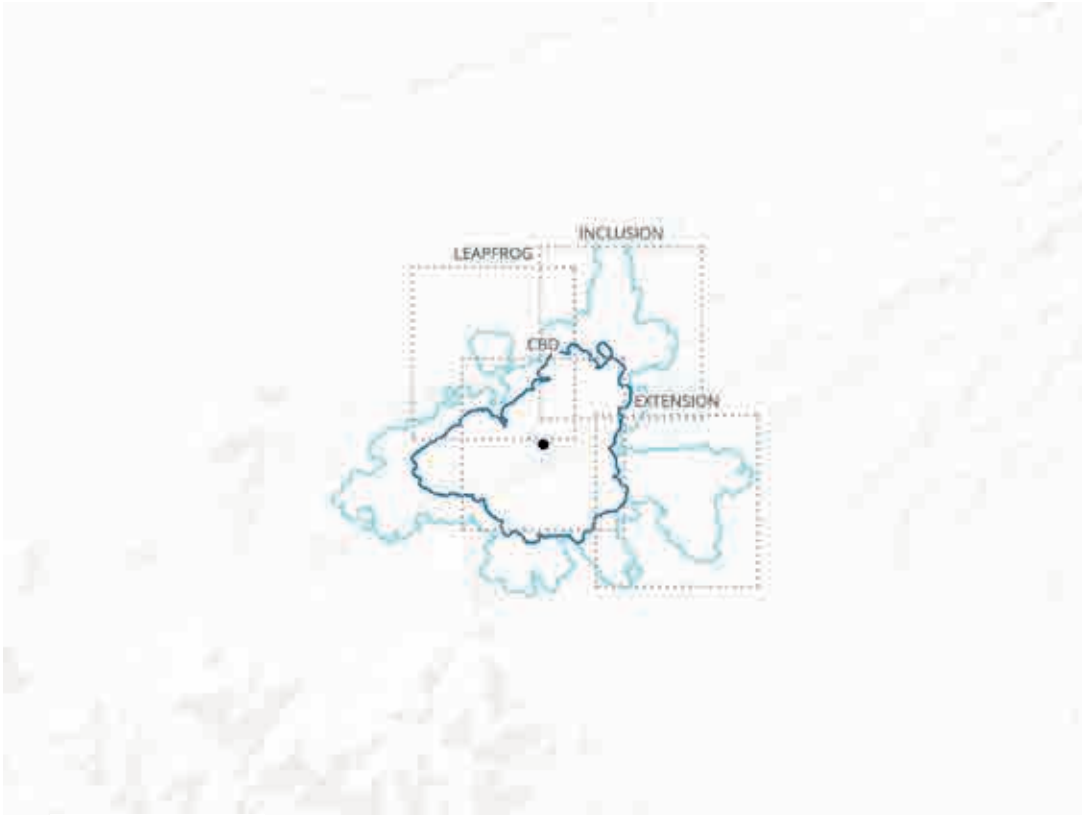


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
17%
25%
52%
24%
31%
39%
24%
62%
10%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
LEAPFROG
CBD
EXTENSION
0
2.5 km
1990 T1
2020 T4

32 /

COASTAL CITY
ELEVATION: 181m
BIOME: DESERTS / XERIC SHRUBLANDS

Lima,* Peru, is located in the biome Deserts & Xeric Shrublands, at 181 meters above sea level. Between 1990 and 2021, it experienced its population grew from 5.6 million to 10.8 million, averaging 2.1% per year. Lima has a high population density compared to the other cities: 107.9 inhabitants per hectare, ranking 8th in population density variation (%) in 2008-2021. Additionally, urban extent increased by approximately 1.9% annually over the last decades, expanding 1.8 times since 1990. The city became more compact compared to other LAC cities, reaching 42nd in 2021. Concerning its ranking of saturation, however, Lima lowered 3 positions, from 3rd to 6th, from 1990 to 2021—yet, resulting in one of the highest saturations in the sample, at 79% in 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

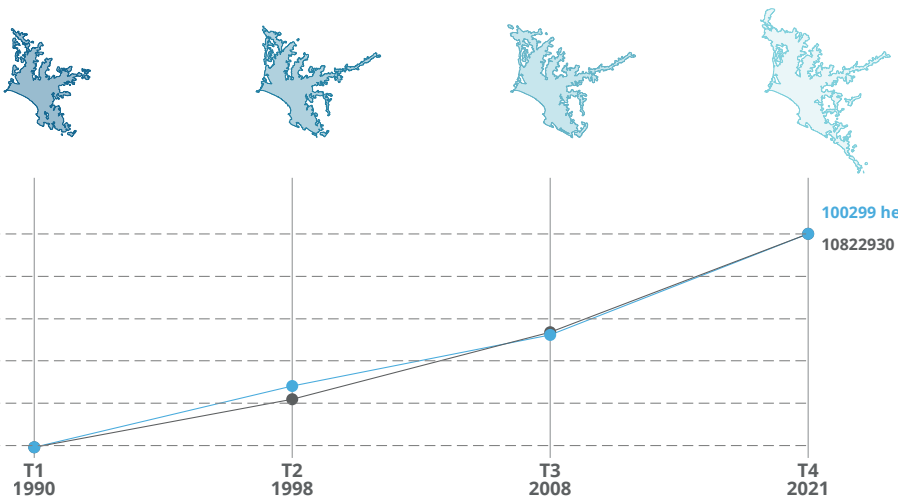


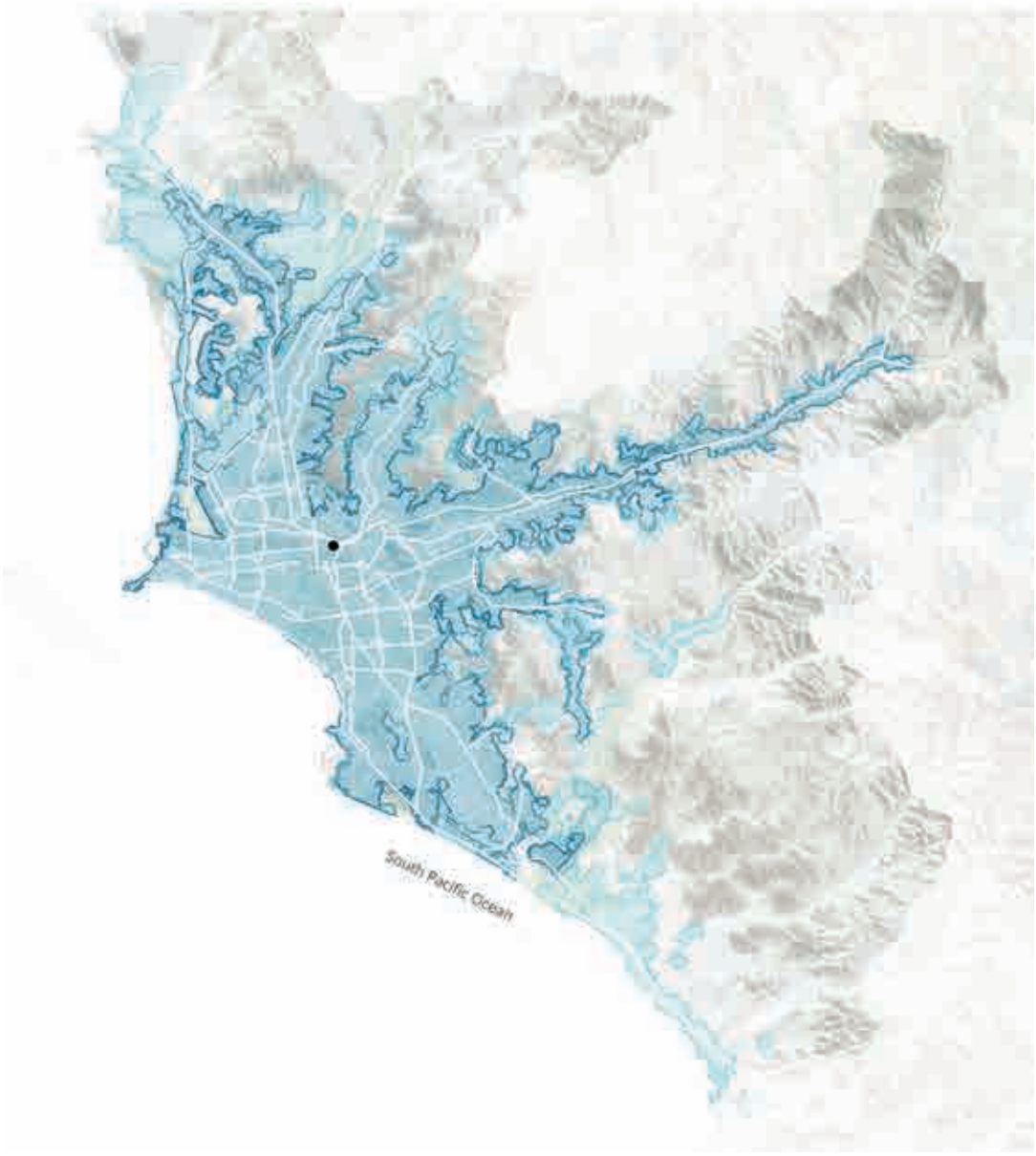
Compactness
rank



Saturation
rank







● Central Business District N -12.045126
E -77.031112

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

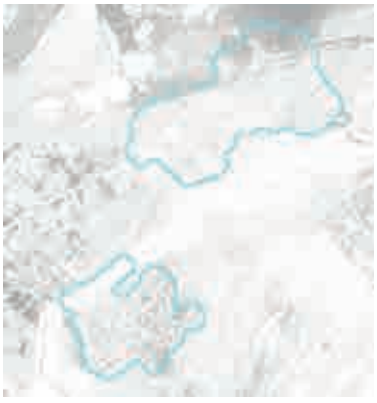
0 2.5 km



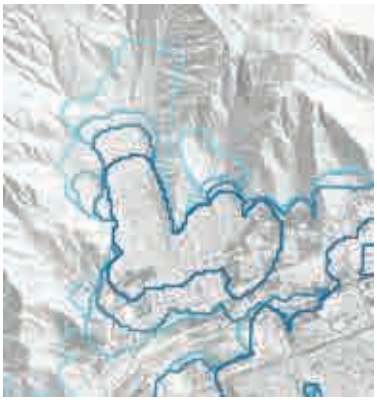
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Lima have been decreasing its contribution to the city's growth: from 33% (1990-1998) to 15% (2008-2021). Extension has increased its already predominance over the years, as it represented 43% in 1990-1998 in contrast to 55% in 2008-2021. Leapfrog's contribution to Lima's urban expansion remained diminutive, but inclusion increased its contribution to the city's expansion from 17% (1990-1998) to 26% (2008-2021).

The average building height in Lima is 2.1 stories, more than one-third higher than the average sample; the average amount of people per dwelling unit in Lima is 3.8, 25% higher than the average of the sample. The residential plot coverage of Lima is 66.9%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

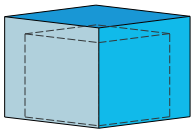
The average building height in Lima is 2.1 stories, more than one-third higher than the average sample; the average amount of people per dwelling unit in Lima is 3.8, 25% higher than the average of the sample.

avg 3.4 people per dwelling unit



3.8 people per dwelling unit

avg 1.6 stories building height

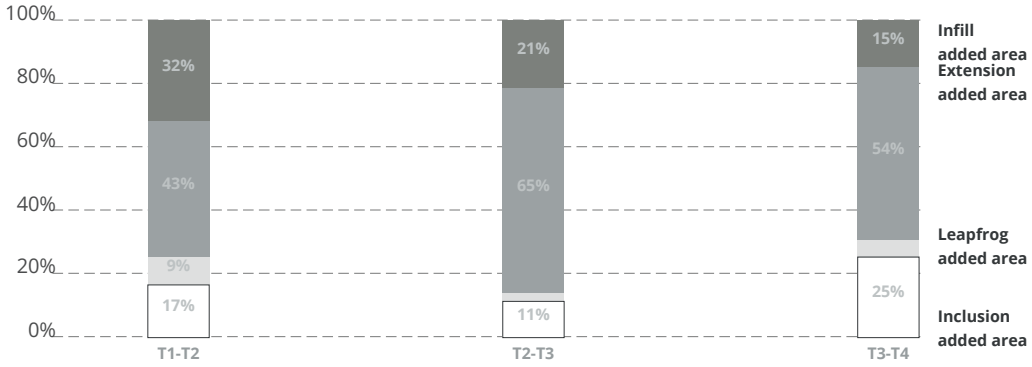


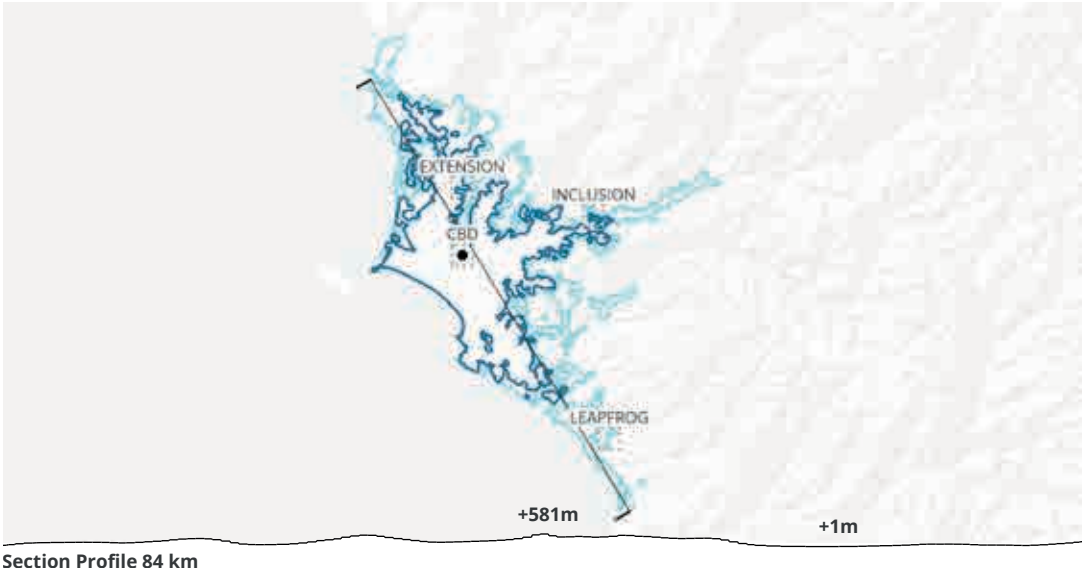
2.1 stories building height

avg 44% plot coverage



67% plot coverage





Section Profile 84 km

2.5 km

1990 T1 2020 T4

33 /

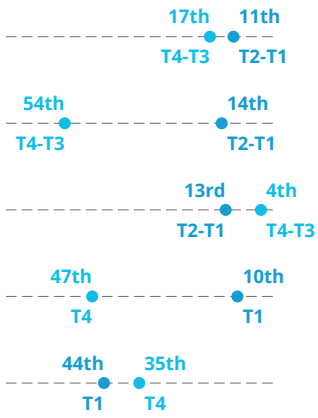
INLAND CITY
ELEVATION: 18m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

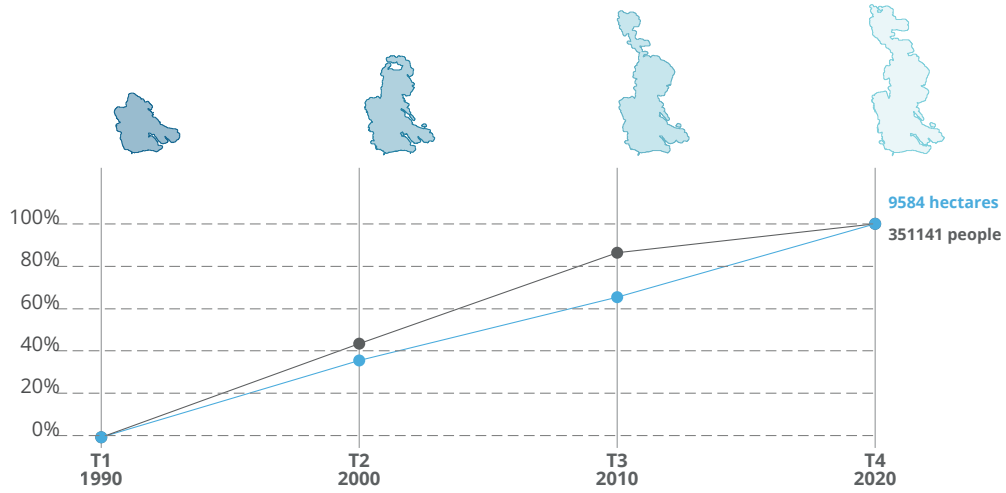
Linhares*, Brazil, is located in the biome Tropical & Subtropical Moist Broadleaf Forests, at 18 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 3.7% per year, from 44 thousand to 135.7 thousand. Urban population density in Linhares increased from 39 people/ha in 1990 to 48 people/ha in 2020; the city ranks 4th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 3.1% annually over the last decades; thus, the city is now 2.5 times the area it had in 1990. Linhares became much less compact compared to other LAC cities, dropping from 10th in 1990 to 47th in 2020. Such a decrease is accompanied by an increase in saturation, rising 10 positions, from 44th to 35th between 1990 and 2020.

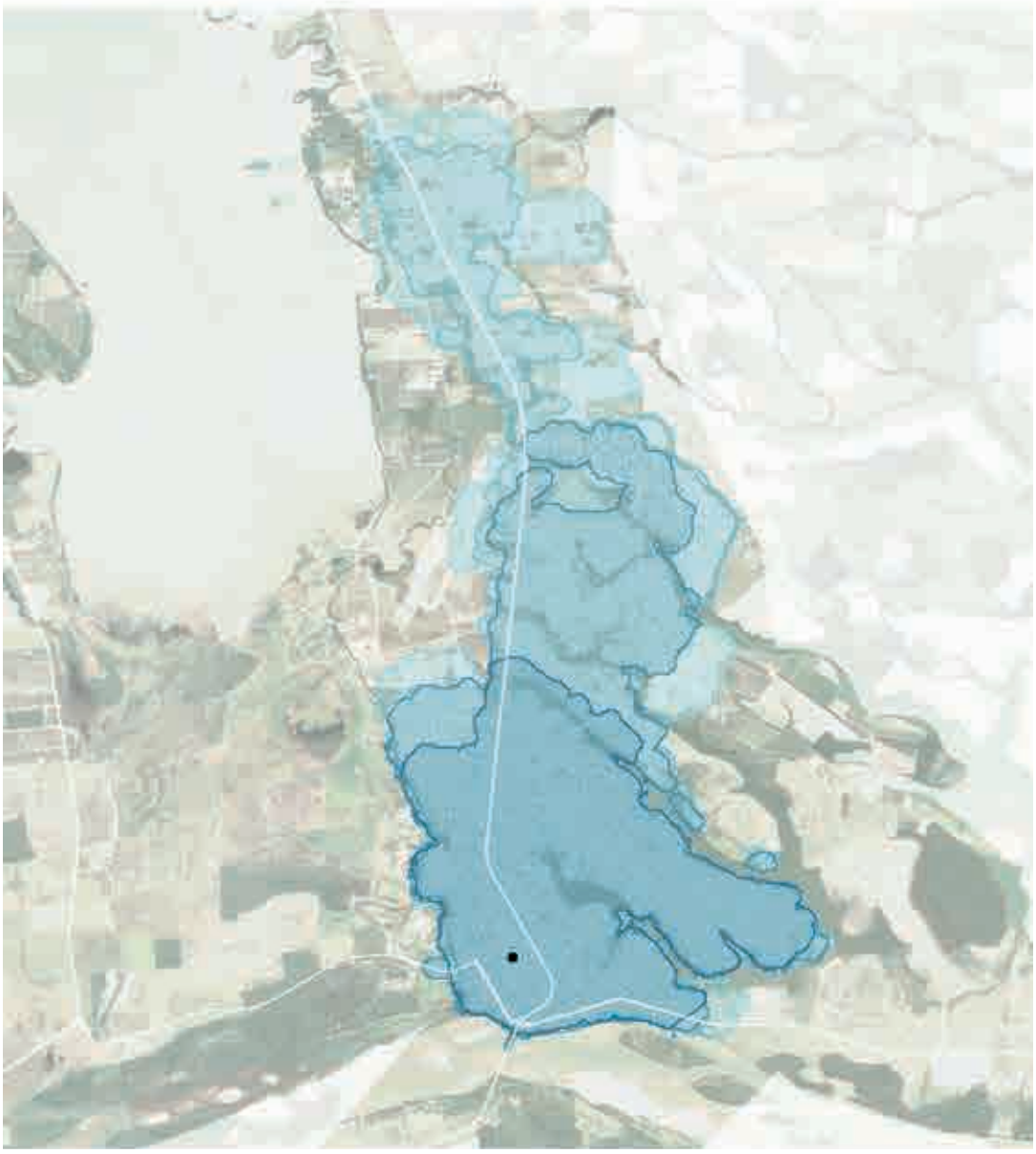




Evaluation metrics rankings:







● Central Business District N -19.400437
E -40.064854

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

33 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that the city mostly grew by infill (31%) and extension (44%) in the last period, differently than the previous period, in which inclusion had a significant contribution of almost 40%. Leapfrog's contribution to Linhares' urban expansion was 15% (1990-2000), lowered to almost 0%, and then increased again to 12% (2010-2020).

Urban population density in Linhares increased from 39 people/ha in 1990 to 48 people/ha in 2020.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



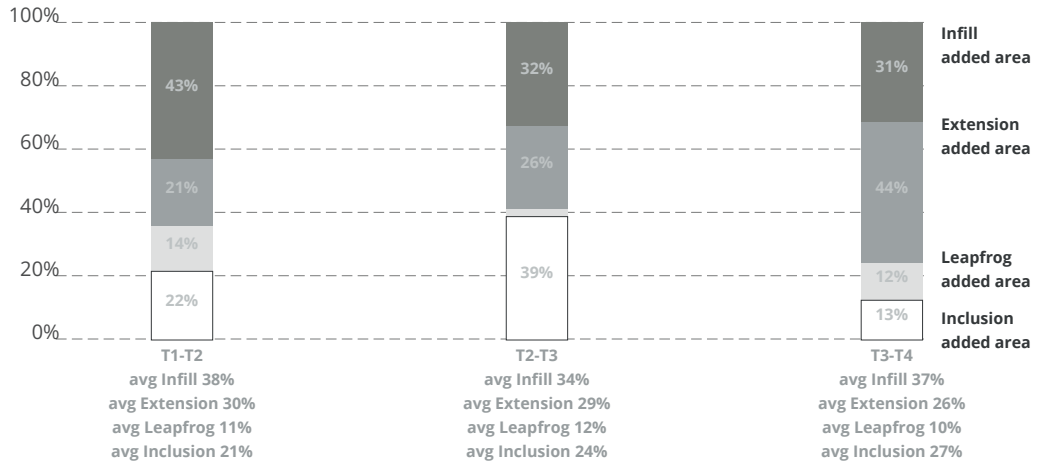
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
43%
21%
14%
22%
32%
26%
39%
31%
44%
12%
13%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
EXTENSION
CBD
LEAPFROG
0
2.5 km
1990 T1
2020 T4

34 /

INLAND CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS / SAVANNAS / SHRUBLANDS

Macapá,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at one meter above sea level. Between 1990 and 2020, Macapá experienced a steady population growth of approximately 3.6% per year, which almost tripled the city's population from 120.9 thousand to 356.6 thousand. Nevertheless, it underwent a considerable increase in urban extent, almost doubling its original size. This process results in a city with moderate population density compared to the other cities: 57.7 inhabitants per hectare, ranking 12th in population density variation (%) in 2010-2020. The city became more compact compared to other LAC cities, rising from 56th in 1990 to 48th in 2020. Such an increase is accompanied by a rise in saturation, gaining 3 positions, from 23rd to 20th between 1990 and 2020.





2020=58

1990=36

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



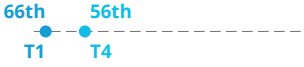
Urban Extent
annual change
rank



Urban population density
annual change
rank

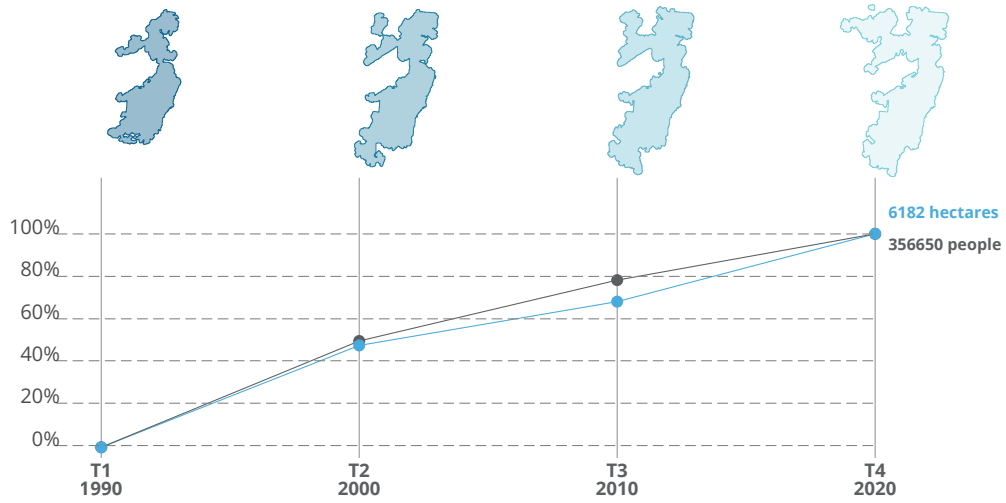


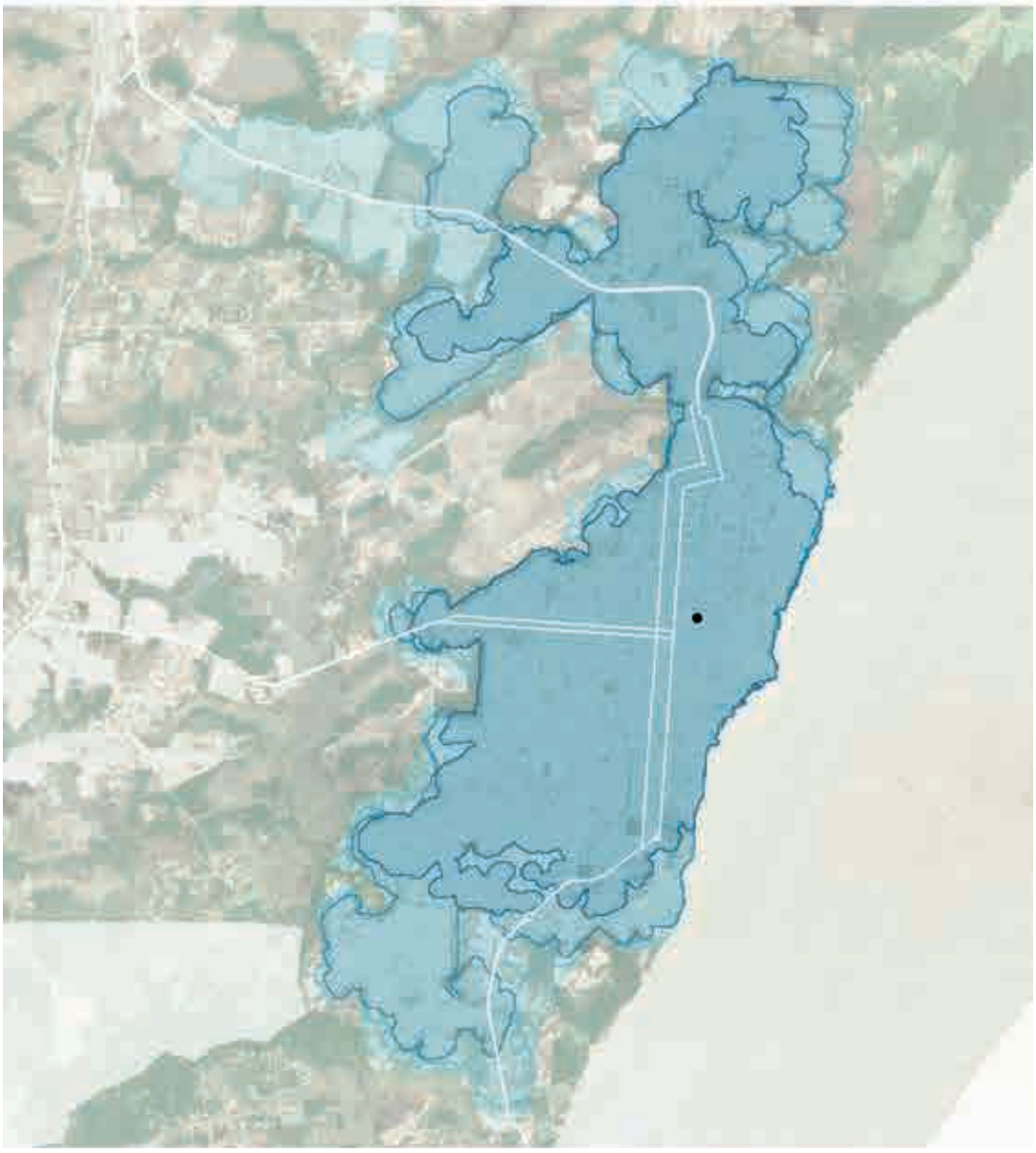
Compactness
rank



Saturation
rank







● Central Business District N 0.03731396
E -51.057280

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude Macapá has been mostly growing through infill and extension, which adds to more than ¾ of the expansion. Even so, Leapfrog's contribution to Macapá's urban expansion was 4% (1990-2000) and reached 12% (2010-2020). On the contrary, inclusion did not vary as expressively, from 14% (1990-2000) to 17% (2010-2020).

Macapá experienced a steady population growth of approximately 3.6% per year, which almost tripled the city's population from 120.9 thousand to 356.6 thousand.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

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Central Business District



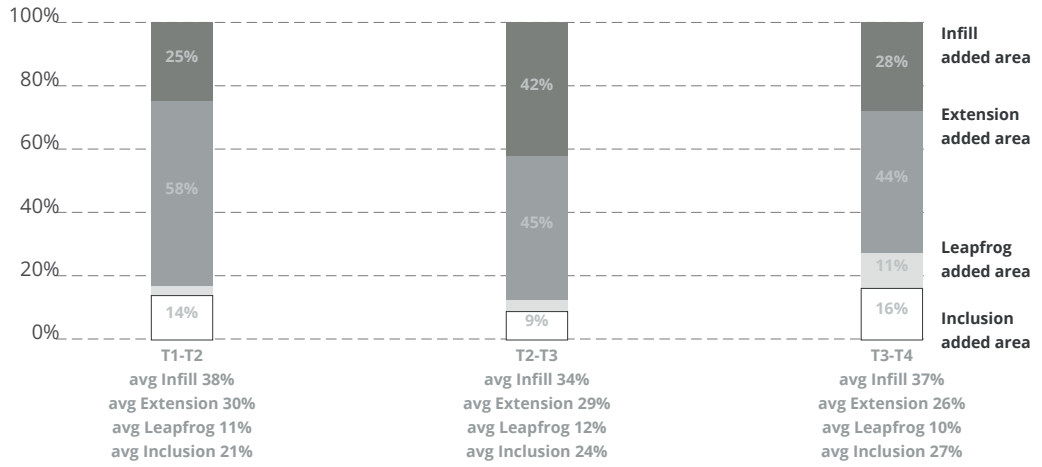
Extension area

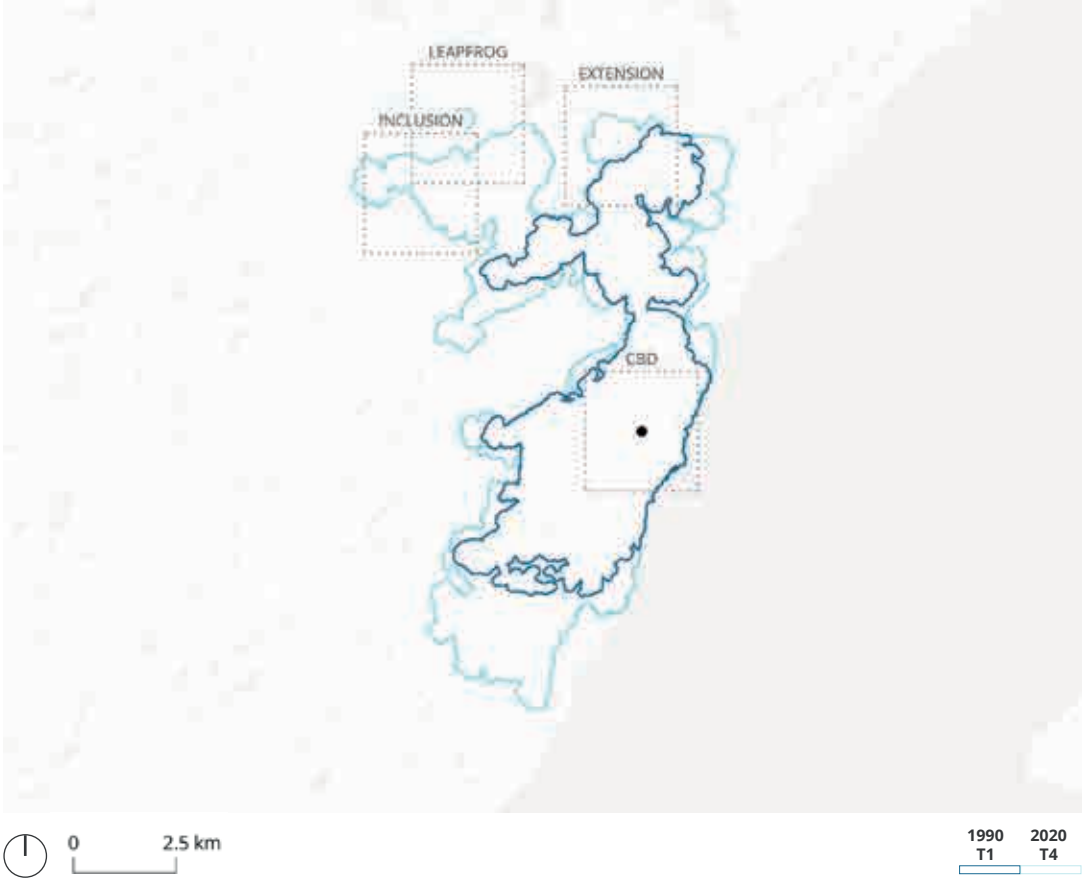


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
25%
58%
14%
42%
45%
9%
28%
44%
11%
16%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
INCLUSION
CBD
0
2.5 km
1990
T1
2020
T4

35 /

INLAND CITY
ELEVATION: 59m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Managua,* Nicaragua, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 59 meters above sea level. Between 1989 and 2020, Greater Managua experienced an expressive population growth of approximately 4.3% per year, more than tripling its inhabitants from 661.9 thousand to 2.5 million. Greater Managua has a high population density compared to the other cities: 120.9 inhabitants per hectare, ranking 30th in population density variation (%) in 2010-2020. Considering the last thirty years, Greater Managua had one of the highest population density variations (%) from 1989-2020, at 0,8% a year. Additionally, urban extent increased by approximately 3.5% annually in the last years, expanding threefold what it was in 1989. In this growth process, the city became more compact compared to other LAC cities, rising from 46th in 1989 to 37th in 2020. A slight decline in saturation followed, but meant a decline of 21 positions in the ranking from 1989 to 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

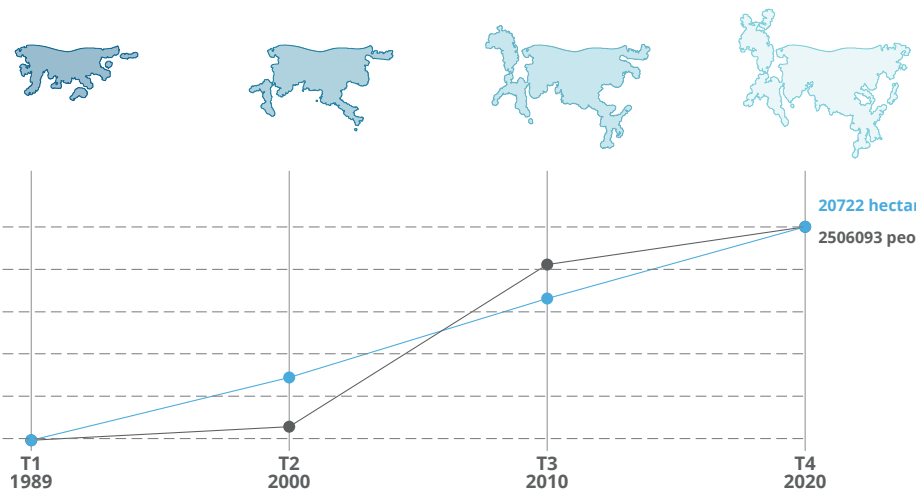
Population Growth
annual change rank
53rd (T2-T1) 35th (T4-T3)

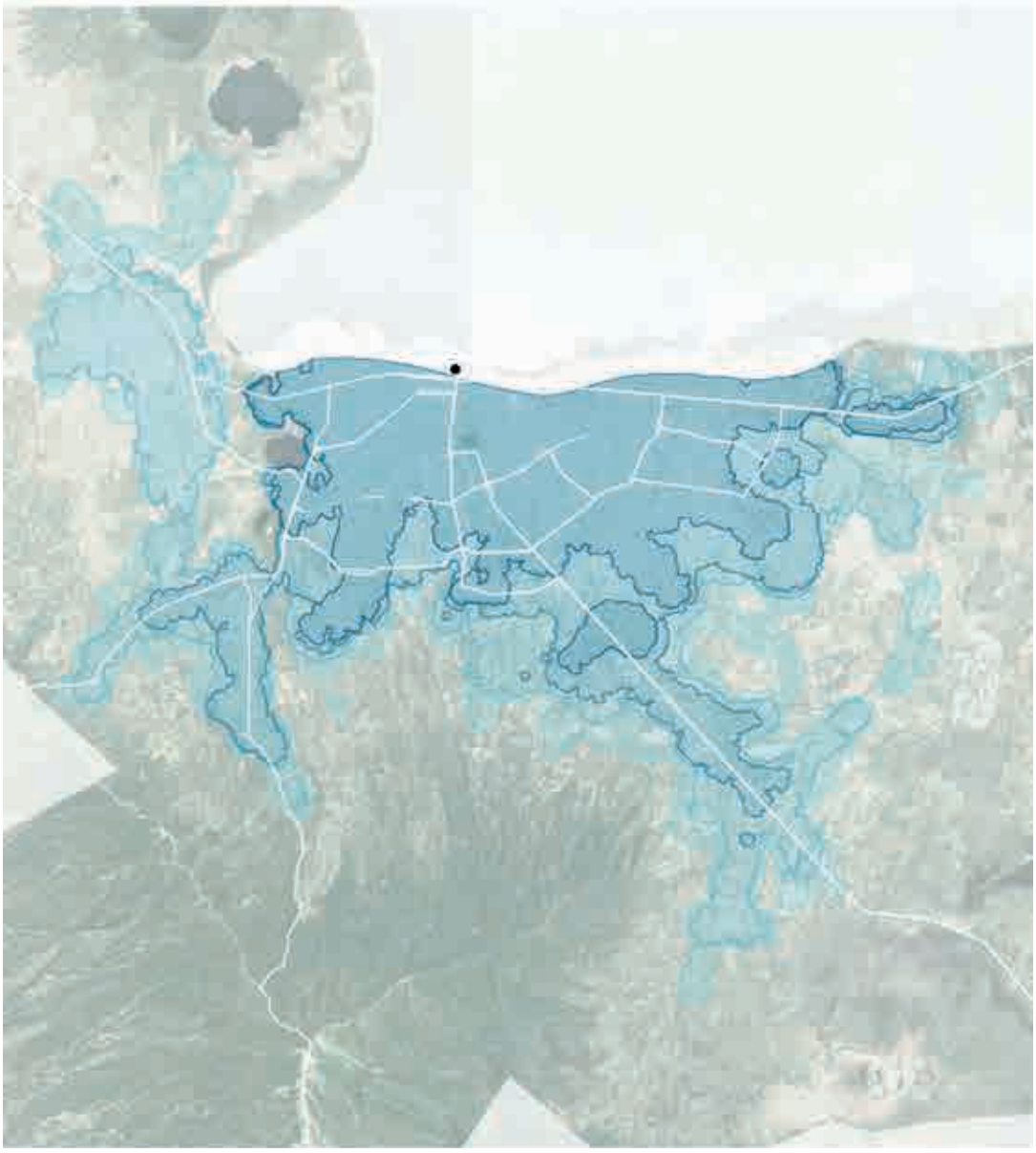
Urban Extent
annual change rank
39th (T4-T3) 24th (T2-T1)

Urban population density
annual change rank
56th (T4-T3) 42nd (T2-T1)

Compactness
rank
66th (T4) 64th (T1)

Saturation
rank
53rd (T4) 30th (T1)





● Central Business District N 12.1568733
E -86.274050

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Managua have been increasing its contribution to the city's growth: from 28% (1989-2000) to 39% (2010-2020). This might help understand the city's increase in density. Extension has halved its significance over the years, as it represented 40% in 1989-2000 in contrast to 24% in 2010-2020. Leapfrog's contribution has remained unchanged at 17%, whereas inclusion increased its contribution to the city's expansion from 17% (1989-2000) to 22% (2010-2020).

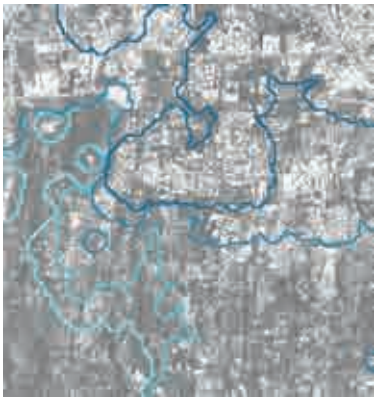
Greater Managua experienced an expressive population growth of approximately 4.3% per year, more than tripling its inhabitants from 661.9 thousand to 2.5 million.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



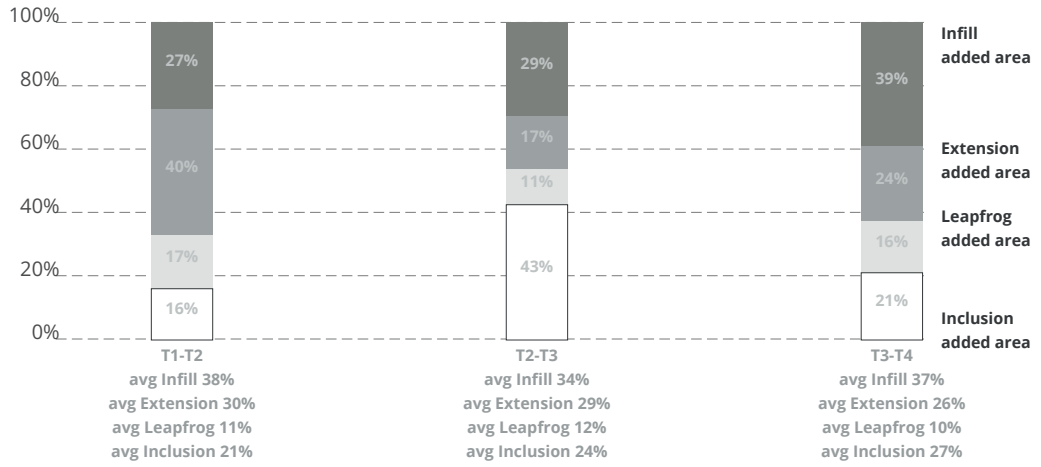
Extension area

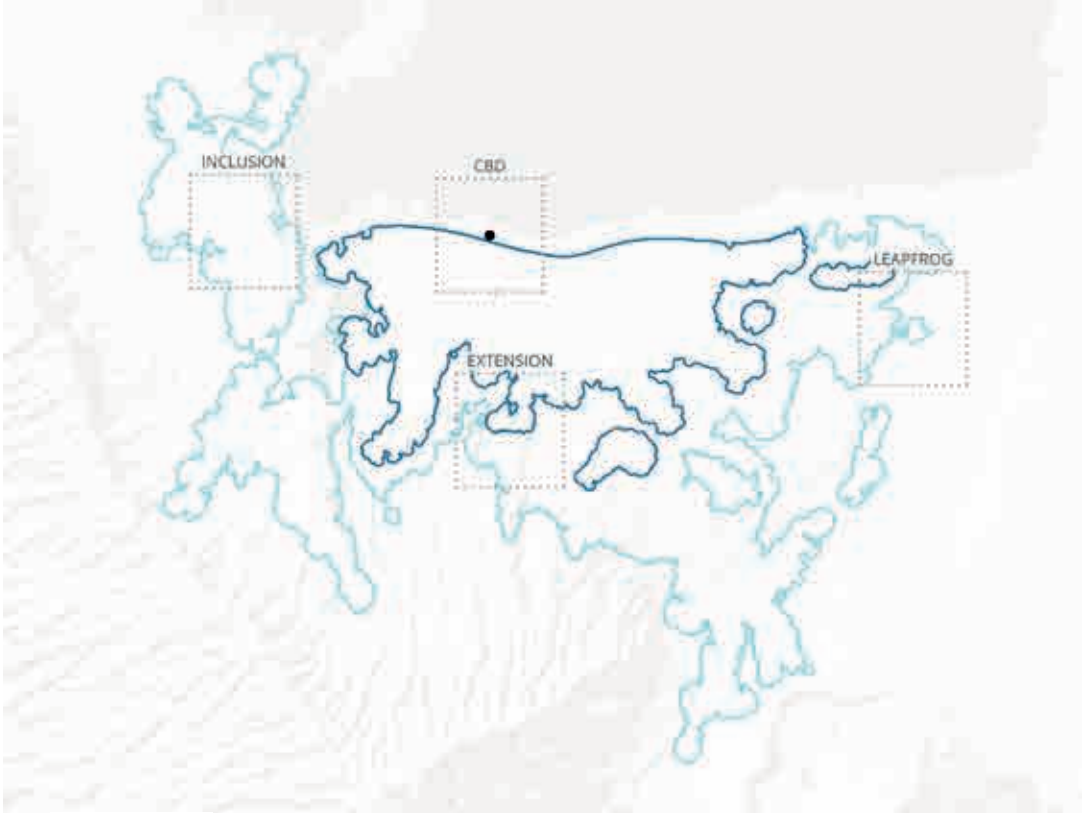


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
27%
40%
17%
16%
29%
17%
11%
43%
39%
24%
16%
21%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%

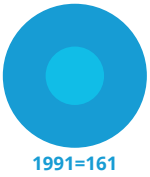

INCLUSION
CBD
LEAPFROG
EXTENSION
0
2.5 km
1990 T1
2020 T4

36 /

INLAND CITY
ELEVATION: 1523m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Greater Medellín,* Colombia, is located in the biome Montane Grasslands & Shrublands, at 1523 meters above sea level. Between 1991 and 2020, the city's population grew at an annual rate of 2.1%, from 2.1 million to 3.9 million. Greater Medellín has a high population density compared to the other cities: 142.3 inhabitants per hectare, the highest in 2020. Moreove 2020. Additionally, its urban extent increased by approximately 2.6% annually in the last years, doubling the city's area in comparison to 1991. In this process, Greater Medellín became slightly less compact compared to other LAC cities and saturation remained close to 75%.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



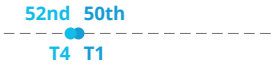
Urban Extent
annual change
rank



Urban population density
annual change
rank

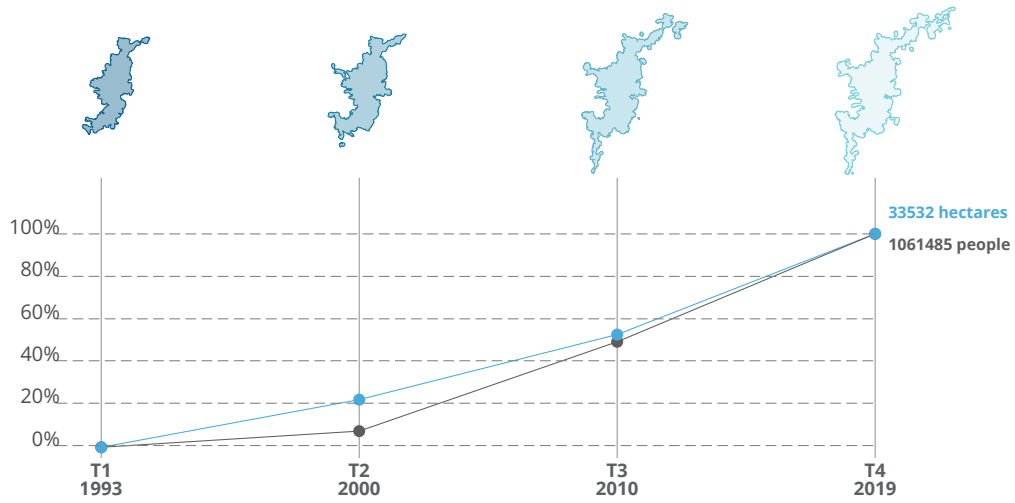


Compactness
rank

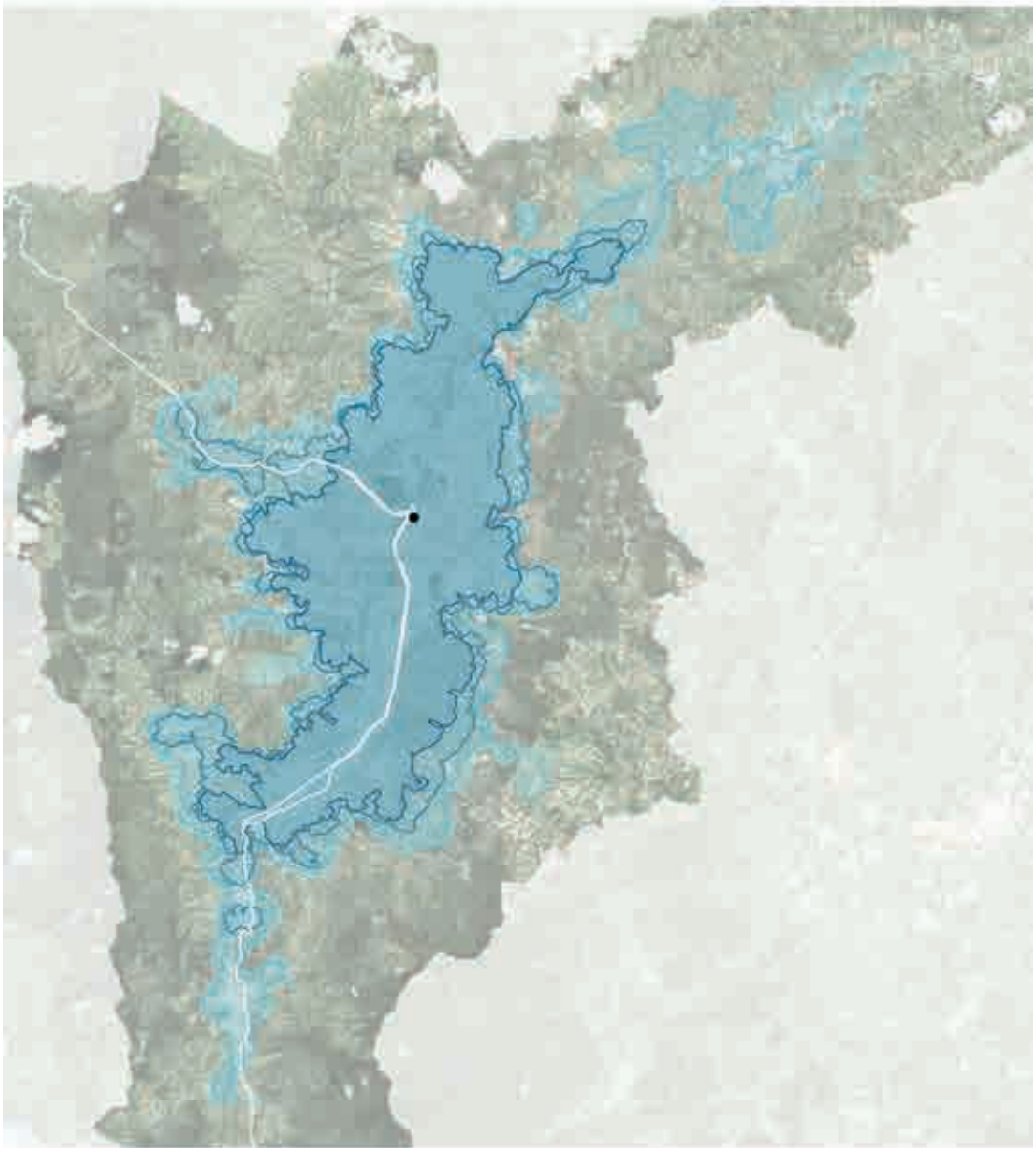


Saturation
rank





GREATER MEDELLÍN — COLOMBIA



● Central Business District N 6.25748051
E -75.573499

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Medellín have not been changing significantly its contribution to the city's growth: from 38% (1991-2000) to 33% (2015-2020). Extension has decreased its significance over the years, as it represented 40% in 1991-2000 in contrast to 26% in 2015-2020. Leapfrog's contribution to Greater Medellín's urban expansion barely increased, in contrast to inclusion's, which almost tripled from 13% (1991-2000) to 30% (2015-2020).

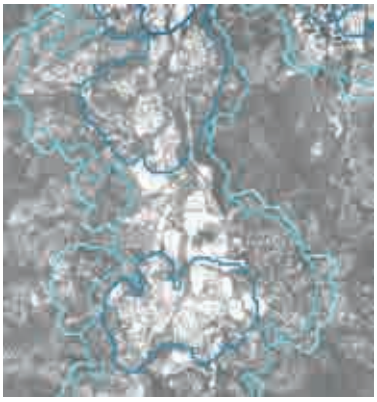
Greater Medellín has a high population density compared to the other cities: 142.3 inhabitants per hectare, the highest in 2020.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

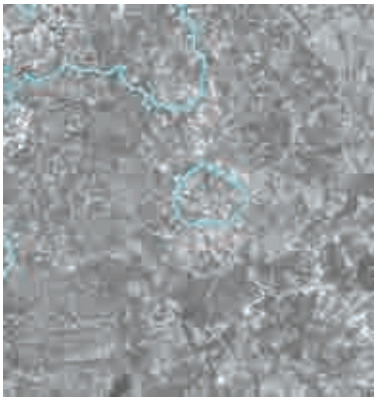
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



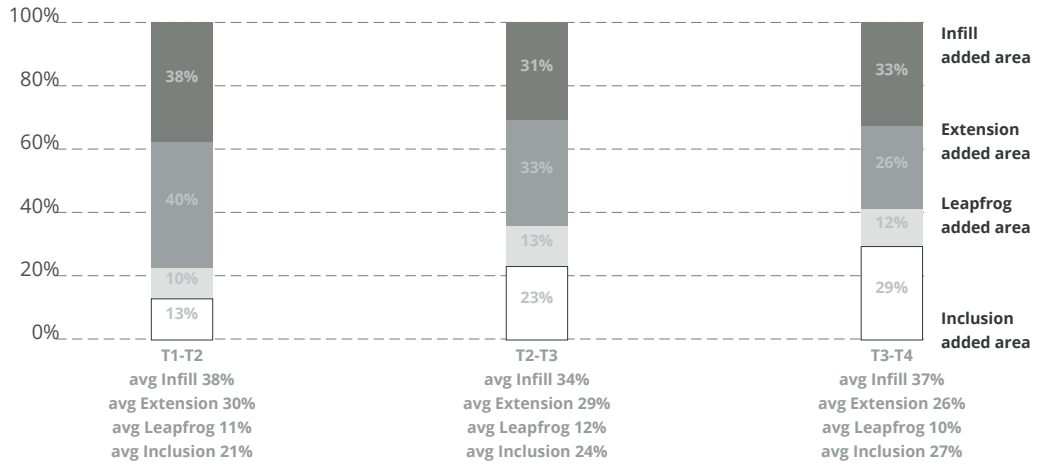
Extension area

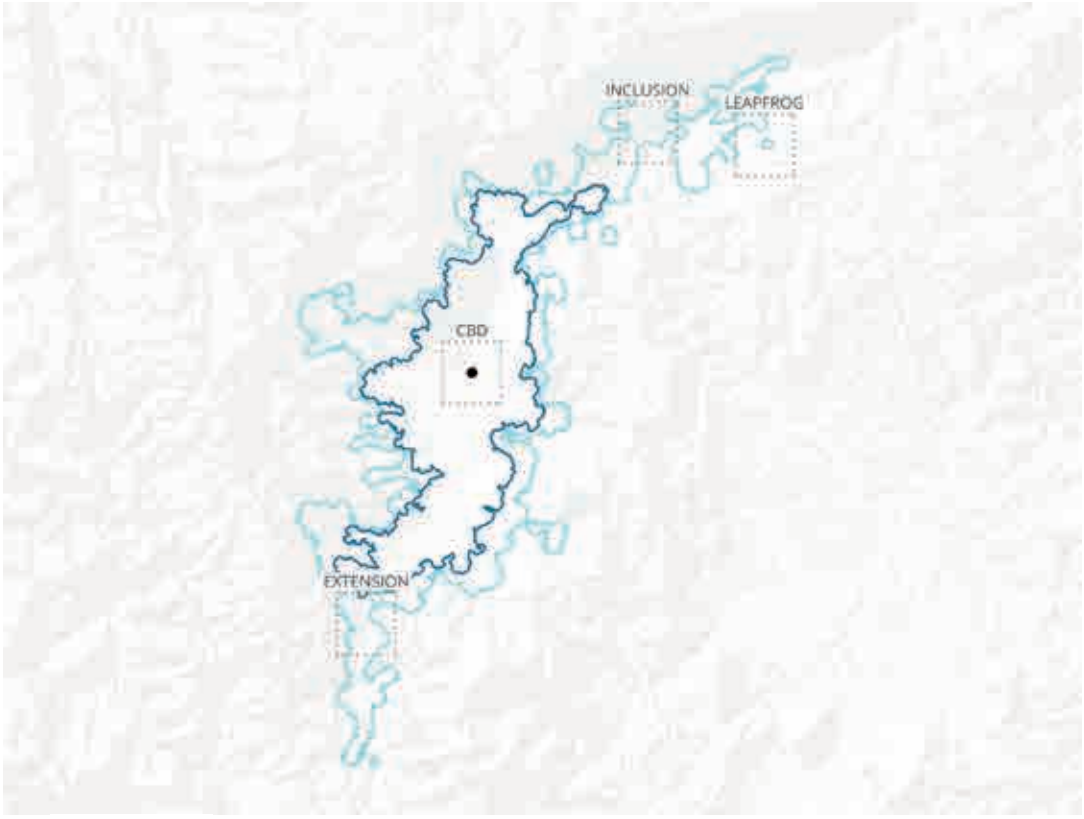


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
38%
40%
10%
13%
31%
33%
13%
23%
33%
26%
12%
29%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
LEAPFROG
CBD
EXTENSION
0 2.5 km
1990 T1
2020 T4

37 /

INLAND CITY
ELEVATION: 857m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Greater Mendoza,* Argentina, is located in the biome Montane Grasslands & Shrublands, at 857 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 1.2% per year, from 654.6 thousand to 962.6 thousand. Greater Mendoza has a low population density compared to the other cities: 33.9 inhabitants per hectare. The city presents a significant decline in population density variation, as it was 27th in 1990-2000 and 50th in 2010-2021. Additionally, urban extent increased by approximately 2.6% annually over the last decades, covering now an area 2.3 times what it was in 1990. A slight increase in the city's compactness cities is accompanied by a decrease in its saturation in comparison to other LAC, falling from 54th to 60th between 1990 and 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

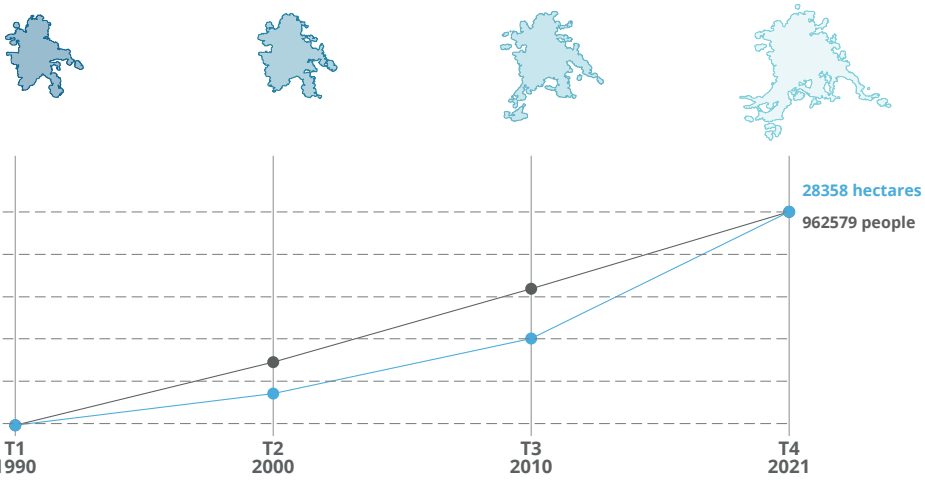


Compactness
rank

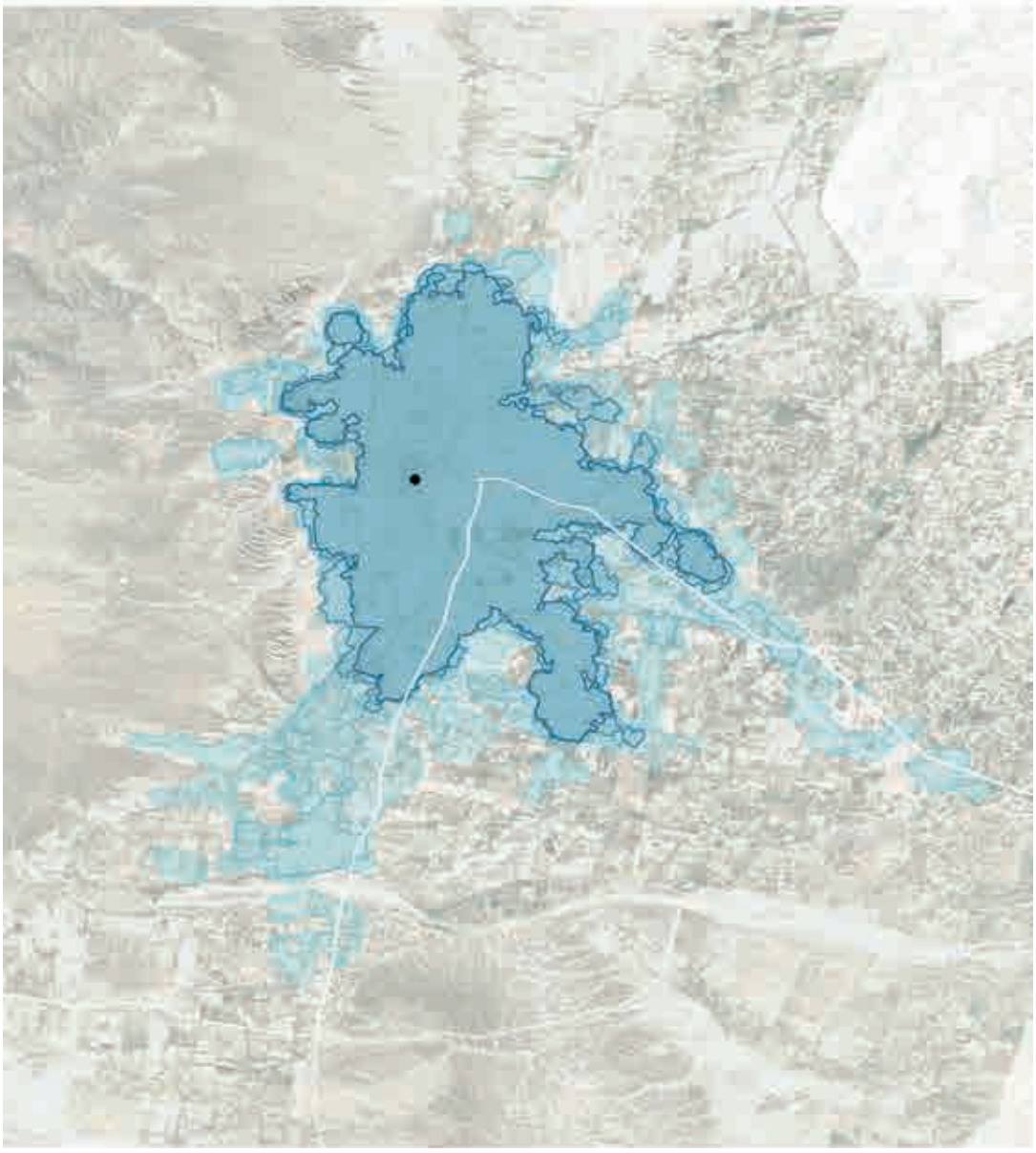


Saturation
rank





GREATER MENDOZA — ARGENTINA



● Central Business District N -32.897654
E -68.843498

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, extension in Greater Mendoza has increased its significance over the years, as it represented 20% in 1990-2000 in contrast to 27% in 2010-2021. Conversely, processes of infill have expressively decreased its contribution to the city's growth from 62% (1990-2000) to 26% (2010-2021), likely related to the city's decrease in population density. Leapfrog's contribution to Greater Mendoza's urban expansion tripled up to 21% (2010-2021). Additionally, inclusion also increased its share from 13% (1990-2000) to 28% (2010-2021).

The average dwelling unit occupancy in Greater Mendoza is 3.5 people per unit, high in comparison to the average of the cities in this Atlas. Greater Mendoza's high dwelling unit occupancy contrasts with its average building story height, averaging 20% lower than the sample's average, at 1.3 stories. The residential plot coverage of Greater Mendoza is 37.1%, considerably lower than the sample average.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

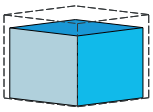
Greater Mendoza's high dwelling unit occupancy contrasts with its average building story height, averaging 20% lower than the sample's average, at 1.3 stories.

avg 3.4 people per dwelling unit



3.5 people per dwelling unit

avg 1.6 stories building height

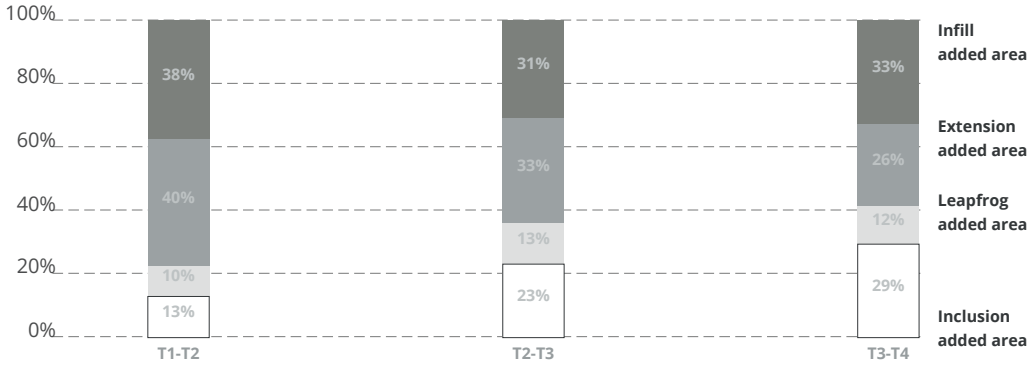


1.3 stories building height

avg 44% plot coverage



37% plot coverage





Section Profile 34 km

0 2.5 km

1990 T1 2020 T4

38 /

INLAND CITY
ELEVATION: 10m
BIOME: TROPICAL /
SUBTROPICAL DRY BROADLEAF FORESTS

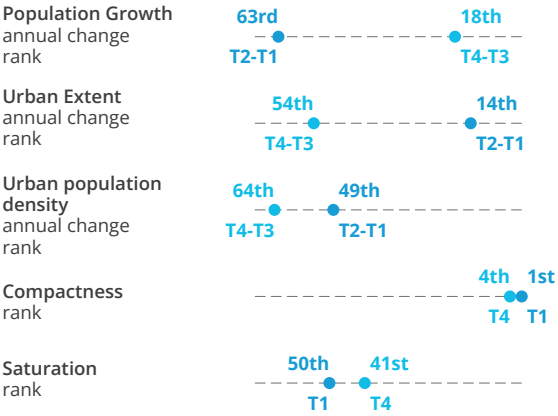
Greater Mérida,* Mexico, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 10 meters above sea level. Between 1993 and 2019, its population grew at an annual rate of 1.9%, from 648.9 thousand to 1.1 million. Greater Mérida has a low population density compared to the other cities: 31.7 inhabitants per hectare, ranking 41st in population density variation (%) in 2010-2019. Additionally, urban extent increased significantly by approximately 4.4% annually over the last decades, three folding its area since 1993. Remarkably, Greater Mérida is one of the most compact cities in the sample, ranking previously as 1st and now as 4th over the studied periods. Compared to other LAC cities, Greater Mérida presented a minor decrease of 2 positions in the saturation ranking.

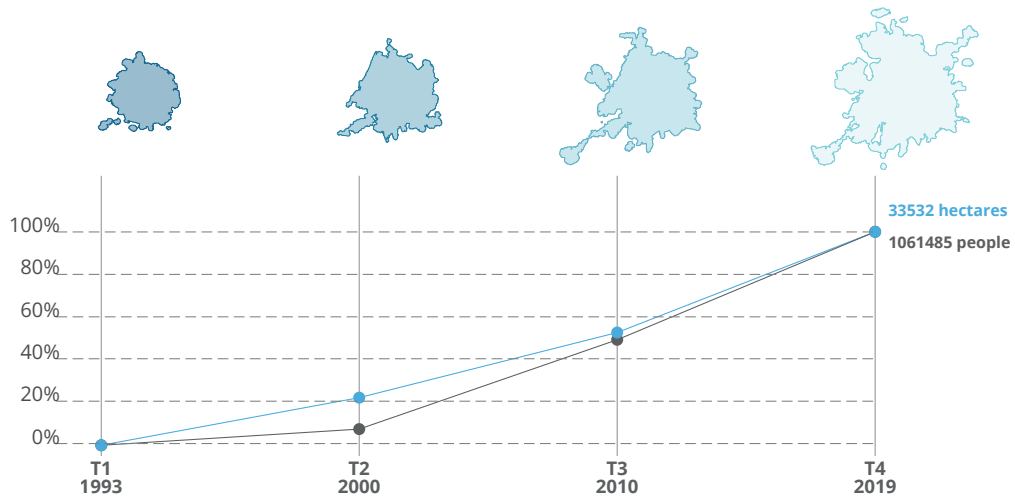


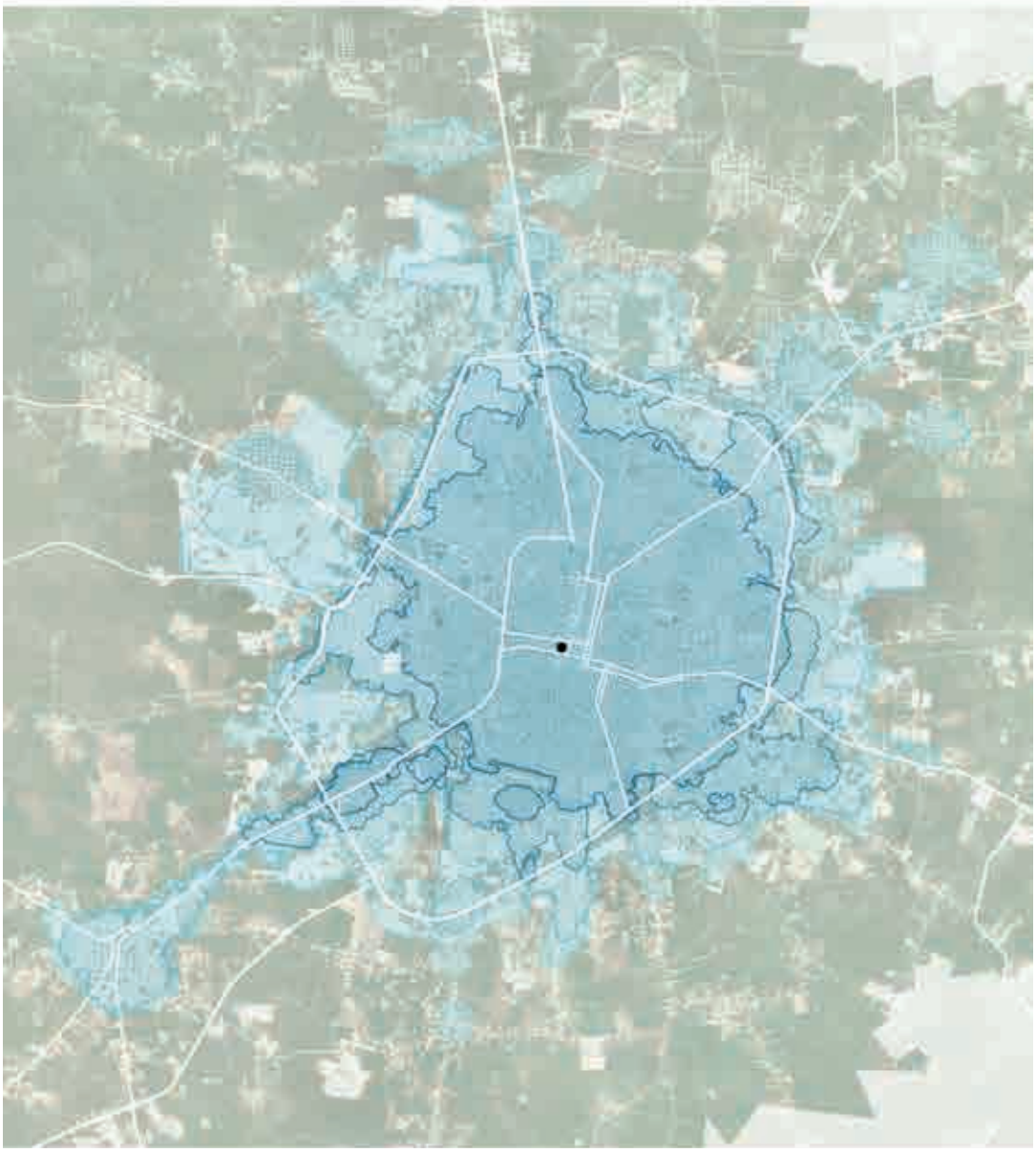


Urban population density
person / hectare

Evaluation metrics rankings:







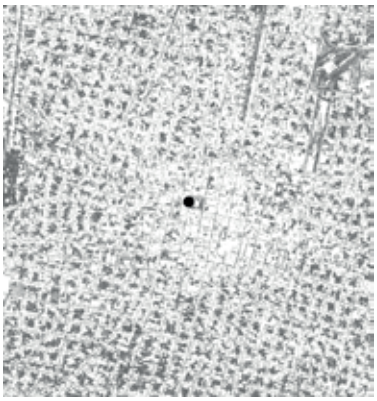
● Central Business District N 20.9671721
E -89.624434

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Mérida almost halved its significance to the city's growth: from 44% (1993-2000) to 27% (2010-2019). Extension has increased its contribution over the years, as it represented 31% in 1993-2000 in contrast to 41% in 2010-2019. Leapfrog's share slightly increased from 12% (1993-2000) to 17% (2010-2019), just as did inclusion's contribution to the city's expansion, from 15% (1993-2000) to 17% (2010-2019).

The average dwelling unit occupancy in Greater Mérida is 3.27 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.3 stories, lower than the sample's average. The residential plot coverage of Greater Mérida is 31.7%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

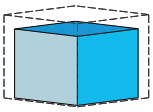
Remarkably, Greater Mérida is one of the most compact cities in the sample.

avg 3.4 people per dwelling unit



3.3 people per dwelling unit

avg 1.6 stories building height

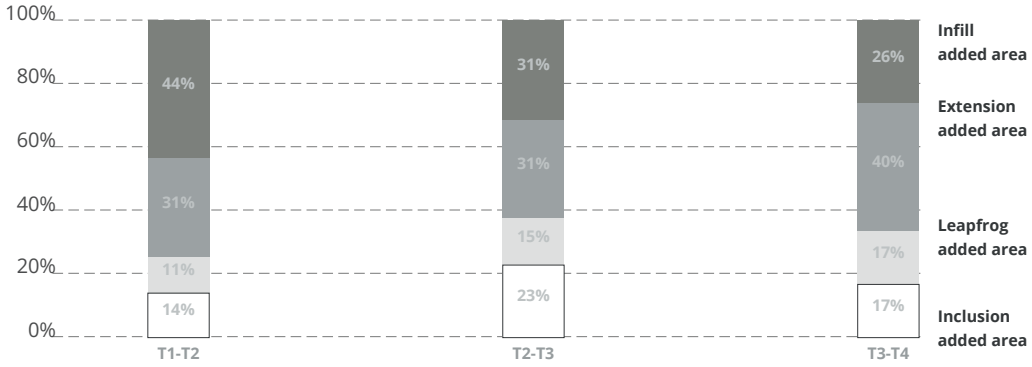


1.3 stories building height

avg 44% plot coverage



32% plot coverage





Section Profile 31 km



1990 T1 — 2020 T4

39 /

INLAND CITY
ELEVATION: 2215m
BIOME: DESERTS / XERIC SHRUBLANDS

Greater Mexico City,* Mexico, is located in the biome Deserts & Xeric Shrublands, at 2215 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 1% per year, from 14.2 million to 19.4 million. Greater Mexico City has a high population density compared to the other cities: 74.3 inhabitants per hectare. However, its population density variation (%) in 2014-2021 is low in the ranking, at -1,6% a year, in comparison to LAC's average of –0,8% a year (1990-2021). Additionally, urban extent in Greater Mexico City increased by approximately 2.6% annually over the last decades, resulting in an area 2.2 times what it was in 1990. A significant part of this expansion happened in the Northeast area. The city became more compact compared to other LAC cities, rising from 28th in 1990 to 21st in 2021 and saturation remained close to 70%.





Urban population density
person / hectare

Evaluation metrics rankings:

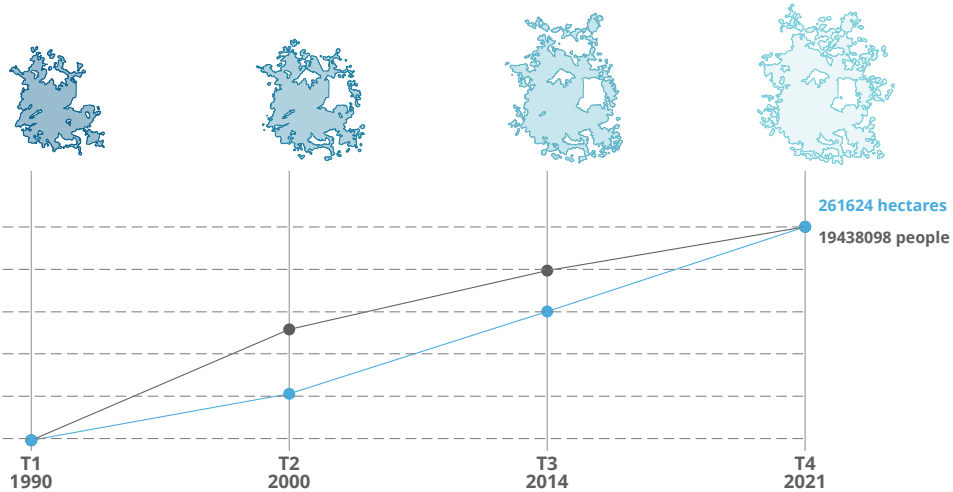
Population Growth
annual change
rank
61st (T4-T3) — 29th (T2-T1)

Urban Extent
annual change
rank
48th (T2-T1) — 22nd (T4-T3)

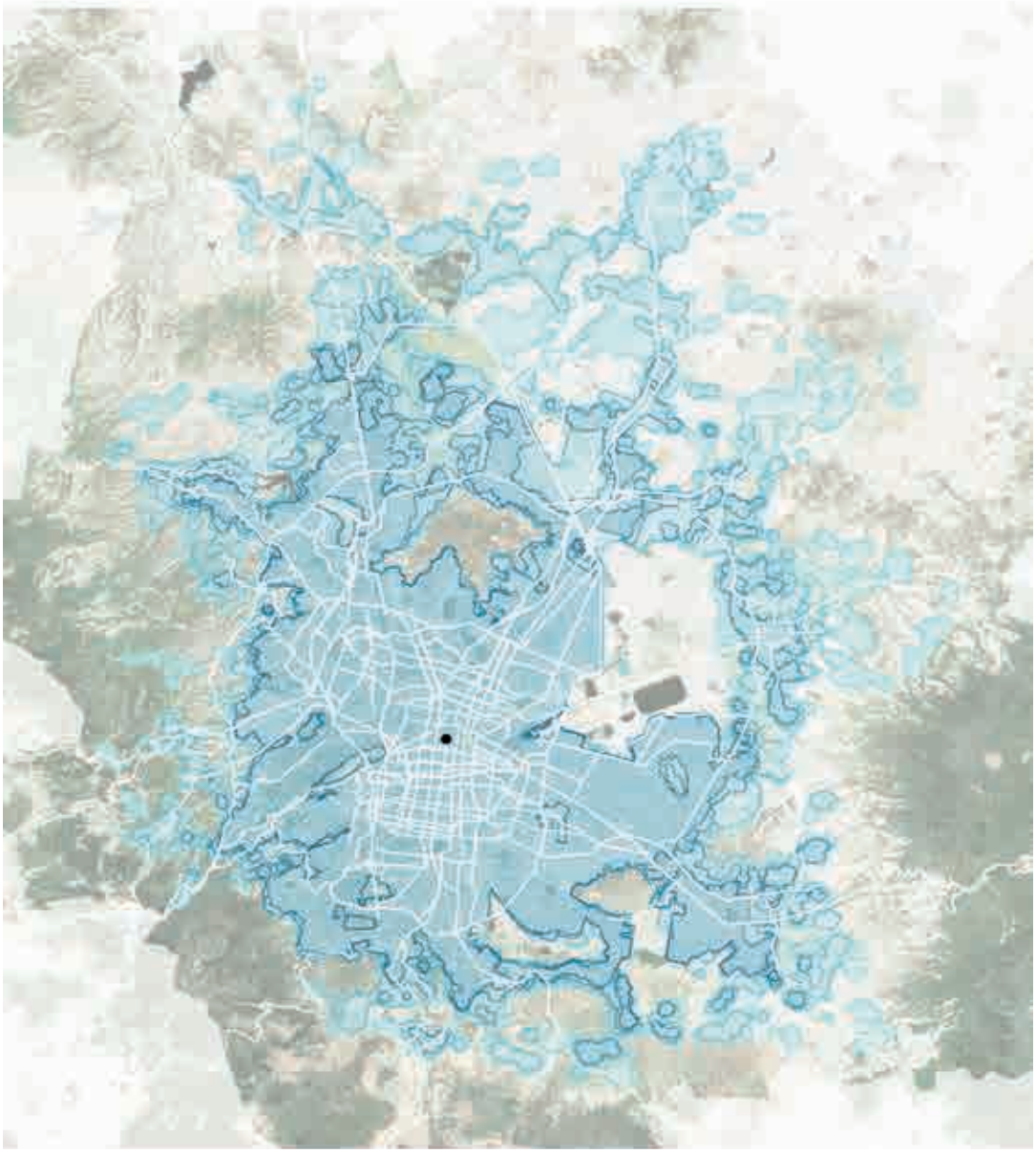
Urban population density
annual change
rank
43rd (T4-T3) — 28th (T2-T1)

Compactness
rank
28th (T1) — 21st (T4)

Saturation
rank
21st (T1) — 10th (T4)



GREATER MEXICO CITY — MEXICO



● Central Business District N 19.4326069
E -99.133326

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

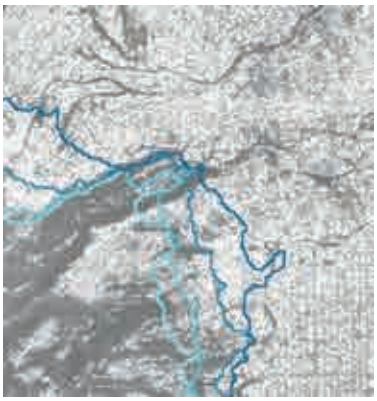
highways — local streets

0 2.5 km

39 /



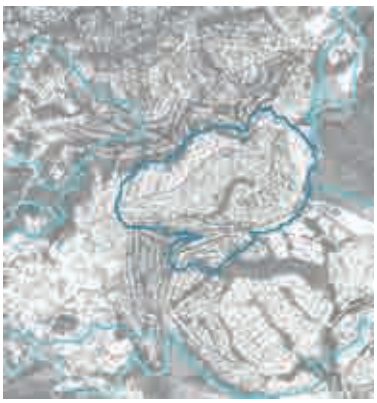
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Mexico City have not been changing significantly its contribution to the city's growth and are above the average for LAC cities. It accounted for 46% (1990-2000) and 43% (2014-2021), whereas for LAC cities it was respectively 38% and 37%. Extension has decreased its significance over the years, as it represented 29% in 1990-2000 in contrast to 24% in 2014-2021. Leapfrog's contribution to Greater Mexico City's urban expansion was 9% (1990-2000) and reached 10% (2014-2021). Additionally, inclusion varied its contribution to the city's expansion from 19% (1990-2000) to 25% (2014-2021).

The average dwelling unit occupancy in Greater Mexico City is 3.5 people per unit. High in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 2 stories. The residential plot coverage of Greater Mexico City is 53.4%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

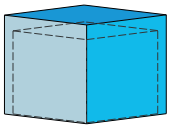
Urban extent in Greater Mexico City increased by approximately 2.6% annually over the last decades. A significant part of this expansion happened in the Northeast area.

avg 3.4 people per dwelling unit



3.5 people per dwelling unit

avg 1.6 stories building height

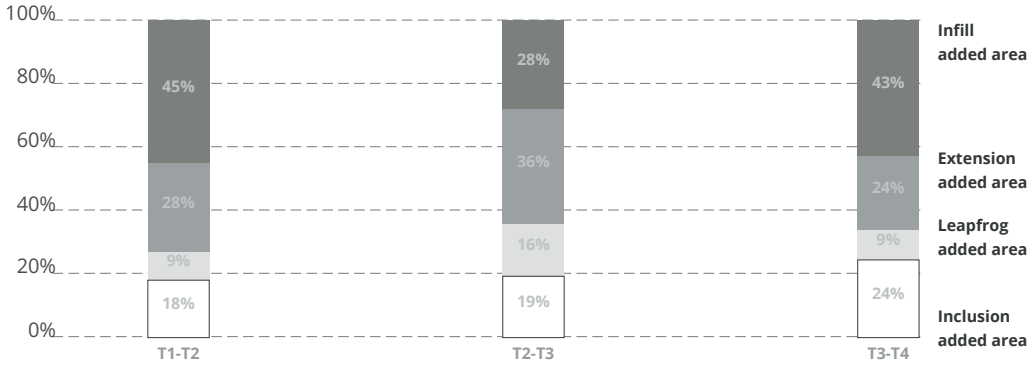


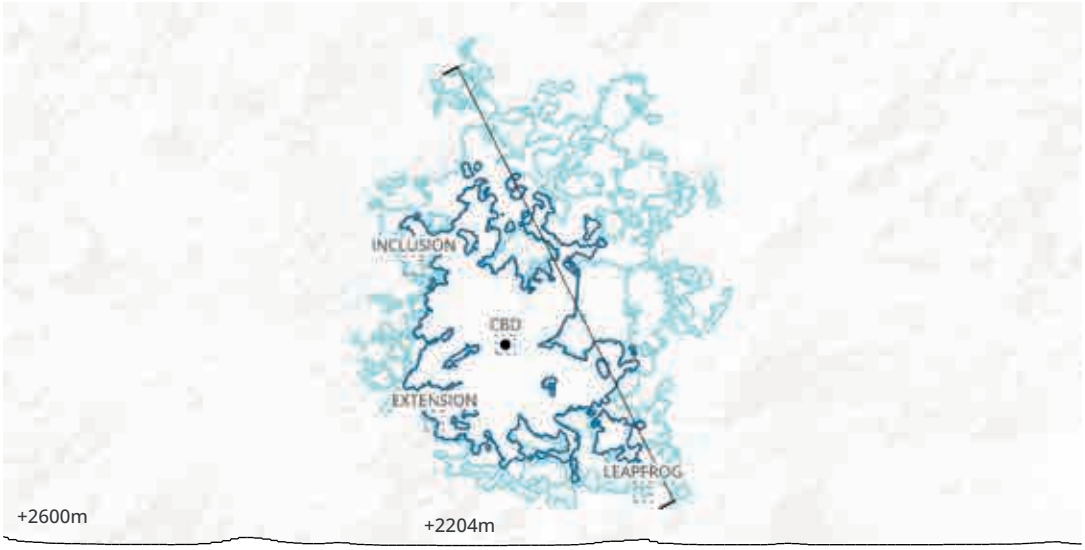
2 stories building height

avg 44% plot coverage



53% plot coverage





Section Profile 92 km





40 /

INLAND CITY
ELEVATION: 556m
BIOME: DESERTS / XERIC SHRUBLANDS

Greater Monterrey,* Mexico, is located in the biome Deserts & Xeric Shrublands, at 556 meters above sea level. Between 1991 and 2019, Greater Monterrey experienced an intense population growth of approximately 7.8% per year, from 496.2 thousand to 4.5 million. It has a moderate population density compared to the other cities: 52 inhabitants per hectare. In urban population density variation (%), its current rank as 16th in 2010-2019 attests to a decline, as Greater Monterrey had the highest annual change in urban population density over 1990 and 2000, ranking 1st in the sample. Additionally, urban extent increased by approximately 3.4% annually over the last decades, expanding 2.6 times what it was in 1991. The city maintained its compactness compared to other LAC cities while its saturation remained close to 71%.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

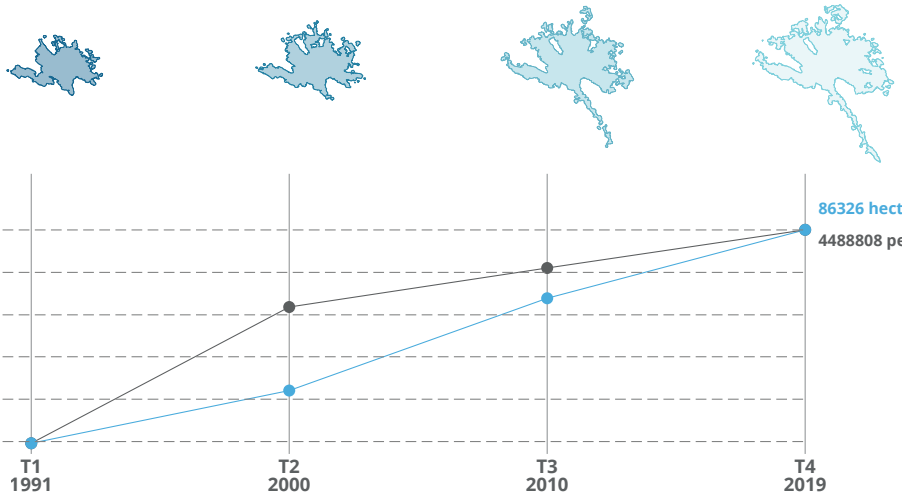


Compactness
rank

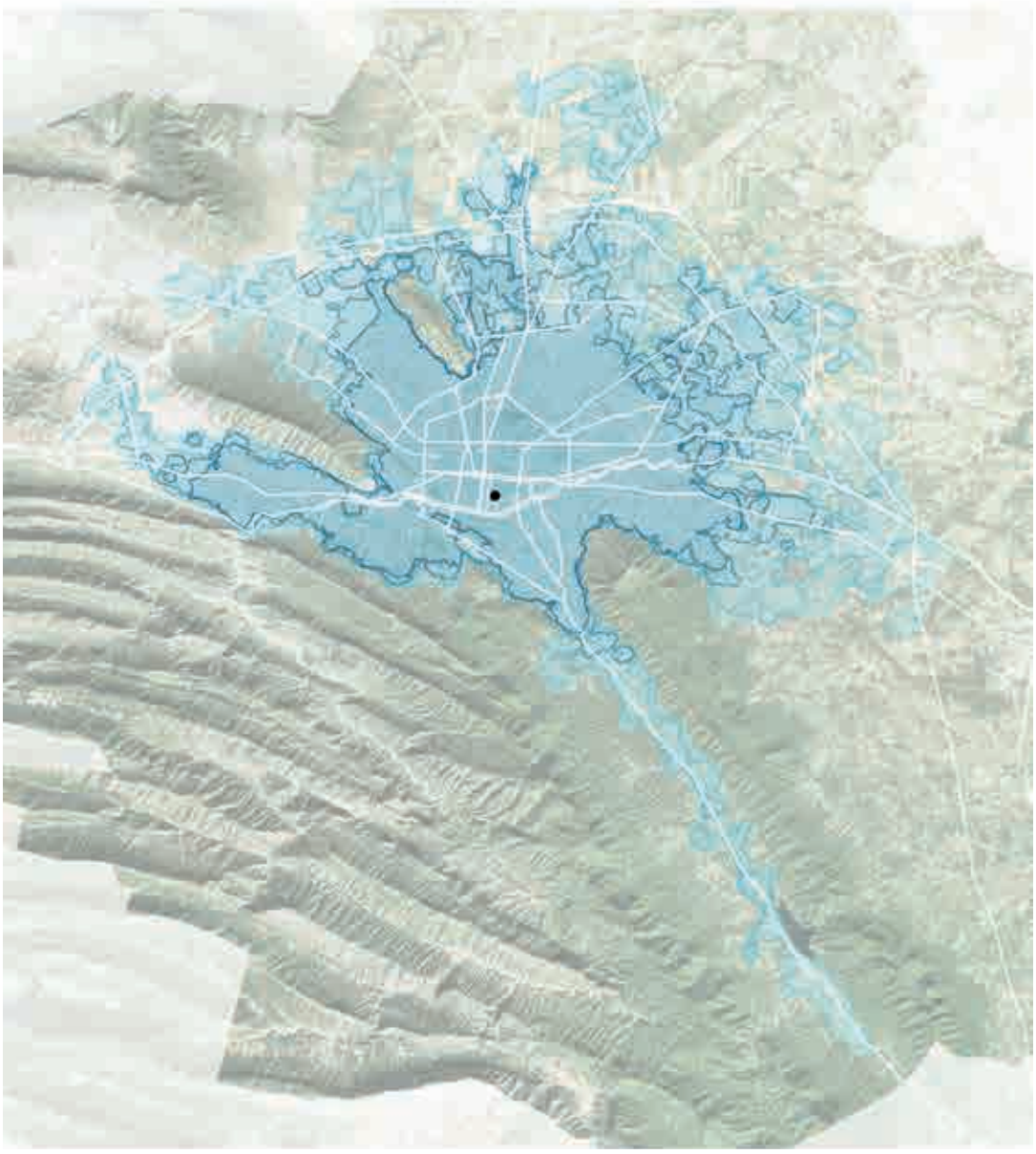


Saturation
rank





GREATER MONTERREY — MEXICO



● Central Business District N 25.6736778
E -100.31084

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Monterrey have not been changing significantly its contribution to the city's growth: from 39% (1991-2000) to 31% (2010-2019). Extension has increased its significance over the years, as it represented 35% in 1991-2000 in contrast to 42% in 2010-2019. Leapfrog's contribution to Greater Monterrey's urban expansion was 14% (1991-2000) and reached 9% (2010-2019). Additionally, inclusion varied its contribution to the city's expansion from 13% (1991-2000) to 20% (2010-2019).

Greater Monterrey experienced an intense population growth of approximately 7.8% per year, from 496.2 thousand to 4.5 million inhabitants.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



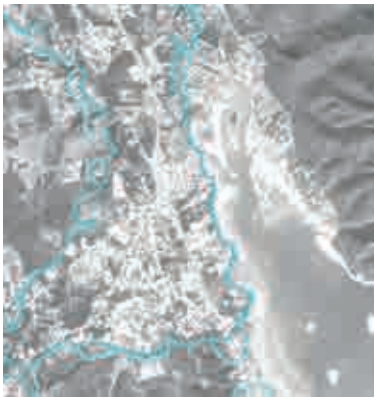
Central Business District



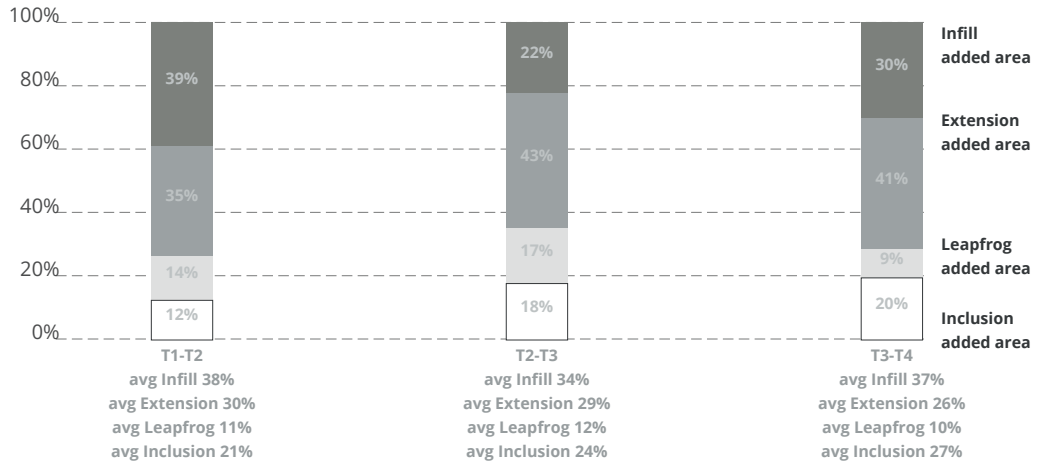
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
39%
35%
14%
12%
22%
43%
17%
18%
30%
41%
9%
20%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0 2.5 km
1991 T1
2019 T4

41 /

COASTAL CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS / SAVANNAS / SHRUBLANDS

Greater Montevideo,* Uruguay, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at one meter above sea level. Between 1990 and 2020, it experienced a low population growth of approximately 0.7% per year, from 1.3 million to 1.6 million. Greater Montevideo has a moderate population density compared to the other cities: 44.6 inhabitants per hectare, ranking 49th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 2.5% annually over the last decades, covering now an area 2.1 times what it was in 1990. The city became much less compact compared to other LAC cities, falling from 31st in 1990 to 61st in 2020. Such a decrease is accompanied by saturation close to 72% throughout the years.



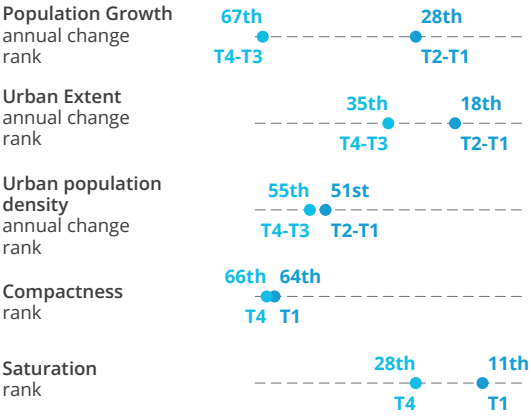


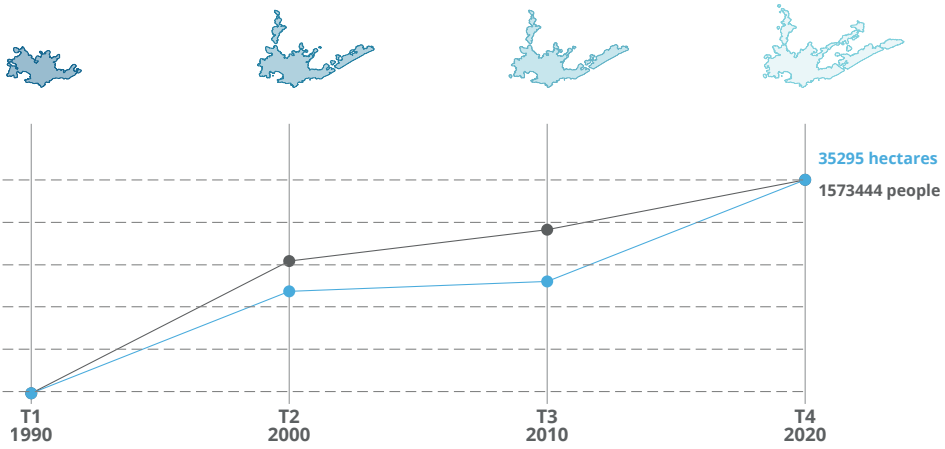
2019=32

1993=61

Urban population density
person / hectare

Evaluation metrics rankings:







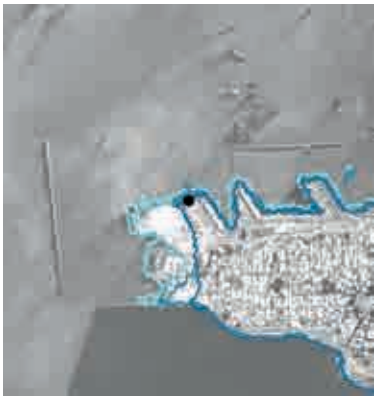
● Central Business District N -34.903729
E -56.218285

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, it is remarkable that over the study period, infill and inclusion represented more than 75% of Greater Montevideo's urban expansion. In contrast, extension has slightly increased its significance over the years, as it represented 12% in 1990-2000 in contrast to 16% in 2010-2020. Additionally, Leapfrog's contribution to Greater Montevideo's urban expansion doubled from 5% (1990-2000) to 10% (2010-2020).

The average dwelling unit occupancy in Montevideo is 2.87 people per unit, low in comparison to the average of the cities in this Atlas. In contrast to the sample, the building story height average of 1.5 stories is also low. Residential plot coverage of Montevideo is 32.5%, meaning a high percentage of unbuilt spaces within plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Over the study period, infill and inclusion represented more than 75% of Greater Montevideo's urban expansion.

avg 3.4 people per dwelling unit

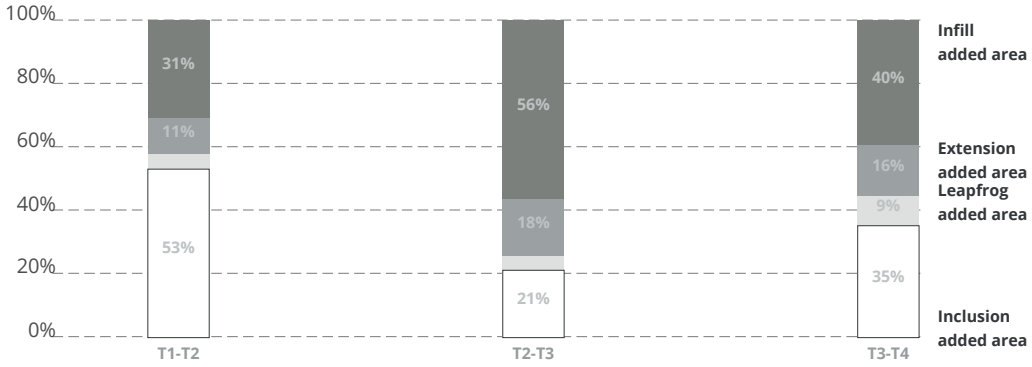
2.9 people per dwelling unit

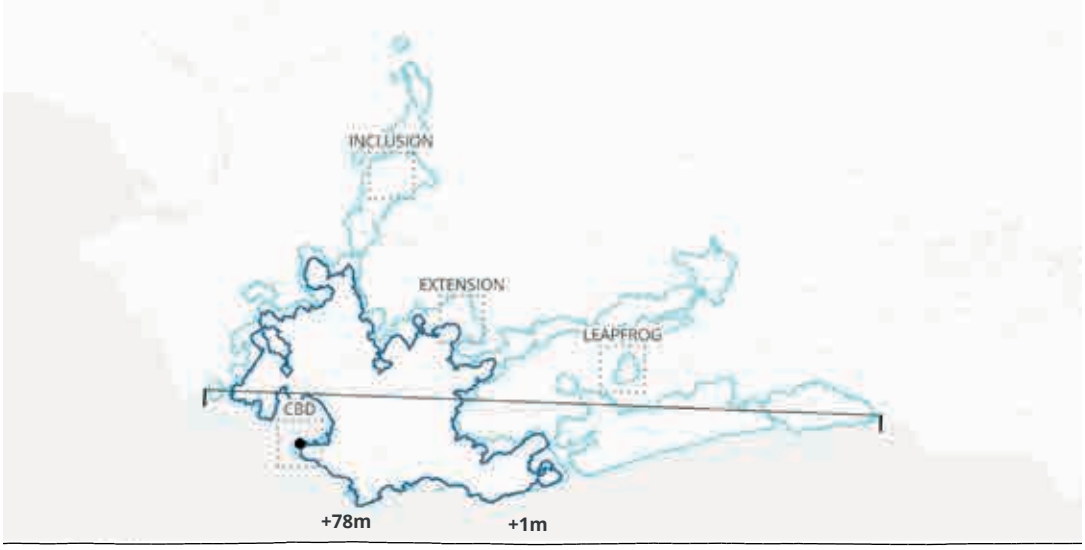
avg 1.6 stories building height

1.5 stories building height

avg 44% plot coverage

33% plot coverage





Section Profile 52 km

0 2.5 km

1991 T1 2019 T4

42 /

COASTAL CITY
ELEVATION: 3m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

Nassau,* Bahamas, is located in the biome Tropical & Subtropical Coniferous Forests, at 3 meters above sea level. Between 1989 and 2020, it experienced a population growth of approximately 1.5% per year, from 139.8 thousand to 224.9 thousand. Over the study period, Nassau became significantly less compact compared to the other cities in the sample, accompanied by low urban population density. The city's density of 19 inhabitants per hectare—amongst the lowest in the sample—results of a decline of its variation, as it dropped from 7th (1989-2000) to 35th (2010-2020). In this process, Nassau's urban extent increased by approximately 1.9% annually over the last decades, encompassing an area 1.8 times what it was in 1989. An increase in saturation followed these changes, in which the city rose 5 positions from 1989 to 2020.



2020=19

1989=21

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



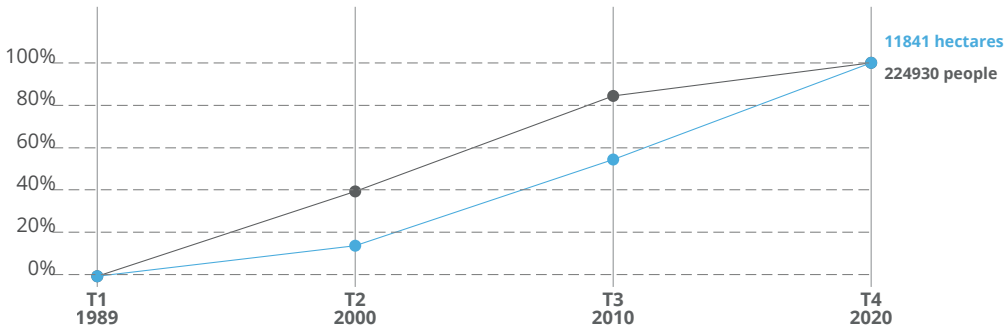
Compactness
rank



Saturation
rank









● Central Business District N 25.0750403
E -77.342138

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

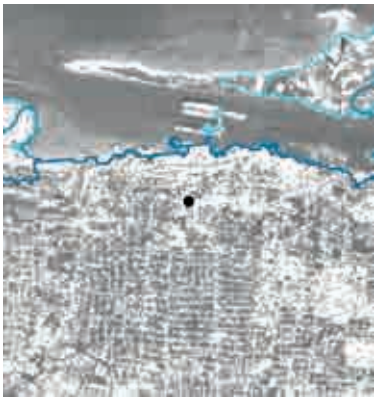
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, infill in Nassau decreased its contribution to the city's growth: from 58% (1989-2000) to 43% (2010-2020)—yet remaining the predominant process. Extension has increased its significance over the years, as it represented 11% in 1989-2000 in contrast to 16% in 2010-2020. Leapfrog's contribution to Nassau's Urban Expansion was 9% (1989-2000) and reached 10% (2010-2020). Additionally, inclusion increased its contribution to the city's expansion from 23% (1989-2000) to 32% (2010-2020).

Over the study period, Nassau became significantly less compact compared to the other cities in the sample, accompanied by low urban population density.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

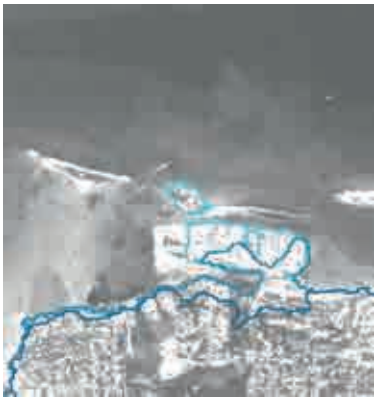
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



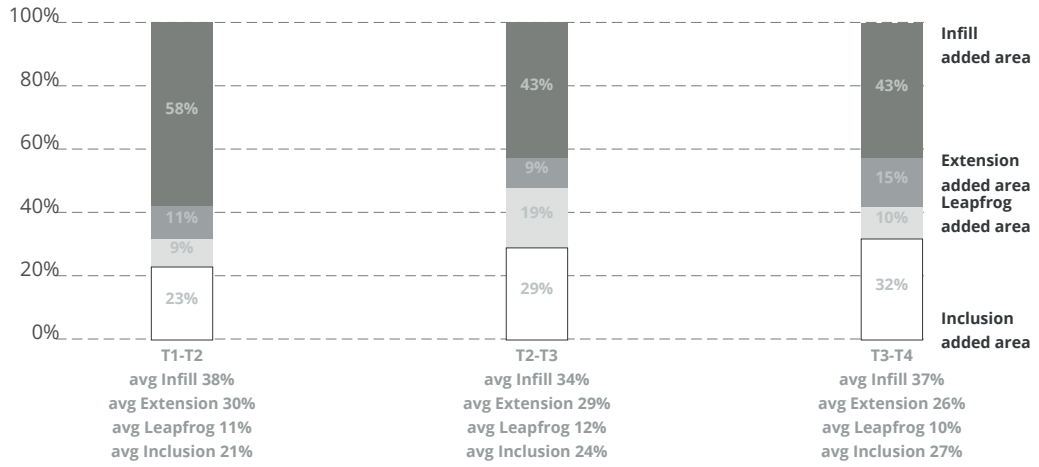
Extension area

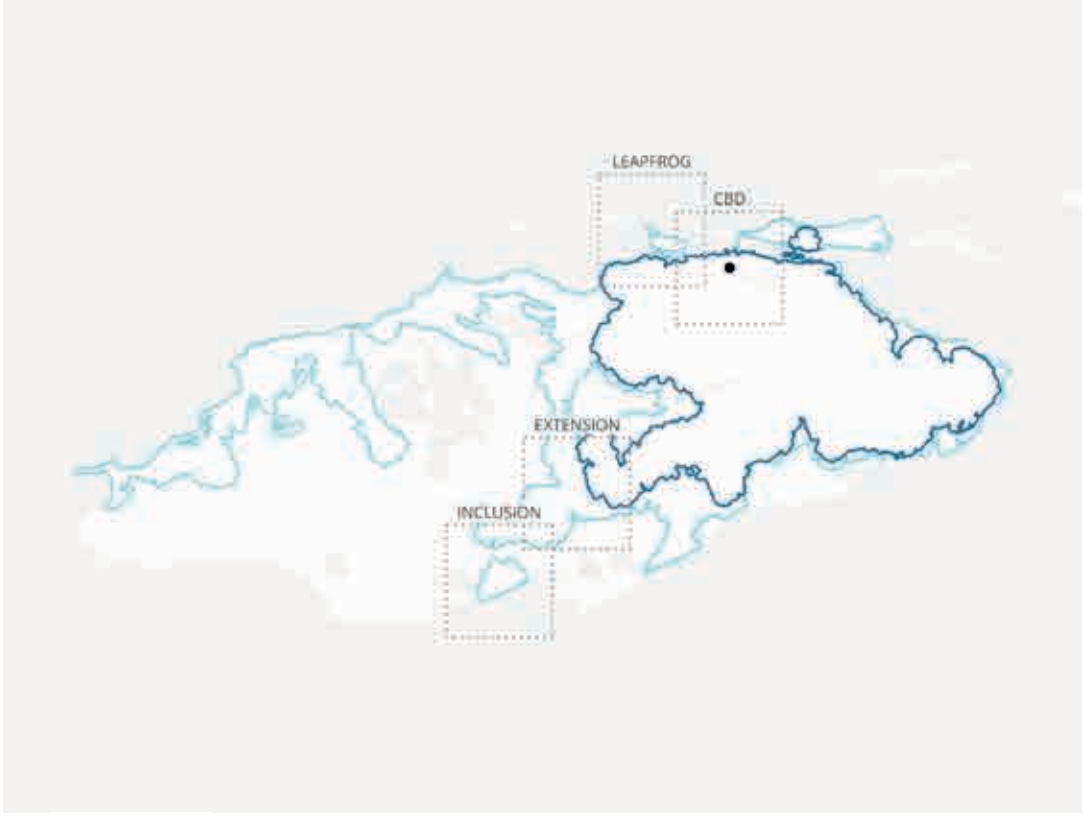


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
58%
11%
9%
23%
43%
9%
19%
29%
43%
15%
10%
32%
Infill
added area
Extension
added area
Leapfrog
added area
Inclusion
added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
CBD
EXTENSION
INCLUSION
0
2.5 km
1991
T1
2019
T4

43 /

COASTAL CITY
ELEVATION: 3m
BIOME: MANGROVES

Greater Niterói,* Brazil, is located in the biome Mangroves, at 3 meters above sea level. Between 1990 and 2021, it experienced a low population growth of approximately 1.8% per year, from 1.06 million to 1.85 million inhabitants. Greater Niterói has a high population density compared to the other cities: 49.5 inhabitants per hectare, ranking 57th in population density variation (%) in 2016-2021. Its urban extent increased by approximately 2.1% annually over the last decades. In other words, the area is now 2.1 times what it was in 1990. In this process, the city became more compact compared to other LAC cities, rising twelve positions in the ranking. With such changes in its urban extent, the city fell five positions regarding saturation in comparison to the sample.

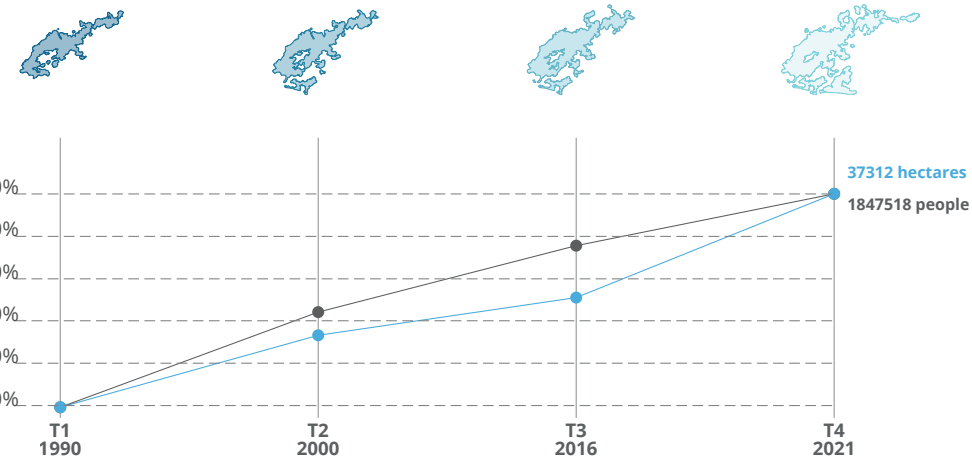




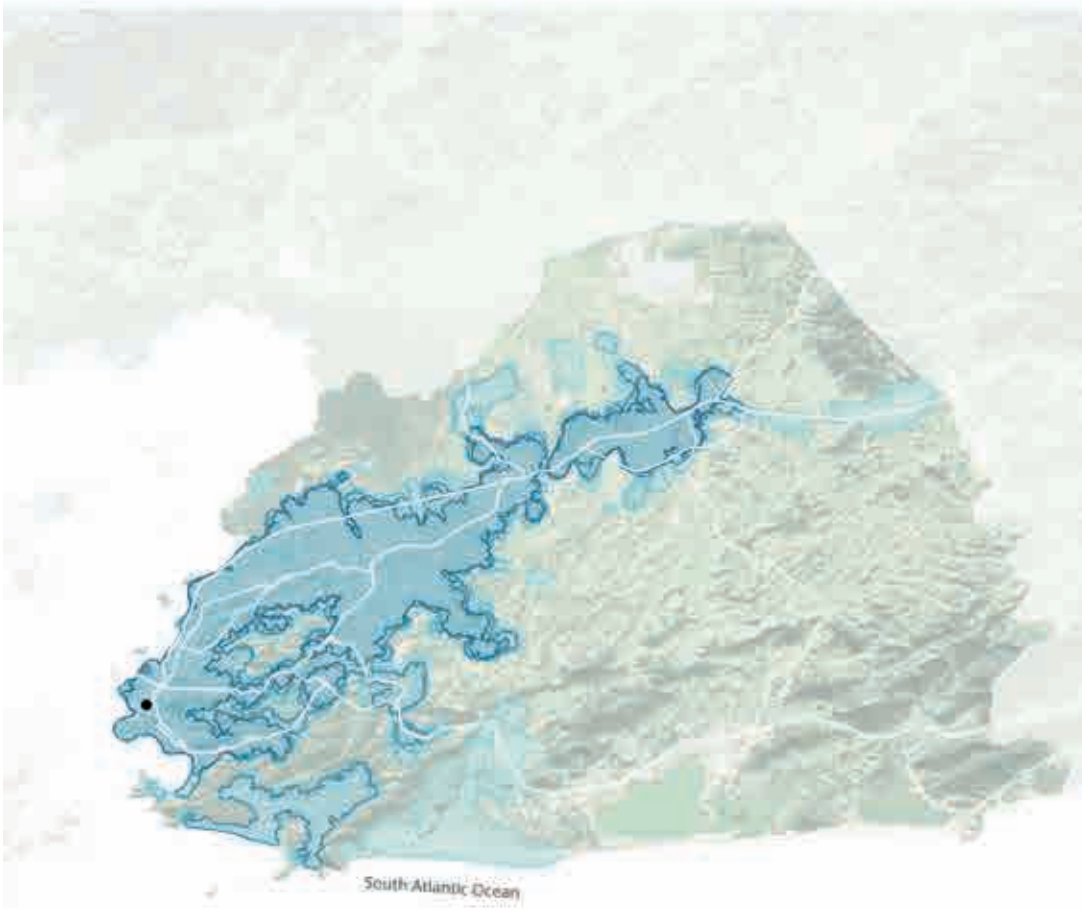
Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth annual change rank	43rd (T2-T1)	19th (T4-T3)
Urban Extent annual change rank	40th (T2-T1)	12th (T4-T3)
Urban population density annual change rank	44th (T2-T1)	21st (T4-T3)
Compactness rank	60th (T1)	51st (T4)
Saturation rank	45th (T1)	39th (T4)



GREATER NITERÓI — BRAZIL



● Central Business District N -22.889512
E -43.119236

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

0 2.5 km

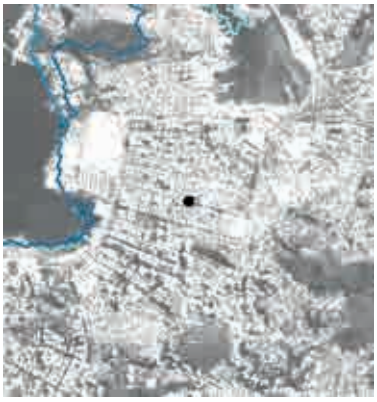
43 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, infill in Greater Niterói has been decreasing from 33% (1990-2000) to 27% (2016-2021). Likewise, extension has decreased its significance, as it represented 22% in 1990-2000 in contrast to 10% in 2016-2021. The city's most significant process for added area is by far inclusion. Not only is it higher than the region's average between 1990-2000, as between 2016 and 2021 58% of Greater Niterói's urban expansion occurred through inclusion.

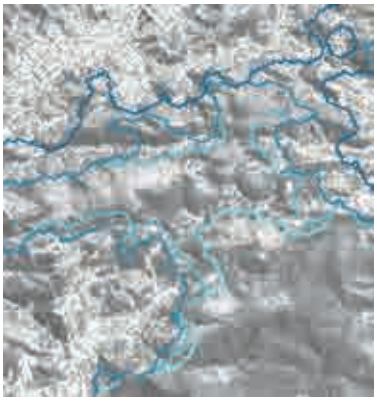
Greater Niterói has a high population density compared to the other cities: 49.5 inhabitants per hectare.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

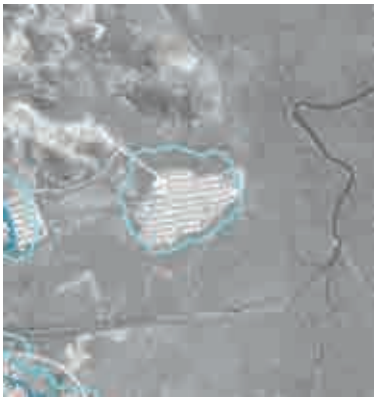
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



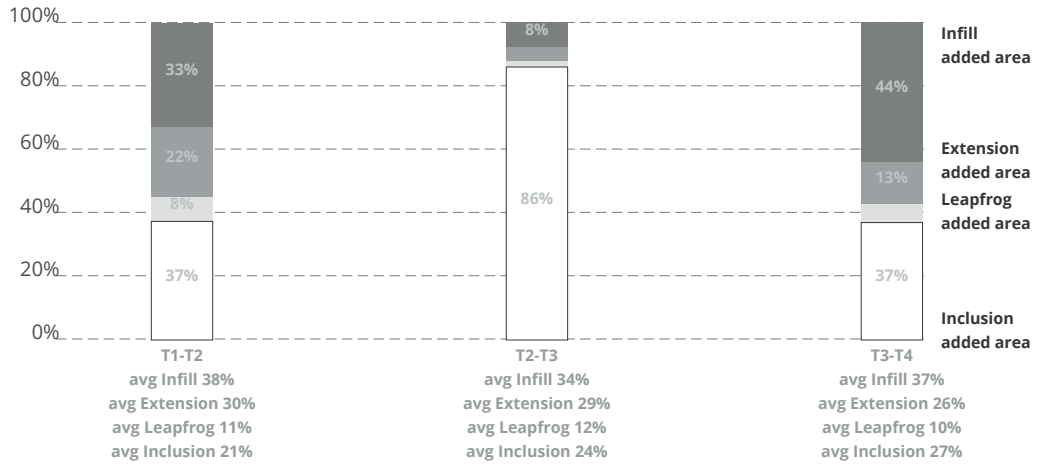
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
33%
22%
8%
37%
8%
86%
44%
13%
37%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1991
T1
2019
T4

44 /

INLAND CITY
ELEVATION: 216m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS / SAVANNAS / SHRUBLANDS

Palmas,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at 216 meters above sea level. Between 1990 and 2021, it experienced an expressive population growth of approximately 12.3% per year, from 5.9 thousand to 272.3 thousand. The city has one of the lowest population densities compared to the other cities: 22.4 inhabitants per hectare, though it was even lower at 7 inhabitants per hectare in 1990. Its annual urban extent increased by 8.4% over the last decades; thus, Palmas' urban extent is now 13.7 times what it was in 1990. The city is among the less compact and most saturated in the sample. Palmas' compactness plummeted from 14th in 1990 to 65th in 2021. Moreover, saturation increased 23 positions, from 66th to 43rd, between 1990 and 2021.



Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

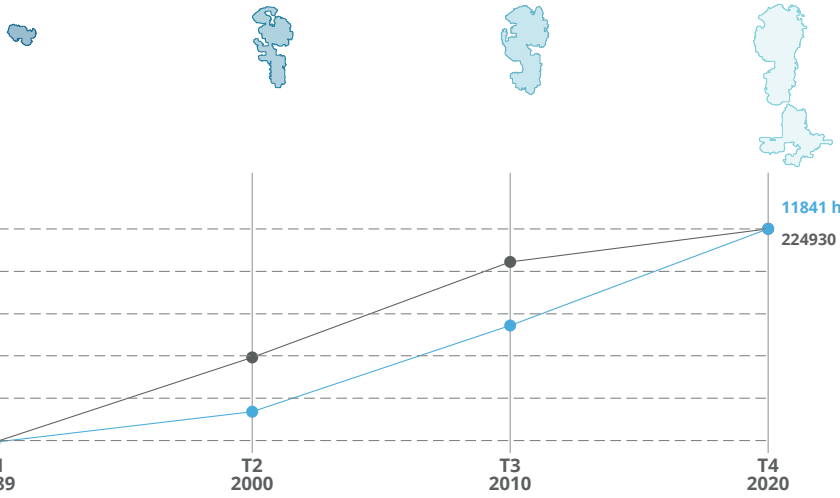


Compactness
rank



Saturation
rank







● Central Business District N -10.185807
E -48.333606

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Palmas more than doubled its contribution to the city's growth: from 11% (1990-2000) to 27% (2013-2021). Extension more than halved its significance over the years, as it represented 59% in 1990-2000 in contrast to 25% in 2013-2021. Leapfrog also expressively diminished its contribution from 15% (1990-2000) and reached 4% (2013-2021). In contrast, inclusion increased its share of the city's expansion from 17% (1990-2000) to 46% (2013-2021).

Palmas' urban extent is now 13.7 times what it was in 1990. The city is among the less compact and most saturated in the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



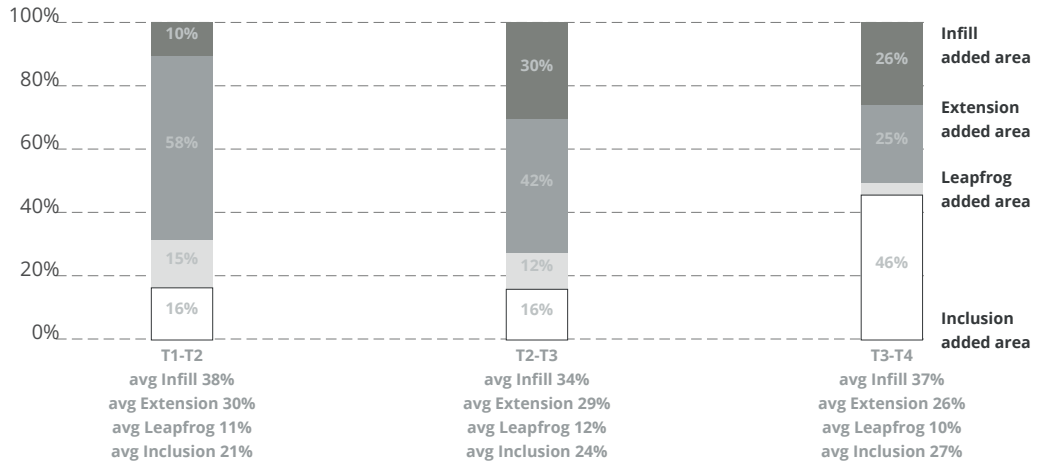
Extension area

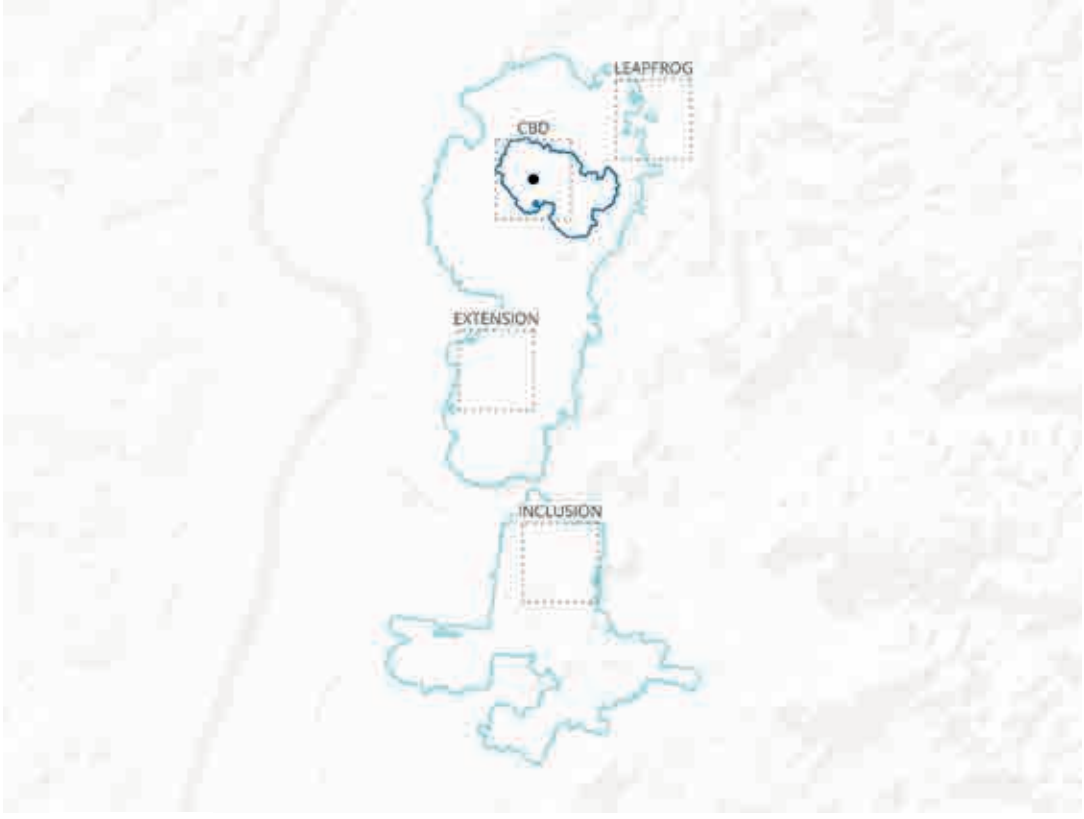


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
10%
58%
15%
16%
30%
42%
12%
16%
26%
25%
46%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
CBD
EXTENSION
INCLUSION
0
2.5 km
1991 T1
2019 T4

45 /

COASTAL CITY
ELEVATION: 11m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

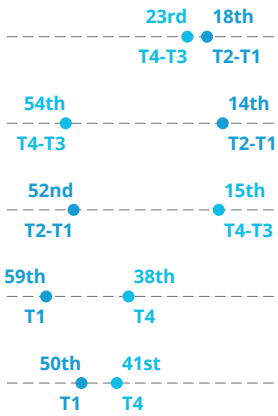
Greater Panama City,* Panama, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 11 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 2.8% per year, from 493.9 thousand to 1.2 million. Despite Greater Panama City's moderate population density compared to the other cities, at 45.5 inhabitants per hectare, it ranks high as 15th in population density variation (%) in 2010-2020. Additionally, its urban extent increased by approximately 3.3% annually over the last decades, covering now an area of 2.7 times what it was in 1990. The city maintained its compactness compared to other LAC cities. When comparing Greater Panama City to the sample, the ranking of saturation varied more expressively, as it fell 25 positions, from 29th to 54th, between 1990 and 2020.

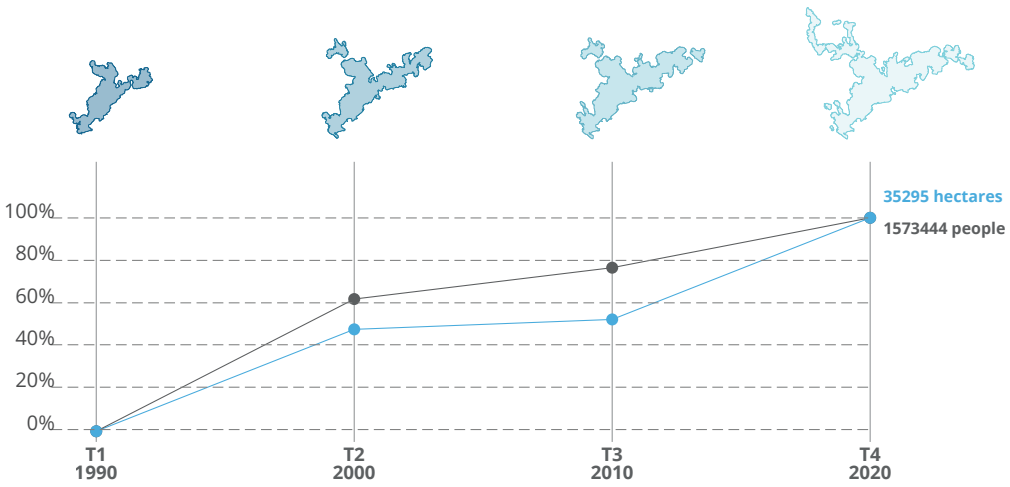




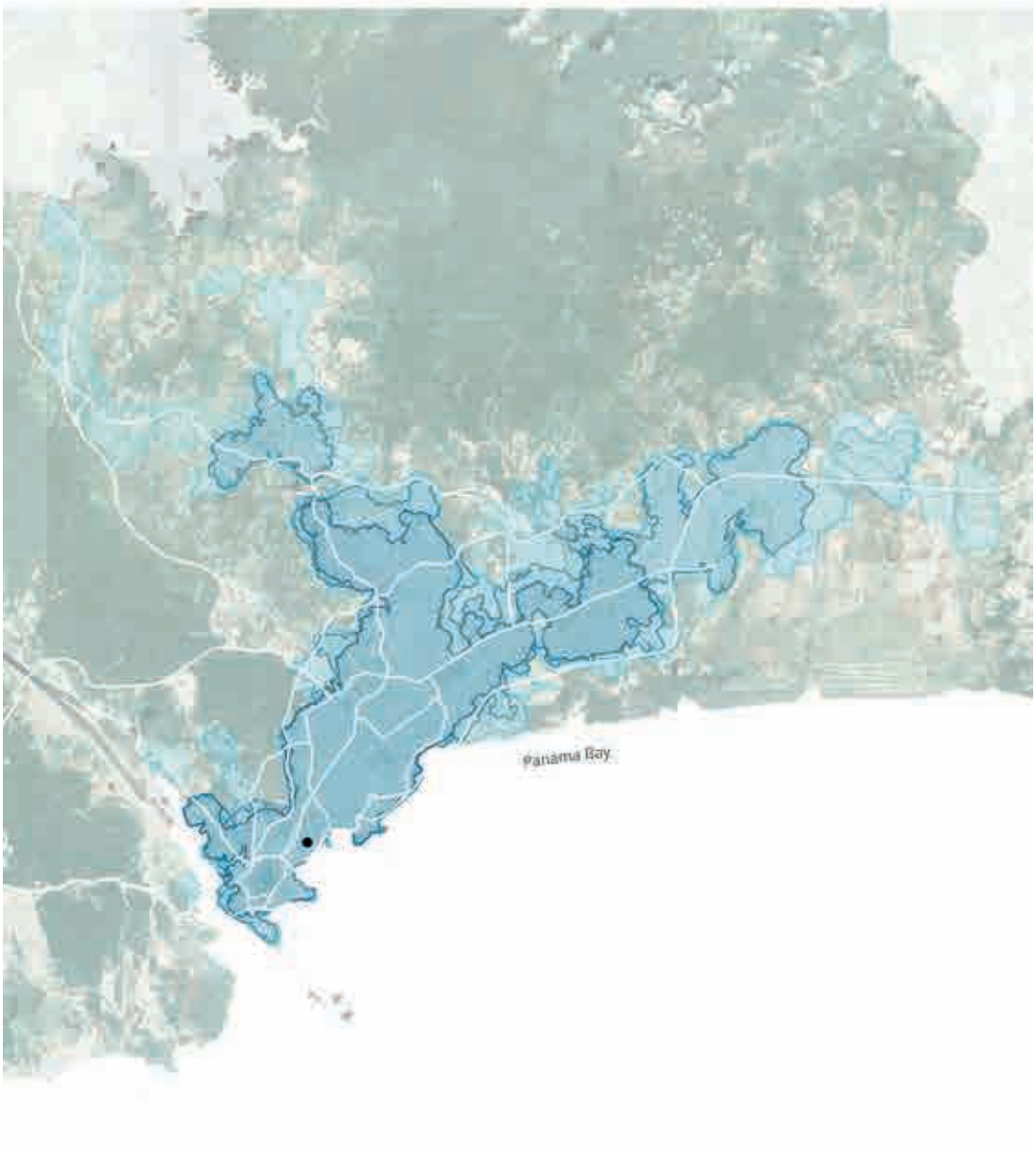
Urban population density
person / hectare

Evaluation metrics rankings:





GREATER PANAMA CITY — PANAMA



● Central Business District N 8.97097528
E -79.534786

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

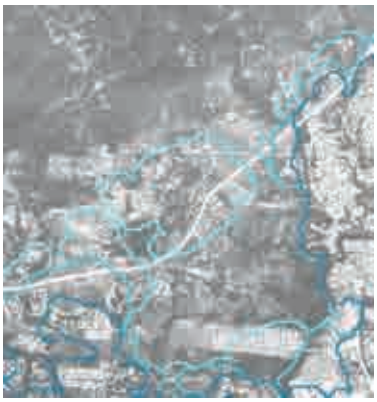
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that 68% of recent urban growth in Greater Panama City occurred through processes of infill and inclusion, a significance that was already dominant in previous years. Extension has decreased its significance over the years, as it represented 34% in 1990-2000 in contrast to 28% in 2010-2020. Following this trend, leapfrog's contribution to Greater Panama City's urban expansion was 8% (1990-2000) and reached 6% (2010-2020).

The average dwelling unit occupancy in Greater Panama City is 3.4 people per unit, moderate in comparison to the average of the cities in this Atlas. The residential plot coverage of Greater Panama City is 42.8%, resulting in a moderate percentage of unbuilt spaces within residential plots. Additionally, the building story height average is 1.7 stories.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

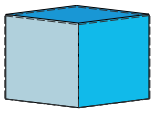
68% of recent urban growth in Greater Panama City occurred through processes of infill and inclusion.

avg 3.4 people per dwelling unit



3.4 people per dwelling unit

avg 1.6 stories building height

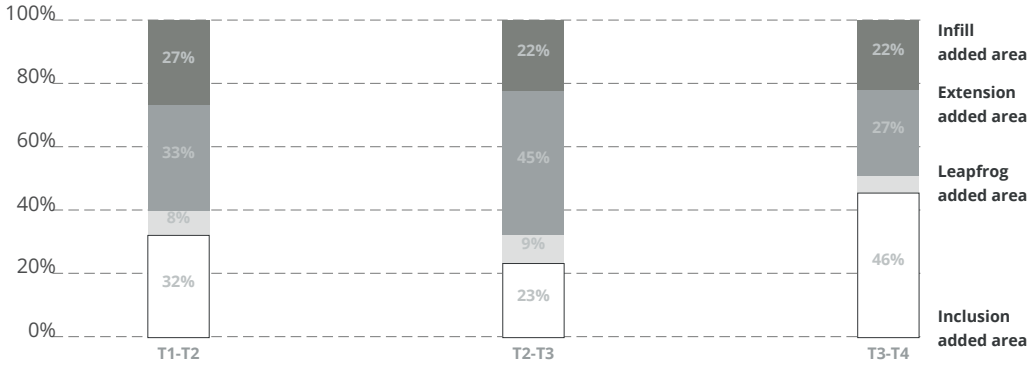


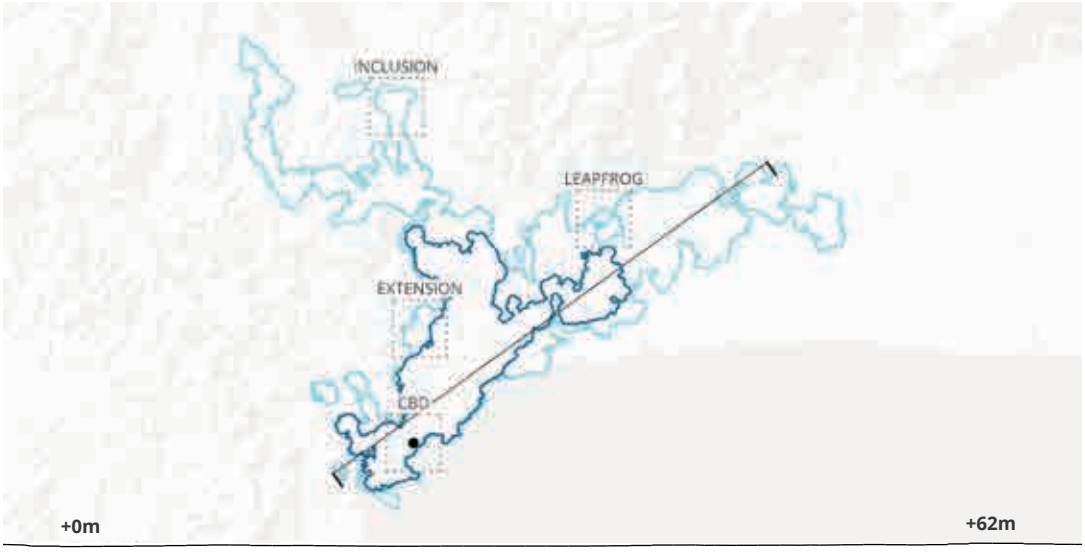
1.7 stories building height

avg 44% plot coverage

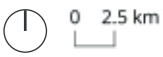


43% plot coverage





Section Profile 34 km



1991 T1 2019 T4

46 /

COASTAL CITY
ELEVATION: 2m
BIOME: MANGROVES

Greater Paramaribo,* Suriname, is located in the biome Mangroves, at 2 meters above sea level. From 1990 to 2020, it experienced an exponential population growth of approximately 2.3% per year, from 192.2 thousand to 382.8 thousand. Greater Paramaribo's urban extent grew even faster, the 7th faster rate from 2010-2020. As a result, the area is 4.3 times what it was in 1990. Greater Paramaribo population density of 14.5 people/ha is the lowest in the sample. The city ranked 65th in population density variation 2010-2020. Even with this fast growth, the city became more compact compared to other LAC cities, rising from 34th in 1990 to 12th in 2020. Such an increase is accompanied by a decline in saturation and its saturation ranking dropped 12 positions, from 51st to 66th between 1990 and 2020.



2020=15



1990=32

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

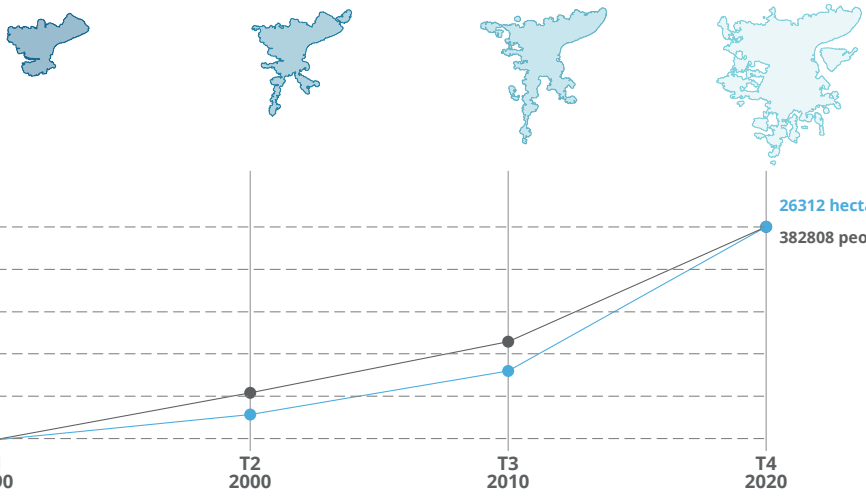


Compactness
rank

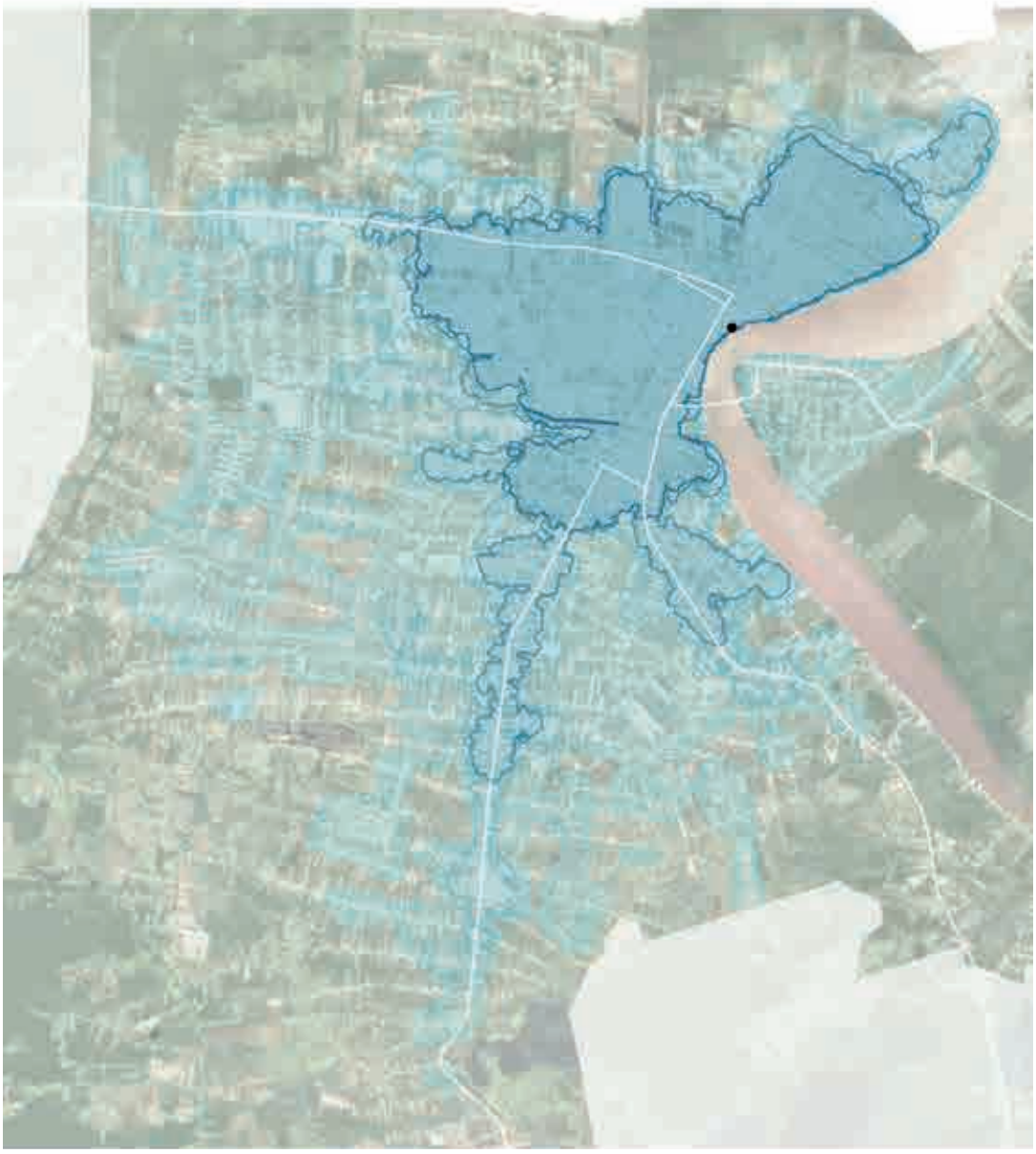


Saturation
rank





GREATER PARAMARIBO — SURINAME



● Central Business District N 5.82342730
E -55.159233

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

0 2.5 km

The process of Urban Expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Paramaribo decreased its contribution to the city's growth to almost half: from 45% (1990-2000) to 23% (2010-2020). Extension has increased its significance over the years, as it represented 14% in 1990-2000 in contrast to 15% in 2010-2020. Leapfrog's contribution to Greater Paramaribo's urban expansion more than doubled: from 10% (1990-2000) to 27% (2010-2020). Additionally, inclusion varied its contribution to the city's expansion from 33% (1990-2000) to 38% (2010-2020).

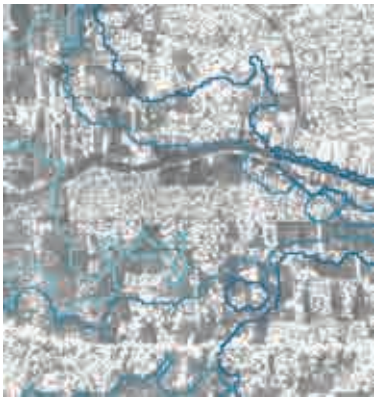
Greater Paramaribo population density of 14.5 people/ha is the lowest in the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



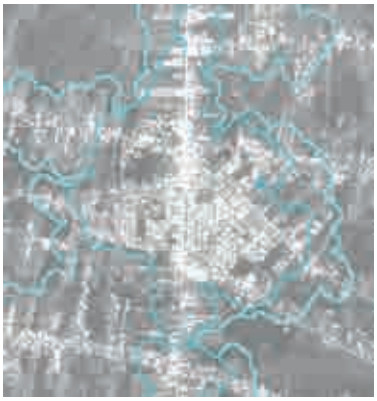
Central Business District



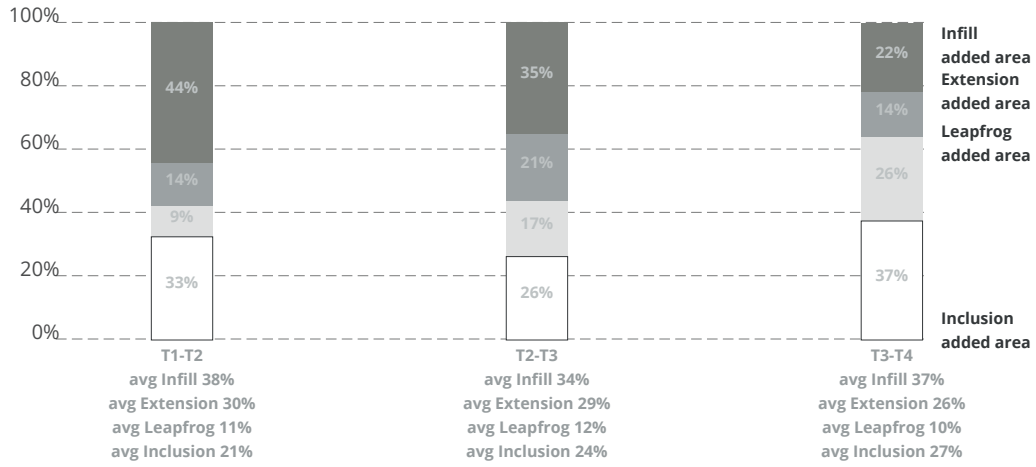
Extension area

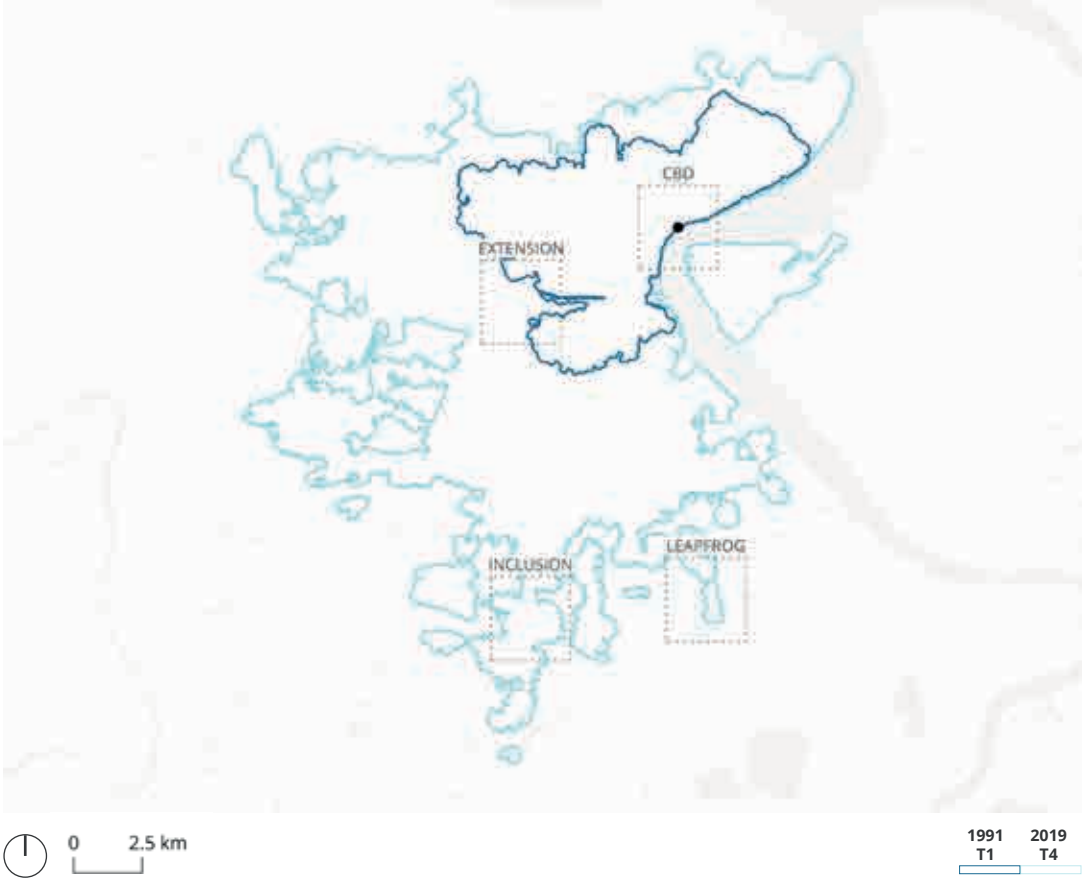


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
44%
14%
9%
33%
35%
21%
17%
26%
22%
14%
26%
37%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%

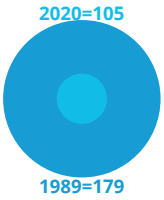

CBD
EXTENSION
INCLUSION
LEAPFROG
0
2.5 km
1991 T1
2019 T4

47 /

INLAND CITY
ELEVATION: 2569m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Pasto,* Colombia, is located in the biome Montane Grasslands & Shrublands, at 2569 meters above sea level. Between 1989 and 2020, it experienced a low population growth of approximately 1.1% per year, from 233.2 thousand to 328.2 thousand. Pasto has a high population density compared to the other cities: 104.5 inhabitants per hectare, but it is not increasing its density at high rates; thus, it ranks 63rd in population density variation (%) in 2014-2020. Additionally, urban extent increased by approximately 2.9% annually over the last decades; as a result, the area is now 2.4 times what it was in 1989. The city became more compact compared to other LAC cities, rising from 17th in 1989 to 9th in 2020. Such an increase is accompanied by a decline in the ranking of saturation considering the sample, falling 5 positions, from 35th to 40th between 1989 and 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



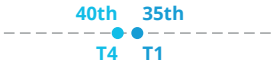
Urban population density
annual change
rank

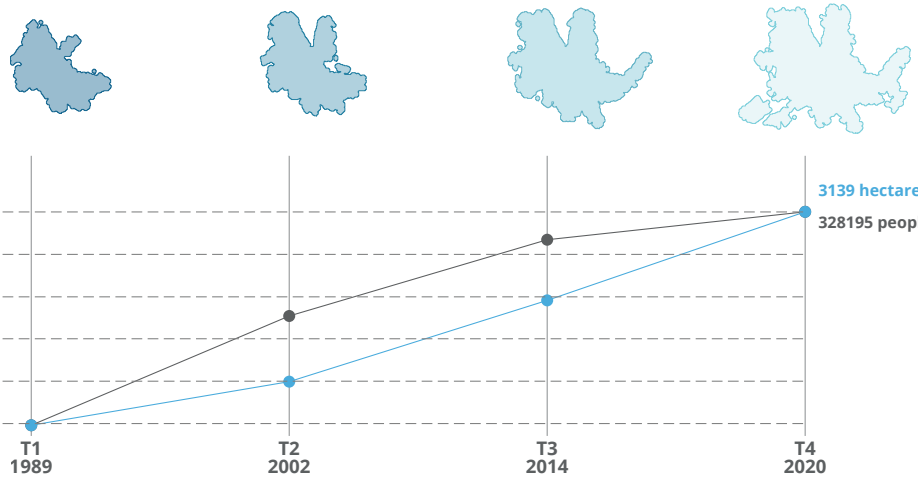


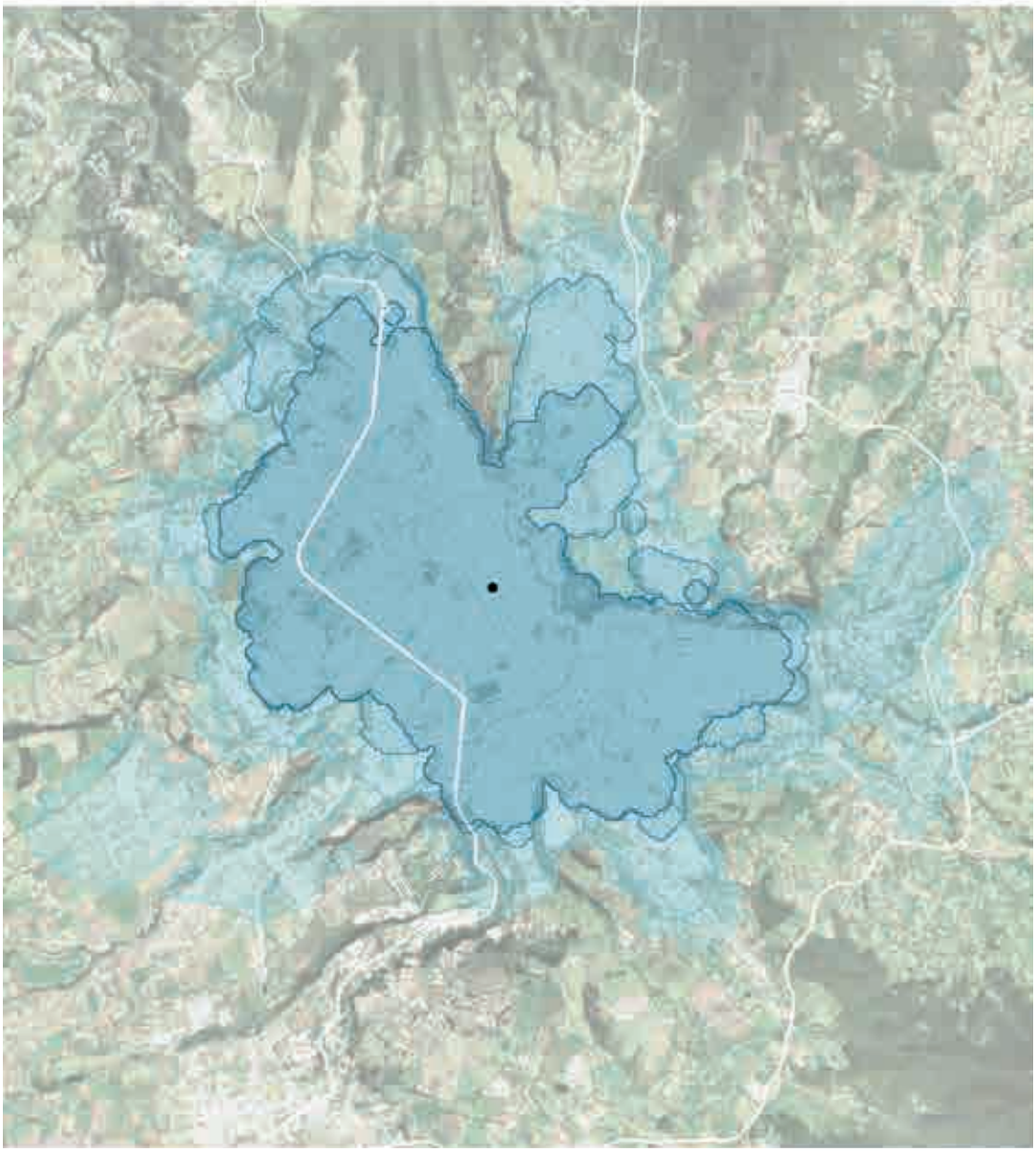
Compactness
rank



Saturation
rank







● Central Business District N 1.20914864
E -77.276284

1991 T1 | 2000 T2 | 2010 T3 | 2019 T4

highways

local streets

0 2.5 km

47 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion over the last three decades, one can conclude that processes of inclusion in Pasto more than doubled its contribution to the city's expansion from 13% (1989-2002) to 28% (2014-2020). Infill in Pasto has changed its contribution to the city's growth from 46% (1989-2002) to 40% (2014-2020). Extension has decreased its significance over the years, as it represented 29% in 1989-2002 in contrast to 24% in 2014-2020. Leapfrog's contribution to Pasto's urban expansion was 14% (1989-2002) and reached 10% (2014-2020).

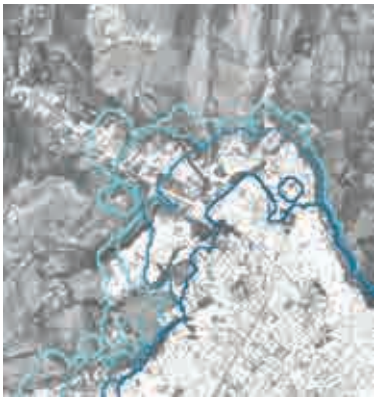
Pasto has a high population density compared to the other cities: 104.5 inhabitants per hectare.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

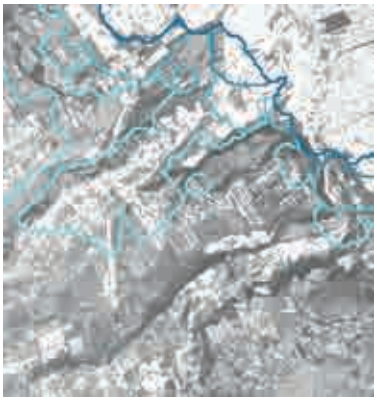
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



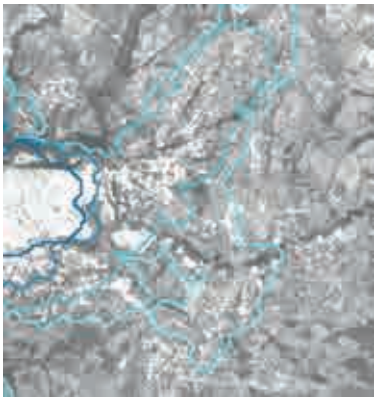
Central Business District



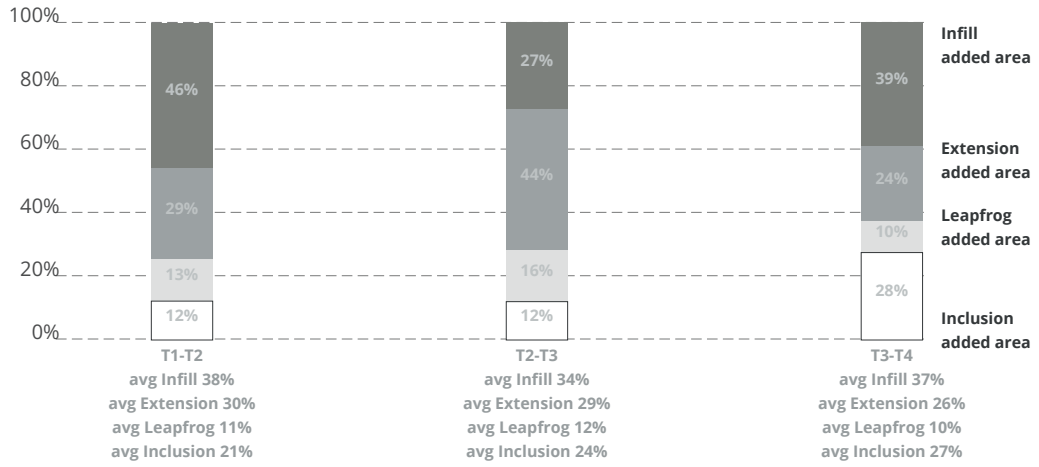
Extension area

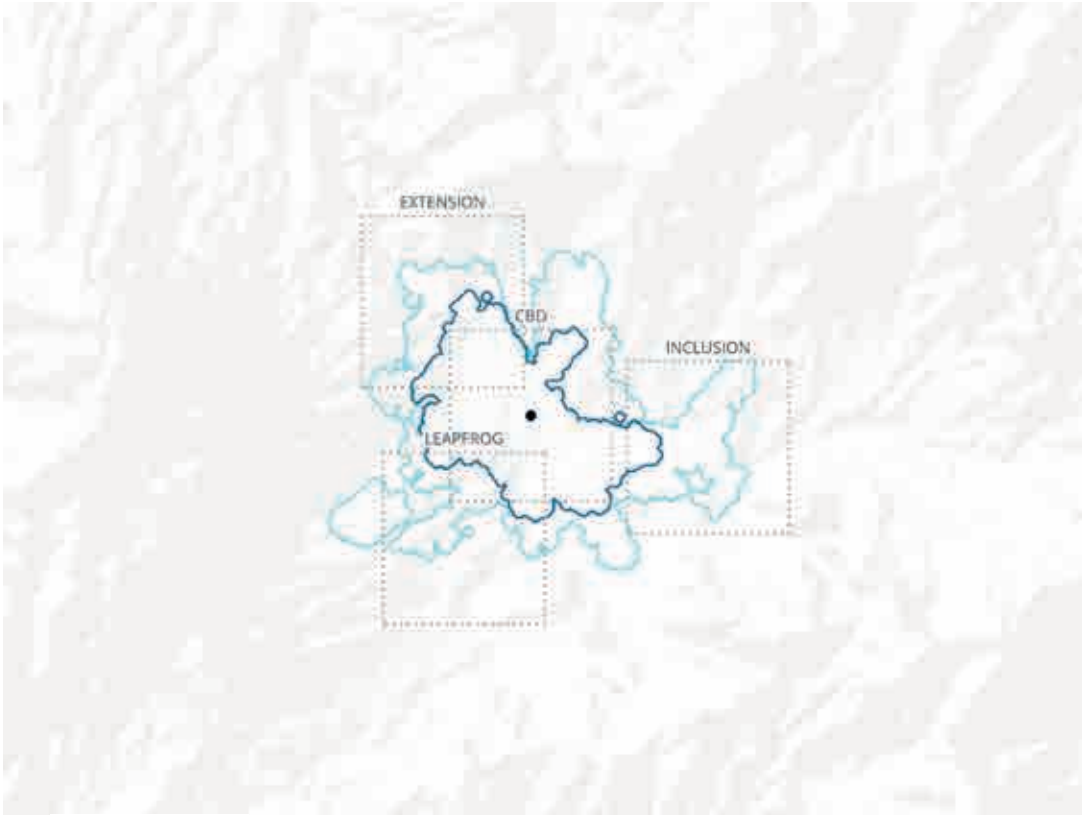


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
46%
29%
13%
12%
27%
44%
16%
12%
39%
24%
10%
28%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


EXTENSION
CBD
INCLUSION
LEAPFROG
0
2.5 km
1991 T1
2019 T4

48 /

INLAND CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS / SAVANNAS / SHRUBLANDS

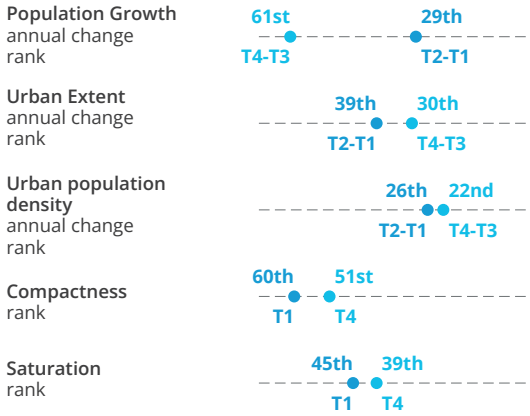
Greater Porto Alegre,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at one meter above sea level. Between 1988 and 2021, it experienced a population growth of approximately 1.4% per year, from 2.1 million to 3.4 million. Greater Porto Alegre has a moderate population density compared to the other cities, 45.9 inhabitants per hectare, and ranks 22nd in population density variation (%) in 2013-2021. Additionally, urban extent increased by approximately 2.1%, which means that over the last decades, the area is now 2 times what it was in 1988. Greater Porto Alegre's rate of urban expansion is close to the medium of the sample but has been decreasing. The city became slightly more compact compared to other LAC cities, rising from 68th in 1988 to 64th in 2021. Such an increase is accompanied by a decline in saturation, dropping 5 positions, from 42nd to 47th between 1988 and 2021.

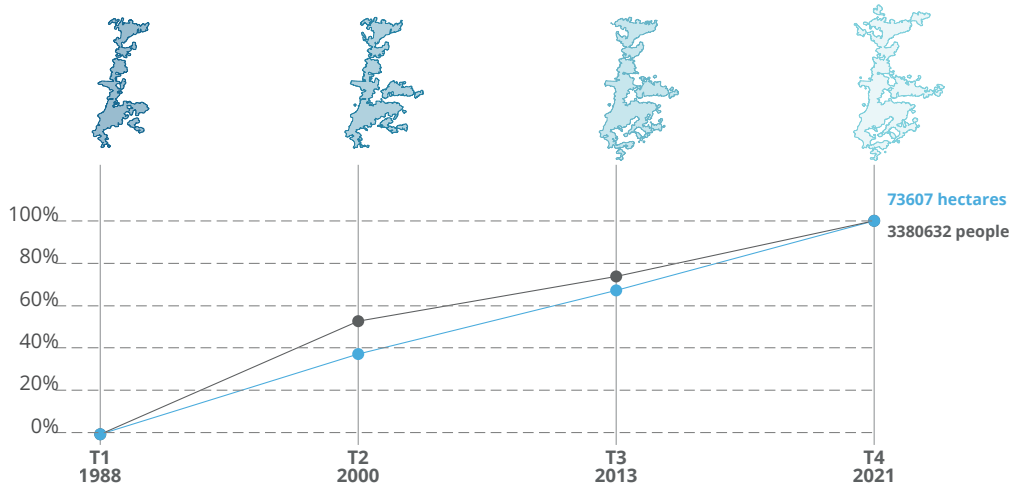




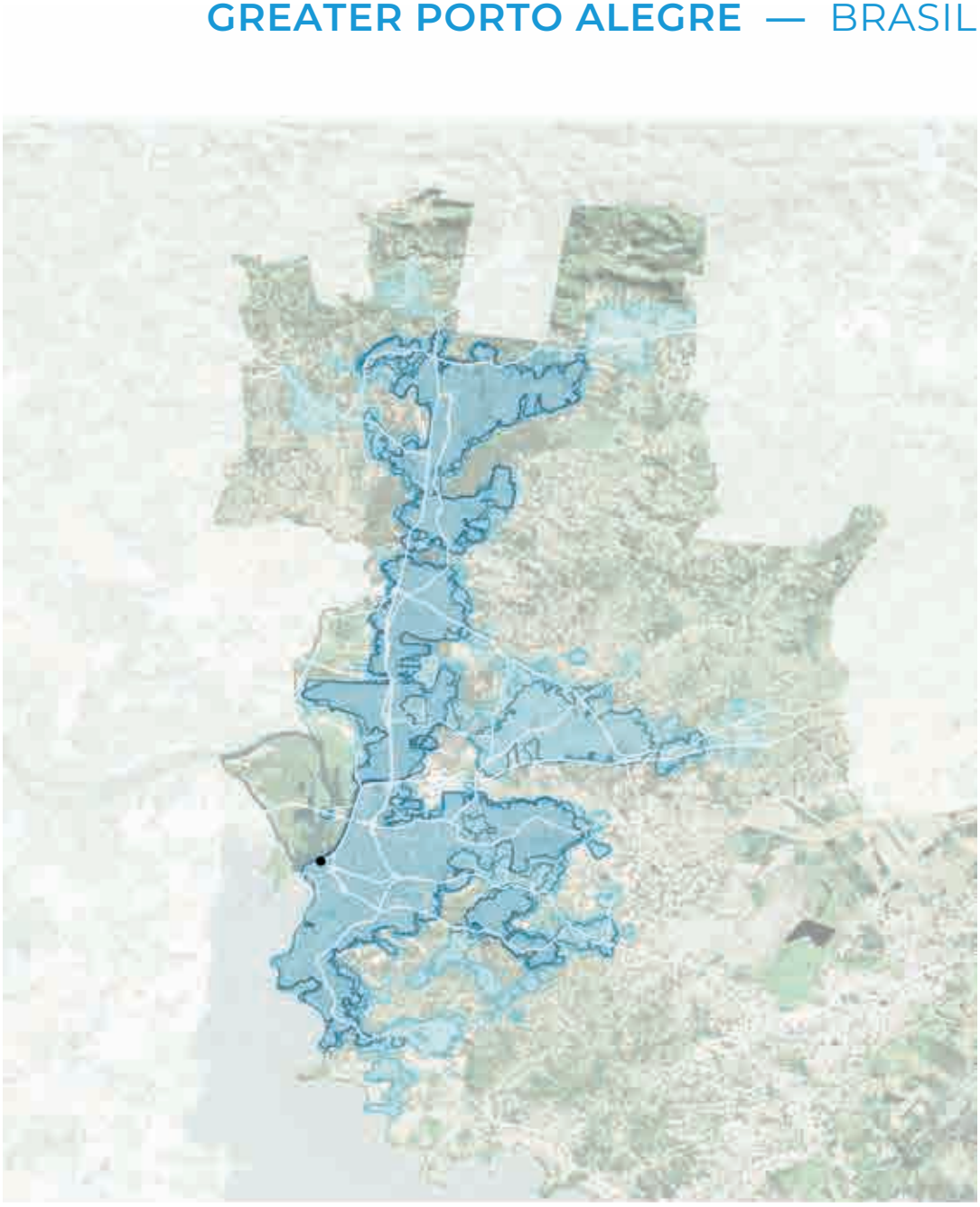
Urban population density
person / hectare

Evaluation metrics rankings:





GREATER PORTO ALEGRE — BRASIL



● Central Business District N -30.028005
E -51.228679

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

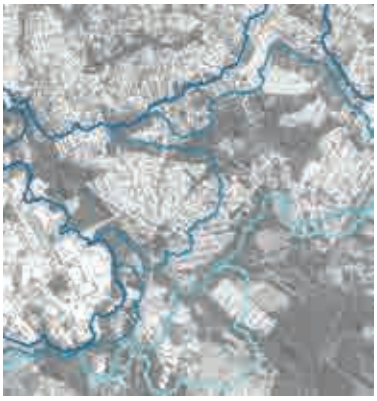
highways

local streets

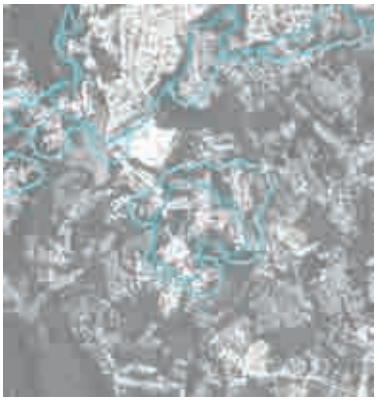
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of leapfrog have not been significant. The other three processes have similar contributions, but infill was more significant in the first decade than the others. In the following decades, infill in Greater Porto Alegre has decreased its contribution to the city's growth from 42% (1988-2000) to 33% (2013-2021). Extension has increased its significance over the years, as it represented 21% in 1988-2000 in contrast to 30% in 2013-2021. Additionally, inclusion varied its contribution to the city's expansion from 34% (1988-2000) to 28% (2013-2021).

The average dwelling unit occupancy in Greater Porto Alegre is 2.9 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.6 stories. The residential plot coverage of Greater Porto Alegre is 42.6%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

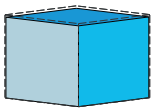
Greater Porto Alegre's rate of urban expansion is close to the medium of the sample but has been decreasing.

avg 3.4 people per dwelling unit



2.9 people per dwelling unit

avg 1.6 stories building height

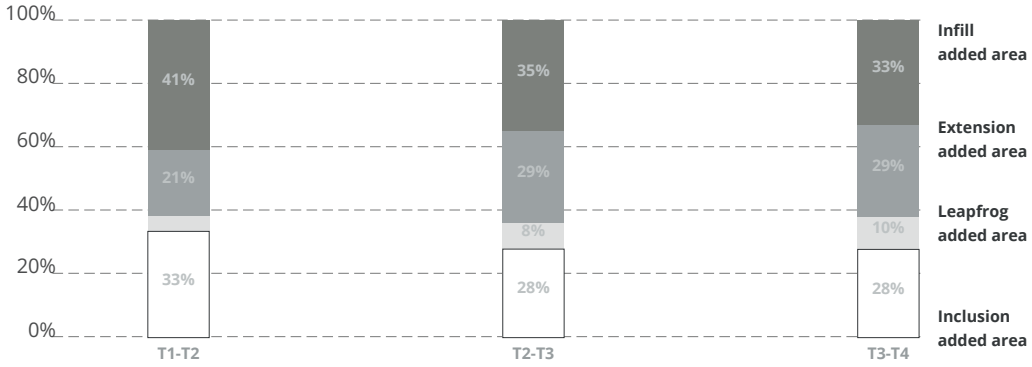


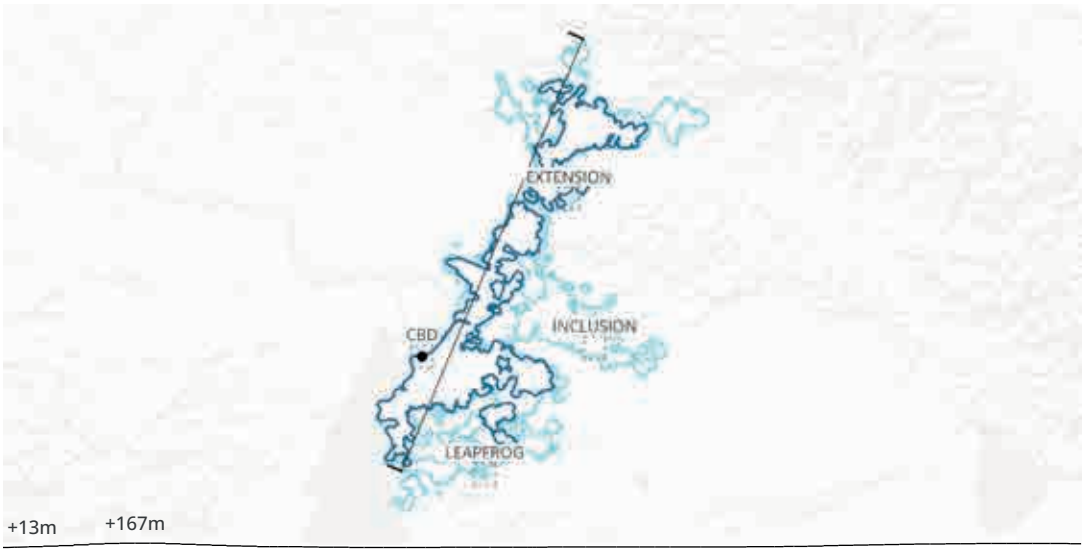
1.6 stories building height

avg 44% plot coverage

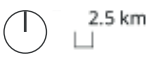


43% plot coverage





Section Profile 76 km





49 /

COASTAL CITY
ELEVATION: 19m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Port-au-Prince,* Haiti, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 19 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 2.6% per year, from 1.2 million to 2.7 million. Urban population density in Greater Port-au-Prince declined from 137 people/ha in 1990 to 73 people/ha in 2020. Additionally, urban extent increased by approximately 4.7% annually over the last decades, which results in an area 4.2 times what it was in 1990. The city became less compact compared to other LAC cities, lowering from 55th in the period 1990 to 59th in 2021. Comparing to the sample, the city declined in the ranking of saturation, from 39th to 49th between 1990 and 2021.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



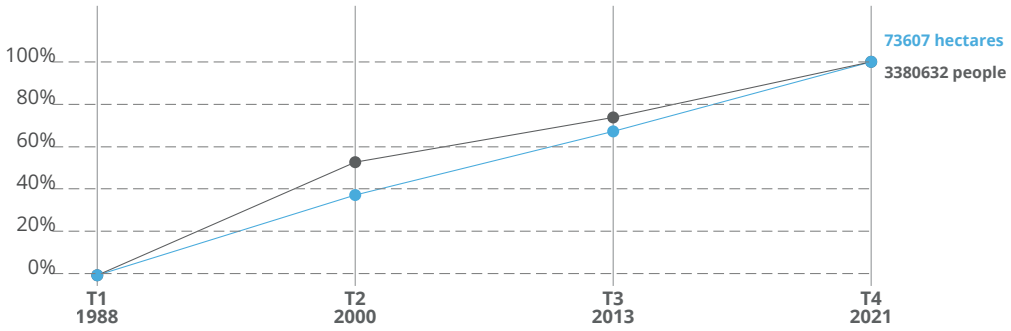
Compactness
rank



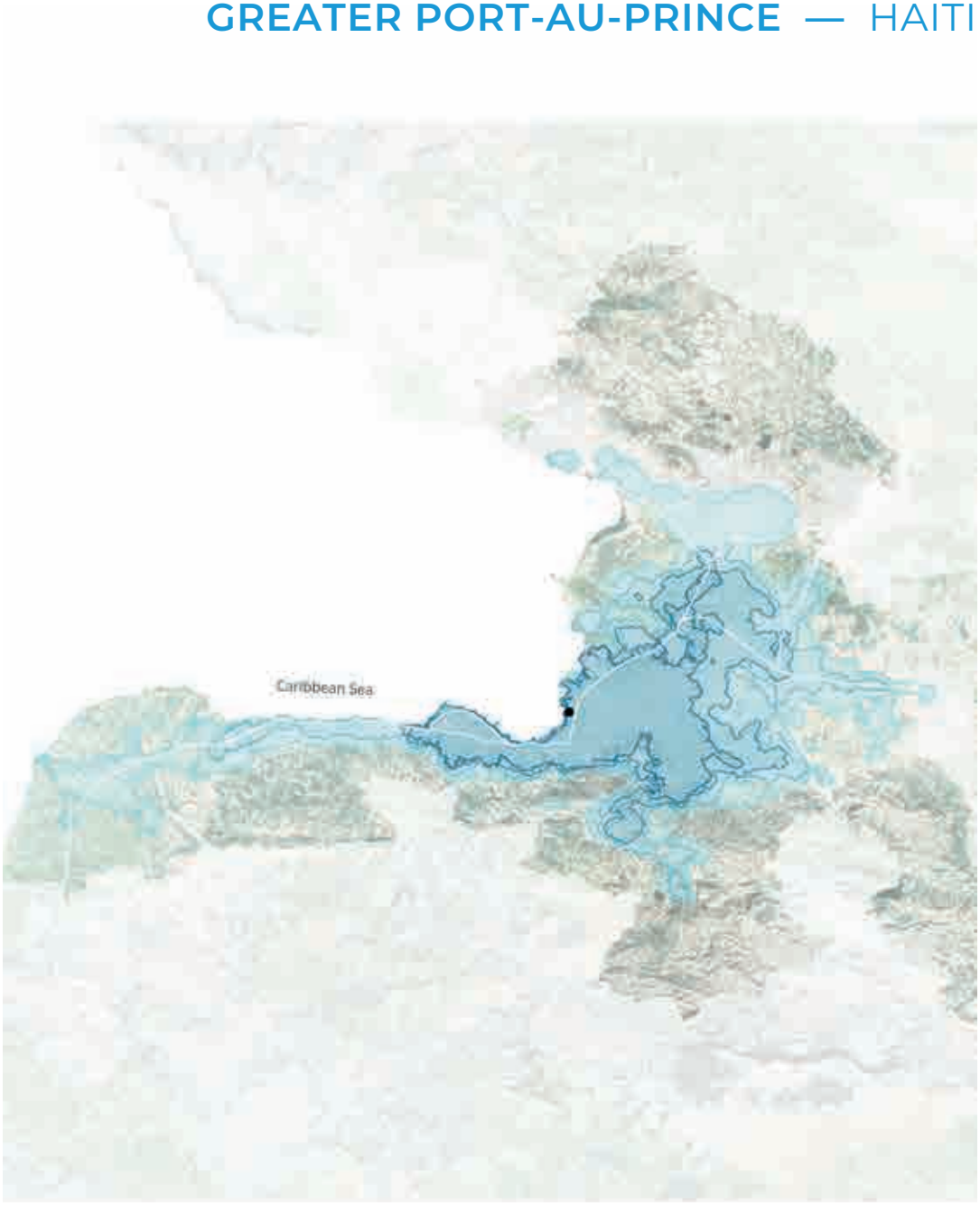
Saturation
rank







GREATER PORT-AU-PRINCE — HAITI



● Central Business District N 18.5504438
E -72.347115

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that most of the urban expansion occurred through processes of infill and extension. Processes of infill in Greater Port-au-Prince have not been changing significantly its contribution to the city's growth: from 25% (1990-2000) to 30% (2010-2021). Extension has increased its significance over the years, as it represented 32% in 1990-2000 in contrast to 48% in 2010-2021. Leapfrog's contribution to Greater Port-au-Prince's urban expansion was 21% (1990-2000) and reached 12% (2010-2021). Additionally, inclusion varied its contribution to the city's expansion from 24% (1990-2000) to 11% (2010-2021).

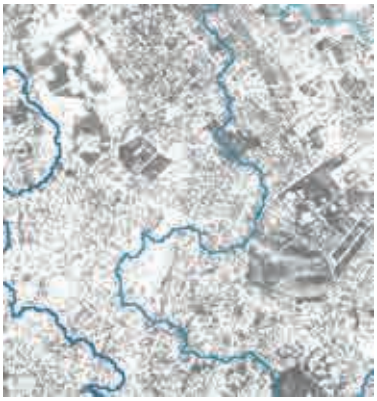
Urban population density in Greater Port-au-Prince declined from 137 people/ha in 1990 to 73 people/ha in 2020. Most of the urban expansion occurred through processes of infill and extension.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



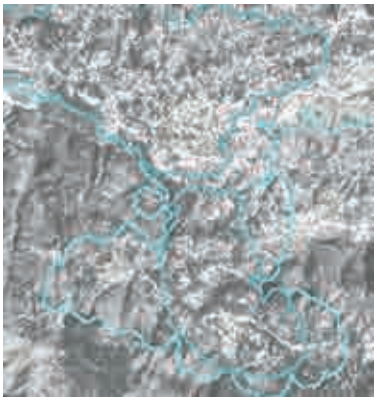
Central Business District



Extension area

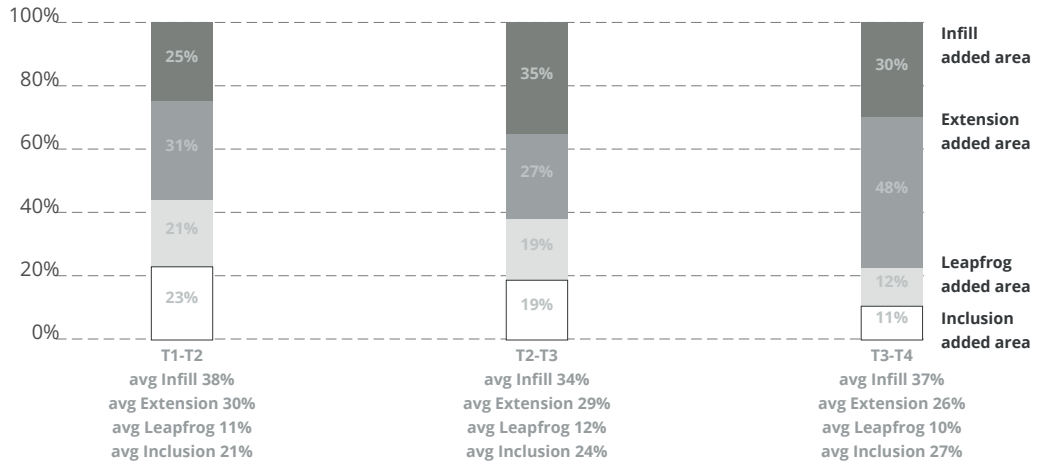


Leapfrog area



Inclusion area

GREATER PORT-AU-PRINCE — HAITI





50 /

INLAND CITY
ELEVATION: 2349m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

Greater Quetzaltenango,* Guatemala, is located in the biome Tropical & Subtropical Coniferous Forests, at 2349 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 5.7% per year, from 77.4 thousand to 456 thousand. Greater Quetzaltenango has a low population density compared to the other cities: 26.1 inhabitants per hectare, ranking 28th in population density variation (%) in 2010-2020. Additionally, Greater Quetzaltenango's urban extent increased by an impressive rate of approximately 7.4% per year over the last decades. As a result, the area is now almost 10 times what it was in 1990. Greater Quetzaltenango compactness declined drastically in comparison to the sample, dropping 49 positions. Such a decrease is accompanied by a decline in saturation and its saturation ranking dropped 27 positions, from 41st to 68th between 1990 and 2020.



2020=45

1990=53

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank
14th (T2-T1) 3rd (T4-T3)

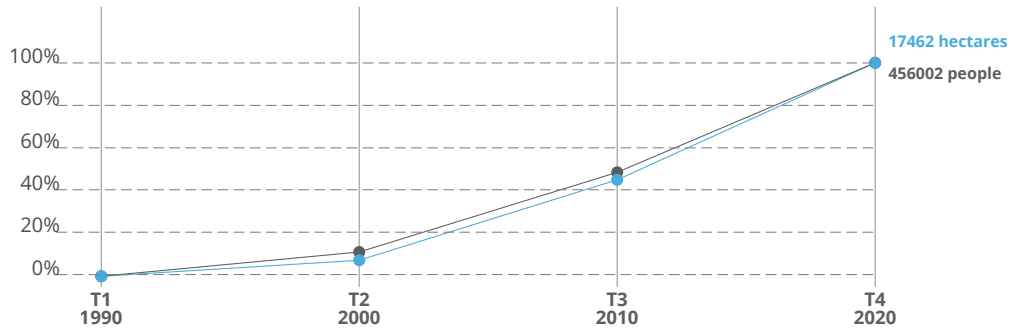
Urban Extent
annual change
rank
15th (T2-T1) 9th (T4-T3)

Urban population density
annual change
rank
55th (T4-T3) 51st (T2-T1)

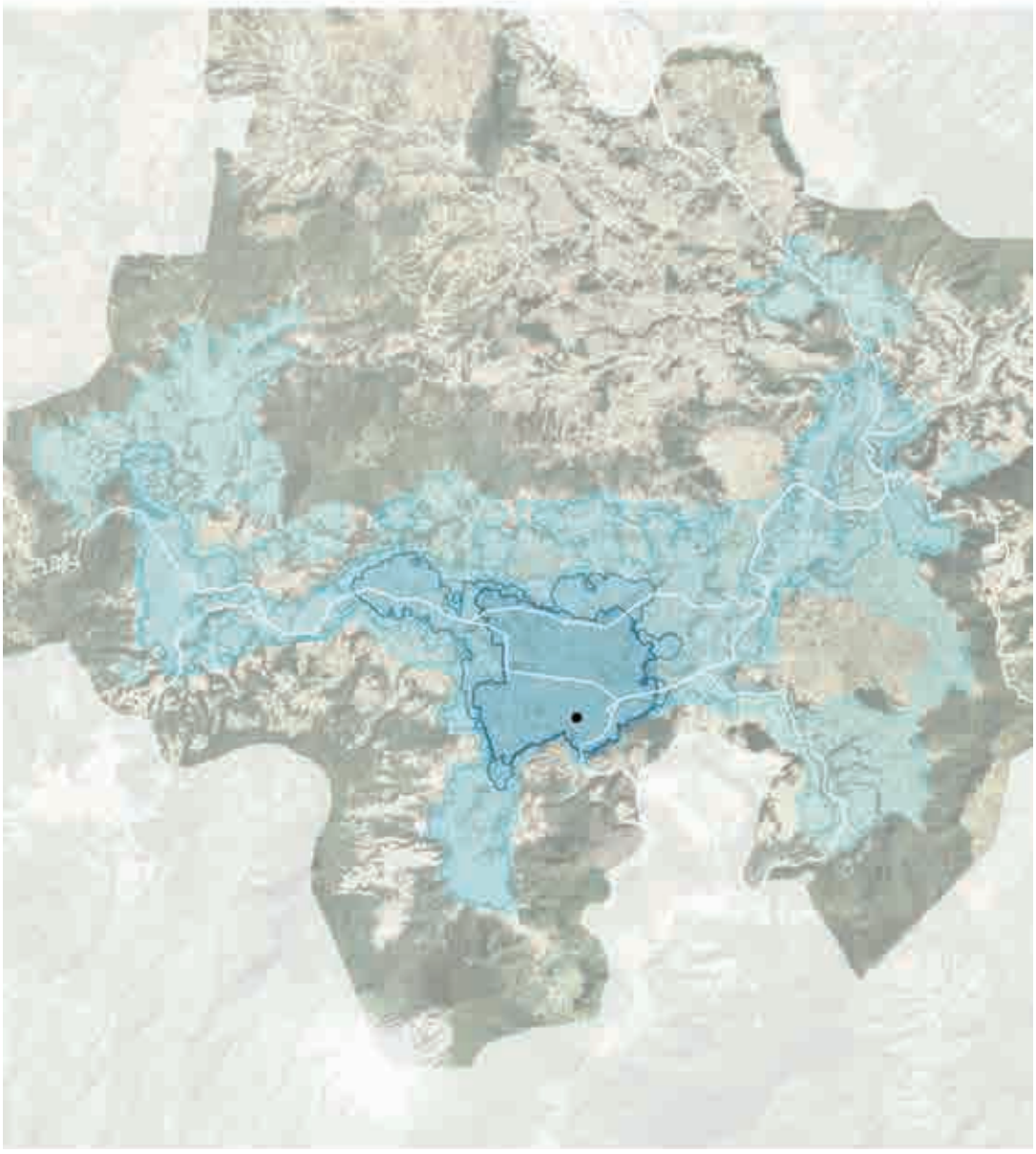
Compactness
rank
53rd (T4) 4th (T1)

Saturation
rank
50th (T1) 41st (T4)





GREATER QUETZALTENANGO — GUATEMALA



● Central Business District N 14.8341722
E -91.518192

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways | local streets

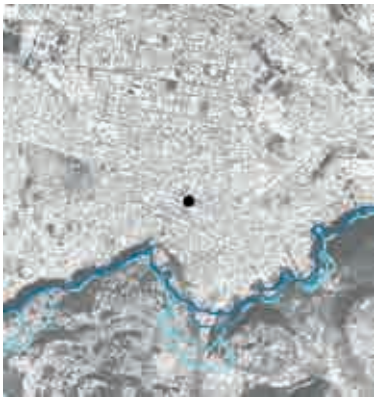
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of inclusion in Greater Quetzaltenango represented almost half of the urban expansion between 2000-2020. This represents an increase in comparison to the first decade, in which inclusion represented only a fifth of the expansion. On the contrary, infill and extension, the first varied from 30% (1990-2000) to 24% (2010-2020), and the second from 19% in 1990-2000 to 14% in 2010-2020. Leapfrog's contribution to Greater Quetzaltenango's urban expansion was 26% (1990-2000) and reached 19% (2010-2020).

Greater Quetzaltenango's urban extent increased by an impressive rate of approximately 7.4% per year over the last decades. As a result, the area is now almost 10 times what it was in 1990.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

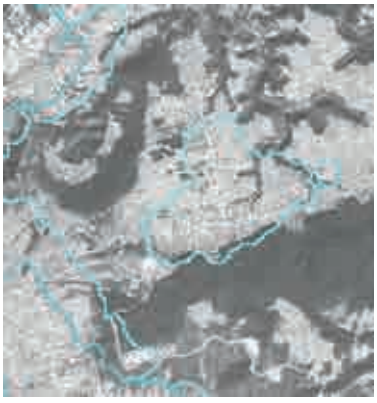
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



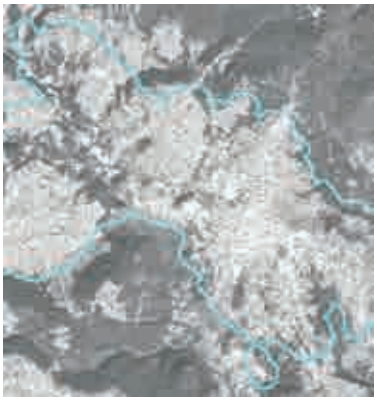
Central Business District



Extension area

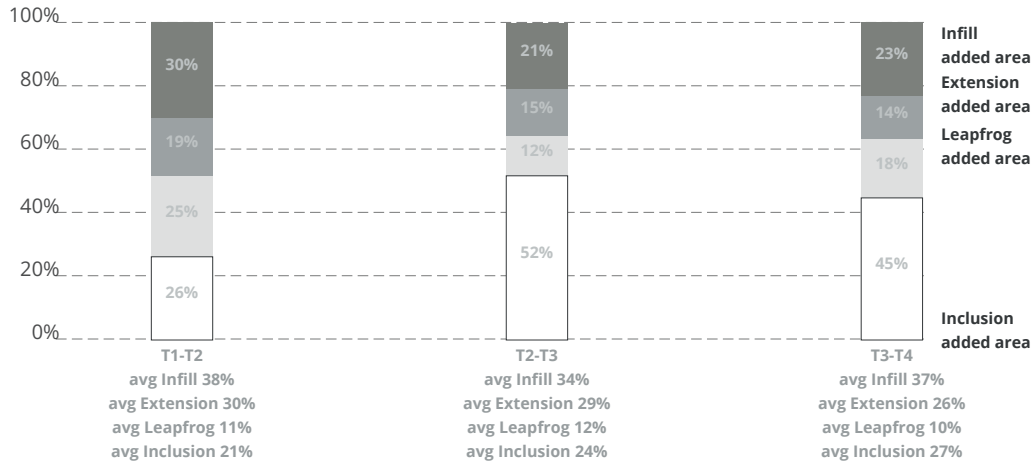


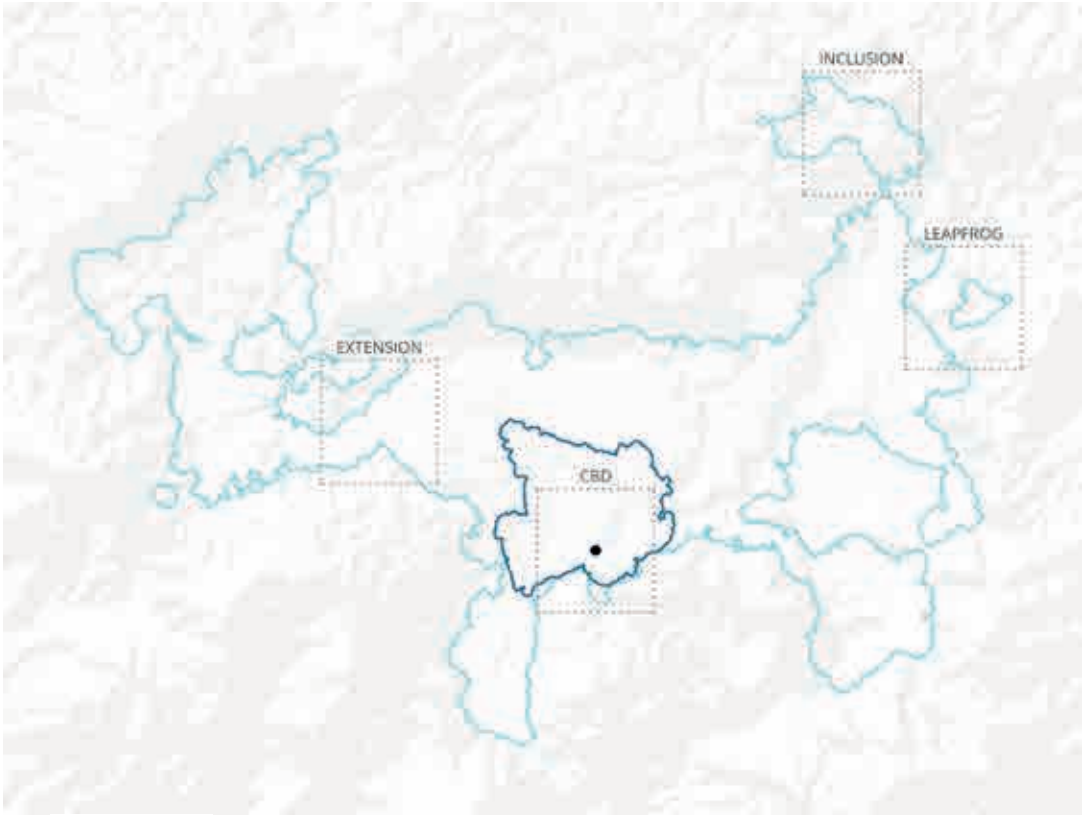
Leapfrog area



Inclusion area

GREATER QUETZALTENANGO — GUATEMALA





51 /

INLAND CITY
ELEVATION: 2745m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Greater Quito,* Ecuador, is located in the biome Montane Grasslands & Shrublands, at 2745 meters above sea level. Between 1988 and 2020, Greater Quito experienced a population growth of approximately 3.6% per year, more than doubling its population in the period: 818.6 thousand to 2.6 million. Greater Quito has a moderate population density compared to the other cities: 49.9 inhabitants per hectare, ranking 52nd in population density variation (%) in 2013-2020. Additionally, urban extent increased by approximately 5.2% annually over the last decades, meaning that the area is now 5.4 times what it was in 1988. The city became more compact compared to other LAC cities, rising from 63rd in 1988 to 45th in 2020. Such an increase is accompanied by a slight rise in saturation, gaining 2 positions, from 53rd to 51st between 1988 and 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



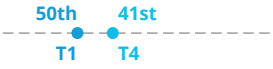
Urban population density
annual change
rank

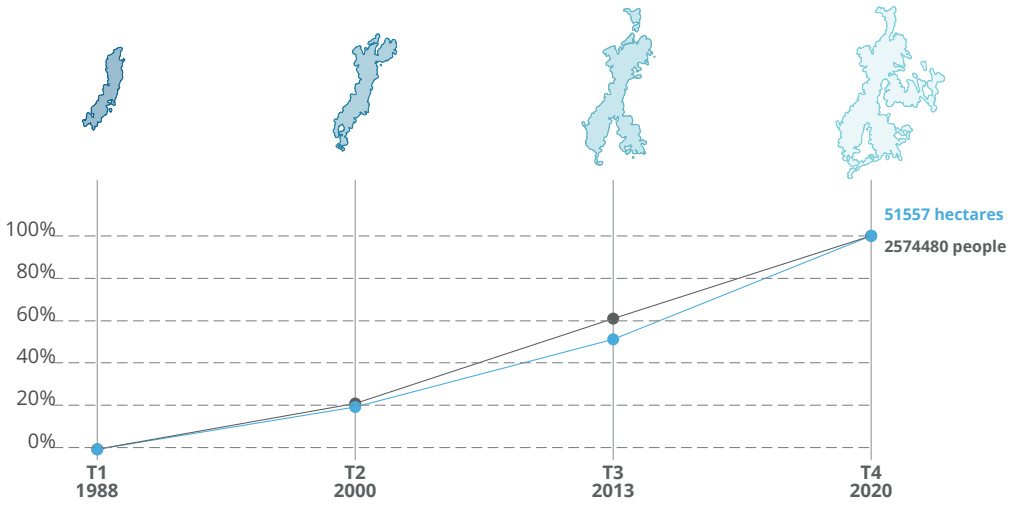


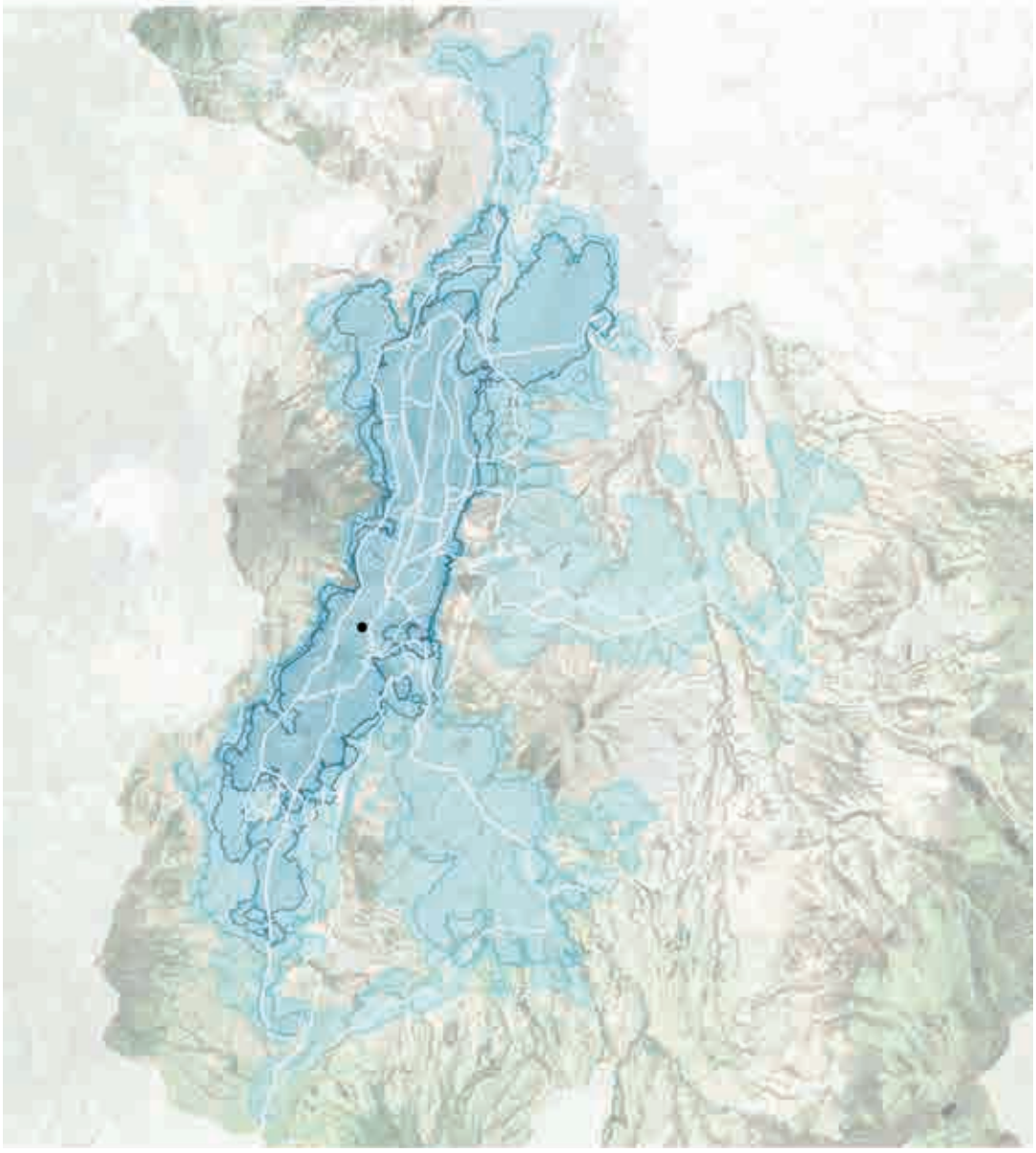
Compactness
rank



Saturation
rank







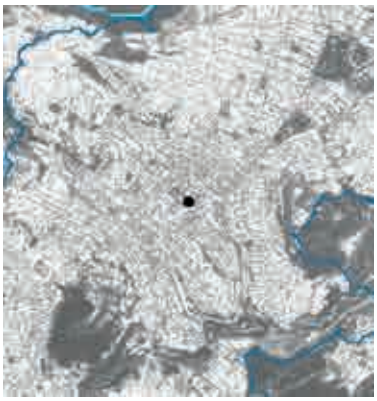
● Central Business District N -0.220859
E -78.510821

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

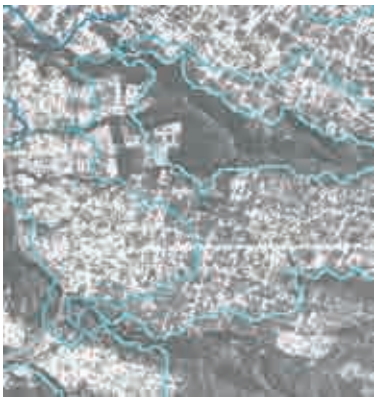
highways

local streets

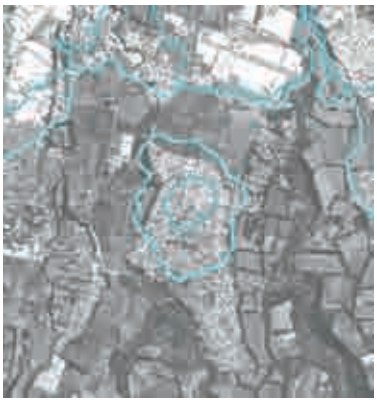
0 2.5 km



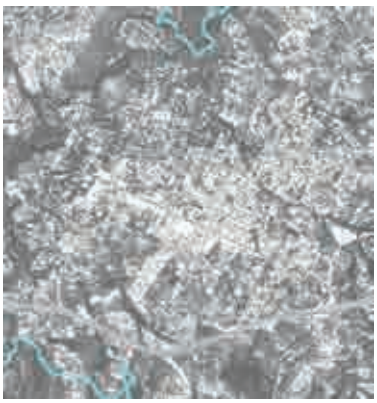
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Quito have not been changing significantly its contribution to the city's growth: from 33% (1988-2000) to 43% (2013-2020). Extension has decreased its significance over the years, as it represented 23% in 1988-2000 in contrast to 15% in 2013-2020. Leapfrog's contribution to Greater Quito's urban expansion was 23% (1988-2000) and reached 16% (2013-2020). Additionally, inclusion varied its contribution to the city's expansion from 22% (1988-2000) to 28% (2013-2020).

The average dwelling unit occupancy in Greater Quito is 2.9 people per unit, low in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.8 stories. The residential plot coverage of Greater Quito is 40.3%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

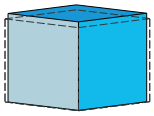
Between 1988 and 2020, Greater Quito experienced a population growth of approximately 3.6% per year, more than doubling its population in the period: 818.6 thousand to 2.6 million.

avg 3.4 people per dwelling unit



2.9 people per dwelling unit

avg 1.6 stories building height

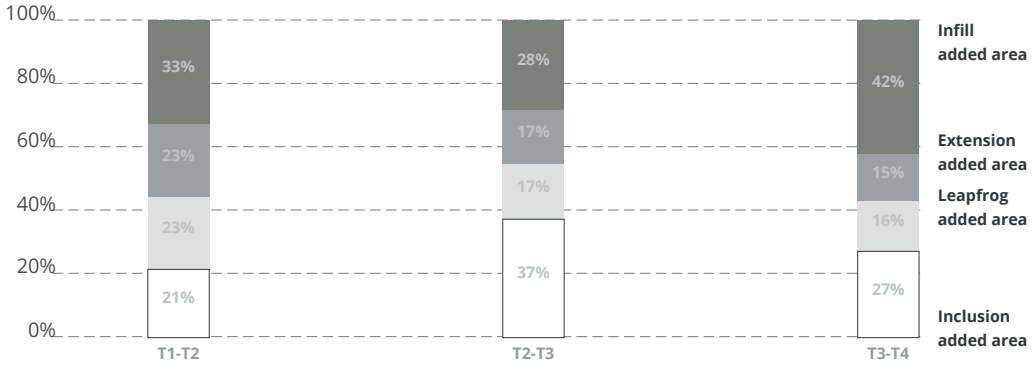


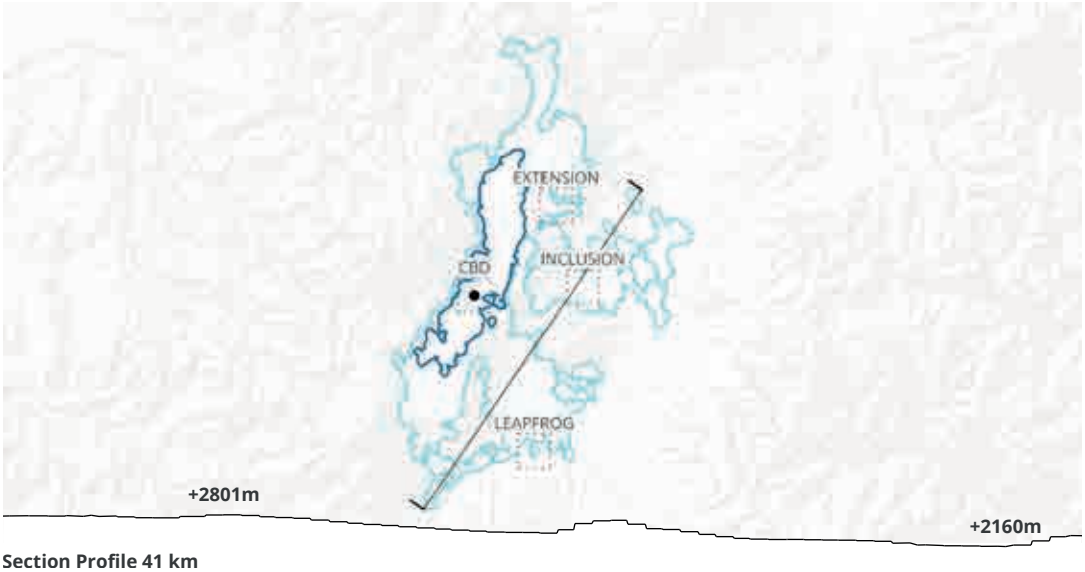
1.8 stories building height

avg 44% plot coverage



40% plot coverage





Section Profile 41 km



1988 T1 — 2021 T4

52 /

COASTAL CITY
ELEVATION: 2m
BIOME: MANGROVES

Greater Recife,* Brazil, is located in the biome Mangroves, at 2 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 1.3% per year, from 2.4 million to 3.5 million. Greater Recife has a high population density compared to the other cities: 80.5 inhabitants per hectare, ranking 20th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 1.7% annually over the last decades. As a result, Greater Recife is almost 70% larger than it was in 1990. The region grew in the coast and direction of highways and, even so, became slightly more compact compared to other LAC cities, rising from 58th in 1990 to 55th in 2020. Moreover, an increase in saturation was also observed, gaining 9 positions, from 31st to 22nd between 1990 and 2020.





2020=50

1988=85

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

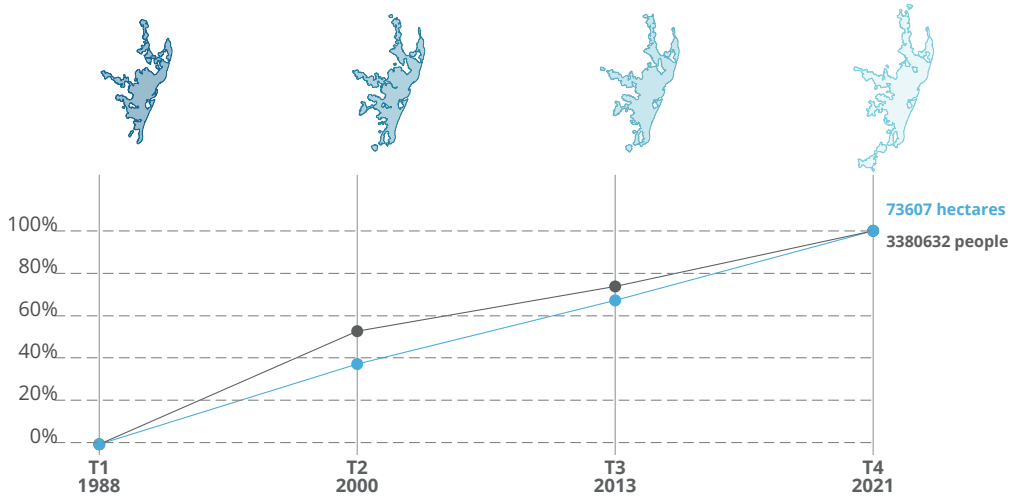


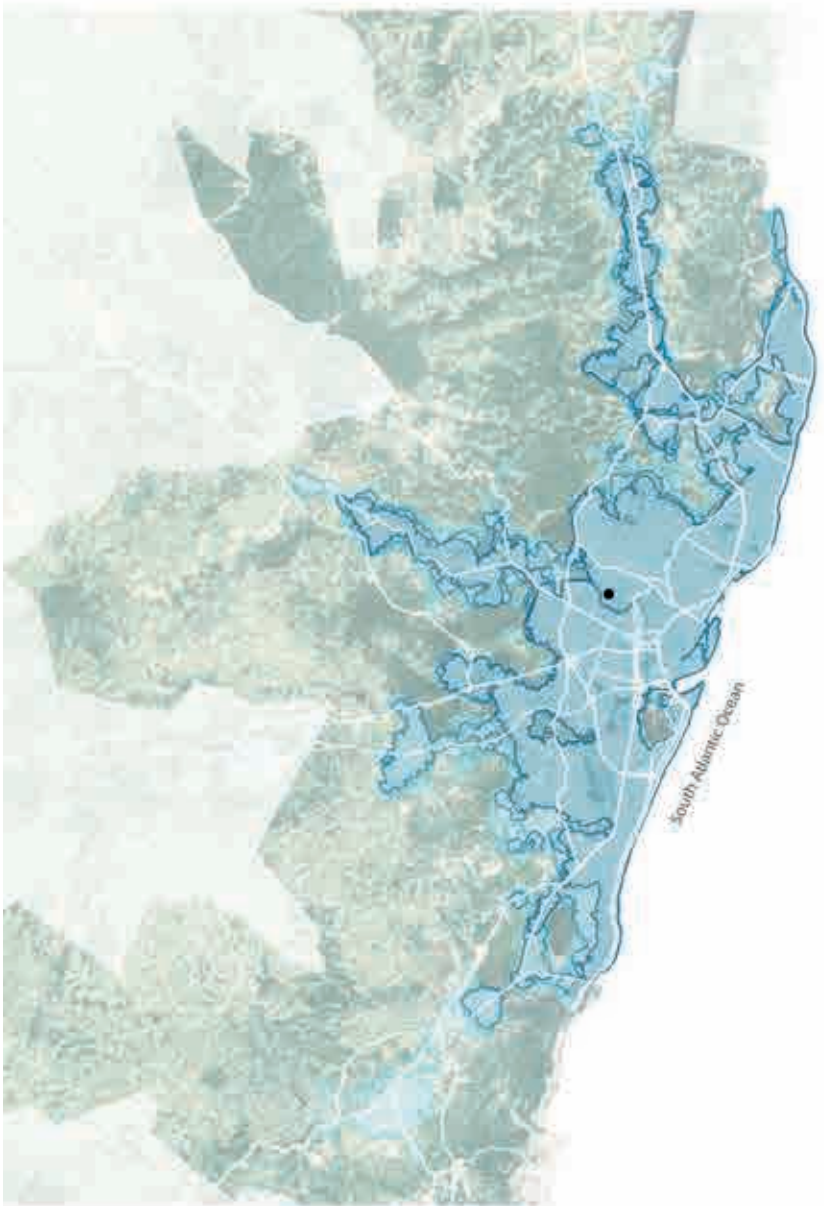
Compactness
rank



Saturation
rank







● Central Business District N -8.0337984
E -34.922253

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways

local streets

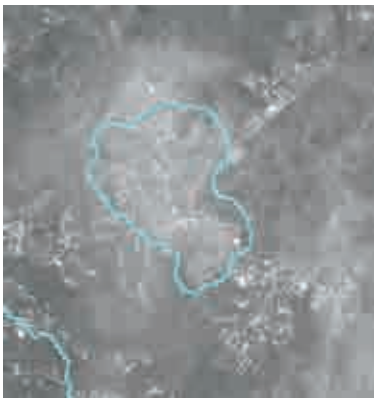
0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** In Greater Recife, infill represented almost half of urban expansion in all periods analyzed. Regarding inclusion, it has increased from 21% (1990-2000) to 27% (2010-2020). Extension has been contributing to a fifth of urban expansion, while leapfrog's contribution is not as expressive.

The average dwelling unit occupancy in Greater Recife is 3.3 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.5 stories. The residential plot coverage of Greater Recife is 49.2%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Greater Recife, infill represented almost half of urban expansion in all periods analyzed.

avg 3.4 people per dwelling unit

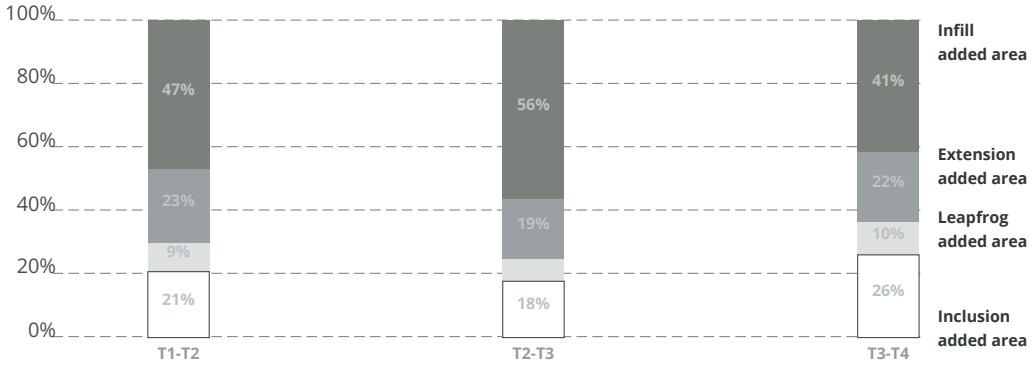
3.3 people per dwelling unit

avg 1.6 stories building height

1.5 stories building height

avg 44% plot coverage

49% plot coverage





Section Profile 60 km

0 2.5 km

1988 T1 2021 T4

53 /

INLAND CITY
ELEVATION: 35m
BIOME: DESERTS / XERIC SHRUBLANDS

Reynosa,* Mexico, is located in the biome Deserts & Xeric Shrublands, at 35 meters above sea level. Between 1991 and 2021, it experienced a population growth of approximately 3.3% per year, from 221.2 thousand to 589.7 thousand. Reynosa has a low population density compared to the other cities: 38.6 inhabitants per hectare, ranking 33rd in population density variation (%) in 2013-2021. Additionally, urban extent increased by approximately 2.7% annually over the last decades, reaching 222% in total. In other words, the area is now 2.2 times what it was in 1991. The city became more compact compared to other LAC cities, rising from 49th in 1991 to 34th in 2021. Such an increase is accompanied by a only slight decline in saturation ranking, dropping 2 positions, from 36th to 38th between 1991 and 2021.



2021=39

1991=32

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



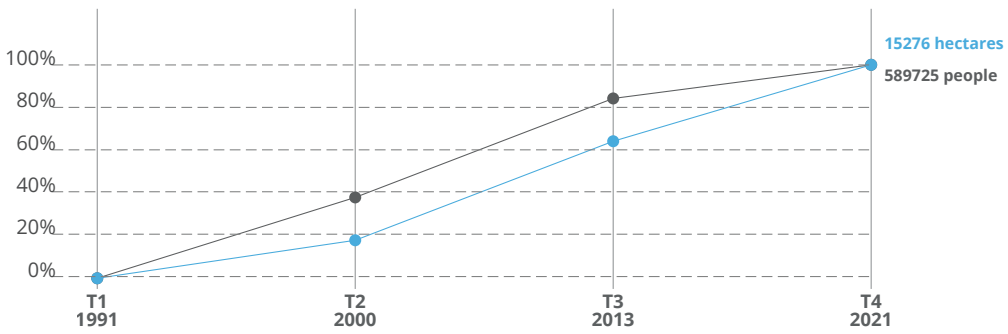
Compactness
rank



Saturation
rank









● Central Business District N 26.0795388
E -98.279815

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways

local streets

0 2.5 km

53 /

The process of urban Expansion results in added area as infill, extension, leapfrog, or Inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that around three-fourths of Reynosa's urban growth occurred through processes of infill and extension, double the average sample. However, extension has decreased its significance over the years, as it represented 48% in 1991-2000 in contrast to 26% in 2013-2021, while infill increased from 29% to 46% in the same periods. Additionally, leapfrog remained around 10%, and inclusion varied its contribution to the city's expansion from 12% (1991-2000) to 19% (2013-2021).

Around three-fourths of Reynosa's urban growth occurred through processes of infill and extension, double the average sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



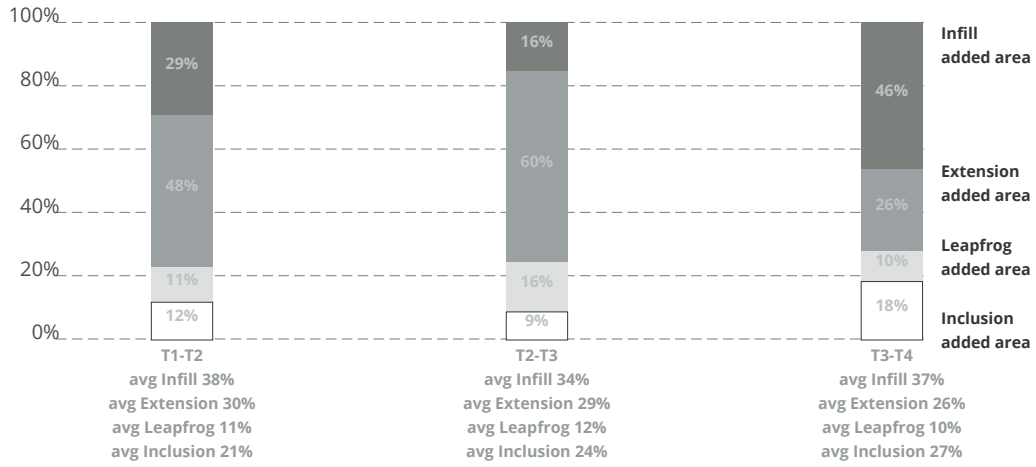
Extension area

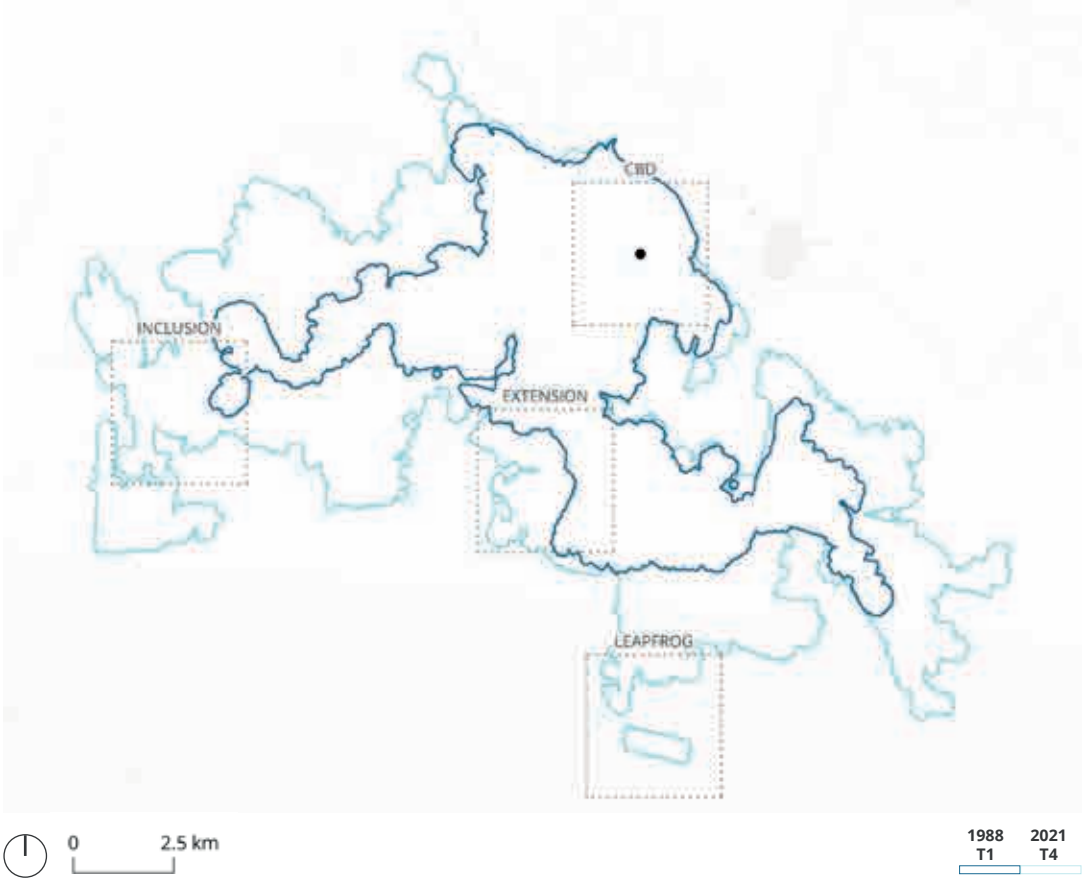


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
29%
48%
11%
12%
16%
60%
16%
9%
46%
26%
10%
18%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


CBD
INCLUSION
EXTENSION
LEAPFROG
0
2.5 km
1988 T1
2021 T4

54 /

INLAND CITY
ELEVATION: 593m
BIOME: TROPICAL / SUBTROPICAL GRASSLANDS / SAVANNAS / SHRUBLANDS

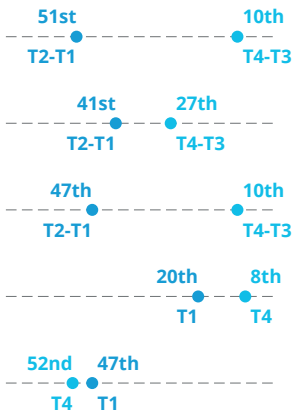
Ribeirão Preto,* Brazil, is located in the biome Tropical & Subtropical Grasslands, Savannas & Shrublands, at 593 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 2% per year—from 361.3 thousand to 675.6 thousand—almost doubling its population. Despite Ribeirão Preto's low population density compared to the other cities—36.5 inhabitants per hectare—its density has been increasing. As a result, population density annual change ranks 10th in 2014-2021, a leap from the previous position of 47th in 1990-2001. Additionally, urban extent increased by approximately 2.8% annually over the last decades. In other words, the area is now 2.4 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 20th in 1990 to 8th in 2021. Such an increase is accompanied by a slight decline in the ranking of saturation compared to the sample, dropping 5 positions, from 47th to 52nd between 1990 and 2021.

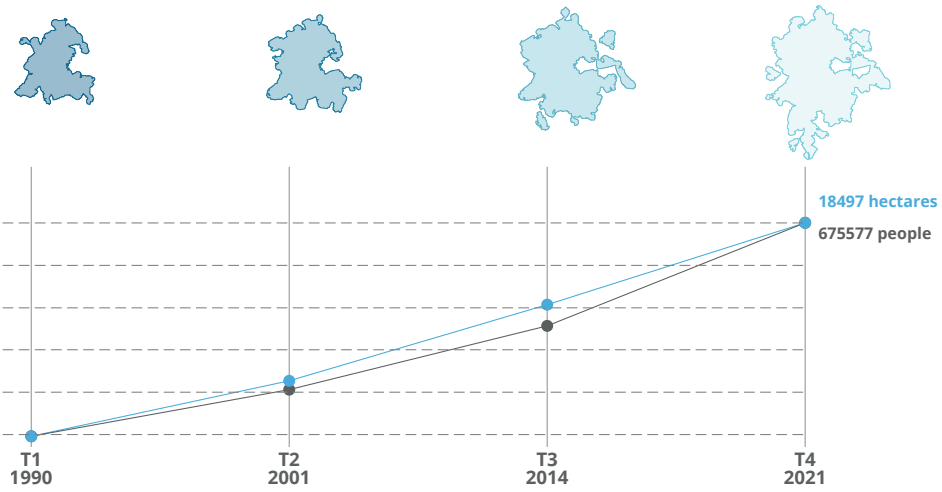




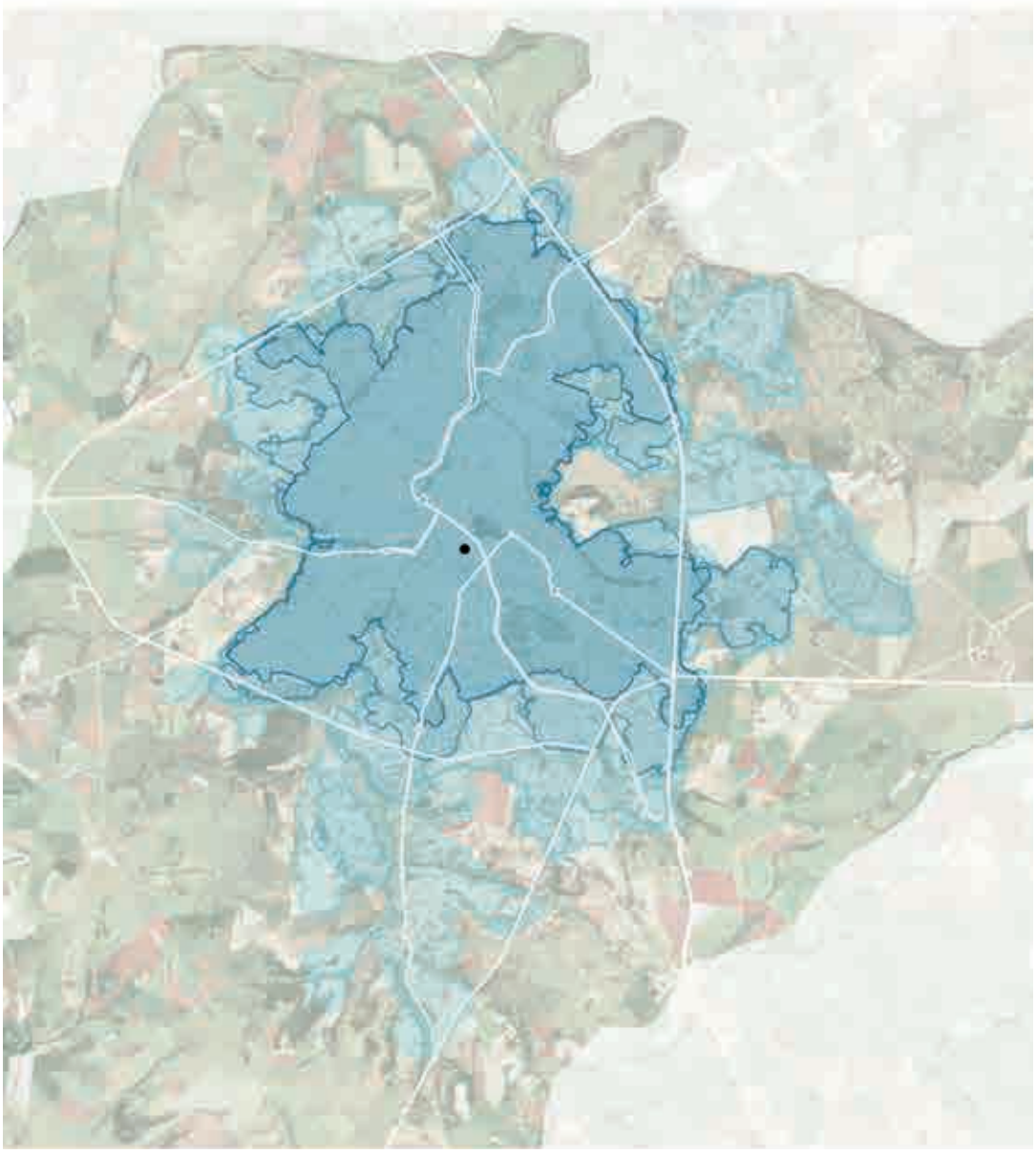
Urban population density
person / hectare

Evaluation metrics rankings:





RIBEIRÃO PRETO — BRAZIL



● Central Business District N -21.177628
E -47.805273

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways | local streets

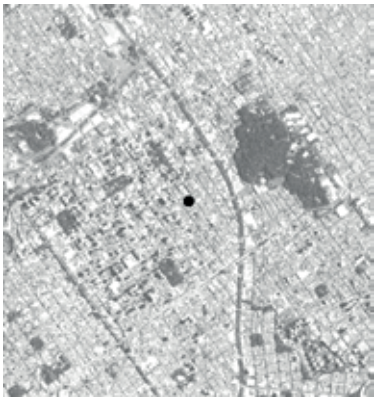
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Ribeirão Preto have been increasing its contribution to the city's growth: from 30% (1990-2001) to 42% (2014-2021). Extension has decreased its significance over the years, as it represented 36% in 1990-2001 in contrast to 28% in 2014-2021. Leapfrog's contribution to Ribeirão Preto's urban expansion was 22% (1990-2001) but lowered to 7% (2014-2021). Additionally, inclusion varied its contribution to the city's expansion from 15% (1990-2001) to 24% (2014-2021).

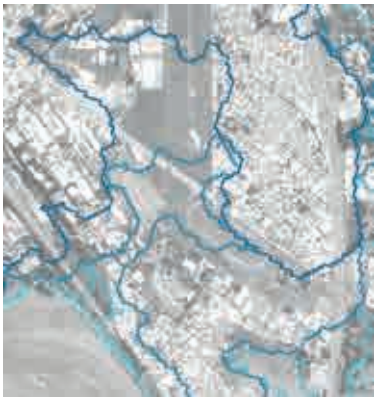
Despite Ribeirão Preto's low population density compared to the other cities—36.5 inhabitants per hectare—, its density has been increasing.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



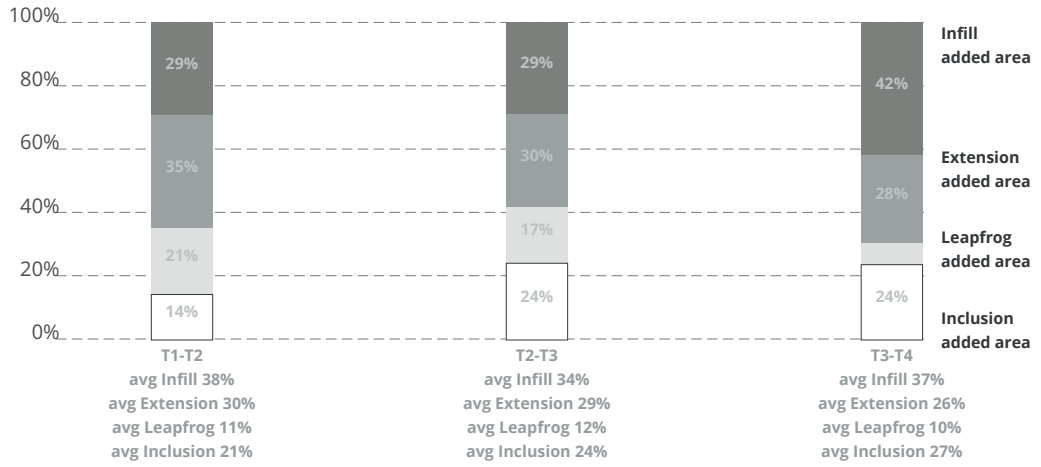
Extension area

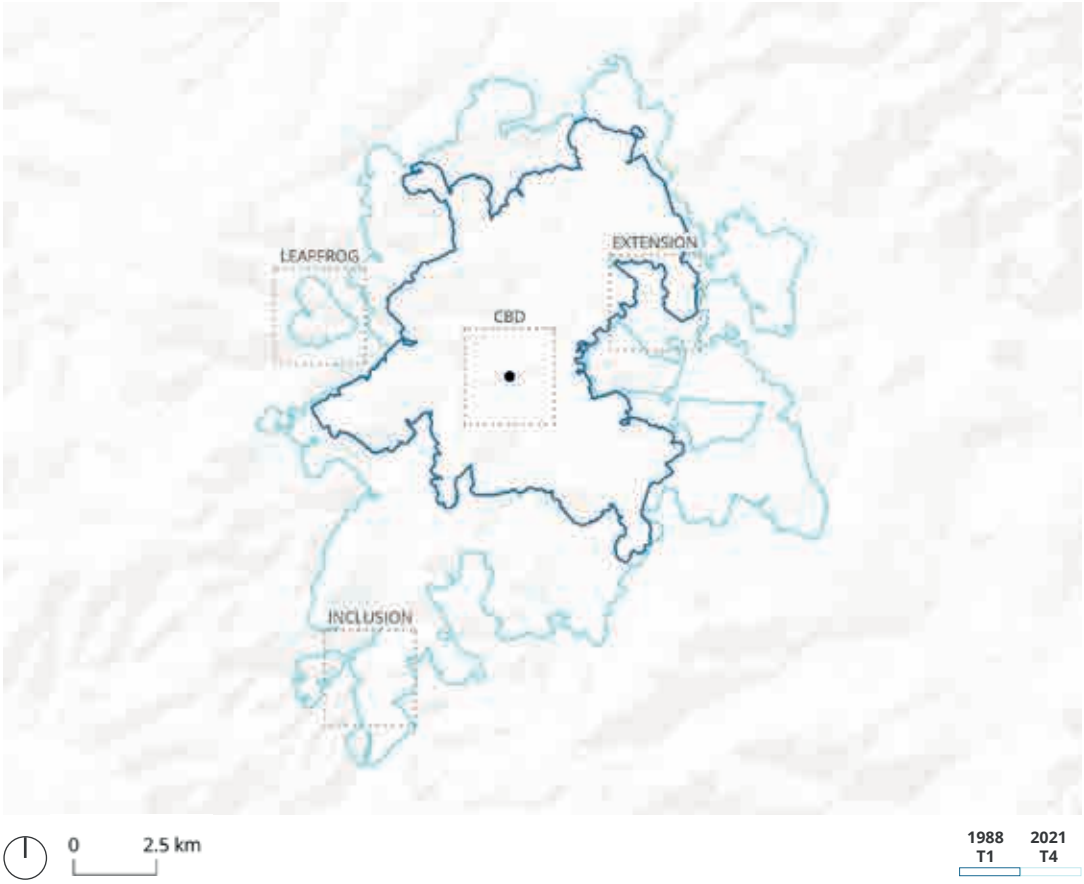


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
29%
35%
21%
14%
29%
30%
17%
24%
42%
28%
24%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1988 T1
2021 T4

55 /

INLAND CITY
ELEVATION: 4m
BIOME: TEMPERATE GRASSLANDS / SAVANNAS / SHRUBLANDS

Rosario,* Argentina, is located in the biome Temperate Grasslands, Savannas & Shrublands, at 4 meters above sea level. From 1989 to 2018, Rosario experienced a slow population growth of approximately 0.5% per year, from 977.7 thousand to 1.1 million. Rosario has a low population density compared to the other cities: 33.1 inhabitants per hectare. However, Rosario is amongst the cities that most increased their density, ranking 26th in population density variation (%) in 2010-2018. Additionally, urban extent increased by approximately 2.9% annually over the last decades, resulting in an area 2.3 times what it was in 1989. Urban extent increase has been more pronounced in the last decade than in the first, resulting in a rise of 19 positions in the rank. The city became slightly more compact compared to other LAC cities, rising from 65th in 1989 to 62nd in 2018. Such an increase is accompanied by a rise in saturation, gaining 5 positions from 24th to 19th between 1989 and 2018.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change rank
55th (T2-T1) — 20th (T4-T3)

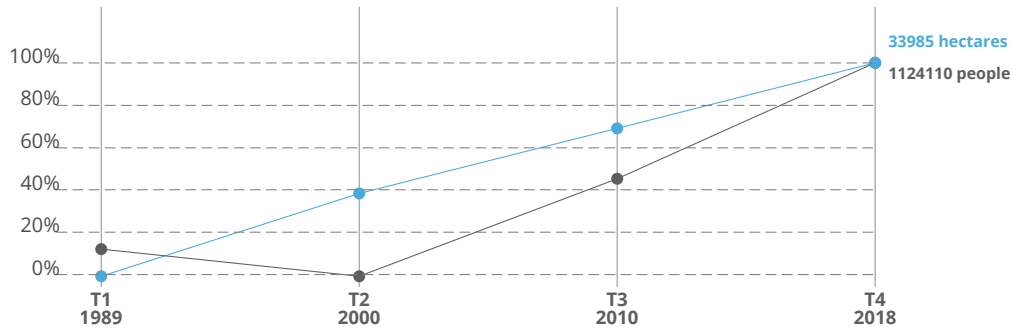
Urban Extent
annual change rank
53rd (T4-T3) — 29th (T2-T1)

Urban population density
annual change rank
56th (T4-T3) — 42nd (T2-T1)

Compactness
rank
66th (T4) — 64th (T1)

Saturation
rank
24th (T1) — 19th (T4)





ROSARIO — ARGENTINA



● Central Business District N -32.947163
E -60.632281

1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways

local streets

0 2.5 km

55 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Rosario have not been changing significantly its contribution to the city's growth: from 41% (1989-2000) to 42% (2010-2018). Moreover, extension has decreased its significance over the years, as it represented 31% in 1989-2000 in contrast to 27% in 2010-2018. Leapfrog's contribution to Rosario's urban expansion was 13% (1989-2000) and reached 9% (2010-2018). Additionally, inclusion varied its contribution to the city's expansion from 17% (1989-2000) to 24% (2010-2018).

From 1989 to 2018, Rosario experienced a slow population growth of approximately 0.5% per year, from 977.7 thousand to 1.1 million.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



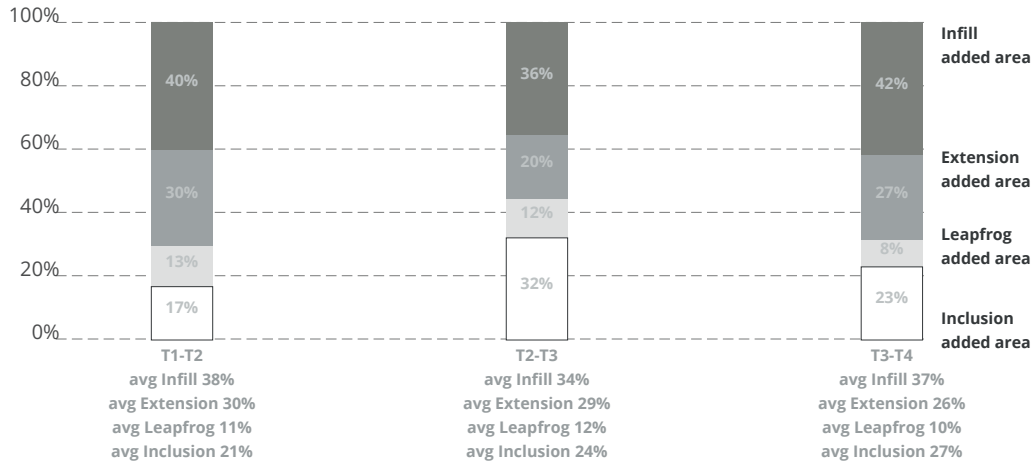
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
40%
30%
13%
17%
36%
20%
12%
32%
42%
27%
8%
23%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0 2.5 km
1988 T1
2021 T4

56 /

INLAND CITY
ELEVATION: 1112m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

Greater San José,* Costa Rica, is located in the biome Tropical & Subtropical Moist Broadleaf Forests, at 1112 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 2.4% per year, from 1.2 million to 2.4 million. Greater San José has a low population density compared to the other cities: 36.9 inhabitants per hectare, ranking 24th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 3.9% annually over the last decades, which results in 323% in total. In other words, the area is now more than 3 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 54th in 1990 to 46th in 2020. Such an increase is accompanied by a slight decline in saturation ranking compared to the sample, dropping 2 positions, from 59th to 61st between 1990 and 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

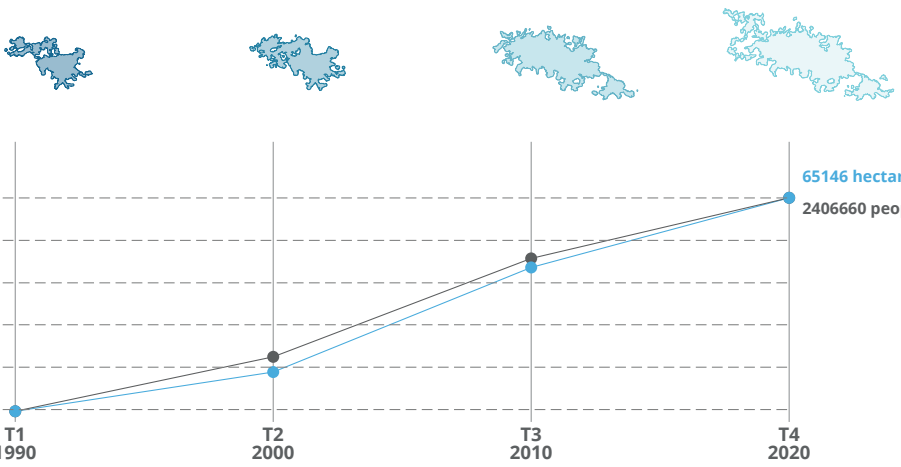


Compactness
rank



Saturation
rank





GREATER SAN JOSÉ — COSTA RICA



● Central Business District N 9.93169513
E -84.09504

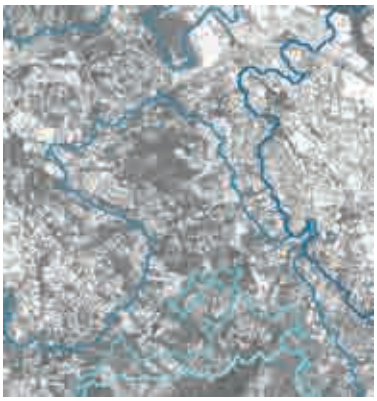
1988 T1 | 2000 T2 | 2013 T3 | 2021 T4

highways | local streets

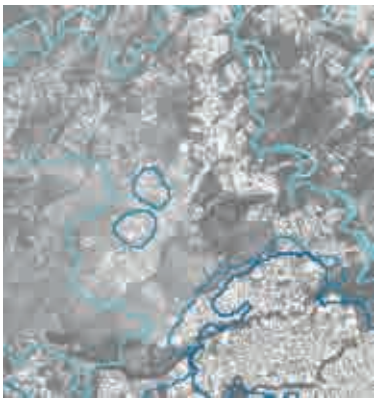
0 2.5 km



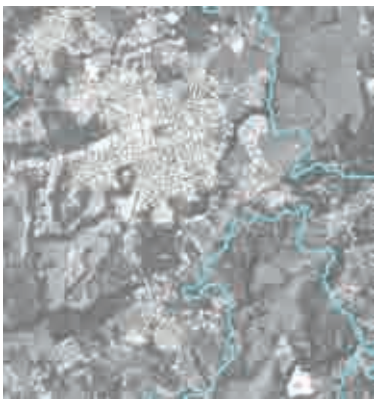
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that In 2010-2020, most of the urban expansion in Greater San José occurred through processes of inclusion, 44%. Extension has decreased its significance over the years, as it represented 21% in 1990-2000 in contrast to 13% in 2010-2020. Leapfrog's contribution to Greater San José's urban expansion was 15% (1990-2000) and reached 7% (2010-2020). Additionally, infill remained contributing to a third of the expansion.

The average dwelling unit occupancy in Greater San José is 3.4 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 2.3 stories. The residential plot coverage of Greater San José is 50.5%, resulting in a low percentage of unbuilt spaces within residential plots compared to other cities.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

In 2010-2020, most of the urban expansion in Greater San José occurred through processes of inclusion, 44%.

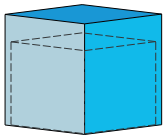
GREATER SAN JOSÉ — COSTA RICA

avg 3.4 people per dwelling unit



3.4 people per dwelling unit

avg 1.6 stories building height

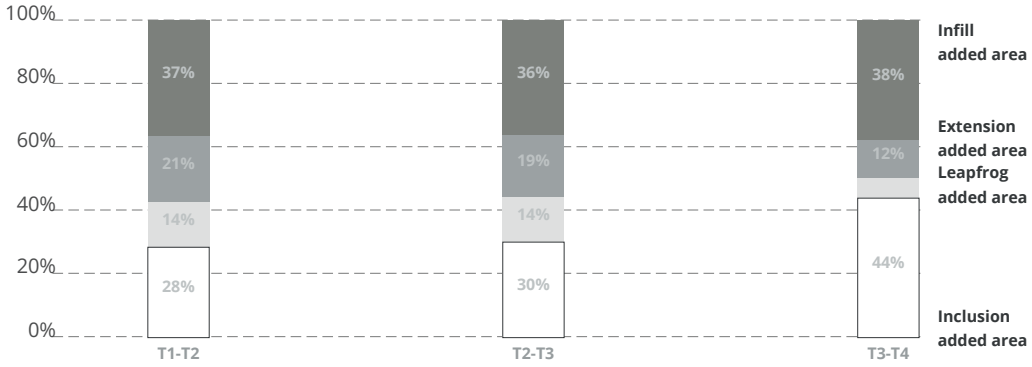


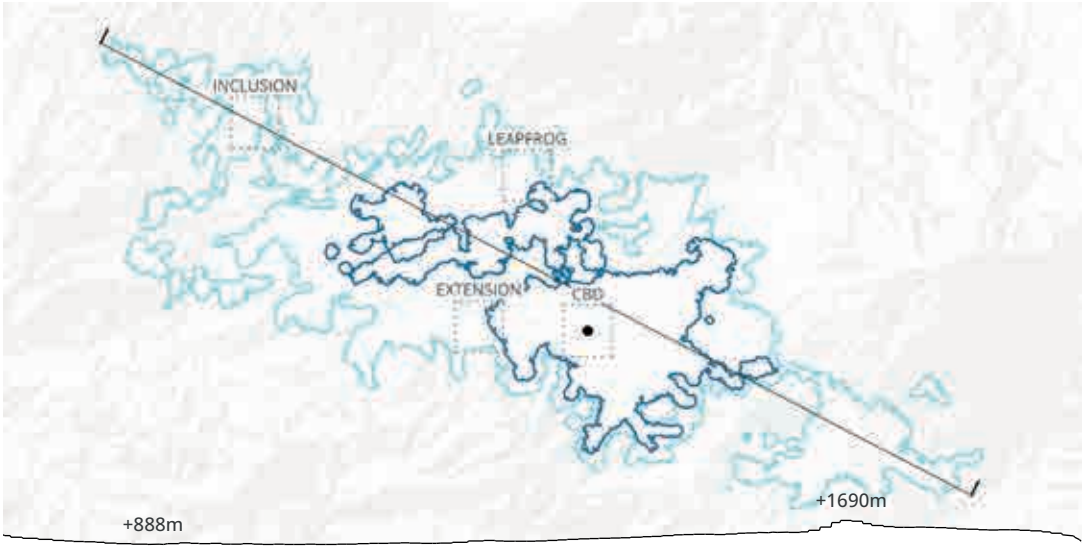
2.3 stories building height

avg 44% plot coverage



50% plot coverage





Section Profile 70 km



1988 T1 — 2021 T4

57 /

INLAND CITY
ELEVATION: 629m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

Greater San Salvador,* El Salvador, is located in the biome Tropical & Subtropical Coniferous Forests, at 629 meters above sea level. Between 1991 and 2020, it experienced a slow population growth of approximately 0.6% per year, from 1.6 million to 1.9 million. Even so, Greater San Salvador has a high population density compared to the other cities: 73.9 inhabitants per hectare. The population density annual variation (%) between 2014-2020 ranks 47th in comparison to other LAC cities. Additionally, urban extent increased by approximately 2.5% annually over the last decades, resulting in 209% in total. In other words, the area is now 2.1 times what it was in 1991. The city became more compact compared to other LAC cities, rising from 51st in the period 1991 to 43rd in 2020. Compared to the sample, saturation ranking declined from 28th to 42nd between 1991 to 2020.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

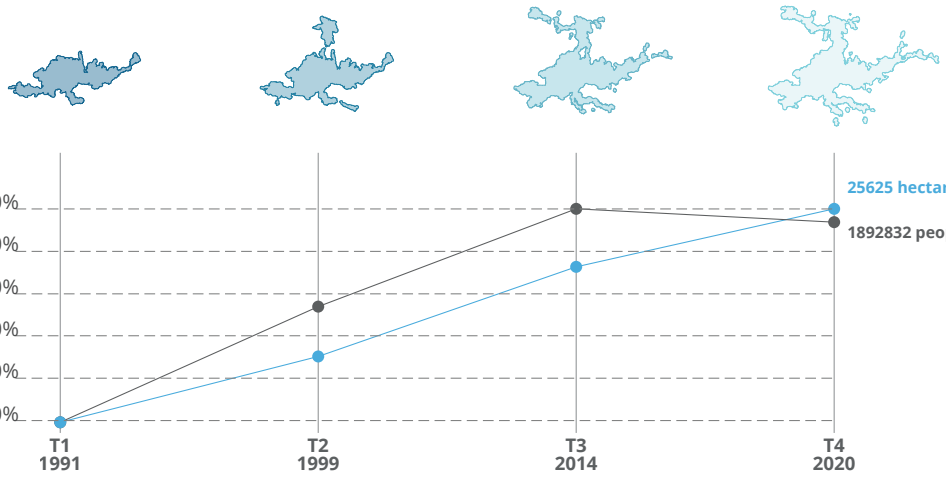


Compactness
rank

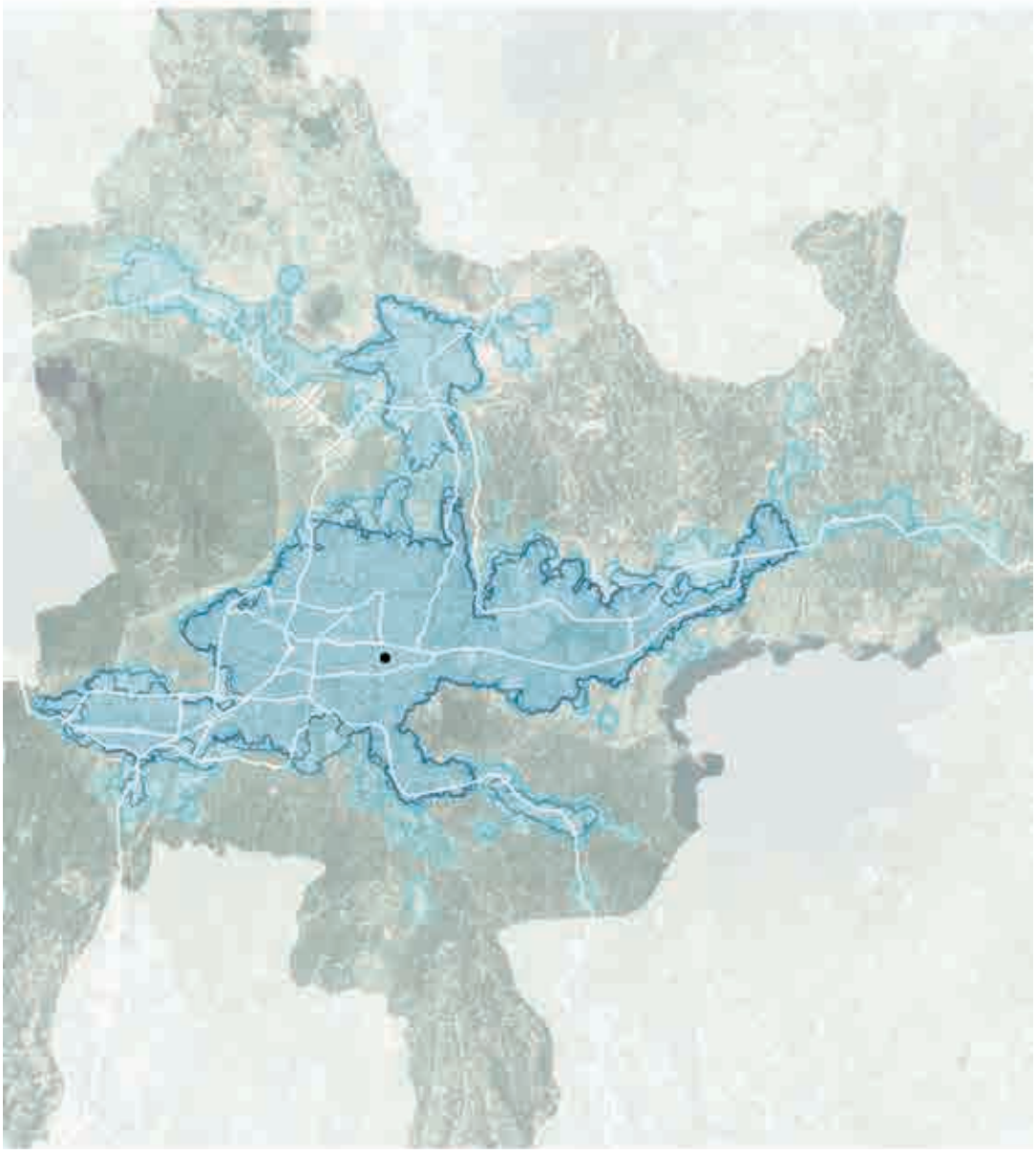


Saturation
rank





GREATER SAN SALVADOR — EL SALVADOR



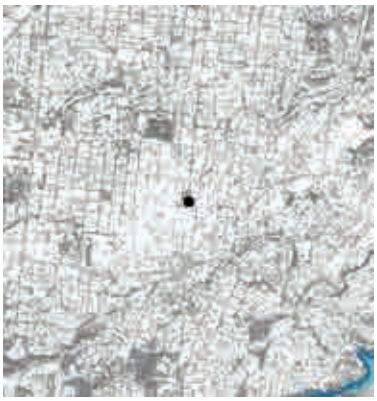
● Central Business District N 13.6980391
E -89.191359

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

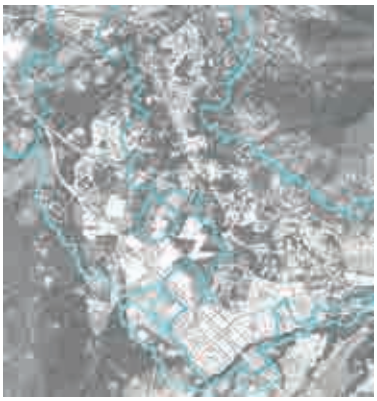
highways

local streets

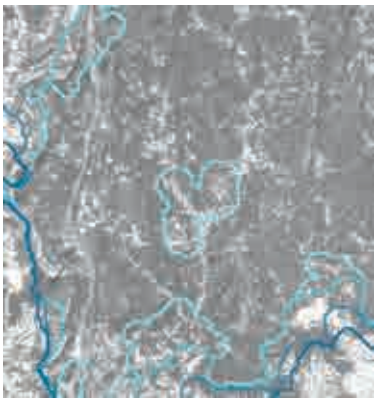
0 2.5 km



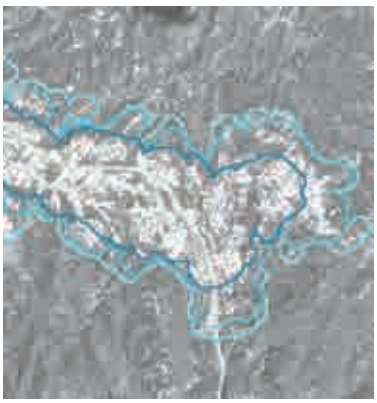
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater San Salvador have not been changing significantly its contribution to the city's growth: from 36% (1991-1999) to 39% (2014-2020). Extension's and leapfrog's variation was not expressive, both contributing to approximately 30% of urban expansion. Additionally, inclusion' contributes to one-third of the city's expansion, 36% (1991-1999) and 31% (2014-2020).

The average dwelling unit occupancy in Greater San Salvador is 3.5 people per unit, moderate in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.8 stories. The residential plot coverage of Greater San Salvador is 36.4%, resulting in a high percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Greater San Salvador has a high population density compared to the other cities: 73.9 inhabitants per hectare.

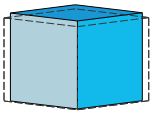
GREATER SAN SALVADOR — EL SALVADOR

avg 3.4 people per dwelling unit



3.5 people per dwelling unit

avg 1.6 stories building height

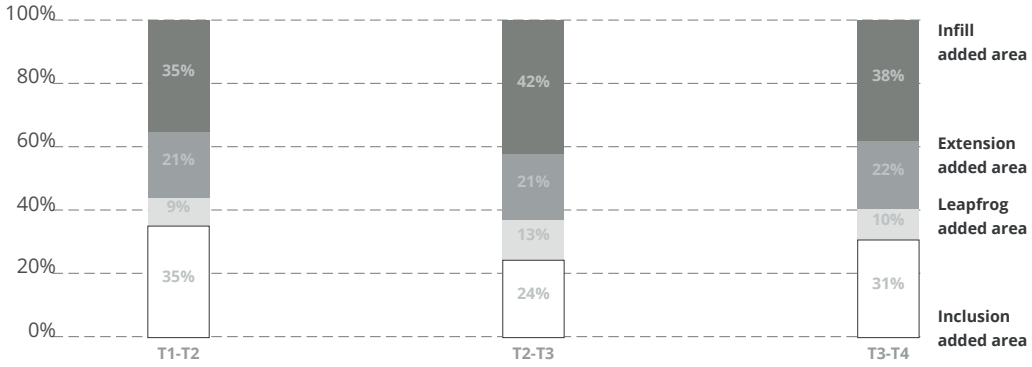


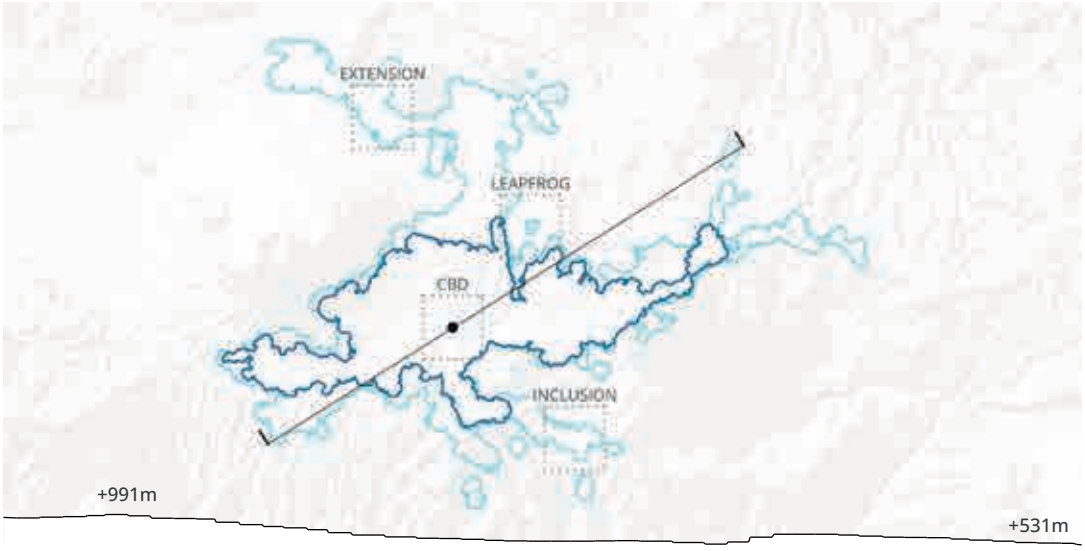
1.8 stories building height

avg 44% plot coverage



36% plot coverage





Section Profile 32 km



1991 T1 | 2020 T4

INLAND CITY
ELEVATION: 617m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

Greater Santa Ana,* El Salvador, is located in the biome Tropical & Subtropical Coniferous Forests, at 617 meters above sea level. Between 1990 and 2020, it experienced a gradual population growth of approximately 1.6% per year, from 135.1 thousand to 221.1 thousand. Greater Santa Ana has a moderate population density compared to the other cities: 47.6 inhabitants per hectare and ranks 27th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 3.2% annually over the last decades, resulting in 258% in total. In other words, the area is now 2.6 times what it was in 1990. The city had a slight increase of 1 position in compactness rank, comparing 1990-2000 and 2020-2010. Moreover, there was a slight decline in the saturation ranking, falling one position, from 61st to 62nd between 1990 tand 2020.



2021=39

1991=32

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

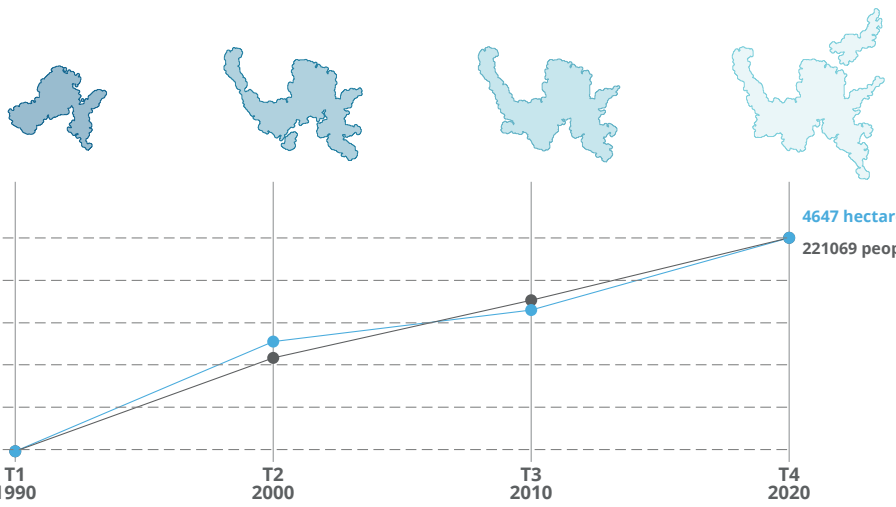


Compactness
rank

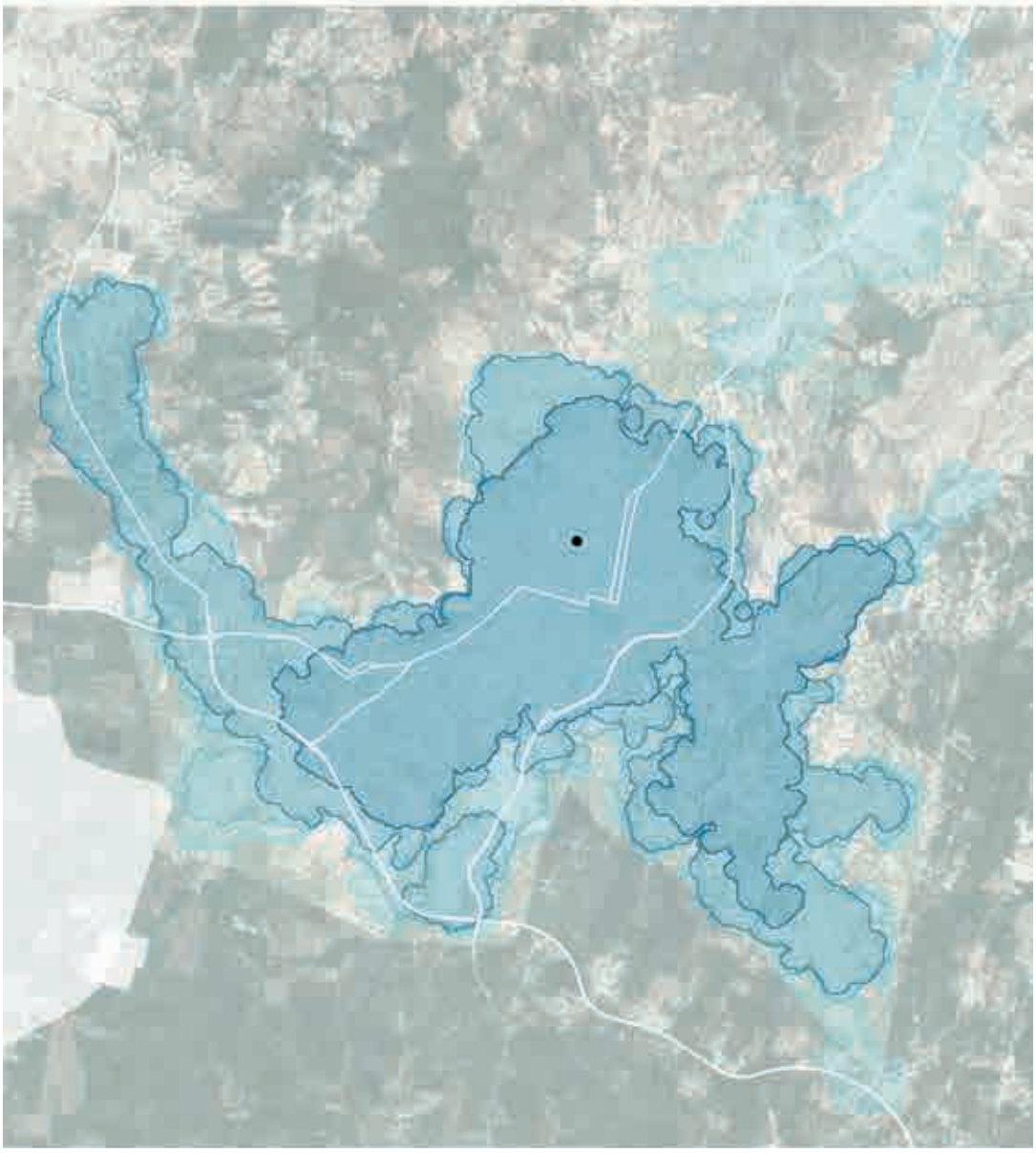


Saturation
rank





GREATER SANTA ANA — EL SALVADOR



● Central Business District N 13.9949769
E -89.557886

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that Between 2010-2020, 55% of Greater Santa Ana's urban expansion in 2010-2020 occurred through processes of inclusion, more than double the average sample. Extension has decreased its significance over the years, as it represented 24% in 1990-2000 in contrast to 14% in 2010-2020. Leapfrog's contribution to Greater Santa Ana's urban expansion was 23% (1990-2000) and reached 4% (2010-2020). Additionally, inclusion varied its contribution to the city's expansion from 24% (1990-2000) to 56% (2010-2020).

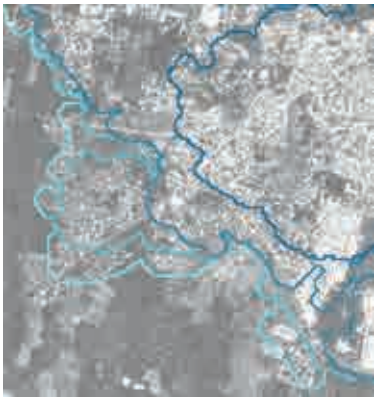
Between 2010-2020, 55% of Greater Santa Ana's urban expansion in 2010-2020 occurred through processes of inclusion, more than double the average sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

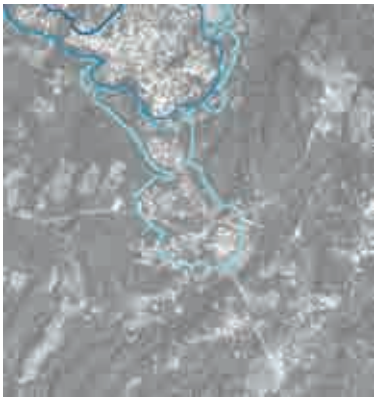
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition*, *Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



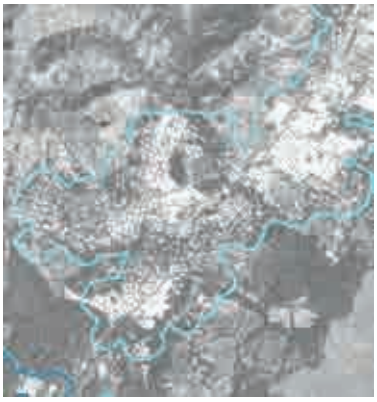
Central Business District



Extension area

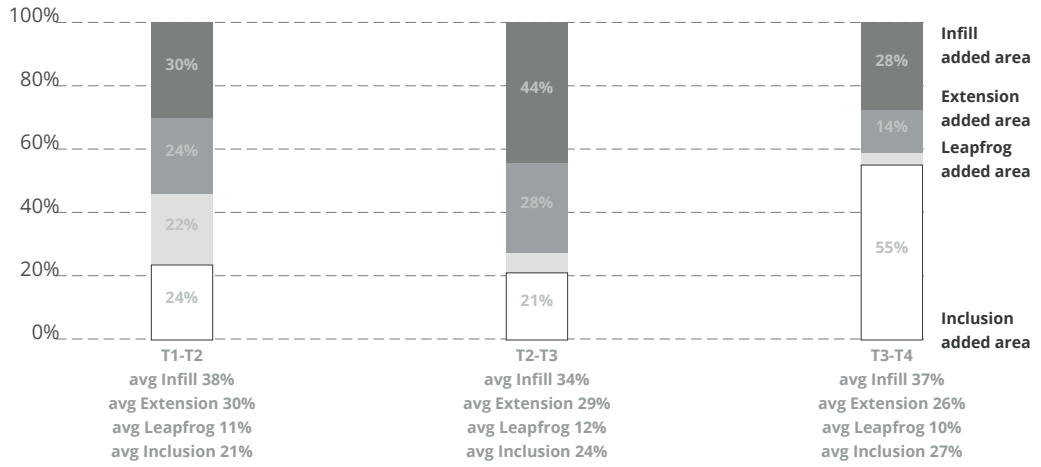


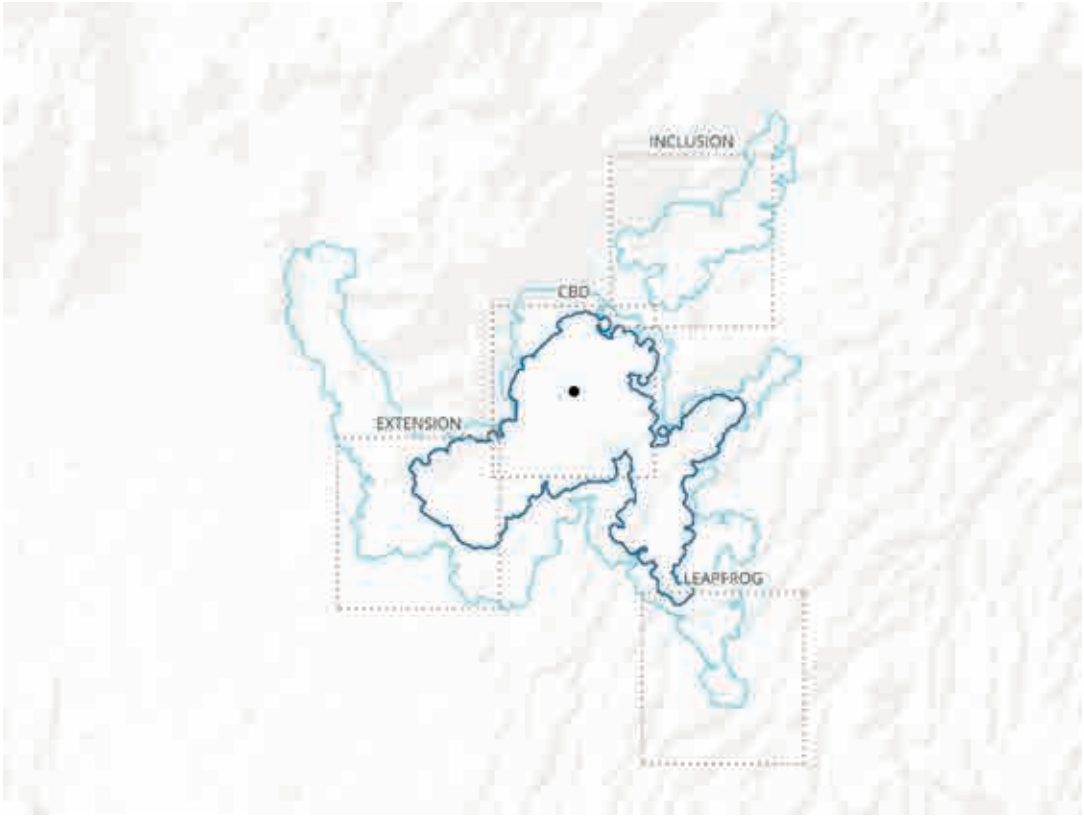
Leapfrog area



Inclusion area

GREATER SANTA ANA — EL SALVADOR





59 /

INLAND CITY
ELEVATION: 20m
BIOME: TEMPERATE GRASSLANDS / SAVANNAS / SHRUBLANDS

Santa Fe,* Argentina, is located in the biome Temperate Grasslands, Savannas & Shrublands, at 20 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 1% per year, from 273.4 thousand to 372.6 thousand. However, it should be noted the increase in population growth rate in the last decade. As a result, the annual change in population growth of Santa Fe rose 53 positions. Santa Fe has a low population density compared to the other cities: 35.9 inhabitants per hectare. Additionally, urban extent increased by approximately 2.5% annually over the last decades, resulting in 215% in total. In other words, the area is now more than 2 times what it was in 1990. The city became less compact compared to other LAC cities, lowering from 41st in 1990 to 60th in 2021. Such a decrease is accompanied by a decline in saturation ranking, dropping 21 positions, from 5th to 26th, between 1990 and 2021.



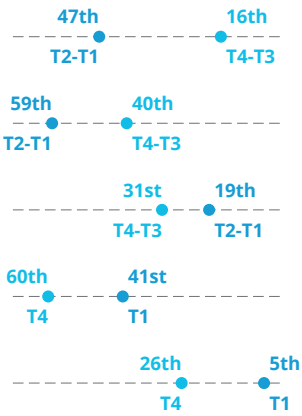
2021=36

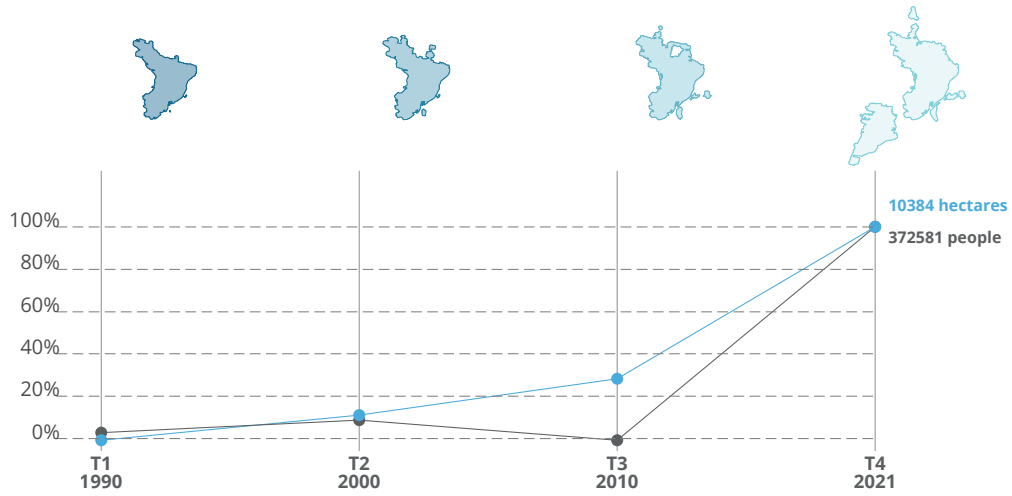


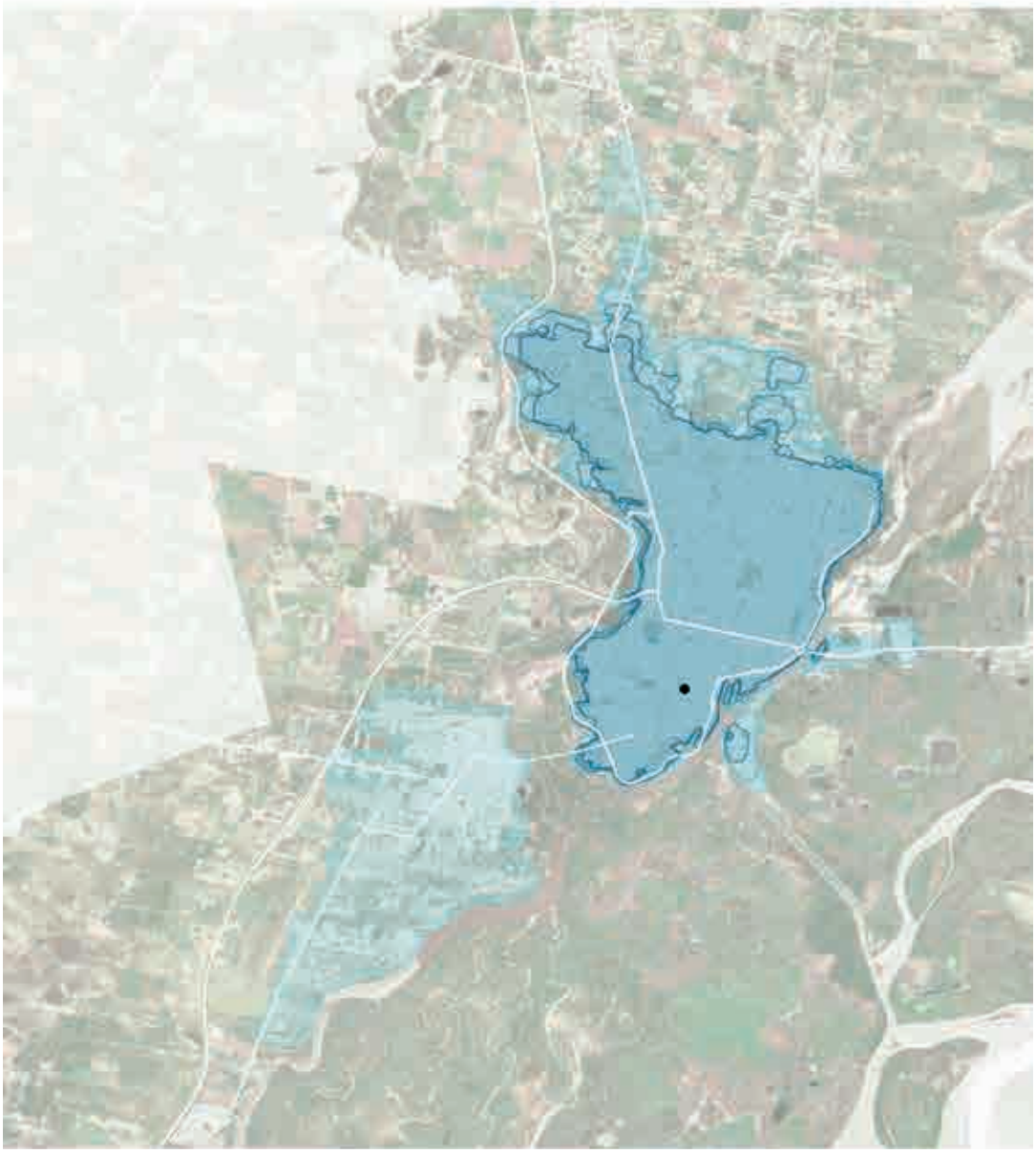
1990=57

Urban population density
person / hectare

Evaluation metrics rankings:







● Central Business District N -31.649784
E -60.712257

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

0 2.5 km

59 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that between 2010-2021, 65% of Santa Fe's urban expansion in 2010-2020 occurred through inclusion, more than 2 times the average of the sample. Additionally, infill's contribution, initially almost 60%, lowered to 26% (2010-2021). Extension has decreased its significance over the years, as it represented 20% in 1990-2000 in contrast to 7% in 2010-2021. Leapfrog's contribution to Santa Fe's urban expansion was 7% (1990-2000) and reached 4% (2010-2021).

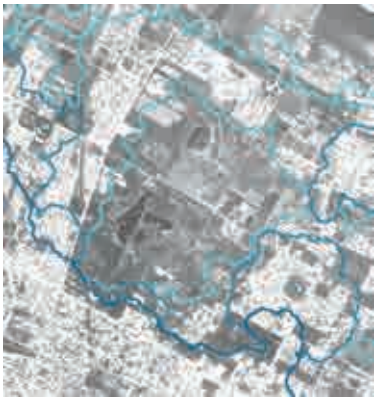
Between 2010-2021, 65% of Santa Fe's urban expansion in 2010-2020 occurred through inclusion, more than 2 times the average of the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



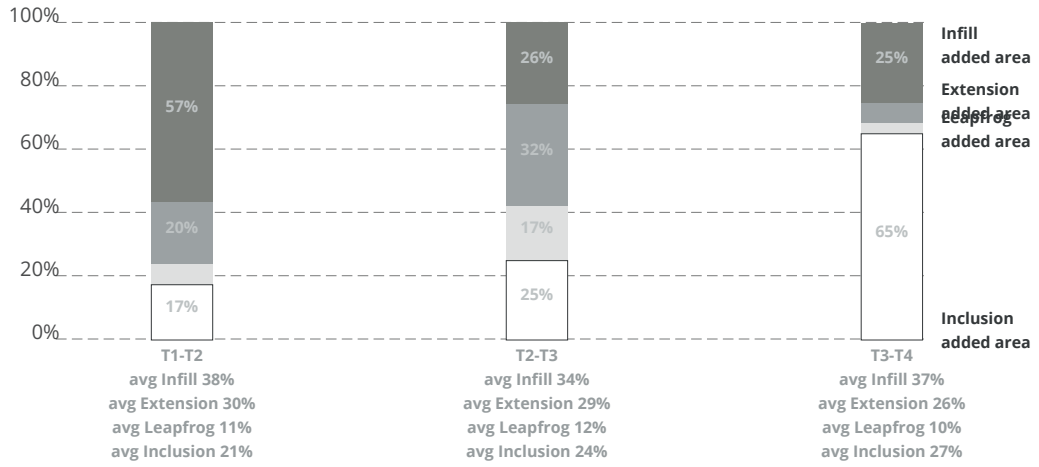
Extension area



Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
57%
20%
17%
26%
32%
17%
25%
25%
65%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1991 T1
2020 T4

60 /

INLAND CITY
ELEVATION: 544m
BIOME: TEMPERATE BROADLEAF / MIXED FORESTS

Greater Santiago,* Chile, is located in the biome Temperate Broadleaf & Mixed Forests, at 544 meters above sea level. Between 1990 and 2020, it almost doubled its population, with an increase of 1.6% per year, from 4.5 million to 7.3 million. Greater Santiago has a high population density compared to the other cities: 71.3 inhabitants per hectare, though it ranks 59th in population density variation (%) in 2014-2020. Its urban extent increased by approximately 2.7% annually over the last decades, expanding 2.2 times since 1990. Areas to the north and southwest in relation to the city center expanded the most. In this process, the city became less compact compared to other LAC cities, lowering from 18th in 1990 to 27th in 2020. Such a decrease is accompanied by a decline in saturation ranking, dropping 12 positions from 1990 to 2020.



2021=36

1990=57

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change rank
61st (T4-T3) — 29th (T2-T1)

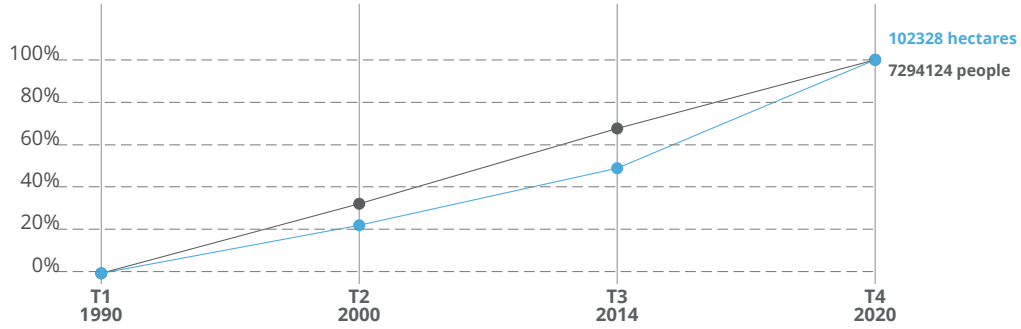
Urban Extent
annual change rank
51st (T2-T1) — 10th (T4-T3)

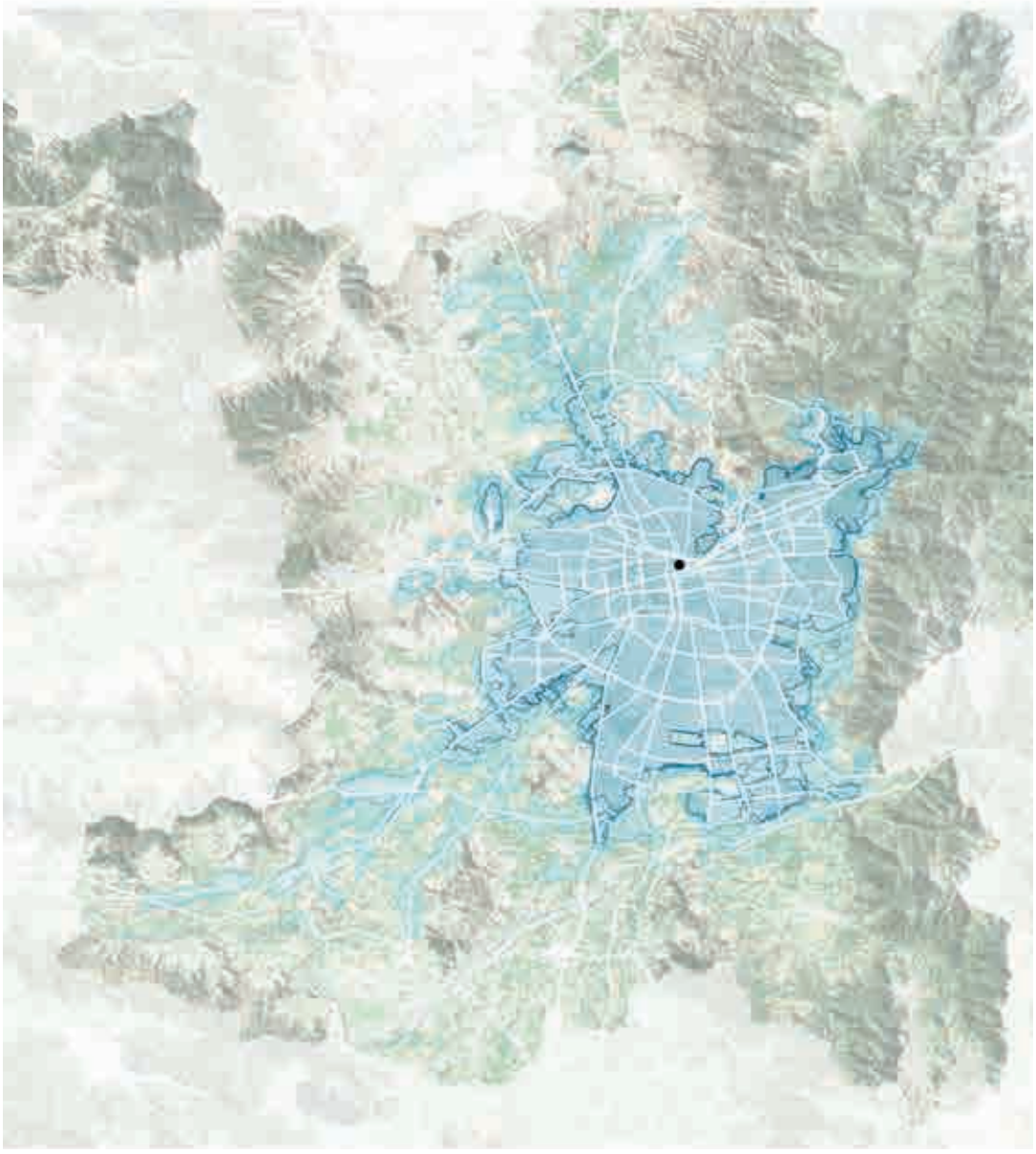
Urban population density
annual change rank
59th (T4-T3) — 35th (T2-T1)

Compactness
rank
27th (T4) — 18th (T1)

Saturation
rank
14th (T4) — 2nd (T1)







● Central Business District N -33.438249
E -70.650719

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways — local streets

0 2.5 km



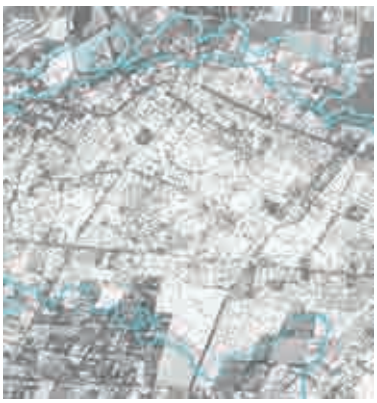
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Santiago have been increasing (23% to 33%) while extension has decreased (53% to 26%). Leapfrog's contribution to Greater Santiago's urban expansion did not change significantly, it was 15% (1990-2000) and reached 17% (2014-2020). However, inclusion more than doubled from 11% (1990-2000) to 26% (2014-2020). The average dwelling unit occupancy in Greater Santiago is 3.2 people per unit, moderate in comparison to the average of the cities in this Atlas. The average building height and the plot coverage in Greater Santiago are respectively 18% and 27% lower than the average sample — for the city, 3.17 people per dwelling unit and 32.5% of plot coverage.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

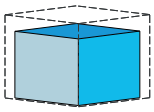
The average building height and the plot coverage in Greater Santiago are respectively 18% and 27% lower than the average sample.

avg 3.4 people per dwelling unit



3.2 people per dwelling unit

avg 1.6 stories building height

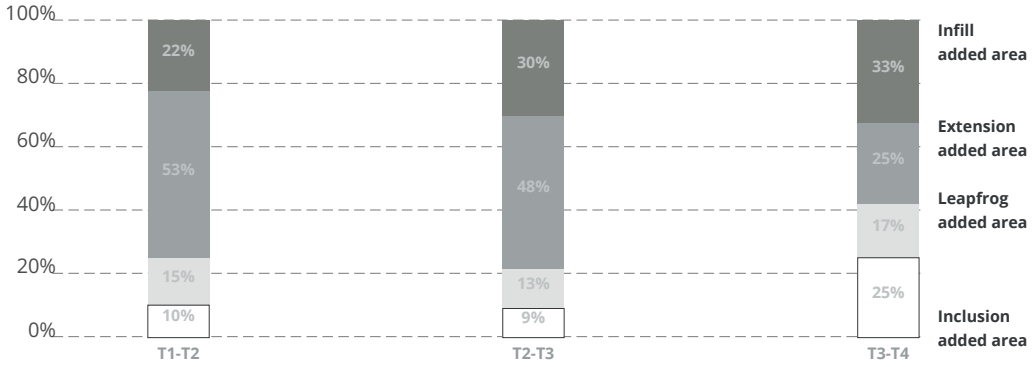


1.3 stories building height

avg 44% plot coverage



32% plot coverage





Section Profile 48 km





61 /

COASTAL CITY
ELEVATION: 1m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Greater Santo Domingo,* República Dominicana, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at one meter above sea level. Between 1991 and 2021, Greater Santo Domingo doubled its population at an annual growth of approximately 2.6% per year, from 1.9 million to 4.1 million. In the last decade, the region's urban population and extent grew at a faster rate than the first decade, gaining 31 and 20 positions in the sample ranking. The urban extent of 2021 is 2.5 of what it was in 1990 due to an annual growth of 3.2%. Greater Santo Domingo has a high population density compared to the other cities: 86.9 inhabitants per hectare, ranking 17th in population density variation (%) in 2010-2021. The city became less compact compared to other LAC cities, lowering from 52nd in 1991 to 58th in 2021 and saturation remained close to 73% throughout the years.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



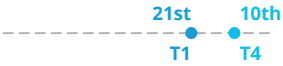
Urban population density
annual change
rank

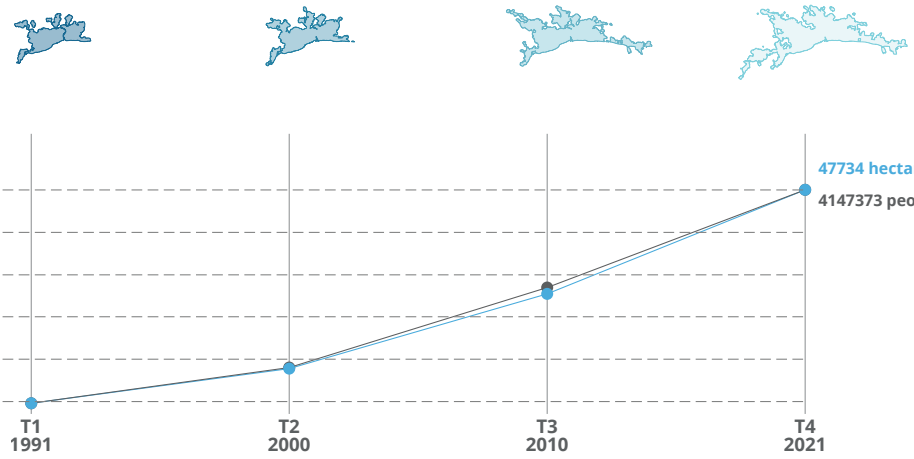


Compactness
rank

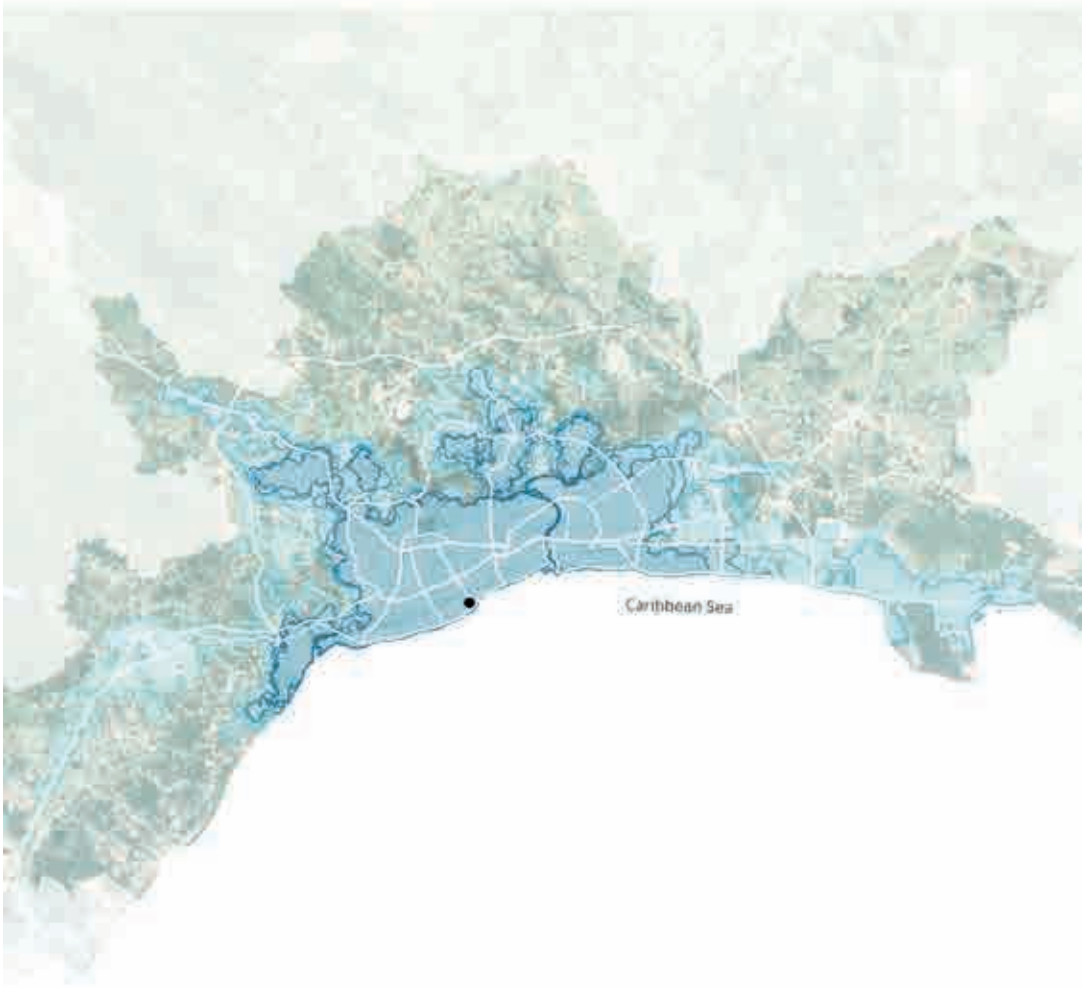


Saturation
rank





GREATER SANTO DOMINGO —
REPUBLICA DOMINICANA



● Central Business District N 18.4482741
E -69.927798

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

0 2.5 km



Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater Santo Domingo have been decreasing its contribution to the city's growth: from 49% (1991-2000) to 38% (2010-2021). Extension has maintained its significance over the years, as it represented 25% in 1991-2000 and 2010-2021. Leapfrog's contribution to Greater Santo Domingo's urban expansion was 13% (1991-2000) and also maintained the percentage (2010-2021). Additionally, inclusion varied its contribution to the city's expansion from 15% (1991-2000) to 26% (2010-2021).

The average dwelling unit occupancy in Santo Domingo is 3.5 people per unit, high in comparison to the average of the cities in this Atlas. Additionally, the building story height average is 1.4 stories. The residential plot coverage of Santo Domingo is 47.1%, resulting in a moderate percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

Greater Santo Domingo doubled its population at an annual growth of approximately 2.6% per year, from 1.9 million to 4.1 million.

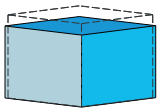
GREATER SANTO DOMINGO —
REPUBLICA DOMINICANA

avg 3.4 people per dwelling unit



3.5 people per dwelling unit

avg 1.6 stories building height

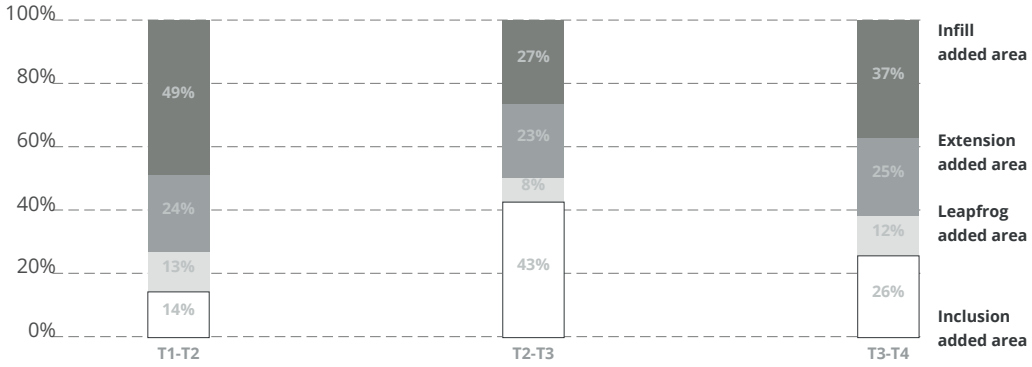


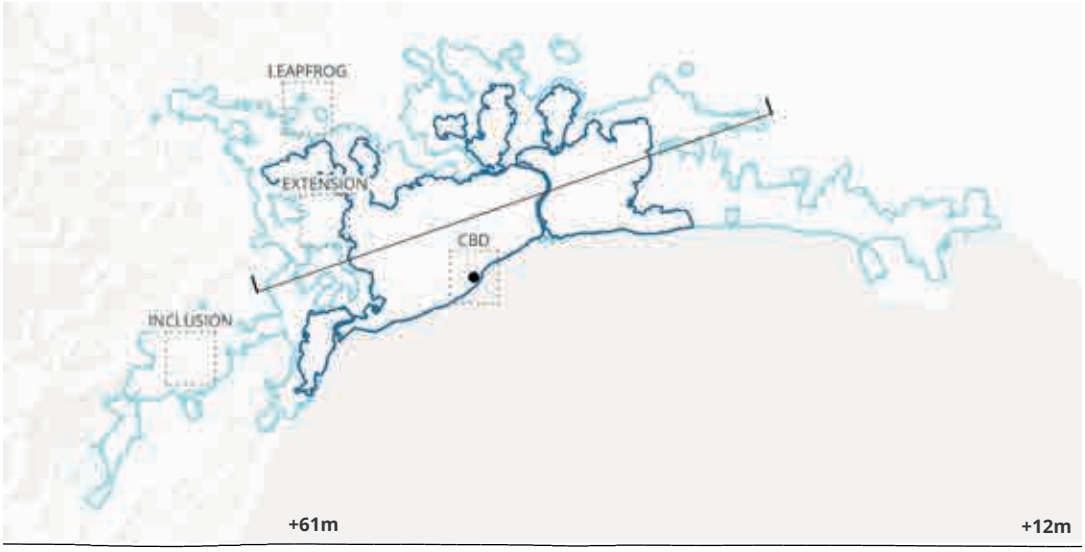
1.4 stories building height

avg 44% plot coverage



47% plot coverage





Section Profile 38 km



1991 T1 2020 T4

INLAND CITY
ELEVATION: 634m
BIOME: TROPICAL / SUBTROPICAL MOIST BROADLEAF FORESTS

Greater São Paulo,* Brazil, is located in the biome Tropical & Subtropical Moist Broadleaf Forests, at 634 meters above sea level. Between 1988 and 2021, it experienced a population growth of approximately 1.4% per year, from 13.6 million to 21.7 million. Greater São Paulo, the most populated conurbation in the sample, reduced its population growth rate between 2014 and 2021 in comparison to 1988-2000. The city has a high population density compared to the other cities: 86.5 inhabitants per hectare, ranking 23rd in population density variation (%) in 2014-2021. In regards to its urban extent, it increased by approximately 1.5% annually over the last decades, resulting in an area 1.7 times what it was in 1988. Compared to other LAC cities, Greater São Paulo maintained its compactness, what was accompanied by a slight decline in the ranking of saturation. In terms of ranking, an increase in Urban Extent and Population growth accompanied by a decrease in Urban Density and Compactness suggests that urban growth accommodation by densification was less meaningful than the average of LAC Cities.



2021=36

1990=57

Urban population density
person / hectare

Evaluation metrics rankings:

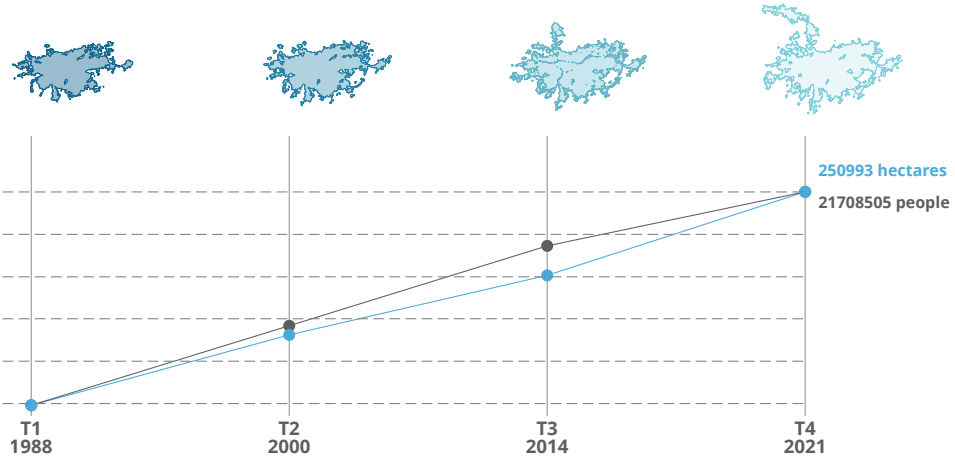
Population Growth
annual change
rank
44th (T4-T3) 40th (T2-T1)

Urban Extent
annual change
rank
59th (T2-T1) 40th (T4-T3)

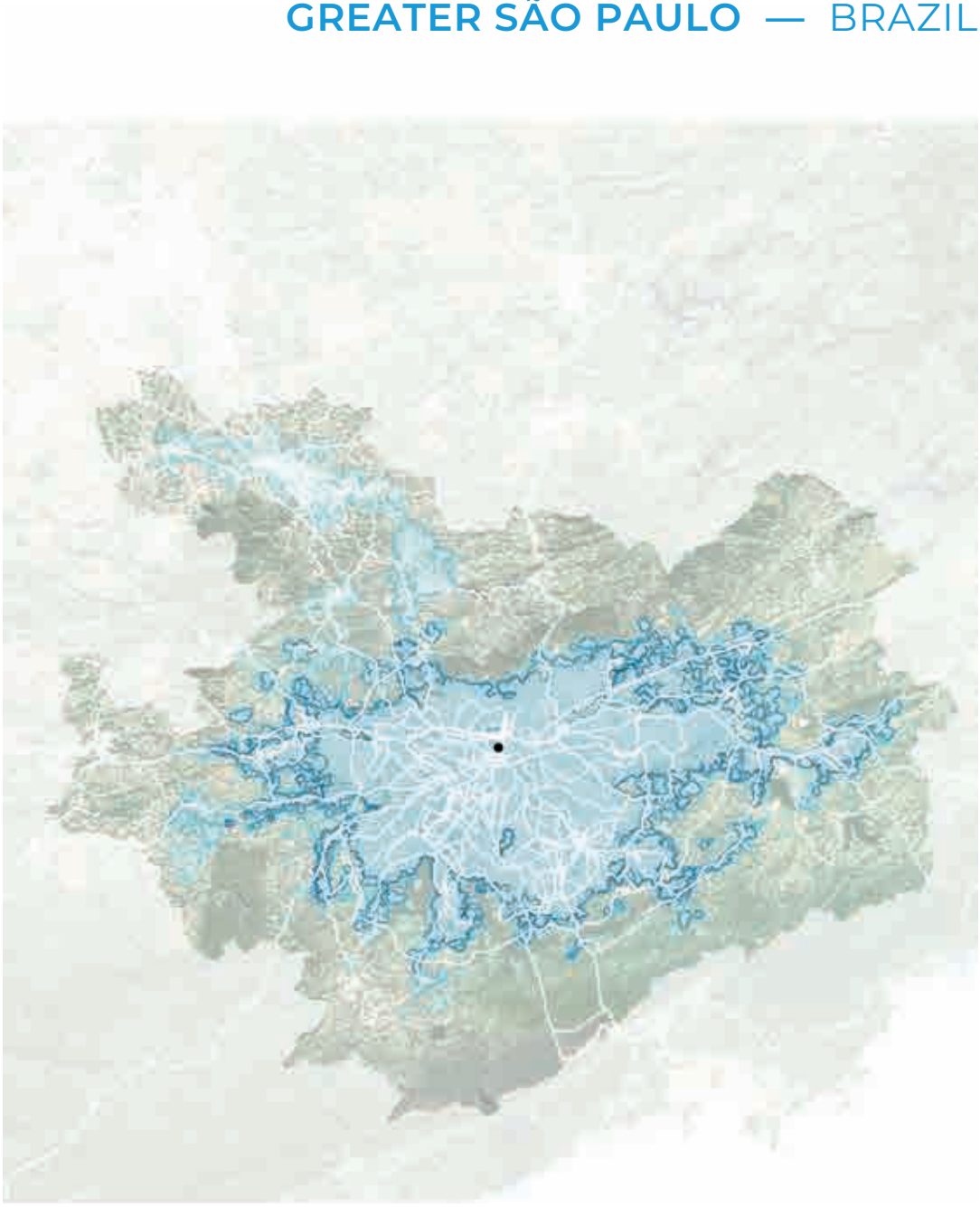
Urban population density
annual change
rank
23rd (T4-T3) 18th (T2-T1)

Compactness
rank
38th (T1) 32nd (T4)

Saturation
rank
9th (T4) 7th (T1)



GREATER SÃO PAULO — BRAZIL



● Central Business District N -23.532999
E -46.632999

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Greater São Paulo have been decreasing its contribution to the city's growth: from 54% (1988-2000) to 42% (2014-2021). Extension has decreased its significance over the years, as it represented 24% in 1988-2000 in contrast to 19% in 2014-2021. Leapfrog's contribution to Greater São Paulo's urban expansion was 10% (1988-2000) and reached 8% (2014-2021). Additionally, inclusion varied its contribution to the city's expansion from 15% (1988-2000) to 32% (2014-2021).

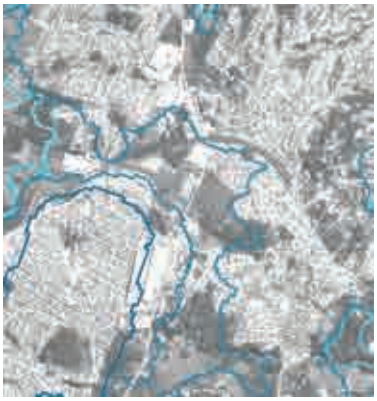
Greater São Paulo, the most populated conurbation in the sample, reduced its population growth rate between 2014 and 2021.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



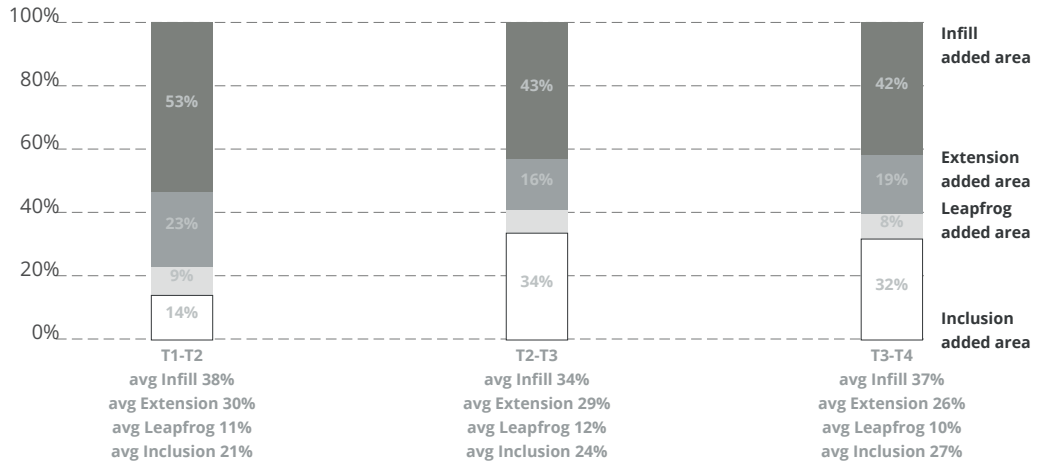
Extension area

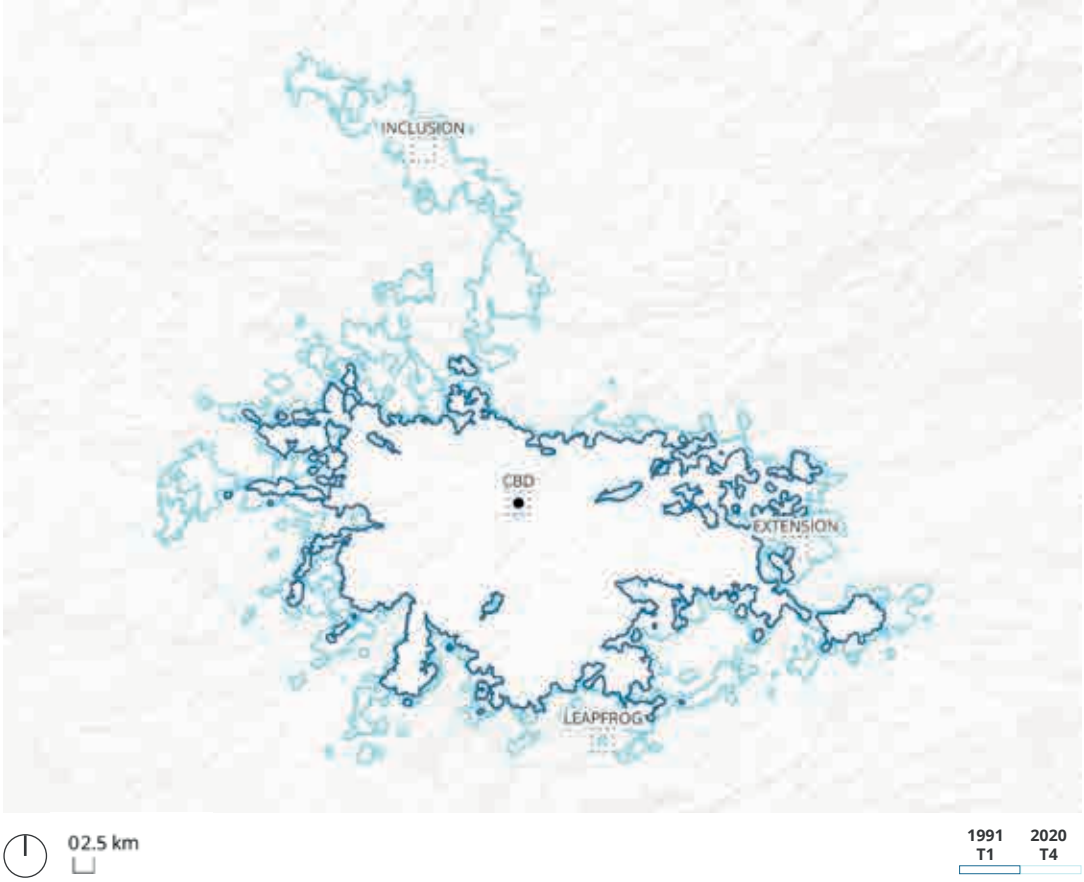


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
53%
23%
9%
14%
43%
16%
34%
42%
19%
8%
32%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
CBD
EXTENSION
LEAPFROG
0 2.5 km
1991 T1
2020 T4

63 /

INLAND CITY
ELEVATION: 2247m
BIOME: MONTANE GRASSLANDS / SHRUBLANDS

Greater Tarija,* Bolivia, is located in the biome Montane Grasslands & Shrublands, at 2247 meters above sea level. Between 1990 and 2022, its population grew expressively at an annual rate of 4.8%, from 48.4 thousand to 223.4 thousand. Between 2016 and 2022, Greater Tarija's annual urban extent growth was the second highest in the sample. It increased by 4.4% annually in the last thirty years; thus, Greater Tarija's urban extent is now 4 times what it was in 1990. Additionally, Greater Tarija has a low population density compared to the other cities: 36.1 inhabitants per hectare. Its current rank at 66th in population density variation (%) in 2016-2022 presents an intense descent from its previous position as 3rd in (1990-2001). From 1990 to 2022, the city's increase in compactness was followed by a minor decline of one position in the ranking of saturation, in comparison to other LAC cities.



2022=36

1990=32

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change rank
4th 3rd
T4-T3 T2-T1

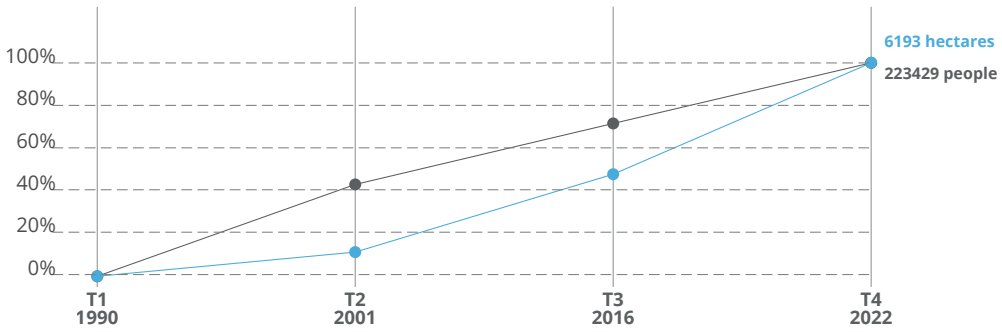
Urban Extent
annual change rank
46th 2nd
T2-T1 T4-T3

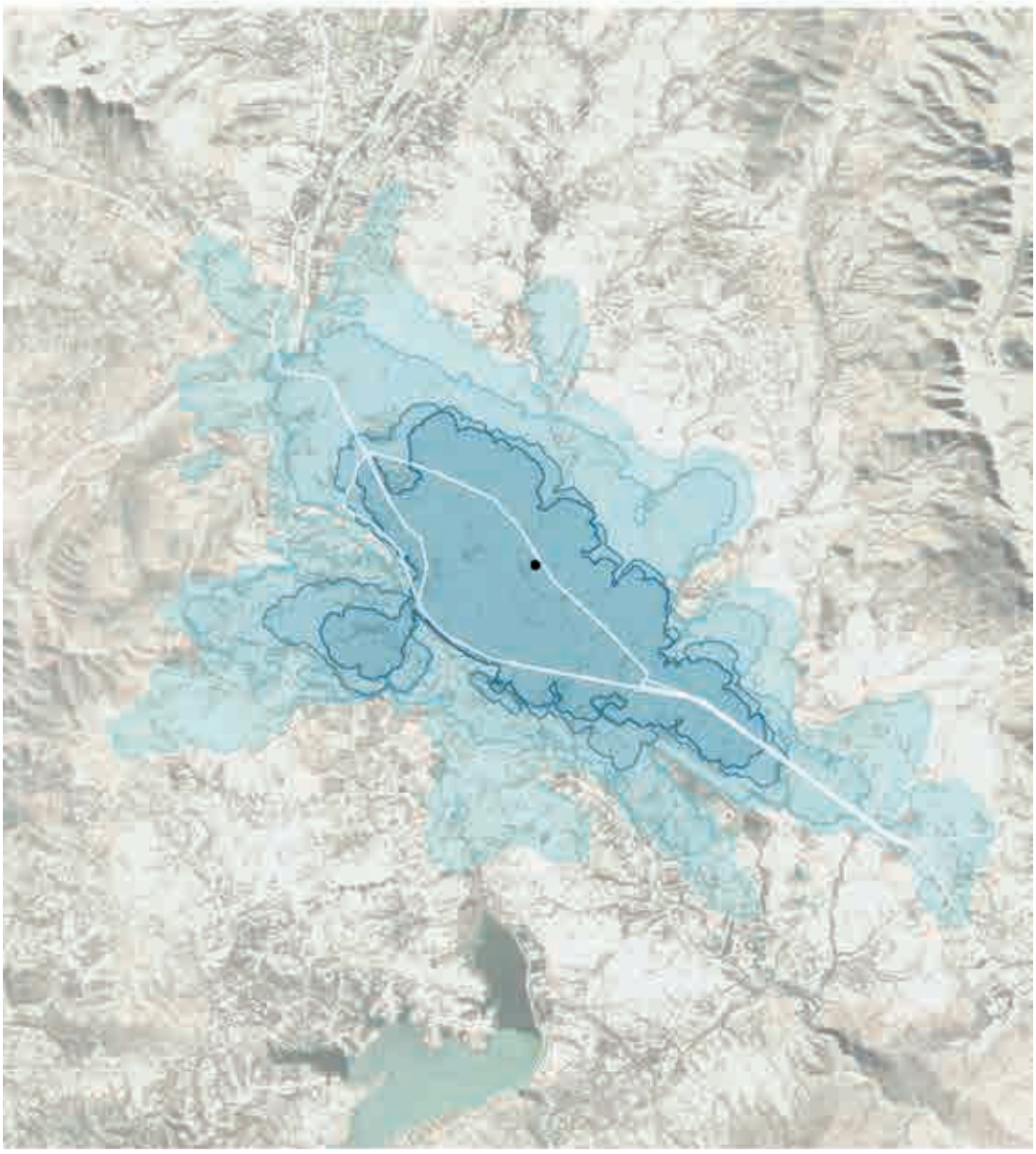
Urban population density
annual change rank
66th 3rd
T4-T3 T2-T1

Compactness
rank
37th 18th
T1 T4

Saturation
rank
45th 39th
T1 T4







● Central Business District N -21.526824
E -64.724054

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

0 2.5 km

63 /

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Greater Tarija slightly decreased its contribution to the city's growth: from 39% (1990-2001) to 31% (2016-2022). Extension followed this trend, as it represented 21% in 1990-2001 in contrast to 16% in 2016-2022. Leapfrog's contribution to Greater Tarija's urban expansion was 17% (1990-2001) and increased to 26% (2016-2022). Additionally, inclusion varied its contribution to the city's expansion from 25% (1990-2001) to 30% (2016-2022).

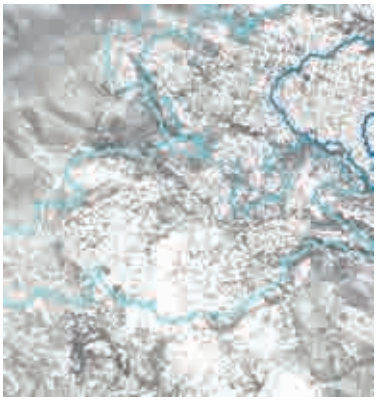
Greater Tarija's urban extent is now 4 times what it was in 1990.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

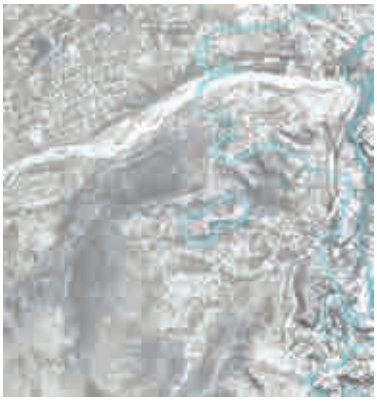
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



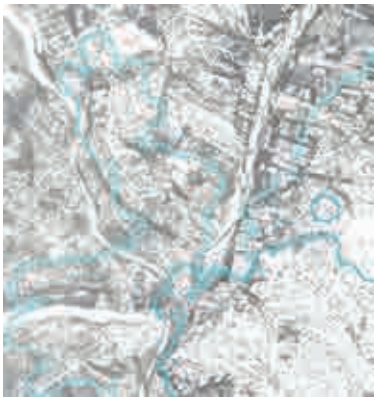
Central Business District



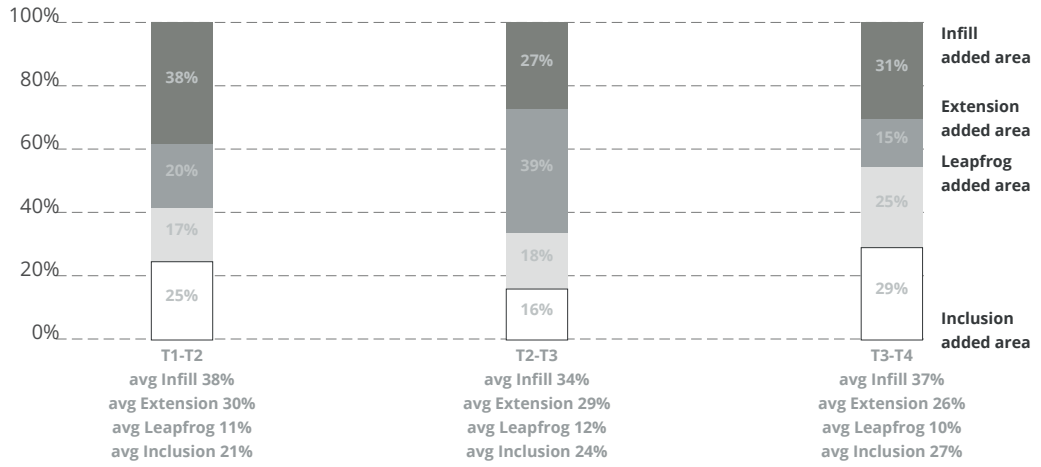
Extension area

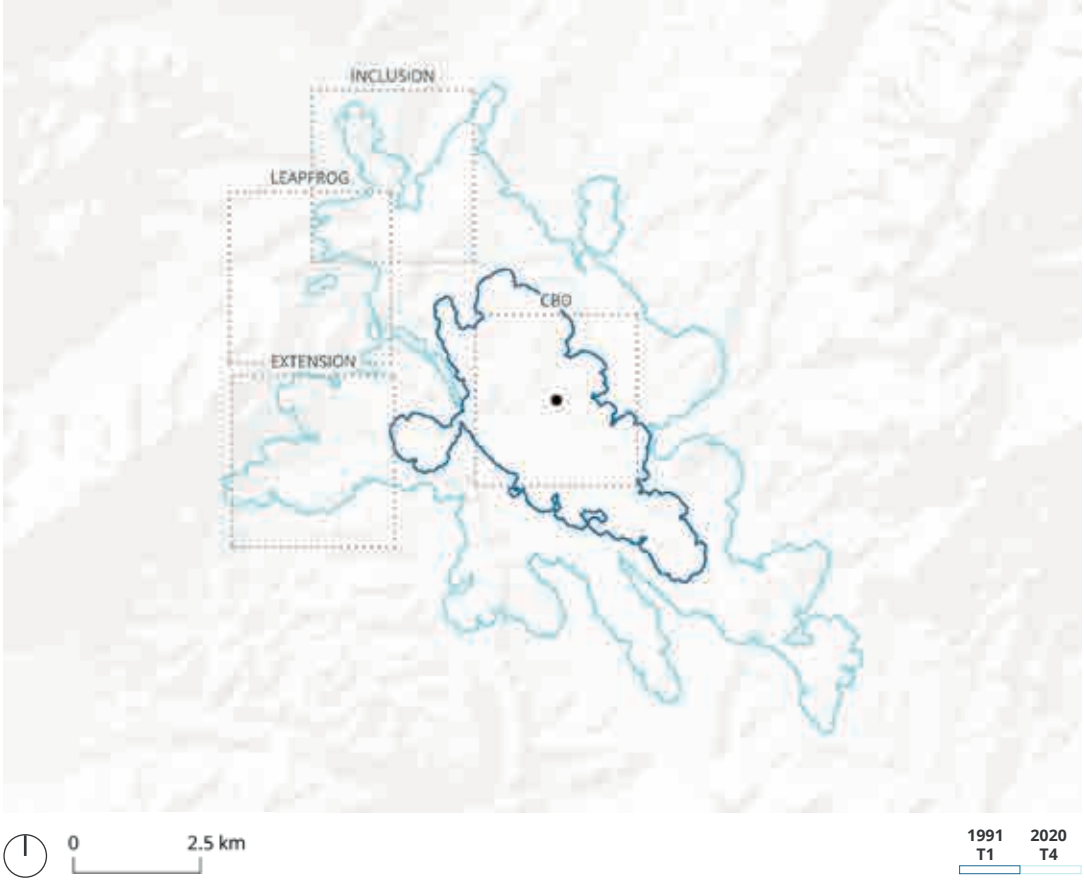


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
38%
20%
17%
25%
27%
39%
18%
16%
31%
15%
25%
29%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
LEAPFROG
CBD
EXTENSION
0
2.5 km
1991 T1
2020 T4

64 /

INLAND CITY
ELEVATION: 937m
BIOME: TROPICAL / SUBTROPICAL CONIFEROUS FORESTS

Tegucigalpa,* Honduras, is located in the biome Tropical & Subtropical Coniferous Forests, at 937 meters above sea level. Between 1990 and 2020, it experienced a population growth of approximately 2% per year, from 552.2 thousand to 1 million. Tegucigalpa has a high population density compared to the other cities: 69.5 inhabitants per hectare, ranking 14th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 2.4% annually over the last decades, resulting in an area now 2.1 times what it was in 1990. Over the studied period, Tegucigalpa was the 6th and 5th most compact city in the sample. Within the same timeframe, saturation spiked in the city, rising 30 positions, from 46th to 16th, between 1990 and 2020.



2021=36

1990=57

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank

41st (T4-T3) 25th (T2-T1)

Urban Extent
annual change
rank

39th (T2-T1) 30th (T4-T3)

Urban population density
annual change
rank

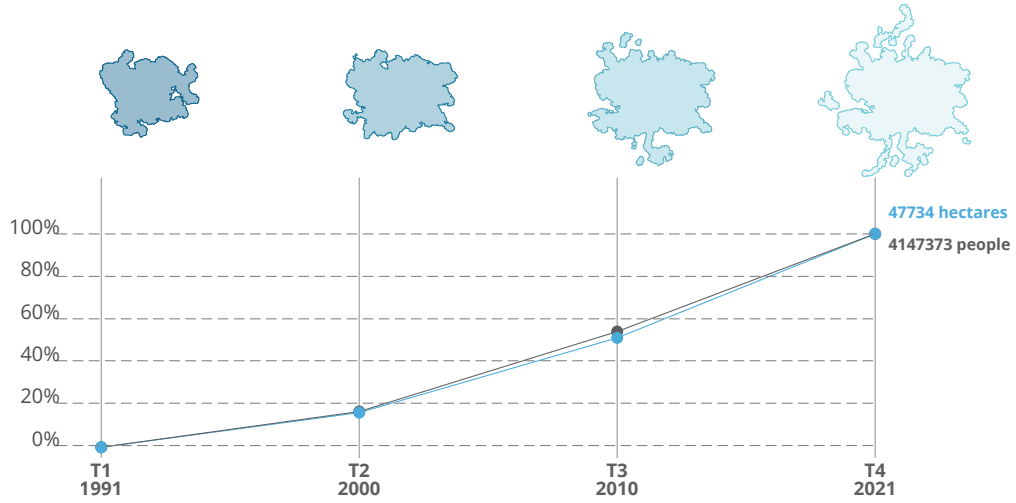
15th (T2-T1) 14th (T4-T3)

Compactness
rank

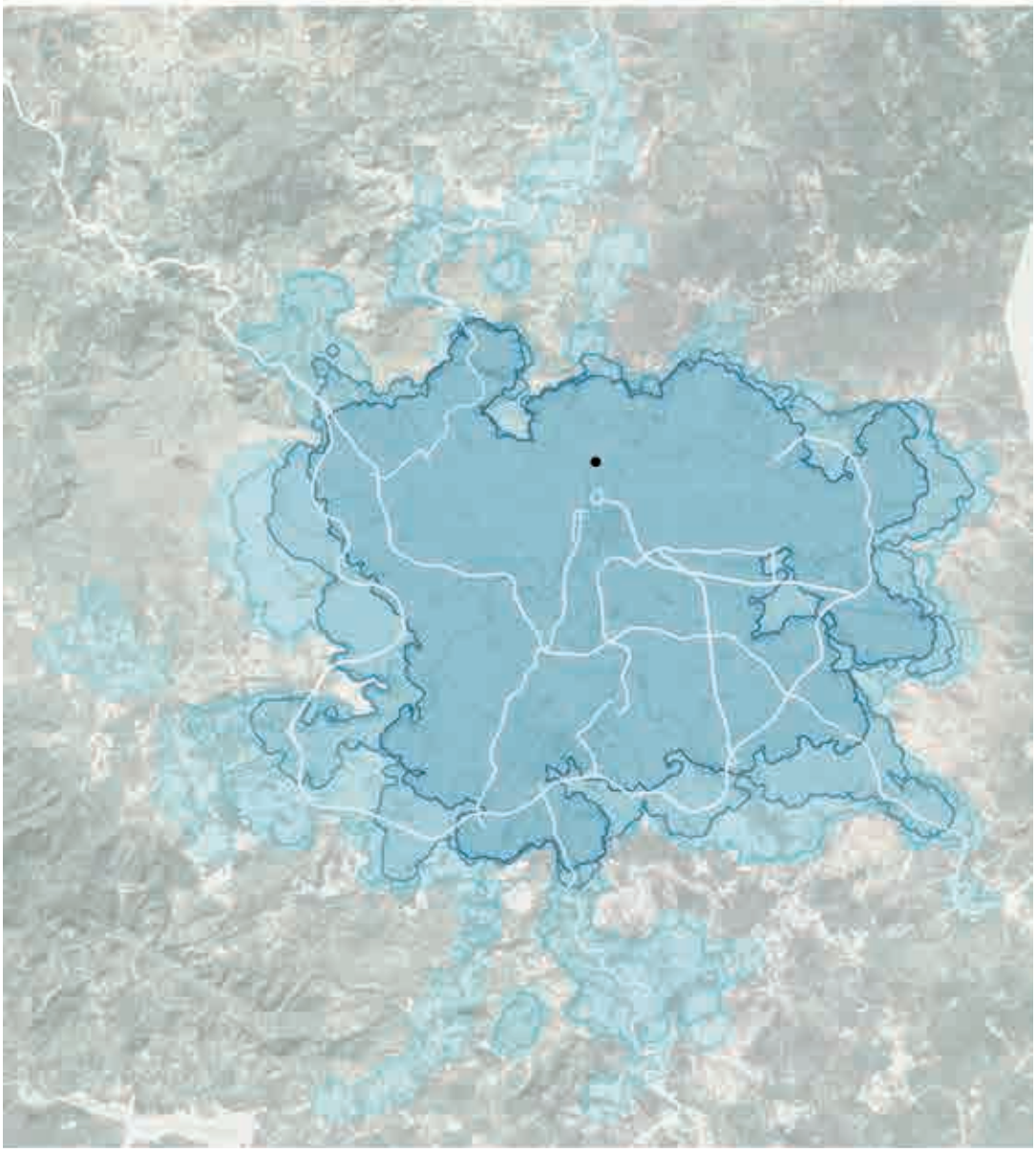
6th (T1) 5th (T4)

Saturation
rank

46th (T1) 16th (T4)



TEGUCIGALPA — HONDURAS



● Central Business District N 14.1044325
E -87.204122

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

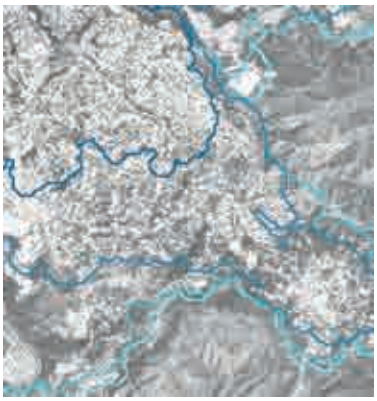
highways

local streets

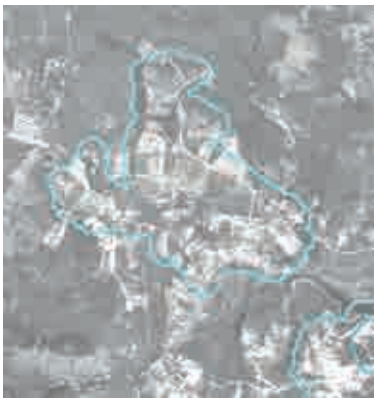
0 2.5 km



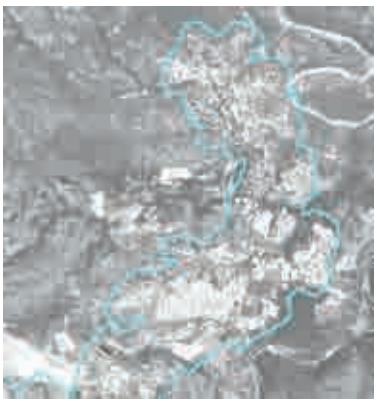
Central Business District



Extension area



Leapfrog area



Inclusion area

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Tegucigalpa have been decreasing its contribution to the city's growth: from 50% (1990-2000) to 29% (2010-2020). Likewise, Extension has decreased its significance over the years, as it represented 38% in 1990-2000 in contrast to 23% in 2010-2020. Leapfrog's contribution to Tegucigalpa's urban expansion increased from 6% (1990-2000) to 11% (2010-2020). Additionally, inclusion spiked its contribution to the city's expansion from 8% (1990-2000) to 39% (2010-2020).

In Tegucigalpa, the average occupancy for dwelling units is 4.3, 27% greater than the average of the sample. Additionally, the building story height average is 1.4 stories. The residential plot coverage of Tegucigalpa is 42.1%, resulting in a low percentage of unbuilt spaces within residential plots.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.

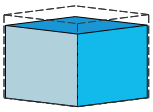
In Tegucigalpa, the average occupancy for dwelling units is 4.3, 27% greater than the average of the sample.

avg 3.4 people per dwelling unit



4.3 people per dwelling unit

avg 1.6 stories building height

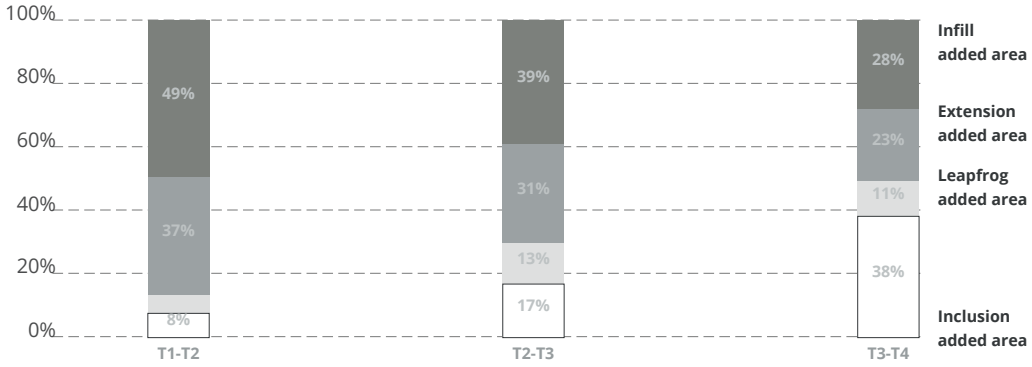


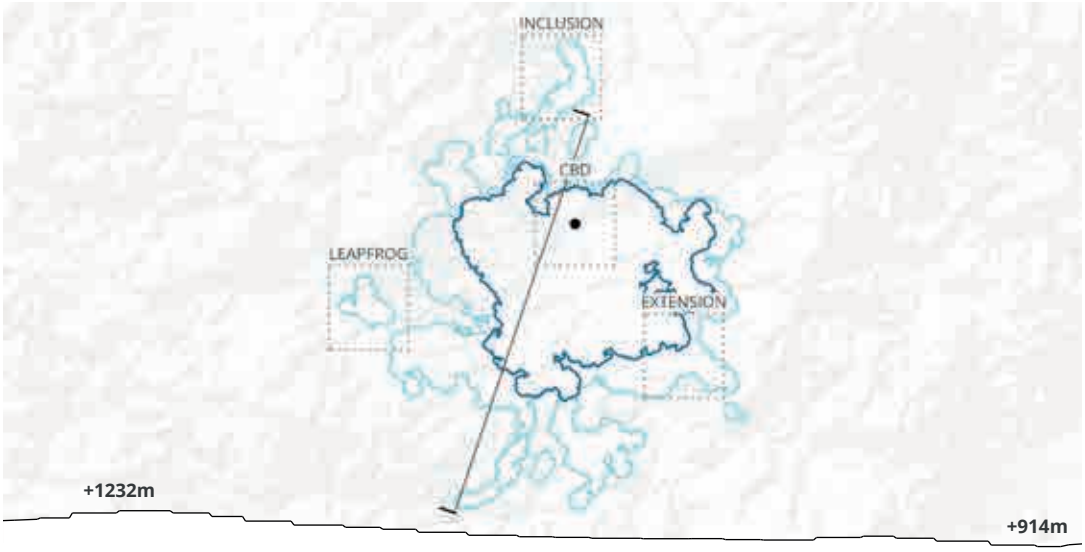
1.4 stories building height

avg 44% plot coverage



42% plot coverage





Section Profile 18 km





65 /

COASTAL CITY
ELEVATION: 30m
BIOME: MEDITERRANEAN FORESTS / WOODLANDS / SCRUB

Tijuana,* Mexico, is located in the biome Mediterranean Forests, Woodlands & Scrub, at 30 meters above sea level. Between 1990 and 2021, it experienced a population growth of approximately 3.2% per year, from 733.3 thousand to 2 million. Despite a moderate population density compared to the other cities, of 53.9 inhabitants per hectare, Tijuana ranked first in population density variation in 2014-2021. Additionally, urban extent increased by approximately 3.2% annually over the last decades, resulting in an area 2.7 times what it was in 1990. The city became more compact compared to other LAC cities, rising from 39th in 1990 to 28th in 2021. Such an increase is accompanied by a rise in saturation, gaining 16 positions from 27th to 11th between 1990 and 2021.



2021=36

1990=57

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank



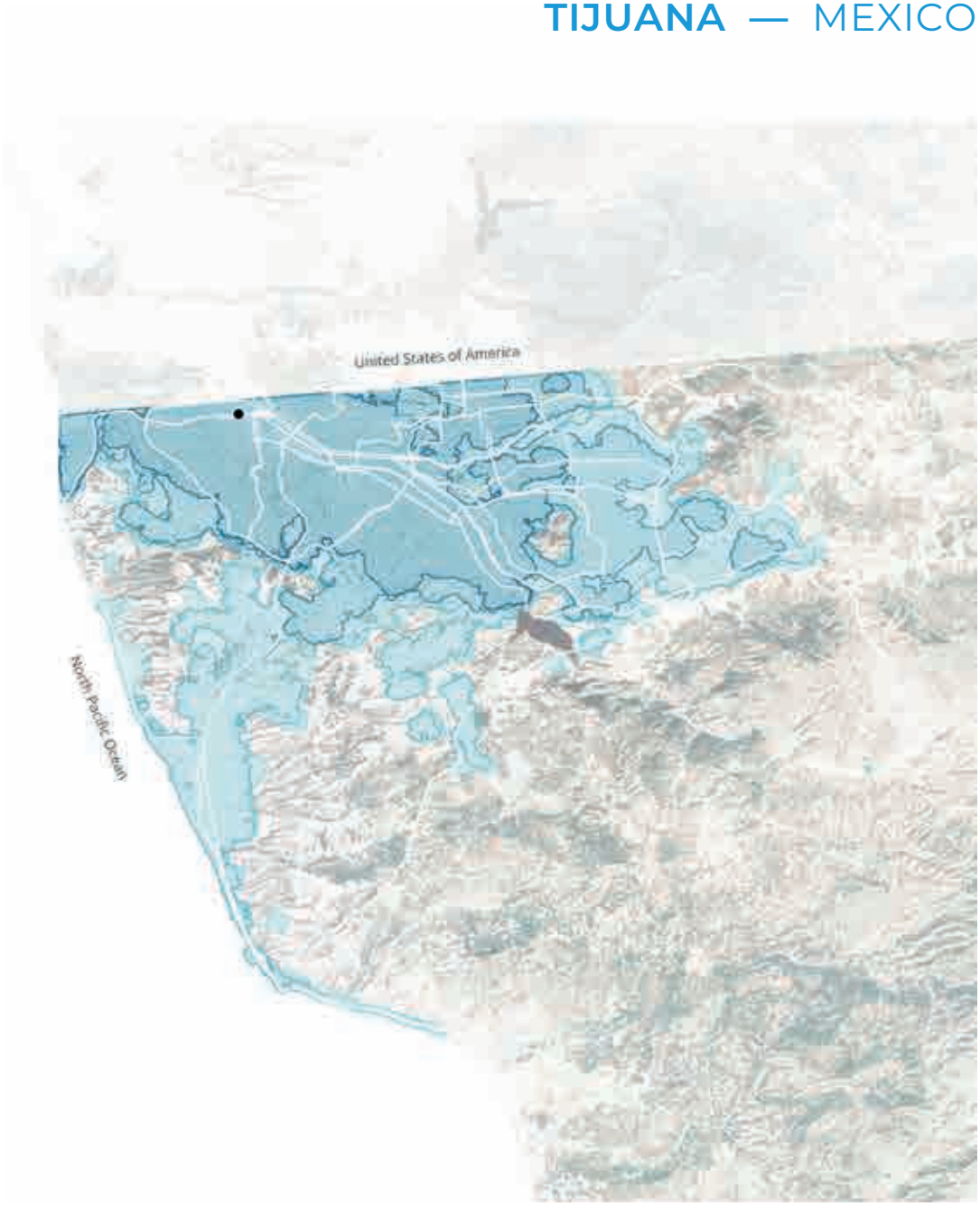
Compactness
rank



Saturation
rank







● Central Business District N 32.5349126
E -117.04172

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Tijuana have been increasing their contribution to the city's growth: from 31% (1990-2000) to 52% (2014-2021). Inclusion represented 25% of the city's urban expansion between 2014 and 2021. Extension has decreased its significance over the years, as it represented 43% in 1990-2000 in contrast to 20% in 2014-2021. Leapfrog's contribution to Tijuana's urban expansion was 10% (1990-2000) and reached 6% (2014-2021).

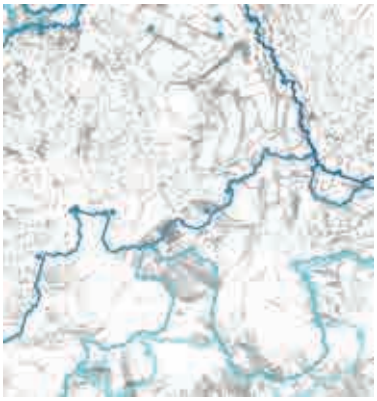
Processes of infill in Tijuana have been increasing their contribution to the city's growth: from 31% (1990-2000) to 52% (2014-2021).

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

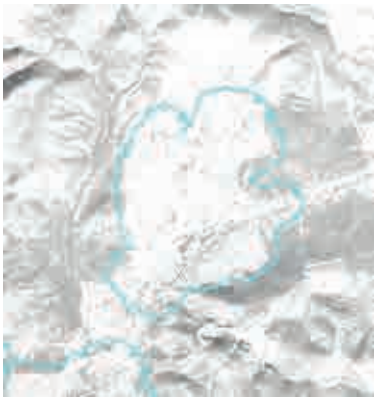
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



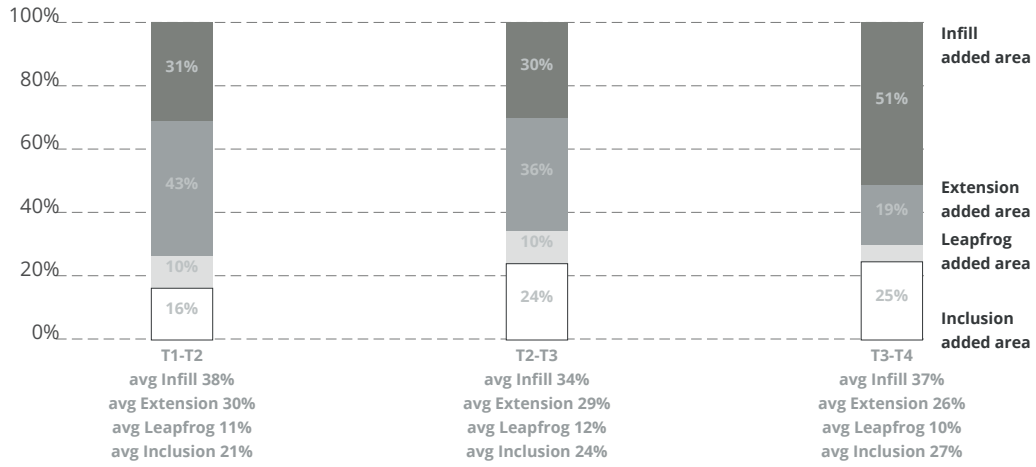
Extension area

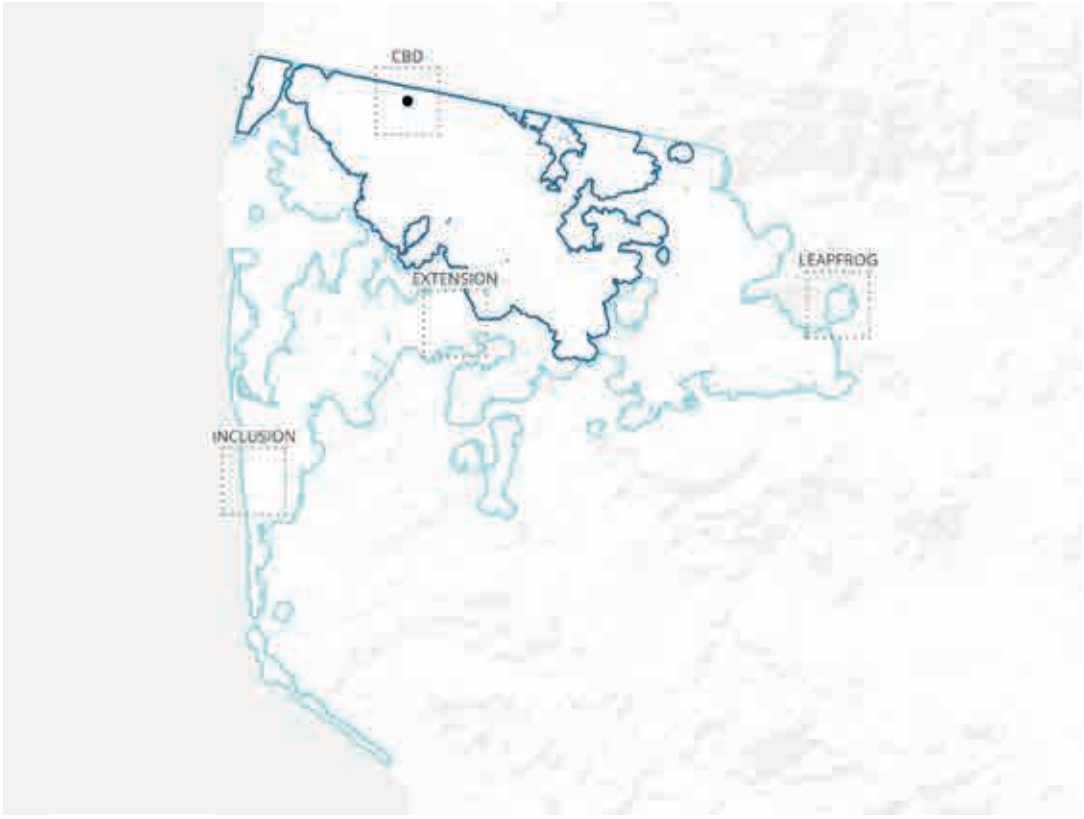


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
31%
43%
10%
16%
30%
36%
10%
24%
51%
19%
25%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


CBD
EXTENSION
LEAPFROG
INCLUSION
0
2.5 km
1991
T1
2020
T4

66 /

INLAND CITY
ELEVATION: 162m
BIOME: DESERTS / XERIC SHRUBLANDS

Valledupar,* Colombia, is located in the biome Deserts & Xeric Shrublands, at 162 meters above sea level. Between 1989 and 2020, its population grew at an annual rate of 3.1%, from 181.6 thousand to 464.2 thousand. Valledupar has a high population density compared to the other cities: 113.4 inhabitants per hectare, ranking 3rd in population density variation (%) in 2011-2020. Additionally, it is one of the few cities in the sample that had an increase in population density variation (%), of 0,9% a year (1989-2020). The city's urban extent increased by approximately 2.2% annually over the last decades, resulting in an area 1.9 times what it was in 1989. The city became yet more compact compared to other LAC cities, rising from 5th place (1990) to becoming the most compact in the sample in 2020. This increase is accompanied by a rise in saturation, gaining 10 positions from 18th to 8th between 1989 and 2020.





2020=113

1989=86

Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

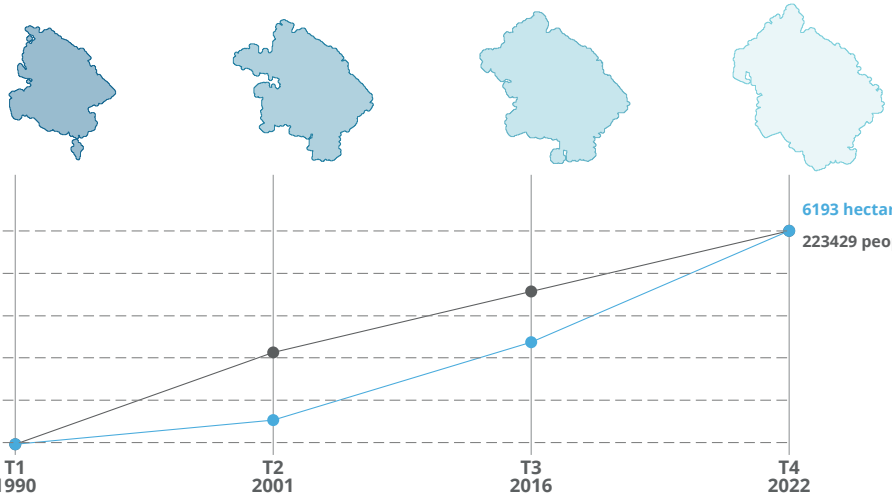


Compactness
rank

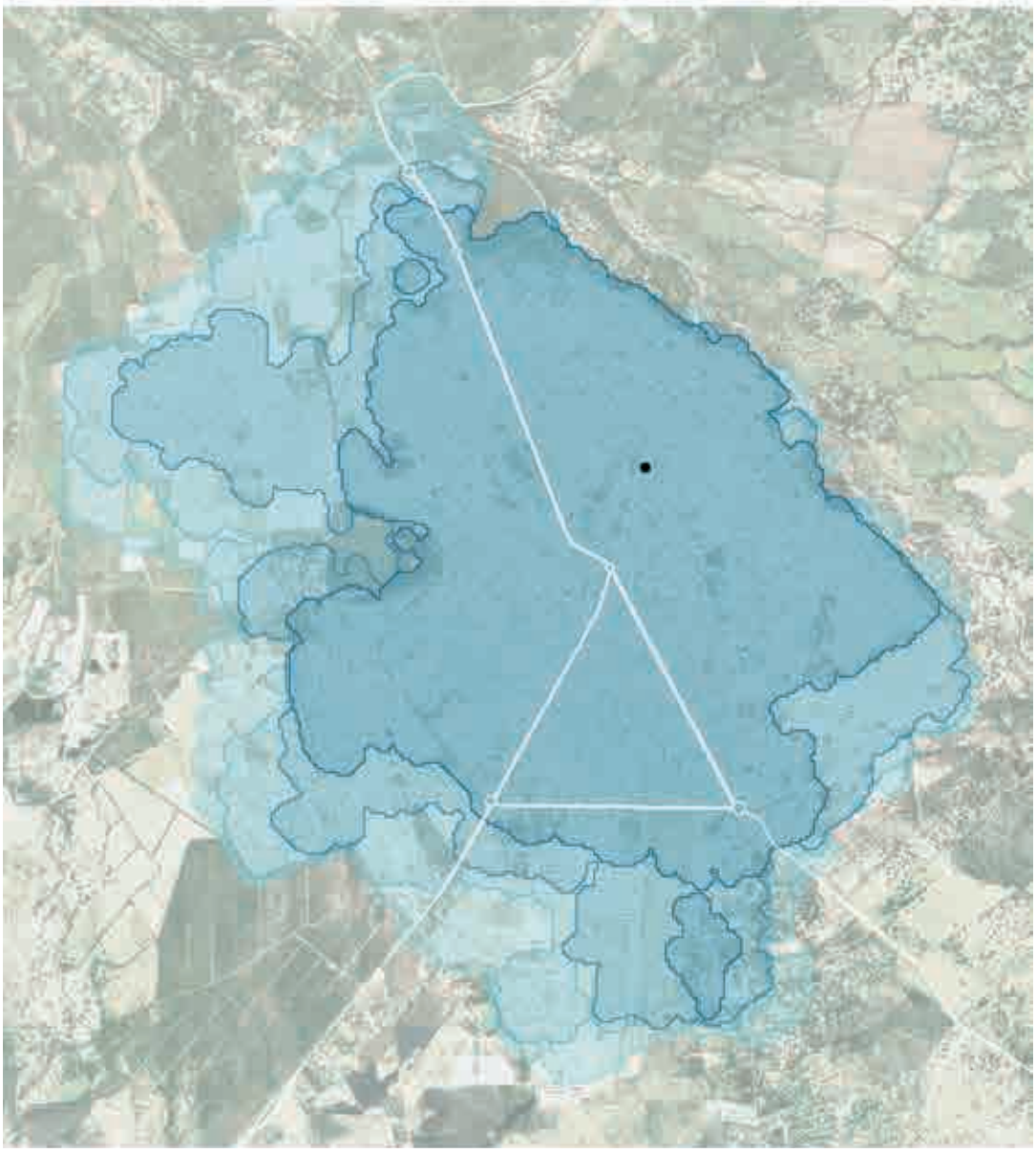


Saturation
rank





VALLEDUPAR — COLOMBIA



● Central Business District N 10.4731849
E -73.250120

1991 T1 | 1999 T2 | 2014 T3 | 2020 T4

highways

local streets

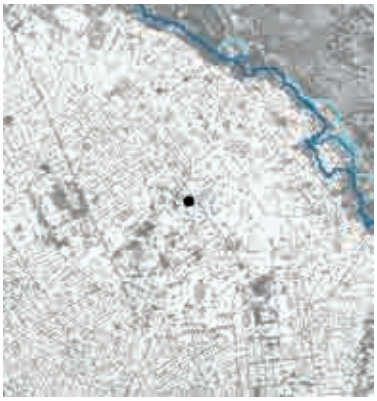
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Valledupar significantly increased its contribution to the city's growth: from 32% (1989-2001) to 54% (2011-2020). Inversely, Extension has decreased its significance over the years, as it represented 55% in 1989-2001 in contrast to 38% in 2011-2020. Leapfrog's contribution to Valledupar's urban expansion declined from 6% (1989-2001) to 4% (2011-2020), as did inclusion's, from 8% (1989-2001) to 5% (2011-2020)—reaching the lowest share in the sample.

Valledupar has a high population density compared to the other cities: 113.4 inhabitants per hectare.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

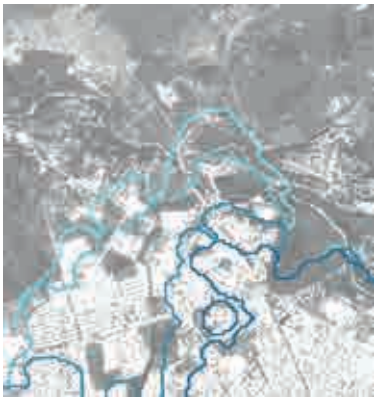
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



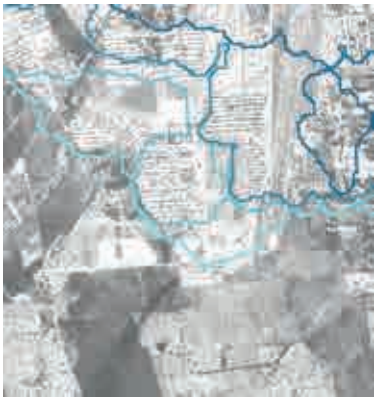
Central Business District



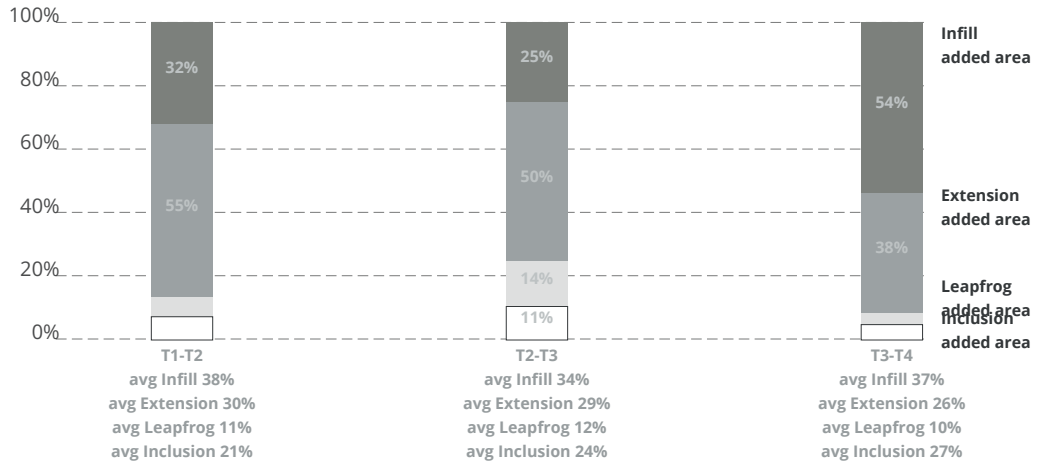
Extension area

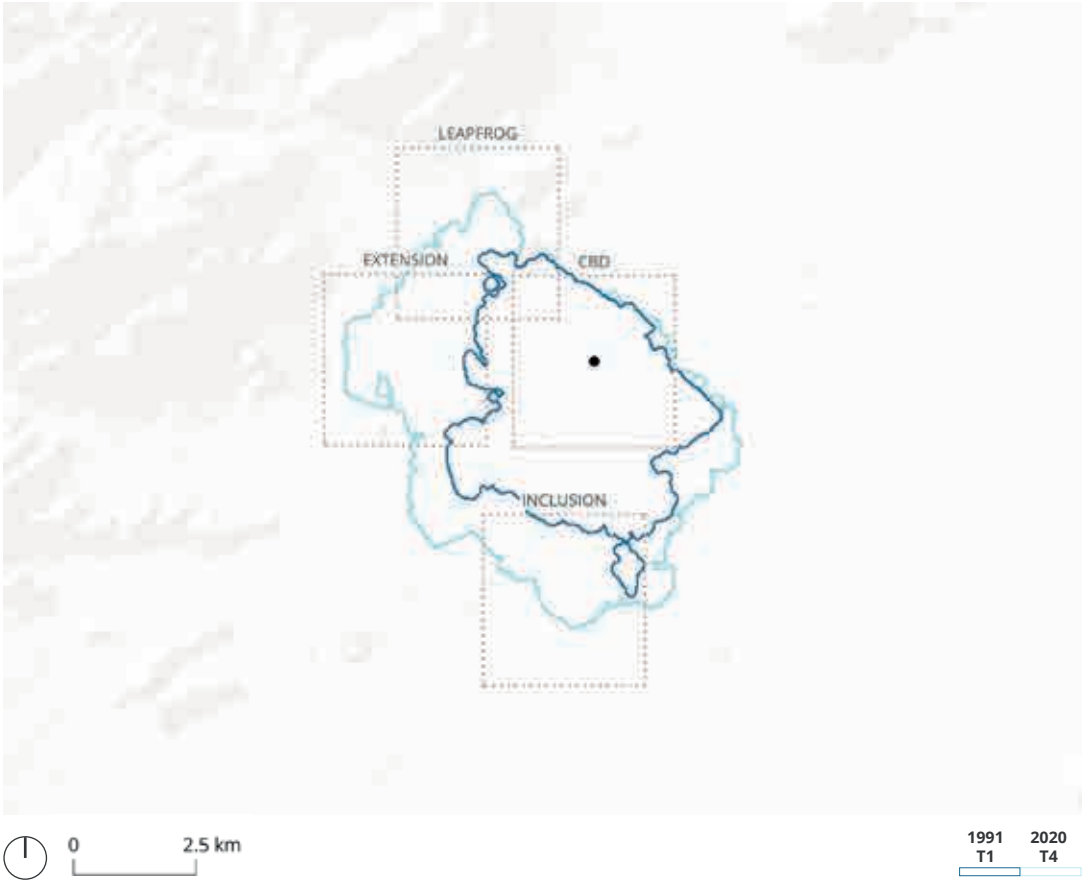


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
32%
55%
25%
50%
14%
11%
54%
38%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


LEAPFROG
EXTENSION
CBD
INCLUSION
0
2.5 km
1991 T1
2020 T4

67 /

COASTAL CITY
ELEVATION: 81m
BIOME: MEDITERRANEAN FORESTS / WOODLANDS / SCRUB

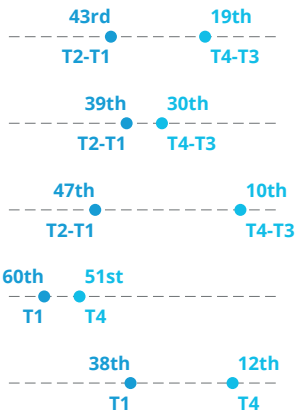
Valparaiso,* Chile, is located in the biome Mediterranean Forests, Woodlands & Scrub, at 81 meters above sea level. Between 1990 and 2020, it experienced a mild population growth of approximately 0.8% per year, from 676 thousand to 864.9 thousand. Valparaiso has a moderate population density compared to the other cities: 51.5 inhabitants per hectare, ranking 13th in population density variation (%) in 2010-2020. Additionally, urban extent increased by approximately 1.9% annually over the last decades, resulting in an area 1.8 times what it was in 1990. Though the city became slightly more compact compared to other LAC cities, rising from 67th in 1990 to 63rd in 2020, it still ranks at the bottom of the sample. In contrast, saturation in Valparaiso spiked 26 positions, from 38th to 12th between 1990 and 2020.



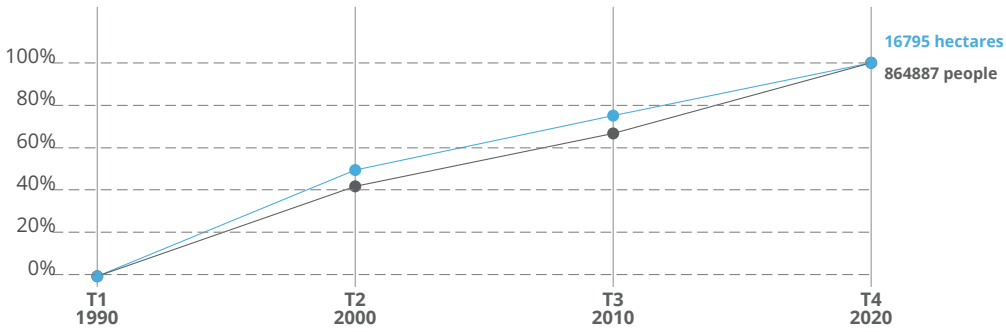


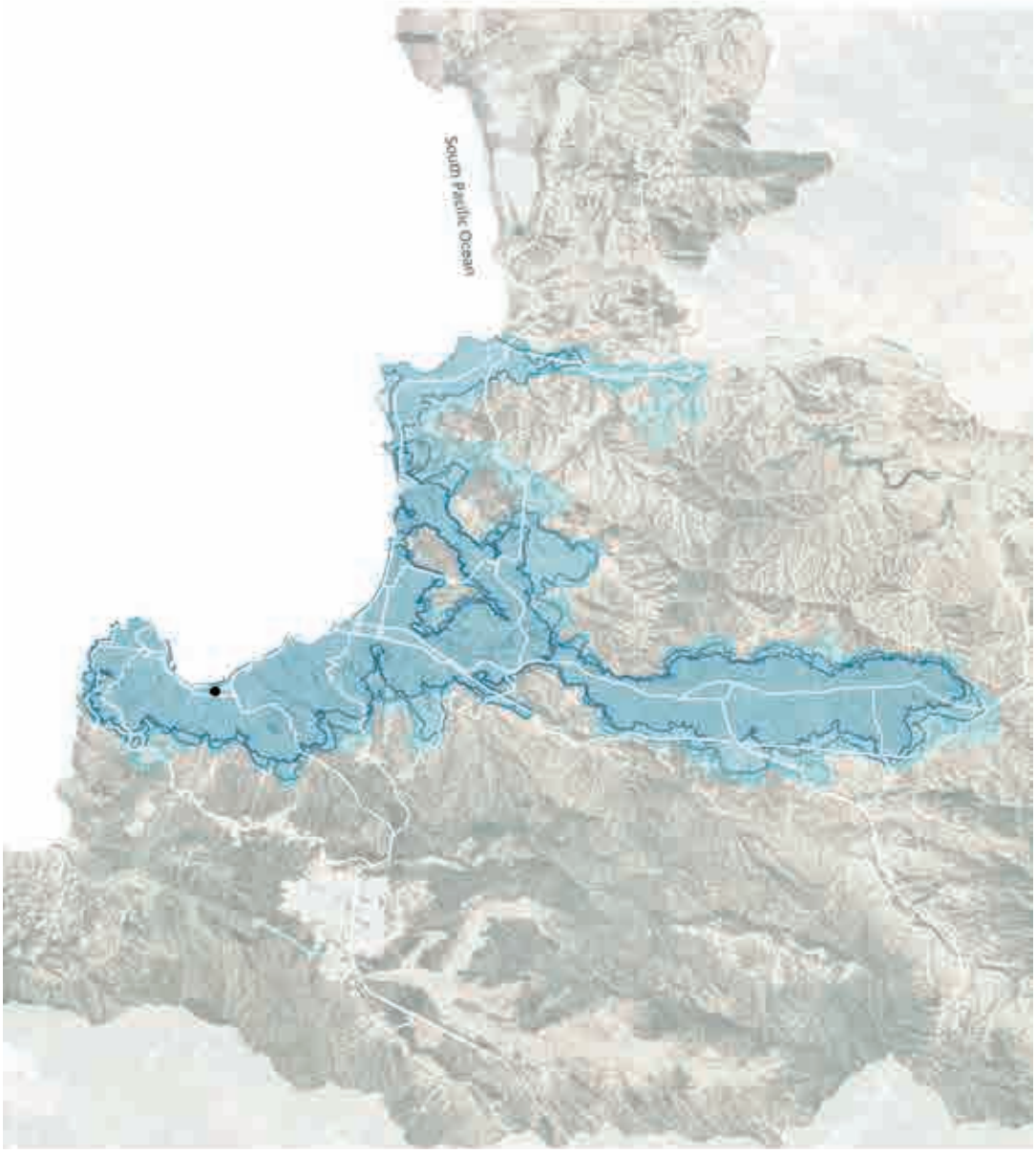
Urban population density
person / hectare

Evaluation metrics rankings:









● Central Business District N -33.045660
E -71.611300

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

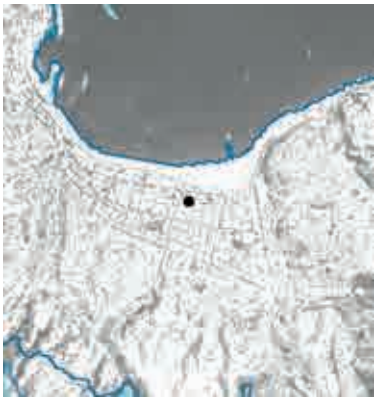
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.** Comparing the contribution of each one of these processes in urban expansion in the last periods, processes of infill in Valparaiso have not been changing significantly its contribution to the city's growth: from 46% (1990-2000) to 47% (2010-2020). However, if considering infill's contribution from 1990 to 2020, Valparaiso presents one of the highest shares of infill amongst the sample. Following this trend, leapfrog's contribution to Valparaiso's urban expansion was 7% (1990-2000) and reached 8% (2010-2020). On the other hand, extension has increased its significance over the years, as it represented 26% in 1990-2000 in contrast to 32% in 2010-2020. Additionally, inclusion declined its contribution from 23% (1990-2000) to 15% (2010-2020).

Valparaiso presents one of the highest shares of infill amongst the sample.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

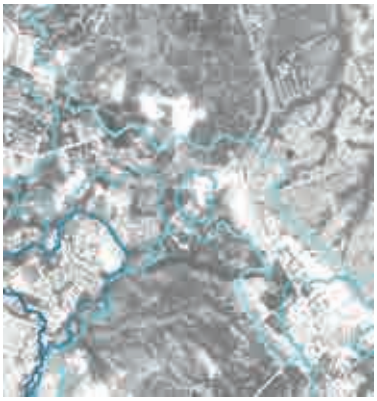
** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



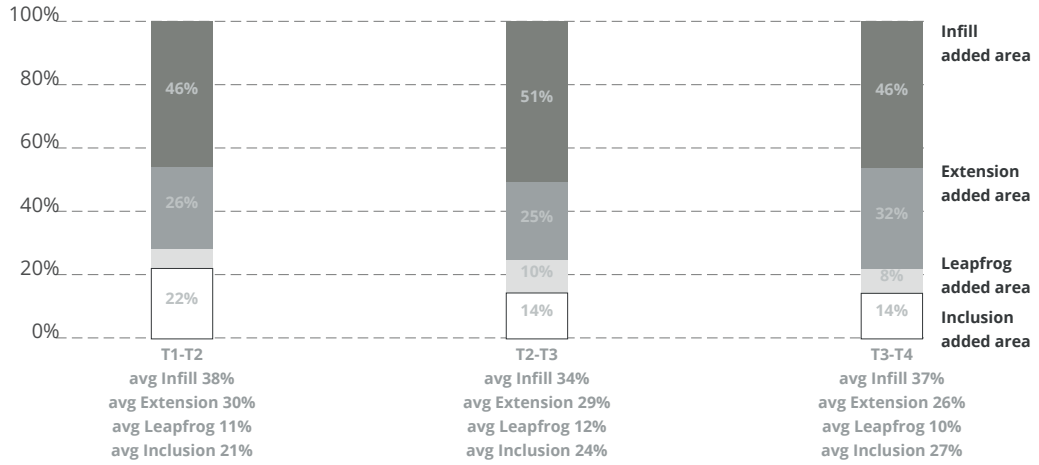
Extension area

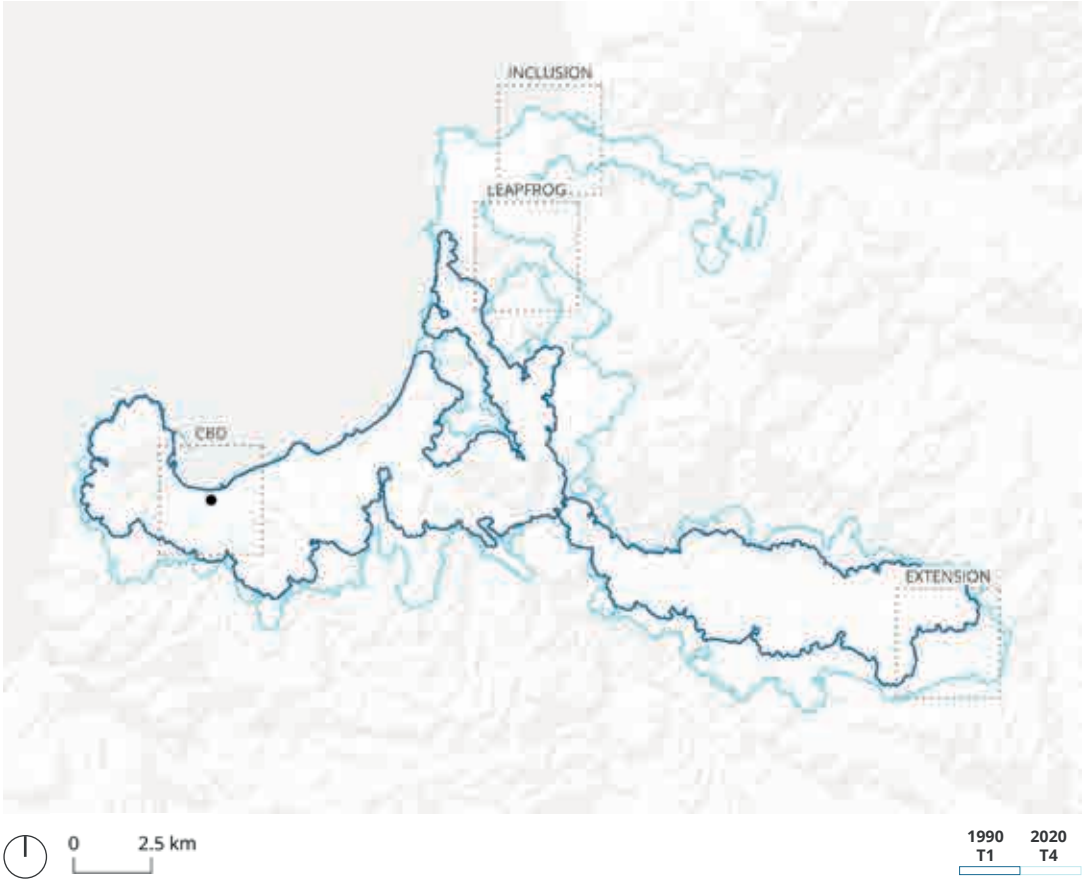


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
46%
26%
22%
51%
25%
10%
14%
46%
32%
8%
14%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
T2-T3
avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


INCLUSION
LEAPFROG
CBD
EXTENSION
0
2.5 km
1990 T1
2020 T4

INLAND CITY
ELEVATION: 529m
BIOME: TROPICAL / SUBTROPICAL DRY BROADLEAF FORESTS

Villavicencio,* Colombia, is located in the biome Tropical & Subtropical Dry Broadleaf Forests, at 529 meters above sea level. Between 1990 and 2019, it experienced a population growth of approximately 3.6% per year, from 154.3 thousand to 456.6 thousand. Yet, between 2014 and 2019, Villavicencio had the highest annual population and urban extent growths within the sample. The city has a high population density compared to the other cities: 91.8 inhabitants per hectare. Additionally, Villavicencio's urban extent increased by approximately 4.7% annually over the last decades, resulting in an area 4.1 times what it was in 1990. In this process, the city's compactness plummeted compared to other LAC cities, lowering from 3rd in 1990 to 36th in 2019. Such a decrease is accompanied by an increase in saturation, rising 4 positions, from 63rd to 59th between 1990 to 2019.





Urban population density
person / hectare

Evaluation metrics rankings:

Population Growth
annual change
rank



Urban Extent
annual change
rank



Urban population density
annual change
rank

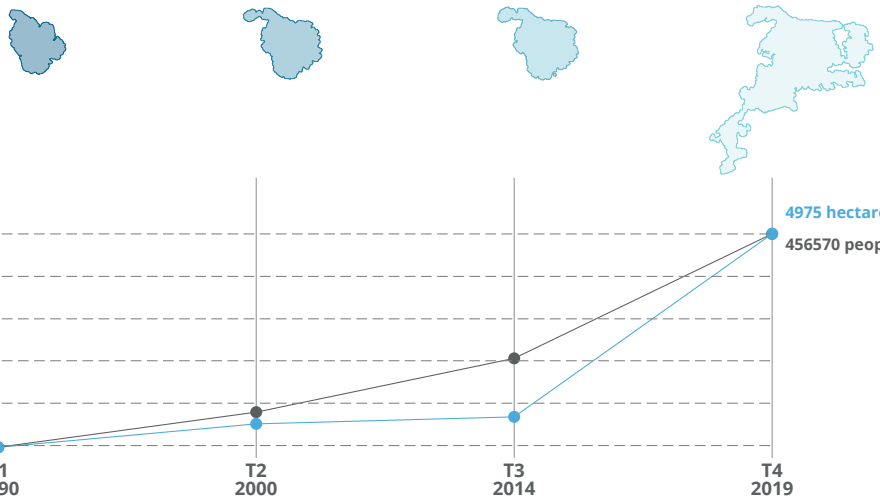


Compactness
rank

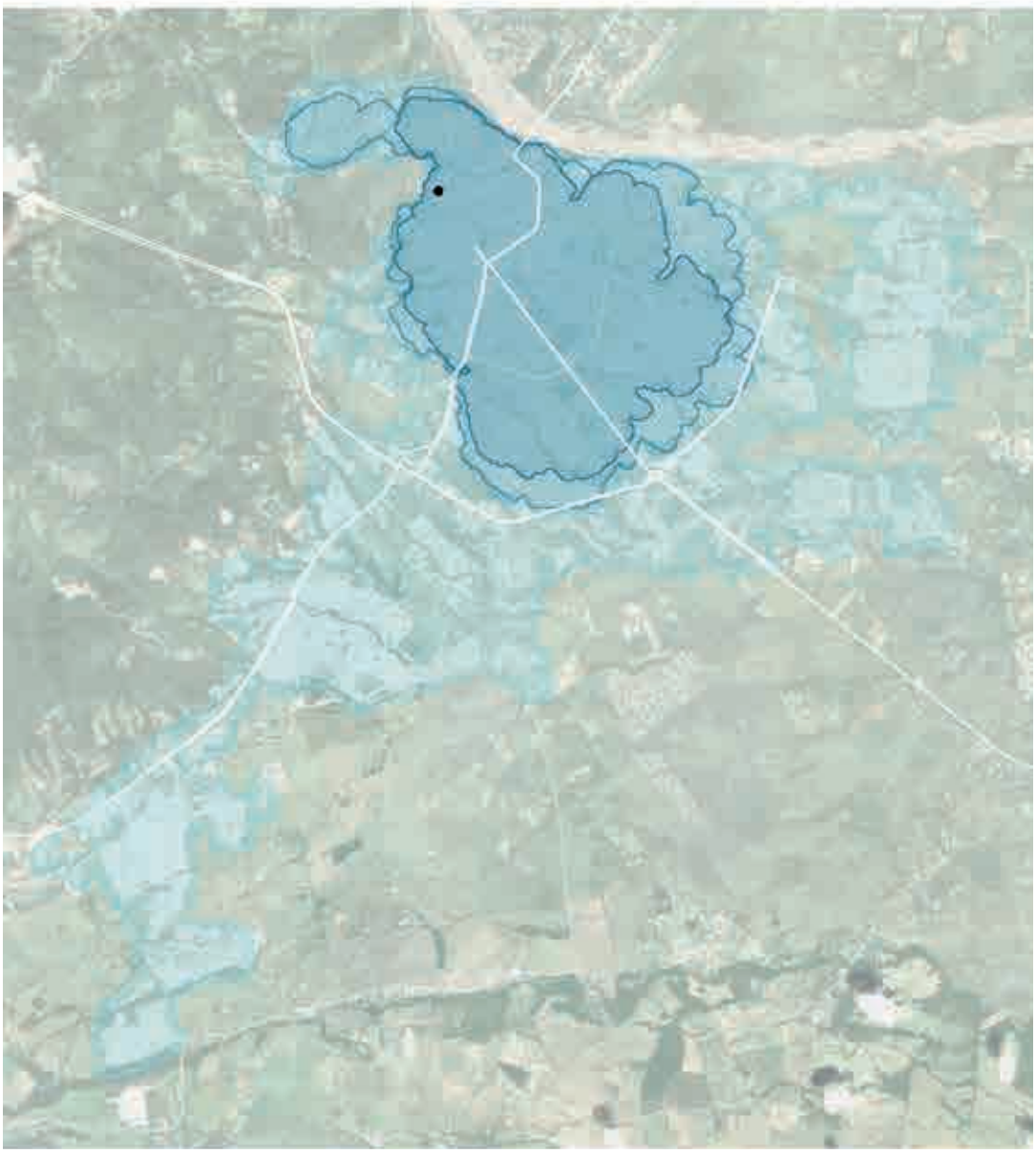


Saturation
rank





VILLAVICENCIO — COLOMBIA



● Central Business District N 4.15223674
E -73.639721

1990 T1 | 2000 T2 | 2010 T3 | 2020 T4

highways

local streets

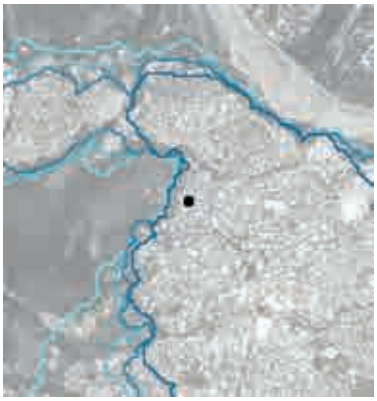
0 2.5 km

The process of urban expansion results in added area as infill, extension, leapfrog, or inclusion.**Comparing the contribution of each one of these processes in urban expansion in the last periods, one can conclude that processes of infill in Villavicencio halved its contribution to the city's growth: from 41% (1990-2000) to 21% (2014-2019). Extension has also decreased its significance, as it represented 43% in 1990-2000 in contrast to 35% in 2014-2019. In contrast, Leapfrog's contribution to Villavicencio's urban expansion tripled from 4% (1990-2000) to 15% (2014-2019), whereas inclusion's doubled from 14% (1990-2000) to 31% (2014-2019).

Additionally, Villavicencio's urban extent increased by approximately 4.7% annually over the last decades, resulting in an area 4.1 times what it was in 1990.

* The Atlas assesses the contiguous built-up areas of each conurbation. The included cities are listed in the appendix.

** Shlomo Angel, Alejandro M. Blei, Jason Parent, et al., *Atlas of Urban Expansion—2016 Edition, Volume 1: Areas and Densities* (New York: New York University; Nairobi: UN-Habitat; Cambridge, MA: Lincoln Institute of Land Policy, 2016), available at http://atlasofurbanexpansion.org/data.



Central Business District



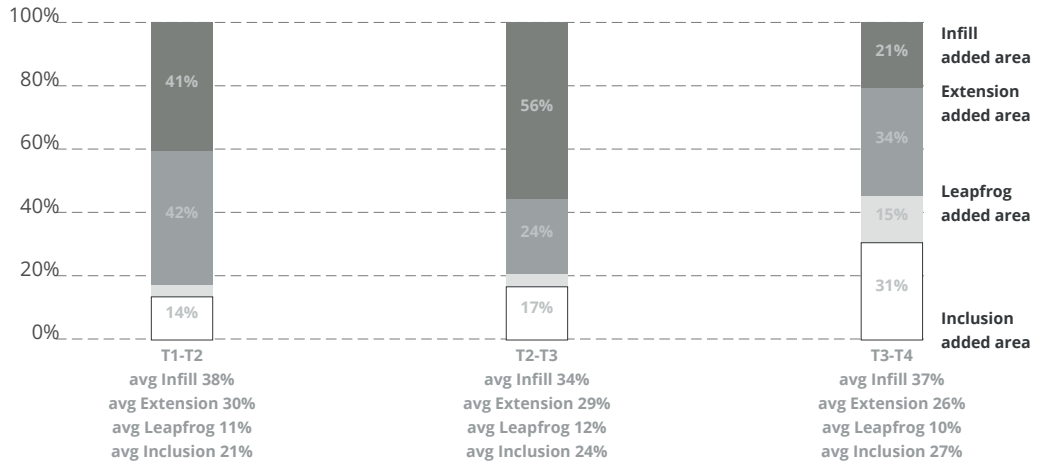
Extension area

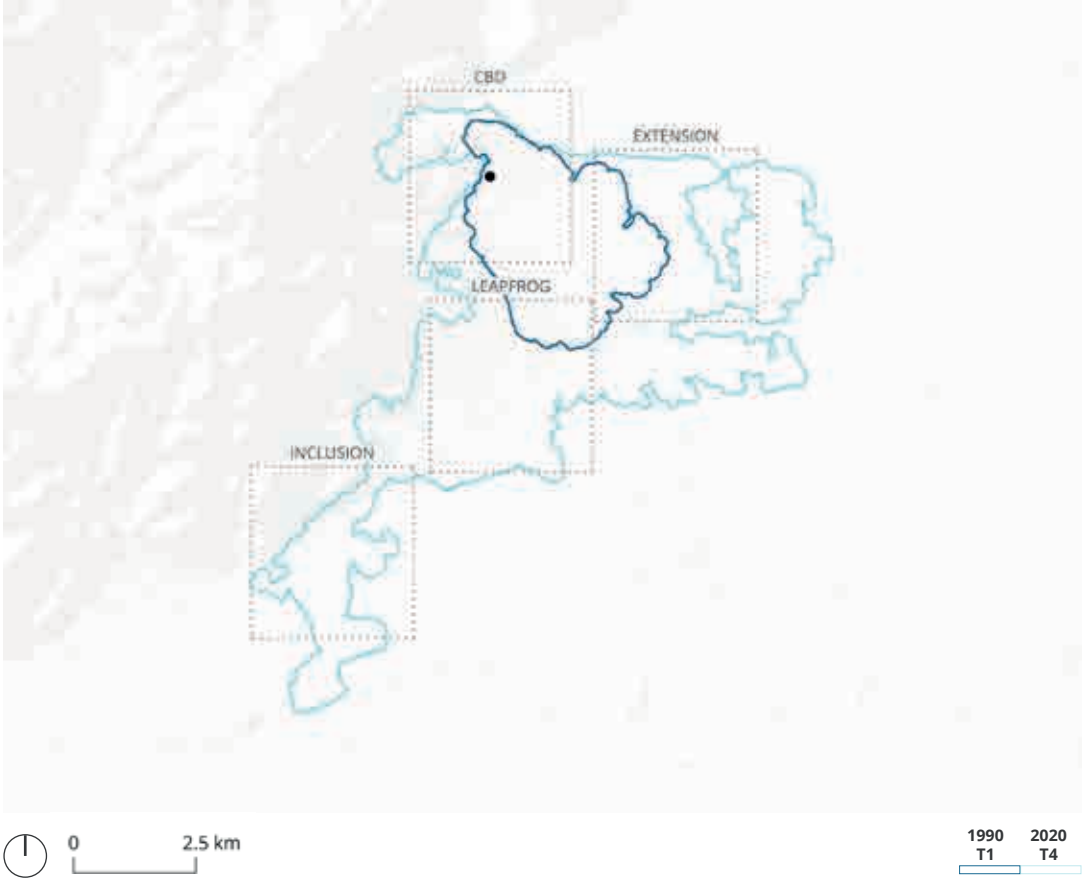


Leapfrog area



Inclusion area


100%
80%
60%
40%
20%
0%
41%
42%
14%
56%
24%
17%
21%
34%
15%
31%
Infill added area
Extension added area
Leapfrog added area
Inclusion added area
T1-T2
avg Infill 38%
avg Extension 30%
avg Leapfrog 11%
avg Inclusion 21%
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avg Infill 34%
avg Extension 29%
avg Leapfrog 12%
avg Inclusion 24%
T3-T4
avg Infill 37%
avg Extension 26%
avg Leapfrog 10%
avg Inclusion 27%


CBD
EXTENSION
LEAPFROG
INCLUSION
0
2.5 km
1990 T1
2020 T4

Assessing Urban Growth in Campo Grande, Mérida, San Salvador

Campo Grande, Brazil

Julia Paiva

with contributions by Martim Furtado

INTRODUCTION

The process of expansion in Brazilian cities is diverse across the country, considering its continental dimensions. Moreover, Brazil is a highly urbanized country, with over 84,3% of its population living in urban concentrations.[1] Despite the significance of cities, the country's average urban density is quite low, at 24 inhabitants per square kilometer.[2] This low population density is mostly settled in precarious urban infrastructure.

Campo Grande (MS) is one of the 27 capitals of Brazil, located in the central region of the country. It has a population of 897.938 inhabitants, according to the IBGE[3] 2022 Census. Campo Grande was the fifth city in which the urbanized area grew the most over the last three decades compared to other Brazilian cities.[4] In the past 22 years, the population has grown nearly 31%.[5]

Campo Grande is the 17th municipality in population size in Brazil. However, the city has the 13th largest urbanized area in the country. Therefore, Campo Grande has a significant urban extent compared to other Brazilian cities and a low population density with an average of 111.09 inhabitants per square kilometer (IBGE, 2022). As a comparison, the city of Uberlândia (Minas Gerais) with a similar population (713,232 inhabitants), has a density 56% higher: 173.32 inhabitants/km^2.

The terrain over which the city of Campo Grande extends is composed of low altitude hills,[6] averaging 5° in slope with few steeper areas alongside creeks. These hills sit right at the division between two major river basins in South America, the Paraná and Paraguay river basins, along the Maracajú range. Due to the city's flat topography, rivers and creeks formed along valleys do not display significant water volume. Moreover, Campo Grande is located in a dry savannah biome (*Cerrado*).[7]

The economic growth has been driving demographic growth and territory occupation. The expansion of economic activity, especially in commerce, services, and agribusiness has driven the demand for jobs and opportunities in the city, attracting migrants from rural areas of Mato Grosso do Sul and other regions of the country, as well as immigrants from Latin American countries such as Paraguay, Bolivia, Venezuela, and Haiti.[8]

Over the past 20 years, the city of Campo Grande has actively expanded its economic activity, attracting these migrants as new residents. As a result, Campo Grande has the 14th largest GDP among the 27 Brazilian capitals (R$30,121,789,000), with the same ranking in terms of GDP per capita (R$ 33,243.63 per inhabitant).[9] Another important consequence of this growth was the territorial occupation increase, both in terms of urban expansion and densification of existing areas.

Since 1960, unplanned growth and lack of infrastructure have led to urban fragmentation and horizontal expansion of the urban fabric.[10] Urban expansion of residential units for all income levels has mainly occurred towards the peripheral areas of the city, whilst the city center remained as a locus of employment and services. Thus, this process pushed the city's limits and collaborated on strengthening mobility axes for commuting residents toward their workplaces.

Differently from other capitals, Campo Grande is not linked to neighboring towns, due to its extensive territory (809.295 ha) and great distance to adjacent towns, more than 30 km[11]. Despite the distance to other towns, Campo Grande is a highly urbanized municipality, in which 98,6% of its population lives in the urban area[12] (Figure 1). In comparison to other LAC cities in this study, Campo Grande has become more dense and spiked its position in increase of Urban Extent Density (inhabitants per urbanized area), 39th to 5th. The increase in Compactness was also significant, rising from 42nd to 2nd, respectively.

This article analyzes the process of urban expansion accompanied by the decrease in population in the central areas of the city. Looking at these dynamics, we particularly engage with the following questions: (1) How was growth accommodated? (2) What forces, other than the plans, influenced the way that growth was accommodated? (3) How did the municipality plan to accommodate growth? (4) To what extent did municipal plans influence the patterns of accommodating growth?

Differently from other capitals, Campo Grande is not linked to neighboring towns, due to its extensive territory (809.295 ha) and to a great distance to adjacent towns, more than 30 km.

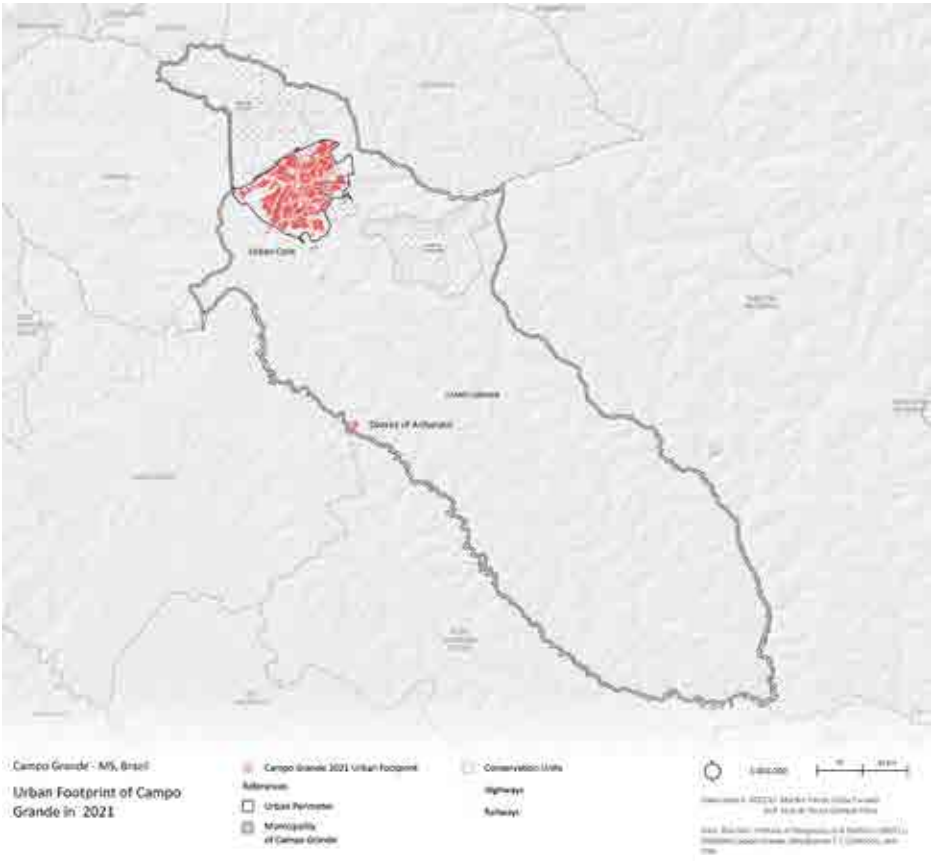


Figure 1: Urban extent within the Campo Grande Municipality.

ASSESSMENT OF URBAN GROWTH

Population Change

Campo Grande has had a considerable increase in population over the years: from 1990-2000, over 26%, decreasing the speed of growth to 14% from 2010-2022. The population density, however, decreased from 1991 to 2000, which suggests that the new population was accommodated in newly developed land, increasing the urban footprint. This tendency has been reversed in the last decade, as the population density increased—even though not as significantly—while the population continued growing (Figure 2).

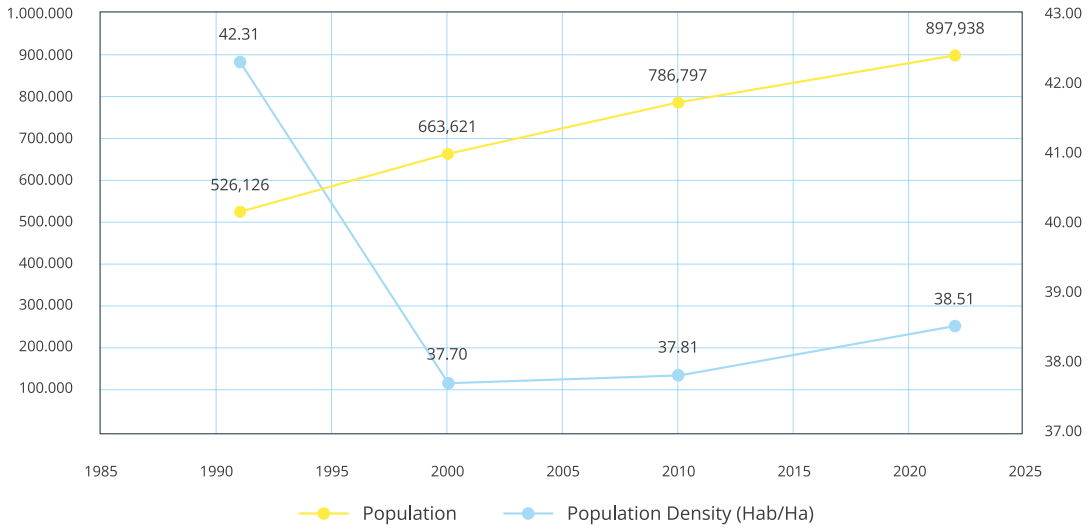
From 1985-2021, the urban area of Campo Grande more than doubled, increasing by 140% – from 9.714,30 hectares to 23.316,89 hectares (Figure 3). This process was not steady, though. Between 1990 and 1994, the city grew the most in five years (25%) and after that, the added area rate decreased over the years. Since 2004, Campo Grande's urban footprint has increased by less than 7% each five-year term, reaching a 4% increase in the urban extent between 2015 and 2019.

Expansion of the Urban Footprint

Most of its urbanized area (96% in 2021) lies within the urban perimeter defined by the planning authority of Campo Grande.[13] The surroundings of the urban perimeter are defined as an urban expansion area, which accounted for 1,68% of the urbanized area in 2021. This area overlaps with two conservation units—APA[14] da Ceroula and APA do Lageado—which allow for controlled settlement. As for the shape of the urban extent, it extends quite evenly in all directions.

The high urban population, however, does not reflect a high urban density, as the average density of the urban area in 2022 was 38,5 inhabitants per hectare. The urban density and urban growth in Campo Grande are concentrated in the peripherical neighborhoods adjacent to the Centro Urban Region. A notable exception is the northern neighborhoods southwest of the center —Taquarussu, Jacy, Piratininga, and Guanandi—which despite decreasing in population are still amongst the densest areas.

In order to interpret the urban expansion of the city, considering the diversity of its neighborhoods, census and MapBiomas data were aggregated at the neighborhood level. Further on, clusters were defined by annual saturation of the neighborhood administrative area—in other words, the ratio of urbanized area and the total area of the neighborhood (adapted from Greenlee, 2022). As a result, three clusters were formed. This paper provides an analysis of the city demonstrating that the neighborhoods within each cluster have a more similar behavior. In sum, the clusters are characterized by (1) saturated perimeters with slow growth; (2) intermediate saturation and growth; and (3) unsaturated perimeter with fast growth.



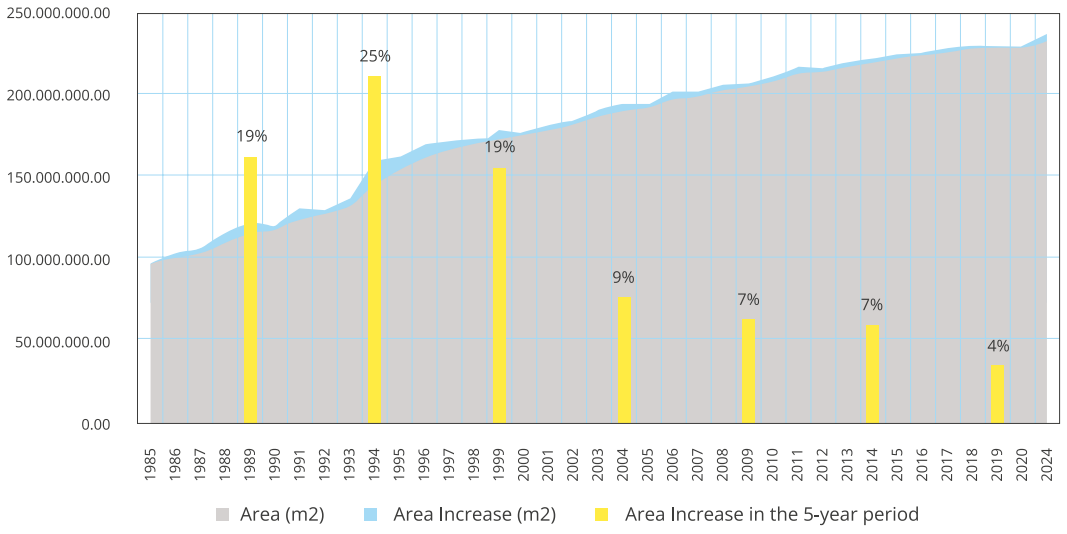


Figure 2: Graphic of Population and Population Density. Data: IBGE and MapBiomas.

Figure 3: Graphic of Urban Area and Increase in Urban Area by Year. Data: MapBiomas.

The expansion of economic activity has driven the demand for jobs and opportunities in the city, attracting migrants from other regions of the country, as well as immigrants from Latin American countries.

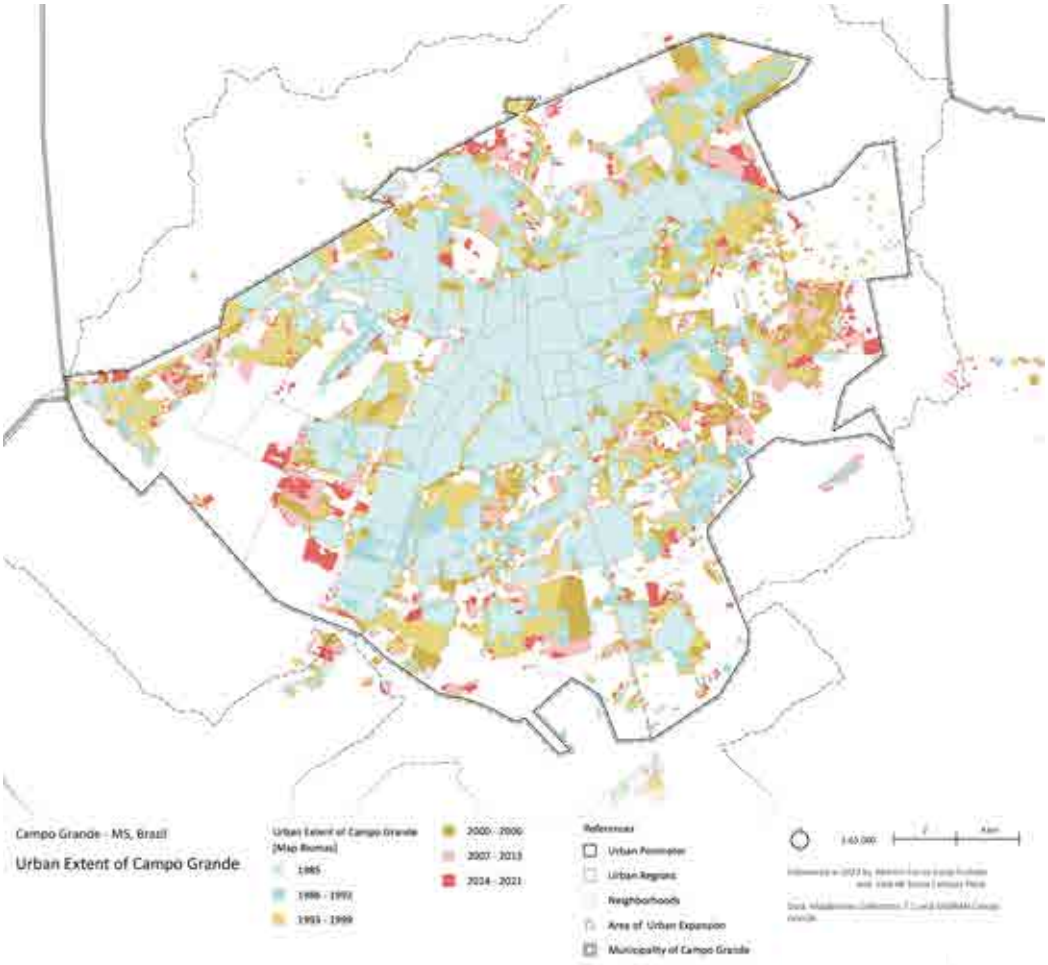
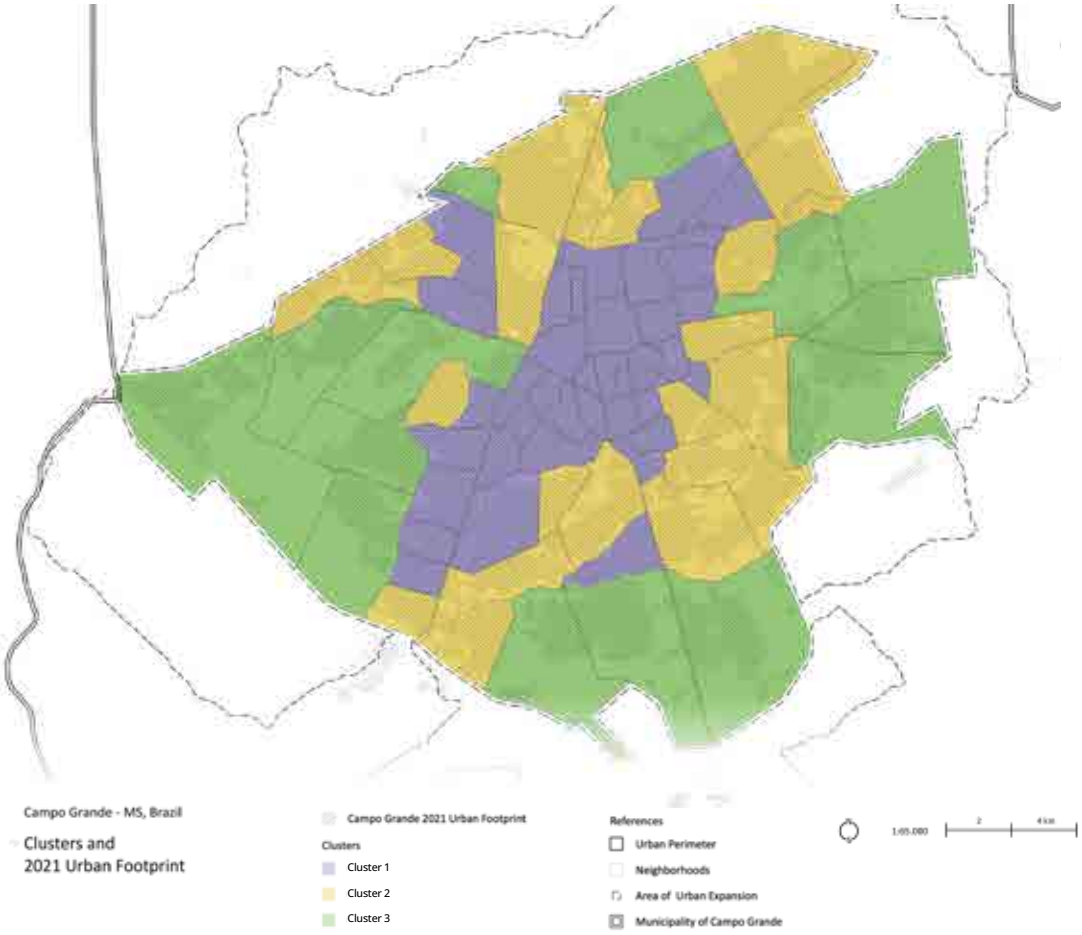


Figure 4: Urban Footprint Expansion in Campo Grande. Data: MapBiomas (2023).

Clusters are characterized by (1) saturated perimeters with slow growth; (2) intermediate saturation and growth; and (3) unsaturated perimeter with fast growth.



Average Saturation of the Neighborhood Perimeters by the Urban Extent Area

Cluster	1985	1990	1995	2000	2005	2010
1	77 %	82 %	88 %	92 %	94 %	95 %
2	23 %	30 %	48 %	60 %	67 %	72 %
3	9 %	12 %	19 %	23 %	27 %	32 %

Figure 5: Map and table describing average saturation by cluster.

Comparing the population change by neighborhood, one can note that most of them are increasing in population, while the central area is losing population (Figure 6).

Neighborhoods in the outer limits of the urban area appear to have the highest increase in population, particularly Centro-Oeste and Noroeste neighborhoods. The area east of the city center had the highest population growth, peaking in the Noroeste neighborhood.

The areas which had a decrease in population are within the oldest urban extent and had reached almost complete saturation of the neighborhoods' perimeters already by 1985 (cluster 1). This suggests that there is a vacancy of already-developed land. Conversely, the increase in population matches the areas more recently urbanized. Once again, the neighborhoods of Centro Oeste and Noroeste are clear examples of neighborhoods that have been intensely developed after the 2000s. Chácara Cachoeira neighborhood, east of the center, is amongst these and had by far the highest increase in population. Neighborhoods that have undergone the most recent urbanization, which are located in the peripheries of the city (cluster 3), present different patterns of population density and growth, demonstrating different patterns of urbanization in each neighborhood.

To assess the reflexes in the shape of the city produced by the urban expansion presented in Figures 2 and 3, the exchange index[15] was calculated for each year. The higher the percentage of the index, the more compact the shape of the urban footprint. Thus, Campo Grande's urban expansion seems to have produced a progressively more compact shape, with a growing exchange index; its growth also resembles the increase of the urban extent seen in Figure 7. In Figure 8, in 2021 most of the urban extent can be found within its correspondent equal area circle. Considering the high correlation of the exchange index to proximity[16] and cohesion[17] indexes, Angel et al. (2018), the urban expansion in Campo Grande has mostly likely undergone a reduction of travel distances, an increase in accessibility within the urban footprint, and "concomitant positive effects for sustainability".[18]

Figure 7 presents the average increase in the exchange index and the urban extent area, as well as the average exchange index for the five years. Despite the increase in the overall exchange index, this index has been increasing at a slower rate than it did in previous periods, just as it is for the increase in the urban extent.

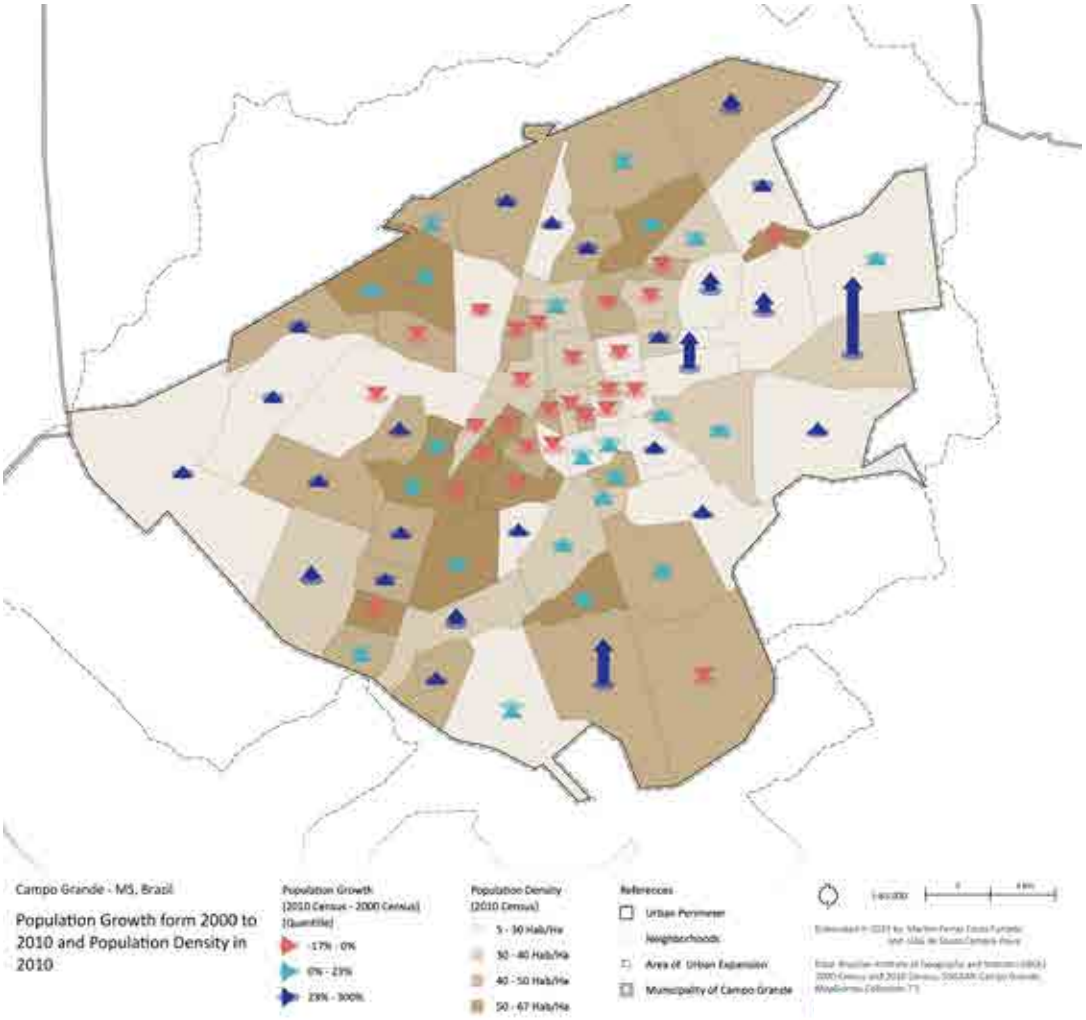


Figure 6: Population Growth from 2000 to 2010 and 2010 density in Campo Grande.

Despite the increase in the overall exchange index, this index has been increasing at a slower rate than it did in previous periods, just as it is for the increase in the urban extent.

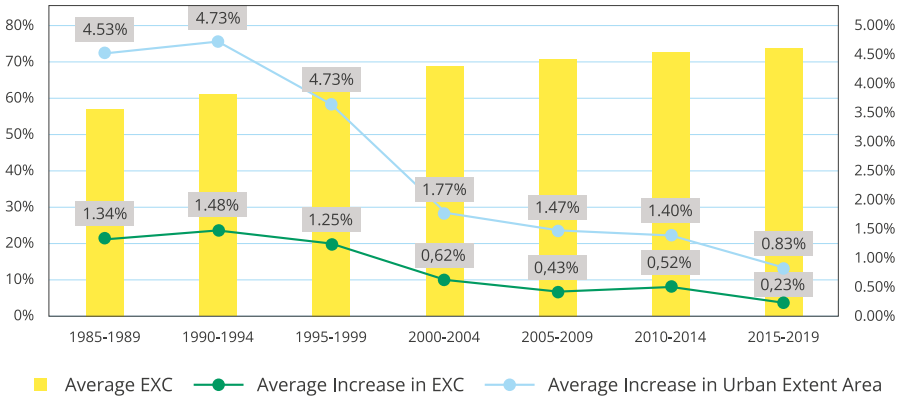


Figure 7: Average Increase in Exchange Index (EXC) and Urban Extent Area.

The increase in compactness in Campo Grande suggests a reduction of travel distances and commuting times, more efficient use of urban infrastructure, and concomitant positive effects for sustainability.

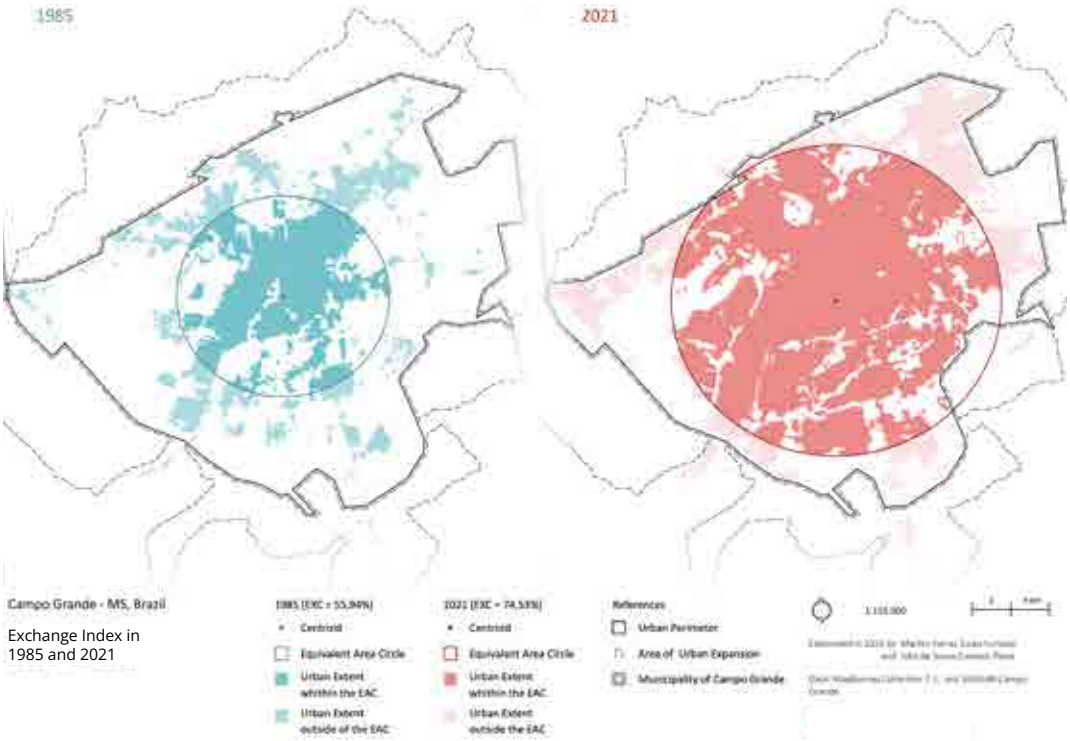


Figure 8: Exchange Index in 1985 and 2021.

The density of dwelling units[19] is of particular interest as Angel et al. (2018) show how this measure is highly correlated to other attributes of a city relevant to the assessment of its compactness: the city's population density, the degree to which the urban extent of the city is saturated by its built-up area and the density of residential floor space in the city.[20]

Cluster 1, in the city center, houses the densest neighborhoods, most with more than 13,3 dwelling units per hectare, above the city average dwelling density of 12,5 D.U./Ha. Within cluster 1, the southern neighborhoods present the highest dwelling density in D.U. Cluster 2, intermediate saturation and growth, presents a lower D.U. density than the city average, most between 9,3 and 13,3 D.U./Ha. Cluster 3 presents D.U. densities below the city average, as expected of neighborhoods with low saturation of the neighborhood area by the urban extent.

Campo Grande experienced an overall decrease in population density, while there has been an overall increase in dwelling density between 2000 and 2010—the decrease in dwelling density is scattered across all clusters (Figure 9).

Cluster 1 presents the slightest increase in dwelling density and the most concentrated population density loss. This points to a scenario in which there is probably a decrease in the average of inhabitants in a dwelling unit and a modest real estate activity. On the other hand, cluster 2 presents an overall increase in dwelling density and an increase in population density. This confirms that these neighborhoods are where the most significant urban growth happened between 2000 and 2010. Once again, the Chácara Cachoeira neighborhood stands out with the highest population and dwelling density growth. In cluster 3, it is possible to see that most neighborhoods that had an increase in population density had also an increase in dwelling density, and vice versa.

According to census data, vertical development (multifamily housing with more than one floor) is mainly concentrated in the central region of the city, within cluster 1. Some apartment units can be found in peripherical neighborhoods due to specific housing developments in both clusters 1 and 2. Overall, single-family houses are predominant throughout the city and almost exclusively compose cluster 3.

Most of the real estate production is concentrated in the neighborhoods within 15 minutes by car from the center, in neighborhoods such as Santa Fé, Carandá, Cruzeiro, and São Francisco. Horizontal developments are concentrated in the neighborhoods of Aero Rancho, Rita Vieira, Noroeste, and Nova Lima, with a standard lot of 360 m^2 at about 15 to 25 min away from the center.[21] Despite vertical developments in more central areas, these have not necessarily contributed to the densification of the center.[22]

Looking at the percentage of rented units in Campo Grande, one can note that private property predominates. Rented units predominate within cluster 1, with some neighborhoods reaching more than 40%. Neighborhoods in cluster 2 have

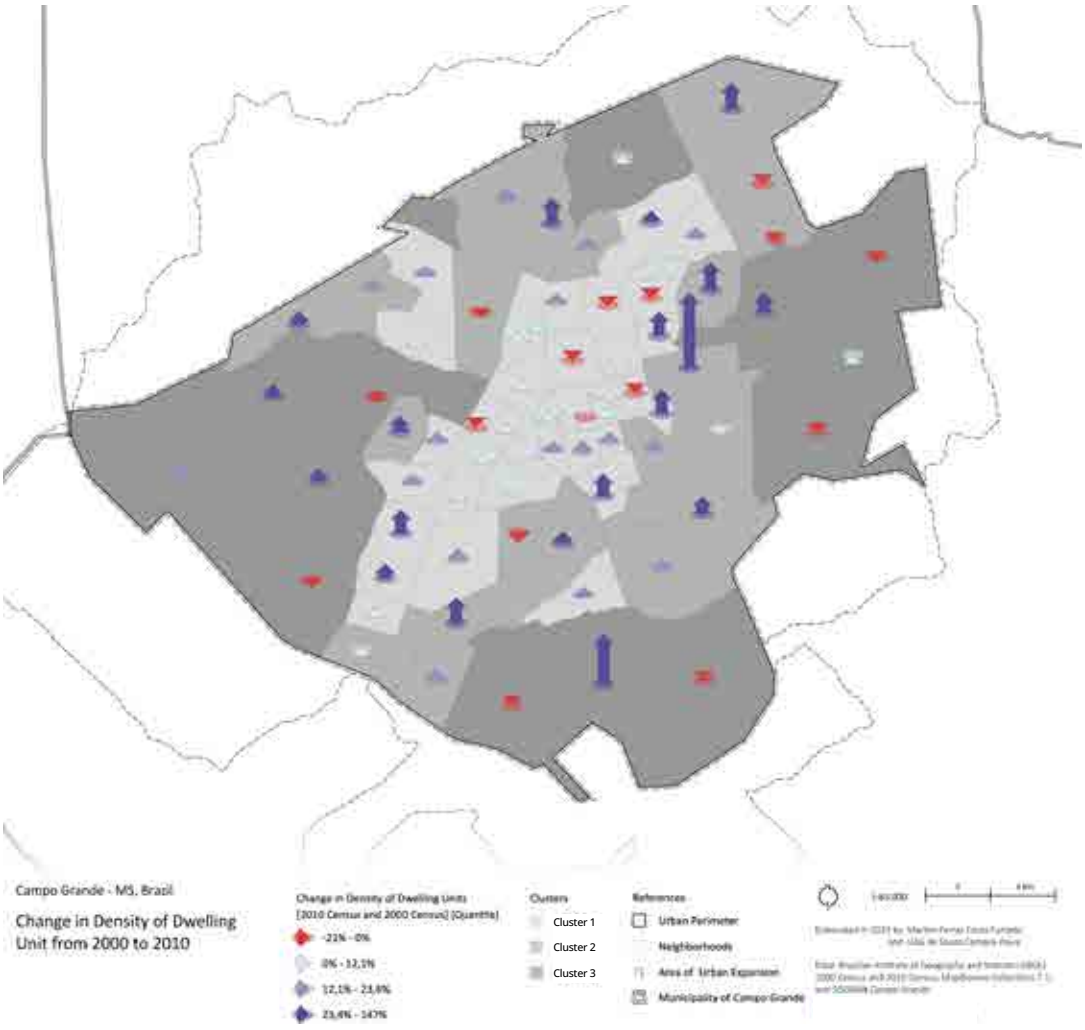


Figure 9: Change in Density of Dwelling Units from 2000 to 2010.

considerable amounts of rented dwelling units, around 20%. The higher percentage of apartments are verified in central neighborhoods of cluster 1. Thus, there seems to be a relevant correlation between apartment and rented units' concentration.

Looking at the built area of each plot in Figure 10 shows a concentric pattern in which the highest areas are in the central neighborhoods and the lowest built areas, are on the edges of the city. This centrality of the highest built-up areas seems to elongate outward along radial roads that connect the outskirts to the center. This is particularly clear in the southern neighborhoods of cluster 1.

In Campo Grande, around 5,000 units are produced annually by the formal real estate market. The region to the east of the city center is one of the most prized by the real estate market, as the president of SECOVI[23] stated, "Prosa[24] is the most desirable region that represents a high demand for housing".[25] The valorization of real estate in the central region, on the other hand, is attributed to the investments in revitalization and commercial characteristics.[26]

Considering the period of 2013 to 2017, Campo Grande went through an "expansion inertia".[27] As stated by Souza,[28] this was caused by the (i) approval of land subdivisions on the edges of the city for all income profiles; (ii) excess in vacant plots in these areas; (iii) underutilization of empty plots in the central area; and (iv) development of horizontal housing projects in the areas outside of the center.

Particularly about the vacancy of already developed land, the 2022 Census shows that 13,64% (or 53.546) of Campo Grande's dwelling units are vacant. This presents a significant growth in vacant dwelling units, as according to the 2010 census Campo Grande had 9,29% (or 26.315). In total numbers, the increase in vacant units was 103% from 2010 to 2022, whereas the increase in dwelling units was of just 39%.

Amongst the forces that drive urban growth, a survey conducted by the project Reviva Campo Grande[29] found that most of the population—51,9% of the participants—did not wish to live in the city center. As for the reasons, this survey cites the high housing prices—both for sale and rented units—, lacking opportunities for medium and low-income families, as well as the general perception of the city center as an unsafe area. The survey also mentions that buildings are perceived as not well-preserved or old and that it is hard to find apartments with parking lots.

Further on, a 14% increase in real estate valorization was observed in 2022, which ranks Campo Grande as the third capital with the highest land value increase.[30] According to FipZap Index,[31] Campo Grande has the lowest real estate price, amongst capitals—at R$5.232,00 per square meter.[32] This price changes intensely within the city, reaching R$7.245,00/$m^2$ at its highest and R$2.900,00/$m^2$ at its lowest. The president of SECOVI stated that this is a moment when housing is accessible to most of the population and describes Campo Grande as a city that attracts new inhabitants and economic opportunities, as well as has good urban quality.[33] In alignment, the president of the Regional Council of Real Estate Realters of Mato Grosso do Sul (CRECI-MS) stated that the current valorization of real estate

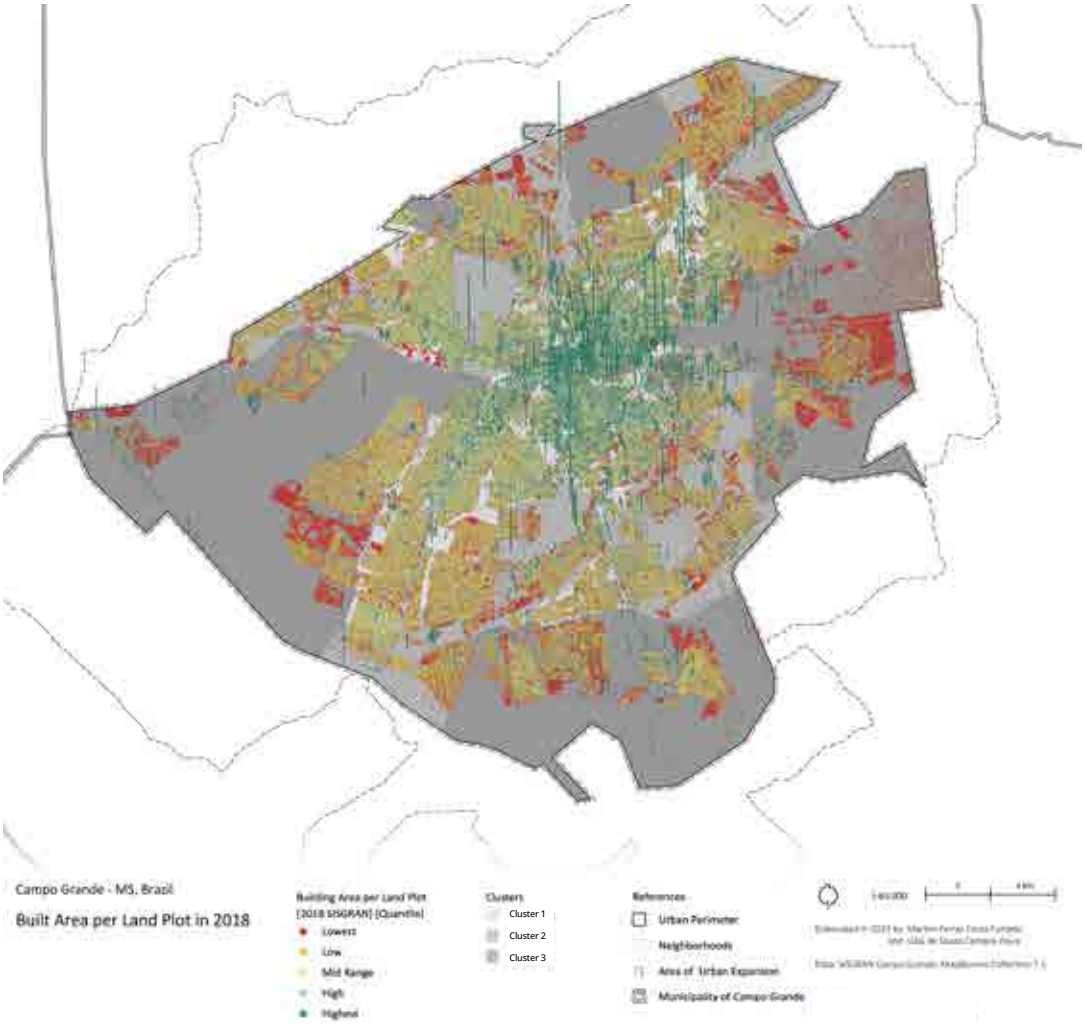


Figure 10: Built Area per land plot in 2018.

in Campo Grande was already expected, as real estate had been expanding even through the pandemic and construction costs have risen.[34]

The appraised land value[35] of the city in 2018 is presented in Figure 11. First, it should be noted how the land with the highest value is concentrated in the more central neighborhoods and to the east. Considering the highest land values, cluster 1 concentrates most of the plots, with a significant presence of high land value plots in cluster 2 as well. Cluster 2 seems to be the place of most contrast in appraised land value, with values ranging from highest to lowest quantile within several of its neighborhoods. Cluster 3 presents overall lower values, where agglomerations of the lowest land value can be easily spotted. There are significant exceptions within the neighborhoods, as well as in the case of Veraneio and Chácara dos Poderes neighborhoods—both to the east, that present the highest land values.

Improvised dwellings[36] had a drastic decrease from 2010 to 2022: from 560 in 2010 to 146 in 2022; in other words, nowadays there is only one-fourth of the improvised dwelling units that existed in 2010. Considering the 2010 spatial distribution of improvised dwellings, most could be found in cluster 1, especially to the south of the central area. In this cluster, the neighborhood of Coronel Antonino stands out as being not only an area of high concentration of improvised dwelling units but also as having a high total number of these units. Neighborhoods to the east of the center, where there has been a significant increase in dwelling units' density and population density present low percentages of improvised dwellings. This contrasts with the dense areas in cluster 1 to the south, where there was a loss of population and there is a significant percentage and gross amount of improvised dwelling units.

Urban Infrastructure

The assessment of Campo Grande's access to basic infrastructure was made by creating indexes based on data from the 2000 and 2010 censuses. The first index, sanitation index, allows to compare the changes in access to sewage and water from one census to the other. First, it is possible to see that only three neighborhoods have undergone a decrease in the index. The highest increase happened in cluster 1 just around the central area, as well as in four peripheral neighborhoods in cluster 1. Cluster 2 had a very moderate increase in Sanitation Index. The central area as well as the neighborhoods that had the highest increase in sanitation access also have the highest values of Road Infrastructure and Sanitation Index;[37] cluster 1 comprises most of these neighborhoods.

Considering the recent and intense urbanization processes identified in Noroeste and Chácara Cachoeira neighborhoods, the first had a low increase in sanitation index and presents extremely low Road Infrastructure and Sanitation Index Values, while the second underwent high increase in sanitations index and presents a high Road Infrastructure and Sanitation Index.

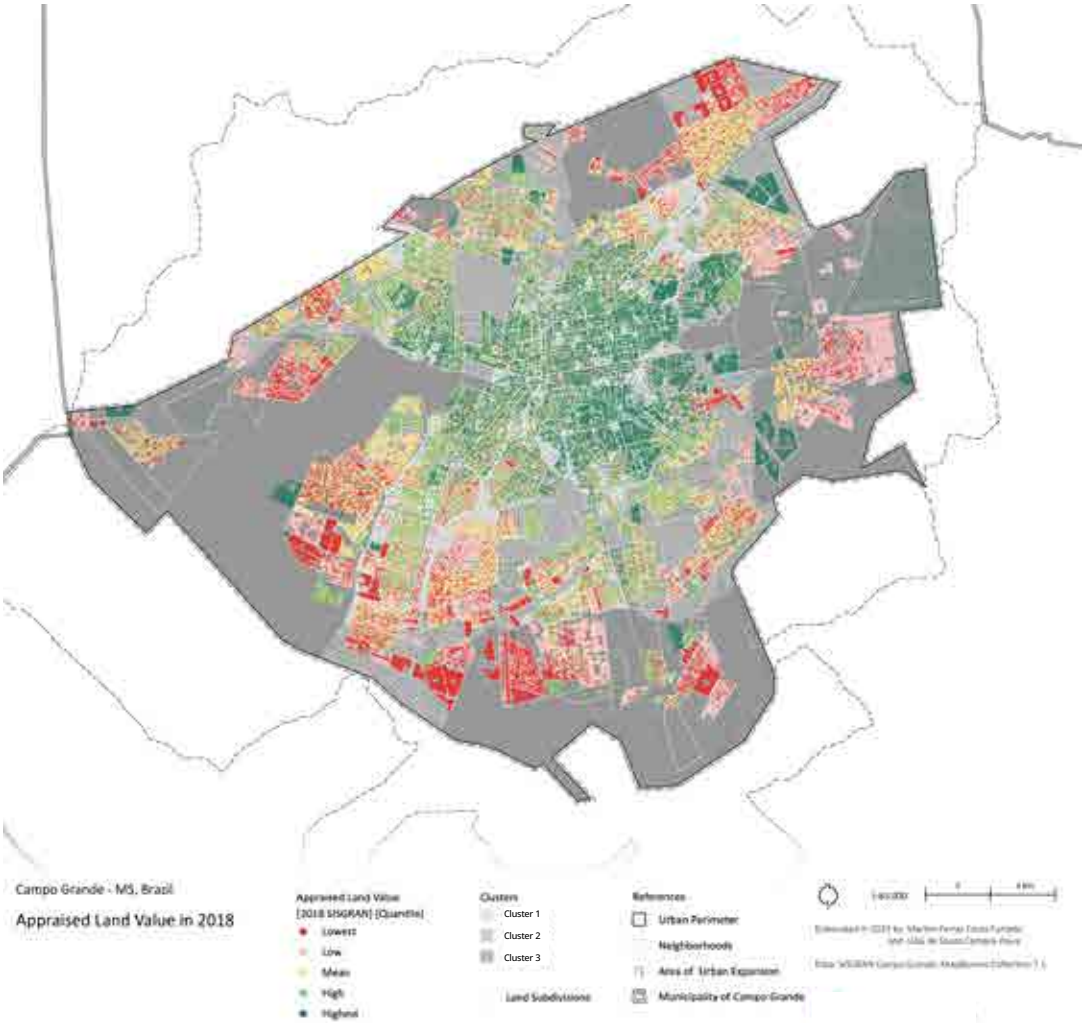


Figure 11: Appraised Land Value in 2018.

Cluster 2 seems to have undergone a moderate increase in sanitation index values and presents average road infrastructure and sanitation index values. This suggests that the significant urban growth identified previously in this report does not necessarily contribute to a significant increase in access to basic infrastructure. Had this been the case, cluster 2 would have presented more significant increases and values. What is clear analyzing the radial structure of Campo Grande, which presents an expected pattern of better access to infrastructure in central neighborhoods which progressively decays as neighborhoods are distant from the center. Moreover, it seems that old neighborhoods far away from the center seem to have had less investment in access to infrastructure than their contemporaries closer to the center.

Campo Grande's urban growth was assessed using a clustering methodology to provide a broader understanding of such dynamics. The main characteristics of each cluster are presented as follows.

Cluster 1 — saturated perimeters with slow growth—encompasses older areas of the city, within or not the city center. This probably contributes to the heterogeneity in neighborhood's dynamics seen within this cluster. Neighborhoods closer to the city center display population loss and a decrease in the densities of inhabitants and dwelling units. Those more distant to the city center do present these trends overall, though less drastically—some even slightly invert trends. This is the most consolidated cluster, where most rented apartment units are found, but this is not reflected in higher values in density.

Cluster 2 — intermediate saturation and growth—seems to be the most homogenous of all three clusters. There has been an overall increase in population as well as in densities of inhabitants and dwelling units. Urban expansion in this cluster seems to have contributed the most to the city's increase in compactness.

Cluster 3 — unsaturated perimeter with fast growth—revealed to be the most heterogeneous in terms of urbanization processes. Inverted trends can be seen in adjacent neighborhoods in most maps, displaying an important contrast despite spatial proximity. However, there is a significant increase in improvised dwelling and dwelling density in most neighborhoods. Therefore, the urban expansion of Campo Grande in peripherical neighborhoods is a complex process and produces distinct neighborhoods.

Contrasts in neighborhoods within clusters 1 and 3 illustrate what seems to be one of the greatest challenges for Campo Grande: the provision of adequate infrastructure. The disparity in infrastructure is verified by comparing more recent and older urbanized areas but also in several neighborhoods that have been urbanized for long—particularly the southern and northern neighborhoods inside cluster 3.

Dynamics in clusters 1 and 2 were inversed. As neighborhoods in cluster 1 had a decrease in population and a low increase in dwelling density, cluster 2 had an increase in both. This suggests that the infill process seen in cluster 2 is also to population migration from cluster 1, besides the overall population growth of the city.

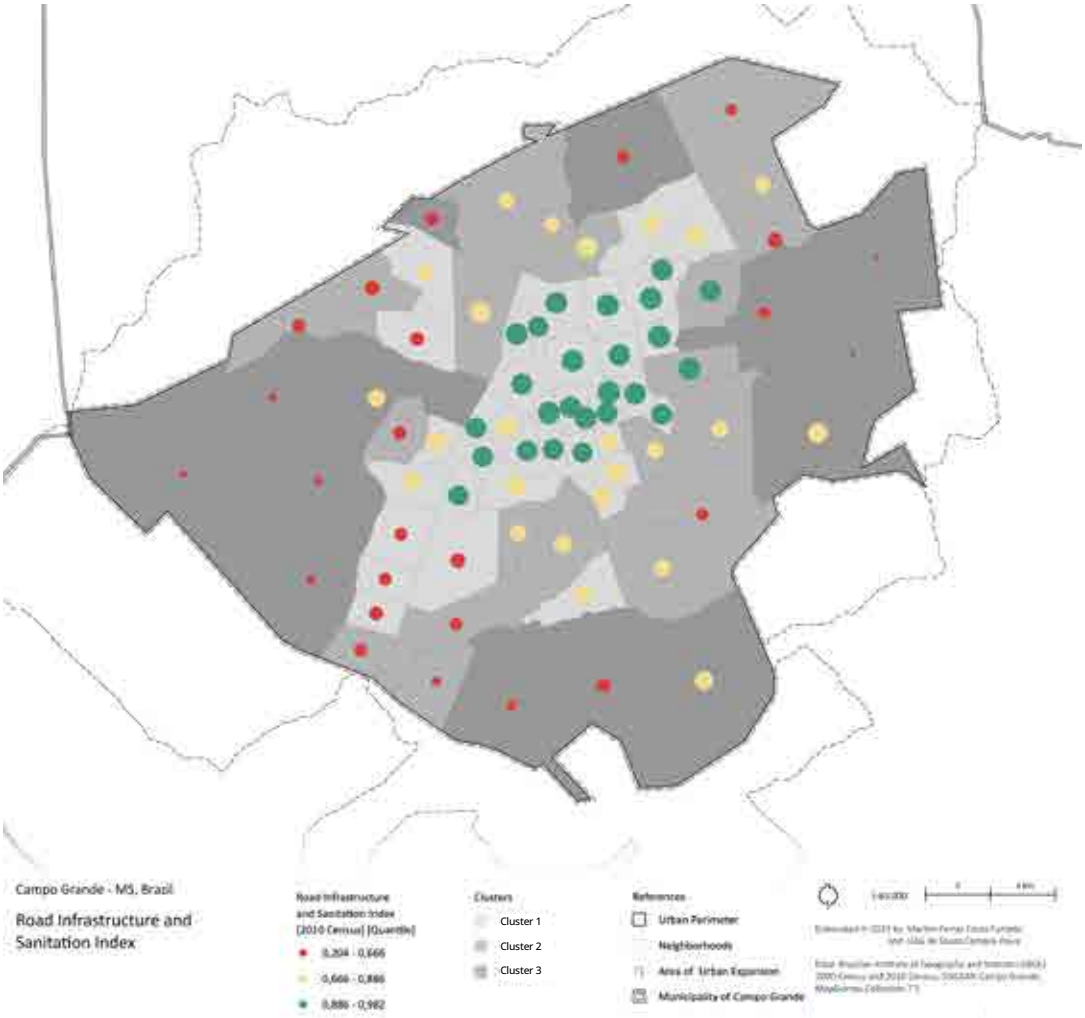


Figure 12: Road infrastructure and sanitation index.

Campo Grande's urban growth was assessed using a clustering methodology to provide a broader understanding of growth patterns. The main characteristics of each cluster are presented as follows:

Cluster 1 — saturated perimeters with slow growth—encompasses older areas of the city, within or not the city center. This probably contributes to the heterogeneity in neighborhood's dynamics seen within this cluster. Neighborhoods closer to the city center display population loss and a decrease in the densities of inhabitants and dwelling units. Those more distant to the city center do present these trends overall, though less drastically—some even slightly invert trends. This is the most consolidated cluster, where most rented apartment units are found, but this is not reflected in higher values in density.

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Cluster 1
saturated perimeters

Cluster 2
intermediate saturation

Cluster 3
unsaturated perimeters

Urban Fabric in
Campo Grande's Clusters

N
S

200 400 m

Elaborated in 2024 by Martim Furtado and Julia Paiva
Data: Google Maps Satellite Imagery

Figure 13: Aerial imagery illustrating the urban fabric of Campo Grande according to the neighborhood clustering.

POLICY AND STRATEGIC RESPONSES TO URBAN GROWTH AND DENSIFICATION

In 1988, the municipal zoning law[38] established the urban perimeter. The city new limits settled a clear division between areas that could receive urban improvements to be part of the real estate market and areas that should remain for primary activities, such as farming. As a result, the urban occupation in rural areas was disincentivized. Even so, the urbanized area has significantly increased within the urban perimeter.

The progression of land subdivision presented in Figure 14 shows how the urban perimeter has not changed much since 1988, but many new developments have expanded the urban occupation. The progressive saturation of this urban perimeter could also be related to the current valorization of real estate in Campo Grande. According to Souza,[39] the new land subdivision is on average 20% vacant, which is even higher in the case of gated condominiums: 40%. These accounts indicate that real estate is one of the key drivers in the expansion of the urban footprint of Campo Grande.

Campo Grande's land policy has been primarily organized by the Urban and Environmental Development Master Plan of Campo Grande.[40] It is in alignment with national guidelines for municipalities, as it adheres to the provisions set forth in the City Statute (*Estatuto das Cidades*), outlined in Federal Law No. 10.257/2001. The City Statute serves as a comprehensive legal framework for urban development and planning, emphasizing the principles of social function, sustainability, and inclusive growth.

Moreover, transportation and mobility planning also receive significant attention in Campo Grande's policies, as evidenced by the Transportation and Urban Mobility Master Plan. This plan is in accordance with the guidelines of the National Urban Mobility Policy (*Política Nacional de Mobilidade Urbana*), as specified in Federal Law No. 12.587/2012. The National Urban Mobility Policy emphasizes the need for integrated and multimodal transportation networks, prioritizing pedestrians, cyclists, and public transit users while promoting the rational use of private vehicles.

The urban policy of Campo Grande, in Mato Grosso do Sul, suggests densification through its latest Master Plan (PDDUA/2018)[41] and associated legislation and plans, such as the Plan for the Revitalization of the Center (2010). The Master Plan defines three macrozones within the urban perimeter, intended to guide the densification of the central region (MZ1), occupying unused or underutilized lots to increase population density and balance economic activities with residential use. The region between the city center and the periphery (MZ2) prioritizes densification, encouraging higher population densities, and encompasses most neighborhoods in the city. The last zone (MZ3) encompasses peripherical neighborhoods and suggests future densifications, as the city grows.

The PDDUA also aims to promote compactness of neighborhoods and urban density compatible with the territory's capacity, public transport, installed infrastructure, and environmental quality. To achieve this, the Master Plan introduces guidelines for land use and control, environmental protection, and potential for densification

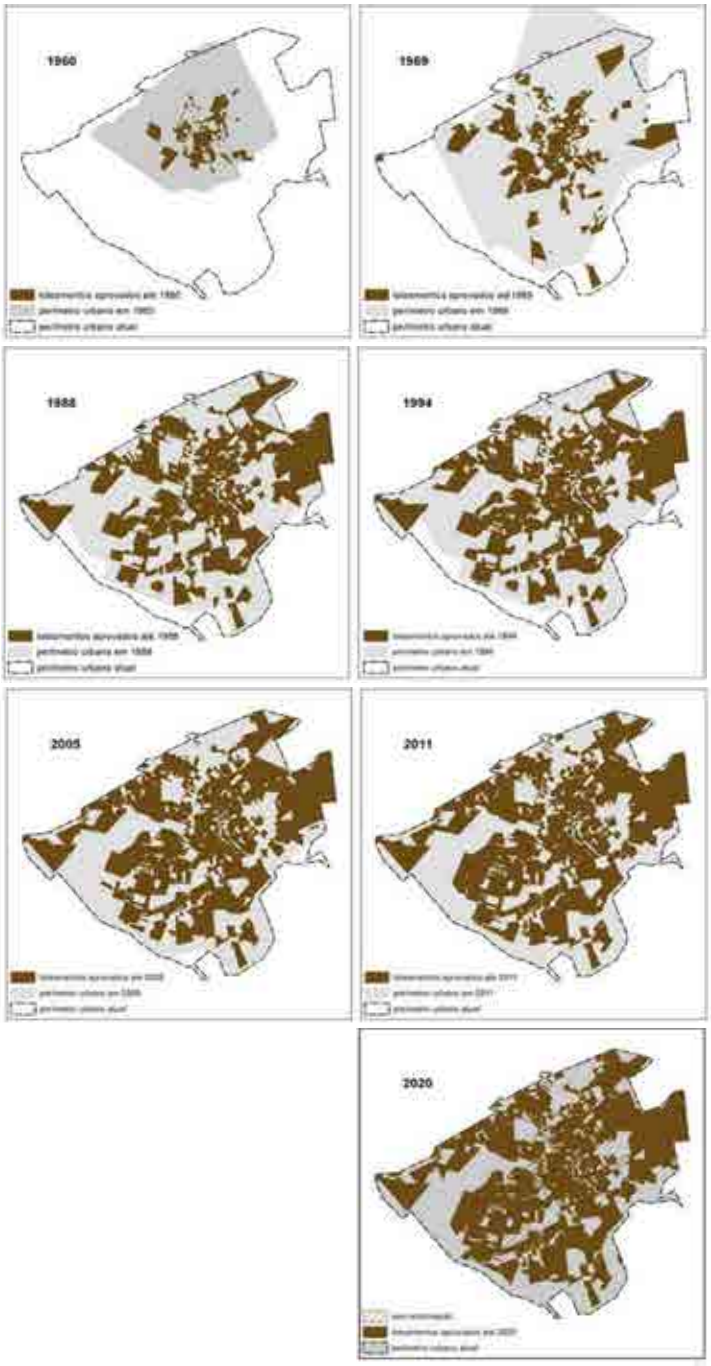


Figure 14: Evolution of the Urban Perimeter and Urban Occupation 1960 - 2020.[42] Source: Planurb.

within these Macrozones. The expected density of each macrozone is 330, 240, 120 inhabitants/ha for MZ1, MZ2, MZ3 respectively.

The PDDUA, associated with the Urban Transportation and Mobility Master Plan (2015), emphasizes Transit Oriented Development (TOD) principles, proposing housing near the central region and over the transport axis to minimize travel distances and stimulate non-motorized modes of transportation. It foresees the expansion of sidewalks, pedestrian zones, cycle paths, and bicycle parking in strategic locations near public transport corridors, facilitating the integration of different modes of transportation and reducing dependence on private vehicles. Moreover, the plan focuses on the central region for real estate expansion and densification, utilizing existing infrastructure efficiently. However, the plan could benefit from more defined rules for densification both in the central area and in the other regions of the city.

The existence of many urban voids poses great challenges to the objectives of the PDDUA. While both the Master Plan and the Urban Mobility Plan support densification, their effective implementation depends on the production of accurate data, public participation, and mostly the coordination of these plans with other urban policies addressed to Campo Grande, in order to promote sustainable and well-connected urban growth.

The same master plan, controversially, suggests policies that can lead to urban sprawl despite their efforts toward densification. It designates several areas around the city for Urban Consortium Operation (OUC) ventures, allowing private and public sectors to promote new real estate development. The distribution of these OUC areas favors developments over transport corridors and areas on the boundary between urban and rural zones rather than densifying the city center. The lack of comprehensive studies to measure the OUC ventures also raises concerns about their potential contribution to sprawl.

The Urban Transportation and Mobility Master Plan of Campo Grande also contains elements that could contribute to urban sprawl. While it aims to improve urban mobility and promote sustainable transportation, the plan proposes an increase in road capacity in the urban axes without clear guidelines for densification along those axes. This emphasis on road expansion can facilitate urban sprawl by encouraging further development in peripheral areas, rather than focusing on compact and well-connected development in the city center.

From the geotechnical, hydric and topographical analysis of Campo Grande's urban territory, environmental zones were defined in the PDDUA. Each zone has its specific parameters for private and public development, including permeabilization index and environmental relevance index. The latest is an environmental urban parameter of land use and occupation, which aims at improving drainage conditions, residual pollution, microclimate quality, and afforestation. The permeabilization index grows from ZA1 to ZA5, from15% to 30%.

As of 2022, Campo Grande has established the Municipal Committee for Climate Change Confrontation.[43] It is a consultive committee composed of 21 city

and state institutions that intends to advise municipal policy in the design and implementation of instruments to facing climate change – all in alignment with the PDDUA.[44] In 2023, IADB hired research for the committee with an inventory on Campo Grande's greenhouse emissions, as to guide municipal policies towards sustainable decarbonization.[45]

CONCLUSIONS

The urban development of Campo Grande and the expansion of the city's extent are processes greatly shaped by real estate dynamics in the city. Land subdivision development seems to be a thriving business despite the not-so-steep increase in population and the city regulation's attempt to promote densification in central areas. The significant increase in dwelling units might further suggest this phenomenon.

Though the urban area of the city lies within a single municipality—and thus abides to a common urban regulation framework—different urbanization processes have been identified mainly in the city's expansion. This diversity is observed in the characterization of dynamics in the three neighborhood clusters. In sum, there seems to be a challenge in promoting population densification in centralities and provision of adequate infrastructure to peripheral neighborhoods despite the efforts of planning guidelines set by the municipal framework—mostly the PDDUA and Urban Mobility Plan.

When assessing the shape of the urban extent of Campo Grande, there is an increase in compactness and homogeneity of urban expansion after 1994 suggesting that after this period there was a more efficient management of urban sprawl. Neighborhoods in cluster 2 have become almost saturated and denser. However, this increase in compactness might not have resulted in an overall increase of population density—as would be expected by the goals set by the Master Plan.

An important aspect of the city's Master Plan is the focus on the environmental zoning. Though goals set by this law are aligned with those of the Urban Transportation and Mobility Master Plan (2015), there is little coordination between the two plans. The recent effort of creating a Municipal Committee for Climate Change Confrontation might be an important step toward more cohesive and sustainable urban planning in Campo Grande.

The scenario presented above indicates that Campo Grande has a planning framework that had a meaningful impact in managing the city's urban growth and expansion. This is further suggested when contrasting the city with other LAC cities in this study, as Campo Grande's rankings spiked in Urban Extent Density and Compactness — though it soared in terms of population growth and increase in urban extent. In all, challenges in already consolidated areas still prevail and new challenges arise, as the city tends to saturate the defined urban area and climate change intensely affects the *Cerrado* biome.

Endnotes

1. According to EMBRAPA, 2017. Available in https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1069928/identificacao-mapeamento-e-quantificacao-das-areas-urbanas-do-brasil, access in 08/09/2023.

2. Data available at: https://www.ibge.gov.br/cidades-e-estados. Accessed on 01/29/2025.

3. Brazilian Institute of Geography and Statistics.

4. The MapBiomas survey indicates the city's growth between 1985 and 2020, based on satellite image mapping. Available at https://mapbiomas.org/

5. Campo Grande's population grew from 683,000 inhabitants (IBGE Census 2000) to 897,938 inhabitants (IBGE Census 2000).

6. In Portuguese, the terrain is named Planaltos Rampeados by https://www.imasul.ms.gov.br/wp-content/uploads/2016/02/Geoambientes-da-Faixa-de-Fronteira-Versao-2016.pdf

7. The city is classified as Aw (Tropical Savannah with dry winters) by the Köppen-Geiger classification as attributed by (https://koeppen-geiger.vu-wien.ac.at/pdf/Paper_2006.pdf)

8. See Correa, Alexandre de Souza et al. Fluxos migratórios no estado de Mato Grosso do Sul (1970-2010) REVISTA INTERAÇÕES, Campo Grande, MS, v. 19, n. 2, p. 325-341, abr./jun. 2018.

9. IBGE 2020. See https://www.ibge.gov.br/estatisticas/economicas/contas-nacionais/9088-produto-interno-bruto-dos-municipios.html?=&t=pib-por-municipio Access in July 10, 2023.

10. L. Y. Queiroz de Oliveira and M. A. de Castilho, "O plano de revitalização urbana da área central de Campo Grande, MS," *Interações (Campo Grande)* 23, no. 1 (2022): 133–48, https://doi.org/10.20435/inter.v23i1.3205. "The exacerbated increase in population, the explosion of the urban fabric, and the unplanned growth observed since the 1960s and onwards, combined with the elaboration of urban ordinances with no civic participation, led to the fragmentation of the urban fabric, the sprawl of urban voids, uncontrolled horizontal expansion, social segregation and the scarce and deficient infrastructure in the areas furthest from the urban center" (free translation).

11. One of Campo Grande's districts is located 43 km to the south of the urban core. Anhanduí is an isolated urban settlement in the intersection of the BR-163 highway and the municipal limit (as seen in Figure 1).

12. Ibid.

13. Campo Grande's urban perimeter is divided into seven administrative subdivisions – the Urban Regions –, each further divided into neighborhoods (74 in total). These neighborhoods are the smallest administrative division set by the municipality.

14. *Área de Preservação Ambiental*, in portuguese. Translates as Area of Environmental Protection.

15. Exchange Index was chosen for this study to assess the urban compactness. This index is calculated as the percentage of the urban footprint area within the Equal Area Circle centered on the urban footprint's centroid (Angel et al., 2016).

16. "The Proximity Index (PRX) of a city is the ratio of the average beeline distance from all points in the Equal Area Circle to its center and the average beeline distance from all points of the city's urban extent to its Central Business District (CBD) identified by its City Hall." (Angel et al., 2018, p. 11)

17. "The Cohesion Index (COH) of a city is the ratio of the average beeline distance from all points to all other points in the Equal Area Circle and the average beeline distance from all points to all other points in the city's urban extent." (Angel et al., 2018, p. 11)

18. Shlomo Angel et al., *Our Not-So-Urban World* (New York: Marron Institute of Urban Management, New York University, 2018), 5.

19. Dwelling units is used here as synonyms of "housing units" and is the term used by different authors when translating the "Unidade Domiciliar" from the Brazilian census.

20. Besides population density, there is no open data on the other attributes for Campo Grande, hence the use of dwelling density as a proxy.

21. F. F. A. Souza, "Relatório Preliminar: Serviços de Consultoria em Viabilidade Econômica e Financeira de Empreendimentos e Intervenções Urbanas" (São Paulo: Trabalho desenvolvido para a Unidade Gestora de Programa do Desenvolvimento Integrado do Município de Campo Grande – Viva Campo Grande II, 2017).

22. Ibid.

23. Real Estate Developers' Union.

24. An eastern Urban Region.

25. *Correio do Estado*, "Com Alta de 14%, Campo Grande Tem a 3ª Maior Valorização Imobiliária Entre Capitais," January 14, 2023.

26. Ibid.

27. F. F. A. Souza, "Relatório Preliminar: Serviços de Consultoria em Viabilidade Econômica e Financeira de Empreendimentos e Intervenções Urbanas" (São Paulo: Trabalho desenvolvido para a Unidade Gestora de Programa do Desenvolvimento Integrado do Município de Campo Grande – Viva Campo Grande II, 2017).

28. Ibid.

29. Alberto Silva, "Plano Local de Desenvolvimento da Área Central: Etapa 3 Diagnóstico Eixo Habitação," PDF, Campo Grande, MS, Brazil, May 2022, https://prefcg-repositorio.campogrande.ms.gov.br/wp-cdn/uploads/2022/05/3prod3_diagnstico_habitacao-prefcg-1652209264.pdf.

30. *Correio do Estado*, "Com Alta de 14%, Campo Grande Tem a 3ª Maior Valorização Imobiliária Entre Capitais," January 14, 2023, https://correiodoestado.com.br/economia/com-alta-de-14-campo-grande-tem-a-3a-maior-valorizacao-imobiliaria/409895/.

31. https://www.fipe.org.br/pt-br/indices/fipezap/ access in 08/10/2023.

32. Ibid.

33. Ibid.

34. *Correio do Estado*, "Com Alta de 14%, Campo Grande Tem a 3ª Maior Valorização Imobiliária Entre Capitais," January 14, 2023, https://correiodoestado.com.br/economia/com-alta-de-14-campo-grande-tem-a-3a-maior-valorizacao-imobiliaria/409895/.

35. "Appraised land value" is used as a translation for "valor venal", a market price registered by the municipality upon transaction of the plot which is used as a reference for property tax (IPTU).

36. Definition provided by IBGE (2003): "[Permanent dwelling] Located in a non-residential unit (shop, factory, etc.) that did not have facilities exclusively for housing. However, on the reference date, it was occupied by a resident. Buildings under construction, train cars, wagons, tents, huts, caves, etc. that were serving as housing on the reference date, were also considered as improvised private domiciles." (IBGE, 2003, 9).

37. The census of 2010 allowed for the assessment of the urban infrastructure around dwelling units. For this reason, the Road Infrastructure and Sanitation Index was created to compare more complex data on urban infrastructure between neighborhoods of Campo Grande in the year of 2010.

38. Municipal Law N° 2.567, August 12th, 1988.

39. F. F. A. Souza, "Relatório Preliminar: Serviços de Consultoria em Viabilidade Econômica eFinanceira de Empreendimentos e Intervenções Urbanas" (São Paulo: Trabalho desenvolvido para a Unidade Gestora de Programa do Desenvolvimento Integrado do Município de Campo Grande – Viva Campo Grande II, 2017).

40. Plano Diretor de Desenvolvimento Urbano Ambiental de Campo Grande - PDDUA, Complementary Law N. 341, December 4th, 2018

41. In Portuguese, "Plano Diretor de Desenvolvimento Urbano" - Complementary Law 341, December 4th, 2018.

42. Awaiting data from the city to further develop analysis.

43. *Comitê Municipal de Enfrentamento às Mudanças Climáticas*, in Portuguese.

44. https://www.campogrande.ms.gov.br/cgnoticias/noticia/campo-grande-institui-comite-municipal-de-enfrentamento-as-mudancas-climaticas/

45. https://www.campograndenews.com.br/meio-ambiente/comite-climatico-inicia-estudo-e-promete-plano-para-descarbonizar-campo-grande

Mérida Metropolitan Area, México

Salvador Herrera Montes

with contributions by Tania Romero López, Daniela Olivares Sánchez

INTRODUCTION

Located in the northwest of the state of Yucatan, Mérida has historically served as a pivotal hub for Mexico's southeastern region, known for its economic, cultural, and administrative significance since its establishment in the 16th century. Recently, this role has encountered competition from Cancún. The Mérida Metropolitan Area (MMA) encompasses 11 municipalities—Acanceh, Conkal, Hunucmá, Kanasín, Mérida, Samahil, Timucuy, Tixkokob, Tixpéhual, Ucú, and Umán.[1]

The terrain across Yucatan, particularly Mérida, is characterized by its flat topography averaging 5 meters above sea level. This landscape, characterized by limestone platforms and limited surface hydrography, has shaped the city's urbanization patterns.[2] Mérida's spatial expansion has been notably influenced by various factors, including water resources critical for sustaining its development and intertwined with availability issues and wastewater management.

In recent years, Mérida has changed its growth pattern, with annual population increasing significantly compared to other LAC cities approached in this study. The city rose from 63rd in terms of population growth between 1993 and 2000 to 18th between 2010 and 2019. In addition, urban extent density also increased, though less pronounced, rising from 67th to 41st amongst LAC cities. Distinct growth patterns are observable within Mérida: the northern and western regions have experienced pronounced expansion, whereas southern areas have seen limited growth due to the presence of the *Cuxtal* ecological reserve. Established in July 1993 as a natural protected area under the Zone Subject to Ecological Conservation, the *Cuxtal* reserve serves to protect vital water sources, conserve ecosystems, promote environmental education, and act as a barrier against uncontrolled urban sprawl.

The city's flat terrain has significantly impacted its construction and real estate sectors, facilitating land subdivision, encouraging investment in urban projects, and influencing real estate speculation. Like other Mexican cities showcasing tourism and economic development, Mérida has attracted both national and foreign populations, influencing its recent urban expansion and structural development.

This document aims to describe and analyze Mérida's urban expansion to understand the growth model it has followed and its resulting urban structure. Moreover, it seeks to understand the interplay between policies, legislation, and the metropolitan phenomenon influencing the expansion and densification processes within the MMA. This study is based on the same data utilized in the Atlas of this book.[3] The work is based on a mixed research approach, which has a central objective of putting quantitative and qualitative data in dialogue to answer the research questions posed.

The research seeks to answer the following questions: (1) What has been the urban growth of Mérida in its territory? What urban growth model has the city followed and what is the resulting urban structure? How has the metropolitan phenomenon been related to the process of expansion and densification? (2) Which policies and other elements have driven expansion and enabled densification at the local level? What are the national and subnational policies related to the process of expansion and densification of the city and to what extent are they coherent? What have been the positive and negative impacts of these policies in this case study?

ASSESSMENT OF URBAN GROWTH

Population Change

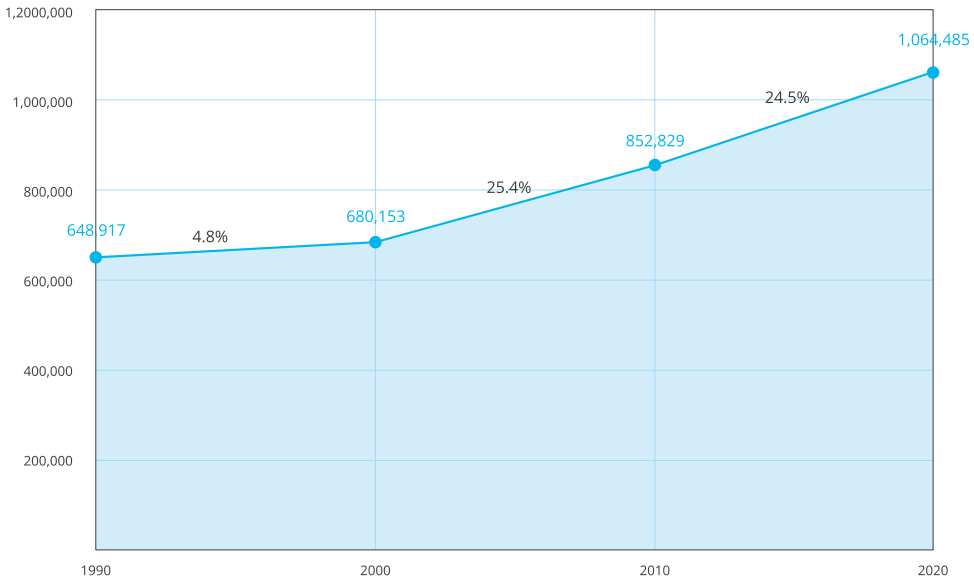
Population is an important driver of the phenomenon of urban expansion. MMA concentrates a total of 1,061,485 inhabitants in an approximate area of 23,900 hectares. The change has had a growing trend, mainly in the decades from 2000 to 2010 and 2010 to 2020, which had an increase of 25.4% and 24.5%, respectively.

While the AMM population has been increasing, urban density has decreased by 47.5% since 1990, going from 61 inhabitants per hectare to 32 in 2020. This suggests that urban expansion has occurred more rapidly than population growth itself.

The following map illustrates the location of the city's densest areas.

Expansion of the Urban Footprint

Urban footprint expansion was analyzed using indexes to address how regular or irregular the shape of the footprint is—these being the proximity[4] and cohesion[5] indexes. For Mérida, both indicators are close to 90% in all four decades, showing a city characterized by a relatively well-defined and regular urban shape. The flat topography has favored this regular urban expansion to a certain extent, as shown in Figure 5.



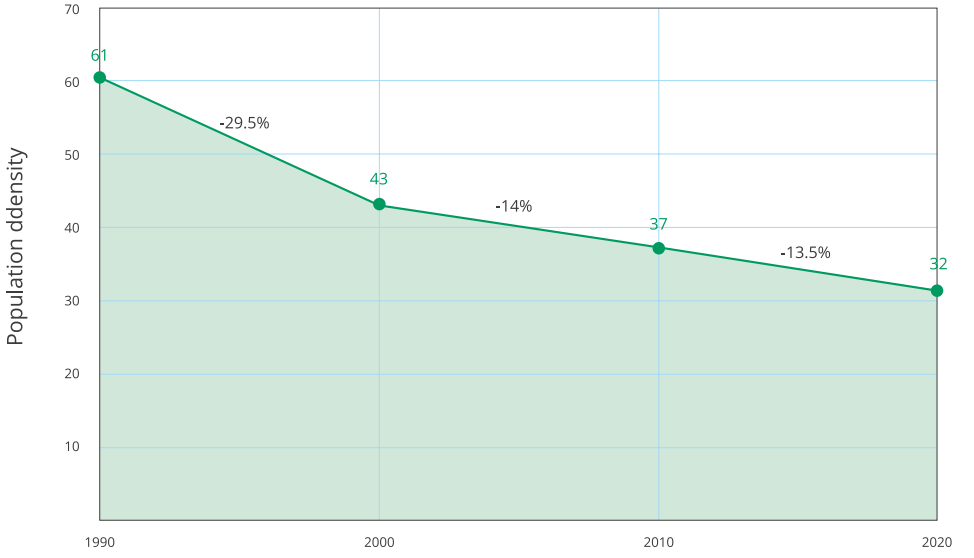


Figure 1: Population growth. Source: Own elaboration based on data from Angel, 2023.

Figure 2: Population density decrease. Source: Own elaboration based on data from Angel, 2023.

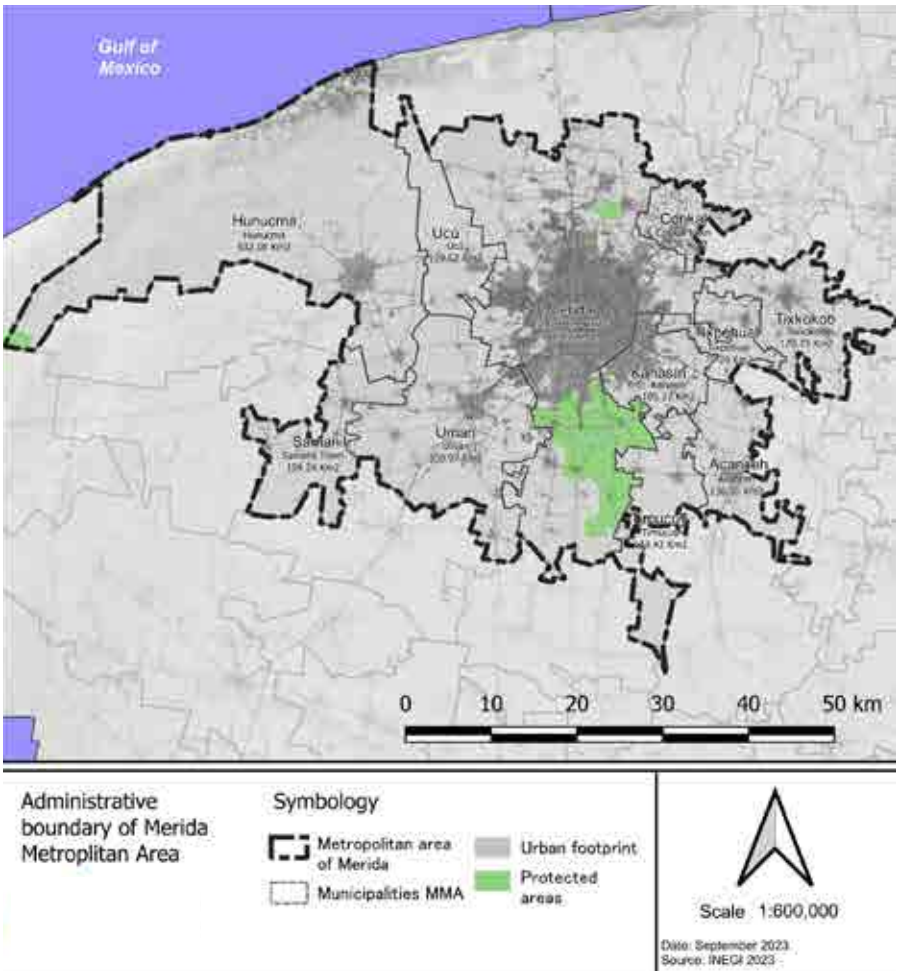


Figure 3: Delimitation and location of the Mérida Metropolitan Area. Source: Own elaboration based on data from the National Institute of Statistics and Geography (INEGI), 2023.

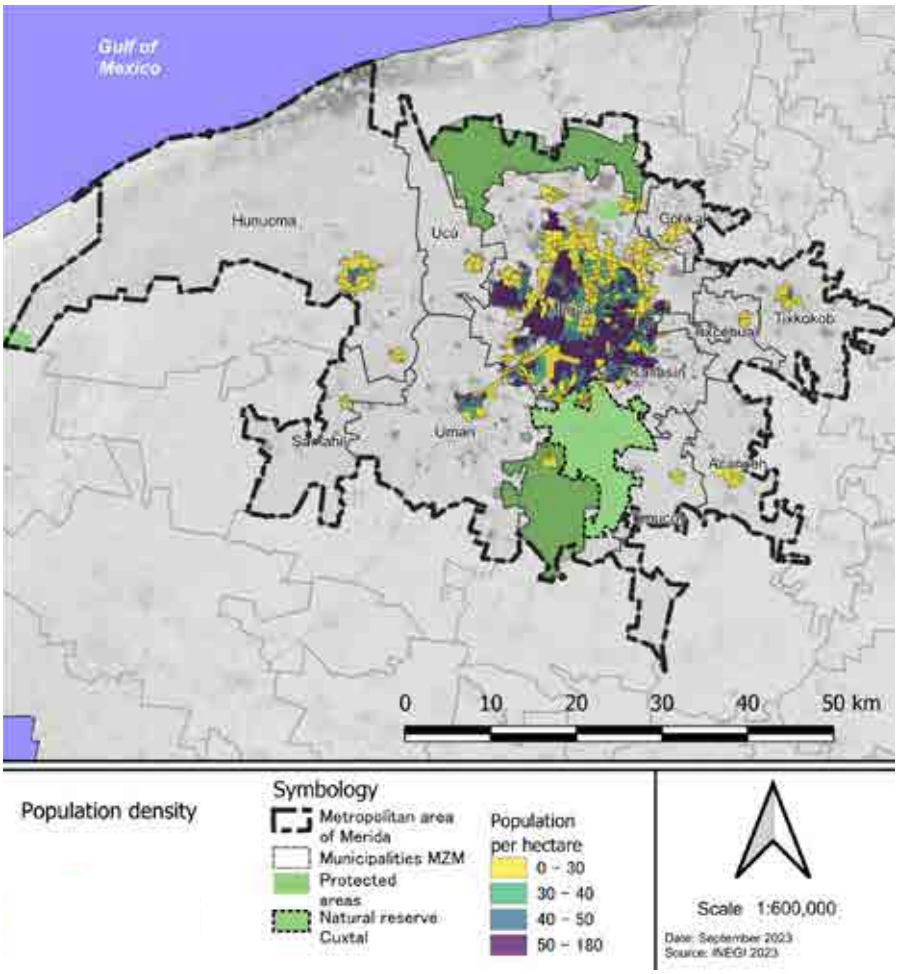


Figure 4: Population density by AGEB of the Mérida Metropolitan Area. Source: Own elaboration based on data from the National Institute of Statistics and Geography (INEGI), 2023.

However, MMA's urban sprawl has been distorting the regular urban footprint over the decades. Certain areas of the peripheries have clustered by aggregating extensions, generating decompaction related to the central area. This phenomenon was investigated by measuring the urban built up area´s circumference for each decade compared to the decade's respective minimum optimal circumference. This method can be used to quantify the decompaction caused by urban sprawl.

In 1990, Mérida's perimeter compared with the optimal circumference results in the first being 2.03 times greater than the latter. By 2020, this ratio was 13.69. Moreover, despite Mérida's characteristic radial urban pattern, urban expansion in recent decades has not followed an orderly radial pattern. This has resulted in increasing distances between the city center and the dispersed peripheral areas, leading to a reduction in urban compactness.

The northern and western regions of the city have experienced a more pronounced growth process. In contrast, expansion has been limited in the southern areas of Mérida, largely due to the presence of the *Cuxtal* ecological reserve.

Hence, urban expansion has gradually decreased the city's density over time. Density[6] in 1990 was 93 inhabitants/hectare, while it reduced to less than half in 2019: 44 inhabitants/hectare. Furthermore, gross urban density[7] within the extended urban area also reduced to half, going from 61 to 32 inhabitants/hectare during the same period.

Mérida's urban extent shows open spaces within the urbanized area. In the last 30 years, more than 2,000 hectares were developed, yet they were dispersed within intermediate open blocks. The proportion of open spaces has increased substantially in these last 30 years, from 10% to 33%. In contrast, the proportion of built-up areas decreased from 90% to 67% in 30 years.

From 1990 to 2020, the population increase was close to 2.5% annually. The total built-up area5 in the same period grew at a rate of almost 5% per year, almost double the rate of population growth—from just over 7,000 hectares to almost 24,000 hectares in 30 years.

In comparison, growth dynamics in rural areas[8] had different behavior in the three periods. From 1990 to 2000, growth was 5.3% annually, slowing significantly from 2000 to 2010, beginning to recover in the latter period.

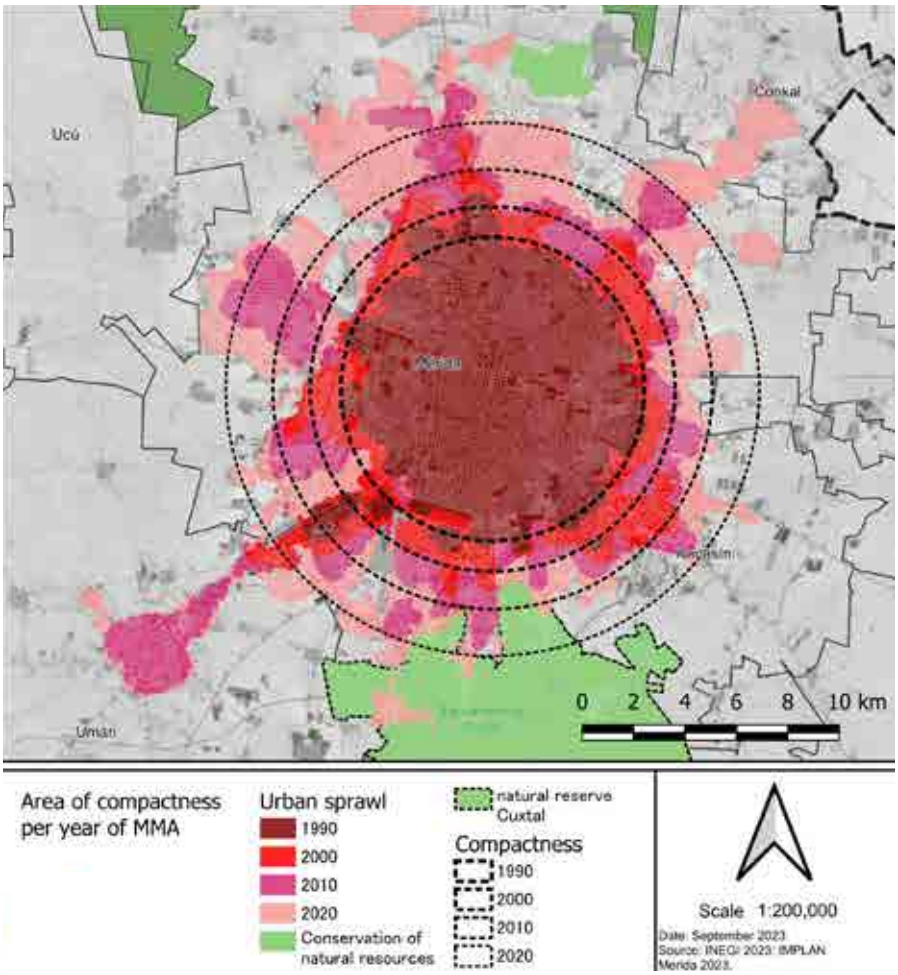
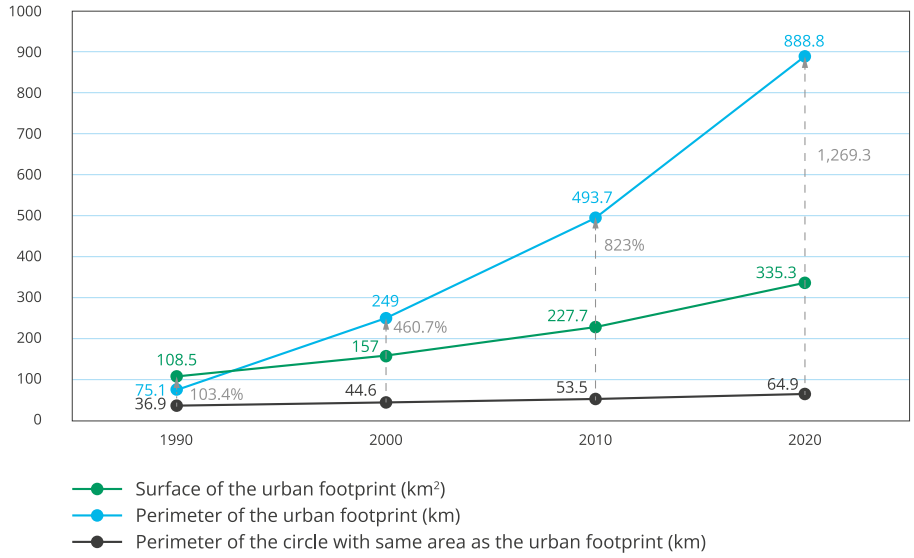


Figure 5: Compactness of Mérida's built-up area by decade Source: Own elaboration based on data from the National Institute of Statistics and Geography (INEGI), 2023.



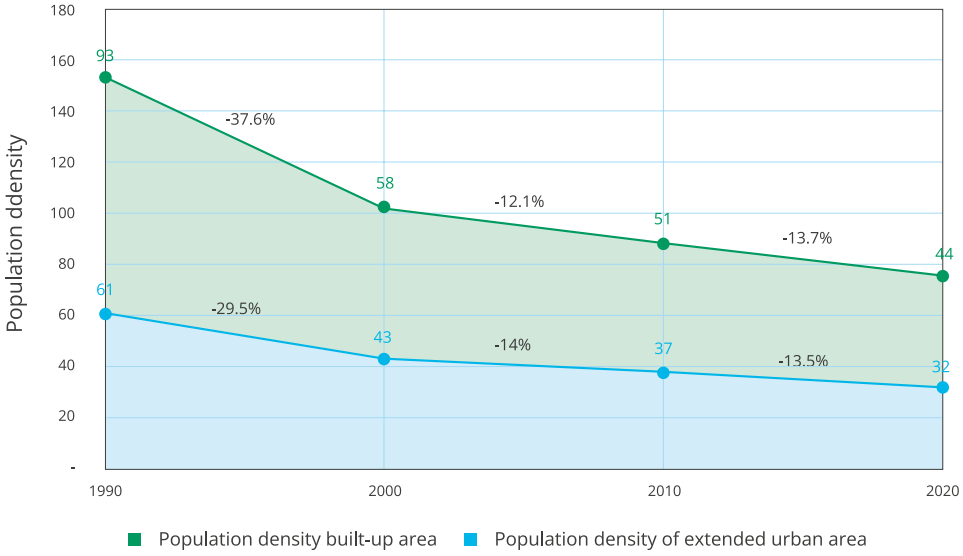


Figure 6: Comparison of the historical Mérida's built-up area and its loss in compactness. Source: Own elaboration based on data from the National Institute of Statistics and Geography (INEGI), 2023.

Figure 7: Urban density. Source: Own elaboration based on data from Angel, 2023.

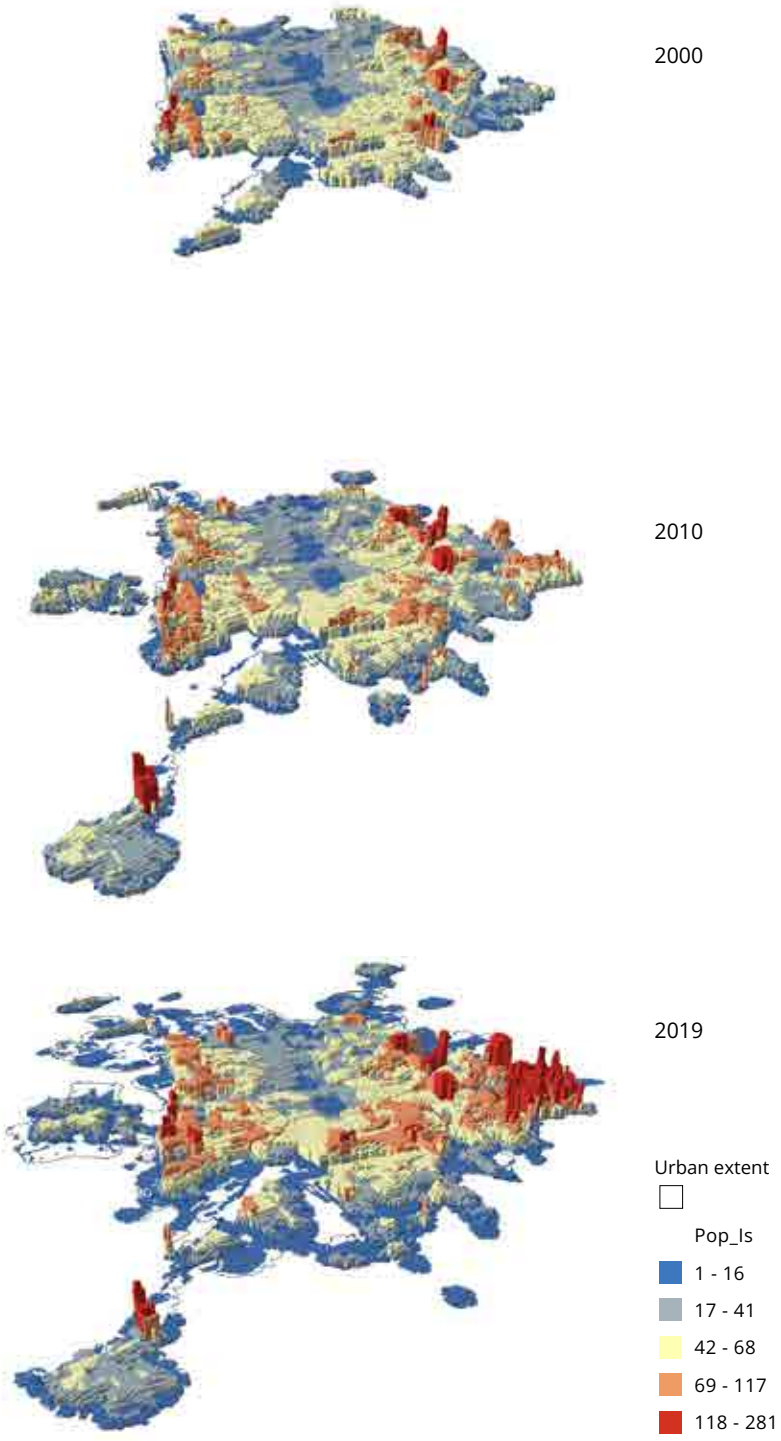
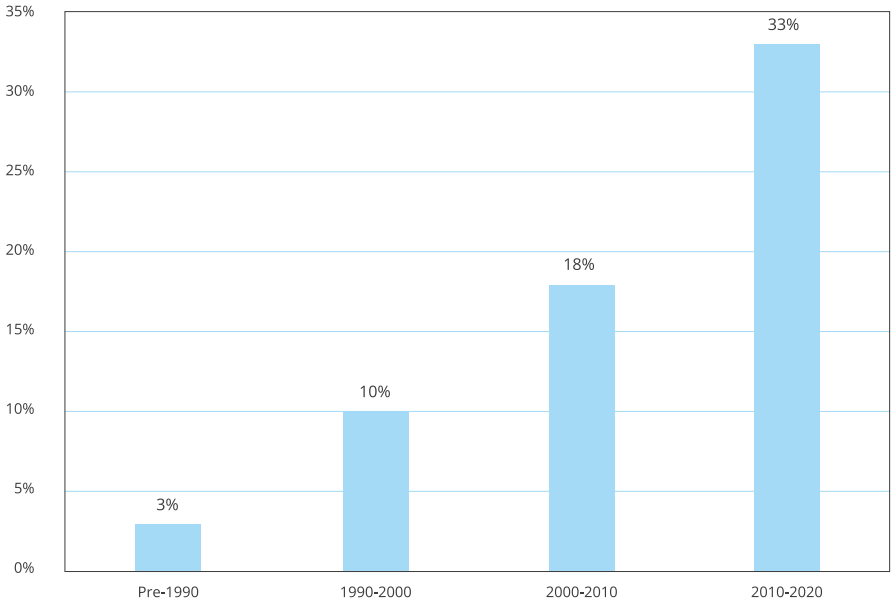


Figure 8: Mérida, Isometric Density. Source: Angel (2023).[9]



Total population and urbanized area in hectares by area, 1990-2020

Population and total areas	1990	2000	2010	2020
Population	648,917	680,153	852,829	1,061,485
Total built area	7,009 ha	11,639 ha	16,689 ha	23,908 ha
Built-up urban area	5,837 ha	10,087 ha	14,265 ha	20,179 ha
Suburban area	1,085 ha	1,437 ha	2,270 ha	3,484 ha
Urbanized rural area	87 ha	115 ha	154 ha	245 ha

Figure 9: Proportion of open space, Metropolitan Area of Mérida Source: Own elaboration based on data from Angel, 2023.

Figure 10: Total population and urbanized area in hectares by area, 1990-2020. Source: Own elaboration based on data from Angel, 2023.

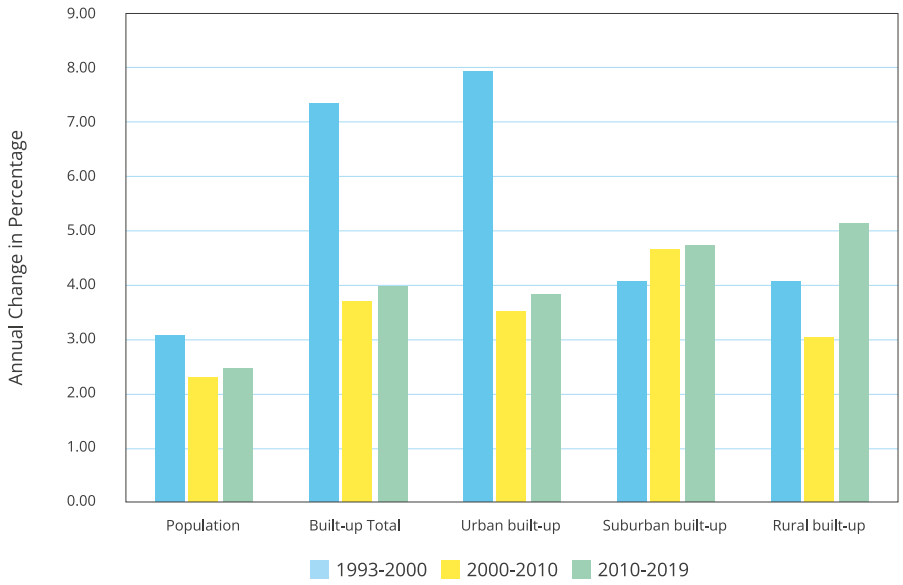


Figure 11: Population growth versus urban expansion in percentage. Source: Own elaboration based on data from Angel, 2023.

Housing Dynamics

The urbanization process in metropolitan Mérida has been characterized by horizontal and expansive physical growth that has given rise to a concentric, yet diffuse and fragmented metropolis. Factors such as the decline of *henequen* activity[10] and the rise of the real estate market in peripheral areas have contributed to this current urban configuration. The urban area extends along the main access roads to the central city, creating a continuous conurbation with Kanasín and metropolitan corridors such as Caucel, Umán, and Progreso, which fulfill various functions and promote a marked urban expansion.

Housing dynamics in the city are highly related to the composition of the built-up area. The percentage of built-up area in informal land subdivisions[11] is significantly lower than in formal land subdivisions, which present more open spaces. Moreover, the proportion of built surface represented by roads declined from 19% in 1990 to 15% in 2010 (Figure 12), when urban expansion responded to housing policies, supported by national organisms such as INFONAVIT, CONAVI, FOVISSSTE, FONHAPO and SHIF;[12] as well as to large housing subdivisions disarticulated from the urban *continuum* and with a lack of urban diversity. Finally, between 2010 and 2020 there was a decrease in the area allocated to road infrastructure to 12%, in part due to the occupation of agrarian land located in the periphery adjacent to the urban area of Mérida, making use of the Agrarian Law of 1992 which facilitated the integration of extensive ejido lands into the real estate market, enhancing continuous land fractionation along major roadways. Such occupation of agrarian lands occurred without planning instruments, which is why public resources for the development of supporting infrastructure, such as roads, were not allocated.

Later, the Urban Development Master Program[13] introduced in 2003 marked a significant policy shift, enabling expansive housing projects in areas like Ciudad Caucel, Los Almendros, Las Américas, and Los Héroes.

At the national level, housing policies implemented around the year 2000 were a catalyst for urban growth, as they aimed to expand access to mortgage financing for lower-income groups and stimulate housing construction. Various programs including financing schemes and federal housing subsidies were created, resulting in significant growth in the real estate market throughout Mexico.

The Urban Development Master Program of 2003 allowed subdivision and construction outside the periphery and in rural precincts. These were occupied by housing projects that promoted an increase in the value of real estate in the metropolis. As of 2003 the master plan facilitated single family suburban developments with a street layout where real estate developments are only connected through one access road that contrasts with the regular grid found within the peripheral road. This situation does not promote the formation of urban centers with orderly and compact growth.

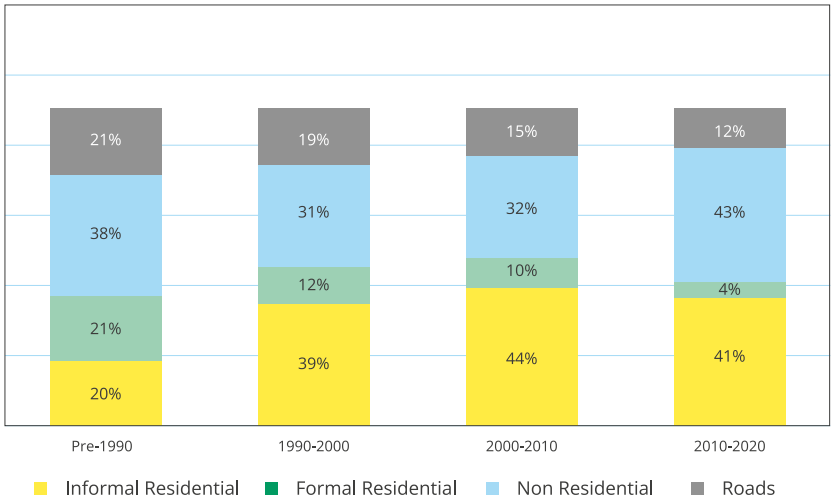


Figure 12: Aerial view of urban expansion 2003 to 2023. Source: Own elaboration, with data from Google Earth, 2023.

Mérida has distinguished itself in recent years in terms of public safety, considering the context of exacerbated violence due to a "war" against organized crime in Mexico that began around 2006. In addition, the city sells itself as offering the best guarantees for economic investment, promoting cultural activities as part of its growth model, and offering an environment full of gastronomic, archaeological, and entertainment options.

Since 2015, Mérida has achieved a record of 17 awards, some national, others international, some awarded by foundations, others by private companies, and even by Mexican government agencies. Mérida's quality of life is evident, but challenges such as the increase in housing prices should not be overlooked. According to the SHF Federal Mortgage Society, Mérida remains among the 20 cities in Mexico with the highest housing prices.

As a result of an intense housing market dynamic, Mérida has attracted new demographics in recent years, including retirees, both domestic and foreign, as well as young students and workers seeking opportunities and a quieter life. People fleeing insecurity from other states of the country have also relocated to the city, along with entrepreneurs who view Yucatán's robust economic growth, especially in Mérida, as a positive indicator for starting new businesses. As a result, Mérida, well-known for its high safety conditions, has had a significant impact, both expected and unexpected, on its urban landscape. While providing shelter to migrants seeking safety is a noble endeavor, it has inadvertently contributed to a notable phenomenon of internal migration.

The Municipality of Mérida has a total of 371,987 housing units, of which 284,682 are privately owned and occupied residences, showing a 2.17% increase in the rate of occupied homes compared to 2010. However, it is estimated that approximately 20% of these residences (approximately 62,000) remain vacant, representing a 3% increase compared to the year 2010.[14]

The housing situation in Mérida reflects divergent realities. On one hand, there is the construction of new real estate developments far from urbanized areas, the promotion of innovative housing typologies in high-value zones, and favorable marketing. On the other hand, there are vacant houses in urbanized areas, a housing deficit in marginalized zones, and insufficient financing systems for improving and acquiring existing housing.

Recently, a new real estate product in the form of investment lots has emerged. Investment lots are seen as a financial asset, expecting or speculating the value of such lots to increase automatically as the real estate market grows in the city, capturing interest of many looking for the opportunity to build or strengthen their assets. This product, in the form of residential lots with affordable prices in the periphery commonly beyond metropolitan city boundaries, are unserved and not connected to the street grid.

Real estate speculation in Mérida has generated various impacts over the past two decades. Local and state authorities have relinquished certain powers



Figure 13: Aerial view of urban expansion 2003 to 2023. Source: Own elaboration, with data from Google Earth, 2023.

in favor of the dynamics of the real estate market. The real estate boom and the concentration of land ownership in the city and its periphery gave rise to a pattern of urban growth characterized by the expansion of multiple nuclei, distant and isolated from each other, with few boundaries. Defined and empty areas led to urban disarticulation, a rapid increase in motorization, pronounced environmental deterioration and fluctuations in housing prices for both sale and rental.

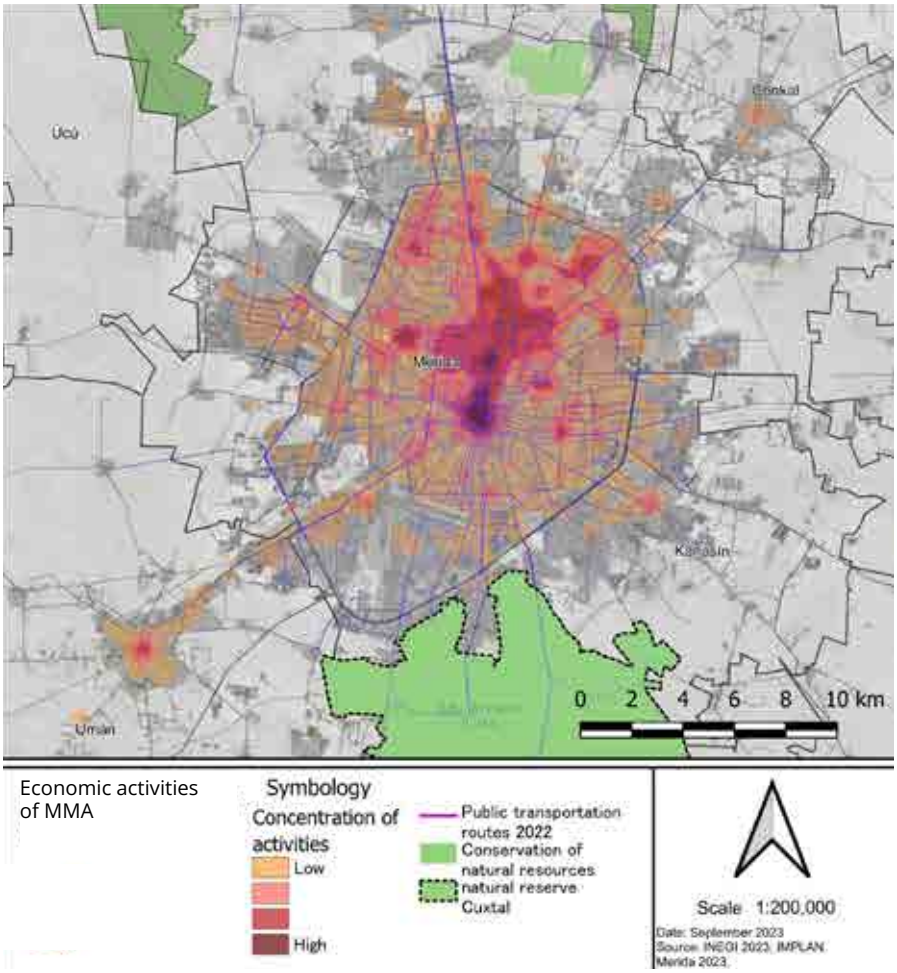
Urban Infrastructure

Road network planning in Mérida shows that its downtown plays a crucial role as the centrality where major businesses, services, and facilities converge as seen in Figure 14. This dynamic has turned the area into the main hub for urban activity. The formation of economic activity corridors from downtown Mérida towards other emerging urban centralities is clearly observed.

Thus, Mérida´s resulting urban structure has three components. First, a central urban area, that expands horizontally along at least seven main roads, which exercises economic dominance in the state and metropolitan urban system. Secondly, an extensive suburban area, which includes a potential land reserve of 30,000 hectares from Mérida's 2003 Urban Development Plan. Projects such as golf courses, industrial parks, and residential megaprojects have been developed in this area. Beyond this, there are still rural areas with high levels of poverty. Lastly, satellite cities make up the system. They consist of dispersed residential complexes, forming a polycentric metropolitan model with average distances of 6.5 km between each urban center. Comparing the total road network surface to the Municipal Urban Development Plans of 2003 and 2018 helps understand the influence of roads in the patterns of expansion (Figure 15). The high presence of local roads suggests a logic of growth based on dispersed settlements (housing complexes). It is also observed that arterial roads which direct and structure development and are defined by urban plans account for 34% of total road surface, 15% of which are located in areas destined to urban growth withing planning instruments.

The metropolitan area is immersed in an employment dynamic that involves commute between Mérida and the surrounding municipalities. Most of the economically active population (EAP) works in the tertiary sector, representing an average of 41.8% at the metropolitan level. Mérida leads in this activity in the metropolis, followed by Conkal and Kanasín. The primary sector has a smaller employment significance in the metropolitan area, as only 8.16% of the EAP is engaged in this activity.

Figure 16 shows the level of centrality achieved by urban centers within the metropolitan area of Mérida. Road network, designed to connect these areas, has fed back impact on urban expansion towards these zones. The red arrows show the direction of the urban expansion happening from the centralities. Most of which occurs towards Mérida´s center and along main roads.



Predominant Land Use	Arterial	Collector	Local
Urban consolidation	5%	13%	18%
Urban growth	15%	3%	18%
Agricultural	7%	0%	8%
Conservation	6%	0%	6%
Total	34%	16%	50%

Figure 14: Urban corridors. Source: Own elaboration based on data from the National Institute of Statics and Geography (INEGI), 2023 and IMPLAN, 2023.

Figure 15: Network-driven growth. Source: Own elaboration based on data from the National Institute of Statistics and Geography (INEGI), 2023.

In the Mérida metropolitan area, the national highway network has played an important role in its expansion—mainly Federal Highway 180, which connects Mérida with the center of the country and with the main port cities located along the Gulf of Mexico. Mérida's regional position, together with its logistical proximity to Port Progreso, established it as the main economic urban center in southeastern Mexico. The northern zone has a low population density, but a high concentration of economic units related to commerce and services. In addition, it continues eastward connecting Mérida to Cancún—through Cholul and Conkál within the metropolitan area. This highway acts as a structuring axis of economic activities in the metropolis.

Furthermore, 281 Federal Highway, which connects Mérida with Celestún, is the road that structures the conurbation of the Caucel housing complex with Mérida, as well as the road that connects distant and dispersed localities such as Ucú and Hunucmá, confirming the relation between the access created by roads and the patterns of urban expansion as shown in Figure 17.

Policy and Strategic Responses to Urban Growth and Densification

At the country level, the Mexican Constitution[15] and the General Law for Human Settlements, Land Management and Urban Development[16] regulate constitutional provisions which mandate that public interest should prevail above the right to private property as stated in Article 27 of the Constitution. Limits to the use of private property can be imposed through zoning regulations according to the general law.

Particularly the latter recognizes planning, regulation, and evaluation of territorial planning of human settlements and urban development as part of the democratic system of national planning. The general law defines two types of zoning: primary and secondary. Primary zoning outlines general land use types in municipal urban development plans, the highest level of municipal urban planning. Secondary zoning assigns specific uses within these areas and is detailed in urban development plans of population centers and partial plans.

Alongside urban law, the regulatory framework to mitigate and reduce the impacts of climate change in Mexico is set by the General Law on Climate Change. It is the basis for the preparation of the national climate change atlas and the response to the international commitments assumed. This planning instrument conceptually dictates the goals to be achieved in the social, economic, and environmental areas. However, it lacks mechanisms to define specific actions in the territory, as well as coordination in the decision-making process with municipalities, which are the main territorial management and administration units. Thus, regulatory instruments on climate change do not provide specific guidelines for mitigation from urban development, zoning, and territorial occupation.

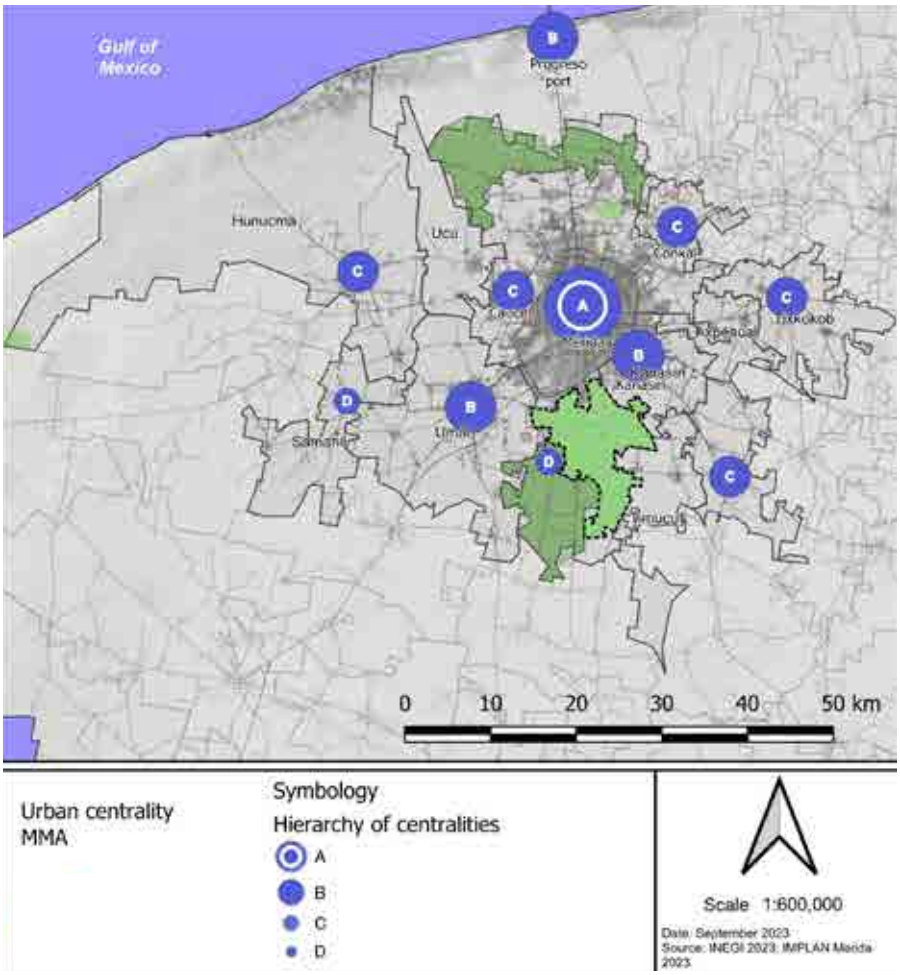


Figure 16: Centralities of the Metropolitan Area of Mérida. Source: Own elaboration based on data from the National Institute of Statics and Geography (INEGI) and IMPLAN Mérida, 2023.

In addition to this coordination challenge, in the 1980s and 1990s a series of neoliberal policies were implemented, promoting the privatization of businesses and public services. These policies had an impact on how property rights are exercised in Mexico, encouraging private investment and reducing regulations that protected social and environmental interests.

On the state level, following the guidance of the state Constitution,[17] an important legislative provision to consider is the Law of Governments and Municipalities of the state of Yucatán, which guarantees the right of residents to promote local development and its benefits in Article 73. In addition, principles such as comprehensiveness and sustainability in development are established. Accordingly, per national and state legislation, municipalities are responsible for formulating, approving, and administering zoning within their territories. Following guiding principles established by law.

The first urban development program for Mérida was introduced in 1980 and marked the beginning of urban planning initiatives that have continued till today. An important initiative was the Urban Development Master Plan of Mérida (PDU 2003-2010) since it opened the possibility of subdividing land and building in areas outside the peripheral ring and in rural communities, initiating a new process of urban expansion that had previously been restricted to the peripheral ring as a barrier to urban growth. This process was enabled by the national agrarian law and the opening of the real estate market to *ejido* lands around Mérida.

Mérida's Municipal Development Program, published in 2018 and currently under revision, does not yet include secondary zoning, complicating urban administration as specific land uses have not been assigned. It establishes four specific policies for territorial planning in line with the capabilities of urban consolidation, expansion, regeneration, and sustainable development, as well as the conservation of natural resources. However, Figure 18 shows that the area originally assigned with a consolidation policy which was delimited by the Mérida beltway has now expanded into what was formerly an expansion policy, mainly to the north and west. Meanwhile, the zones designated with sustainable development and regeneration policies have undergone significant natural impacts due to the expansion process.

The 2018 plan mentions the need to create compact areas that promote densification through social, technical, regulatory, and fiscal transformations. However, it does not provide the essential tools to achieve this purpose explicitly and precisely. Moreover, the concern that urban development strategies lack a metropolitan perspective remains. Specifically, municipalities such as Conkal, Samahil, Timucuy, and Umán do not possess a municipal development program. In addition, Kanasín, Hunucmá, and Tixpéhual have not seen updates to their programs, since the initial publications which date back 8 to 10 years. This complicates the implementation of orderly and coordinated growth throughout the metropolitan city.

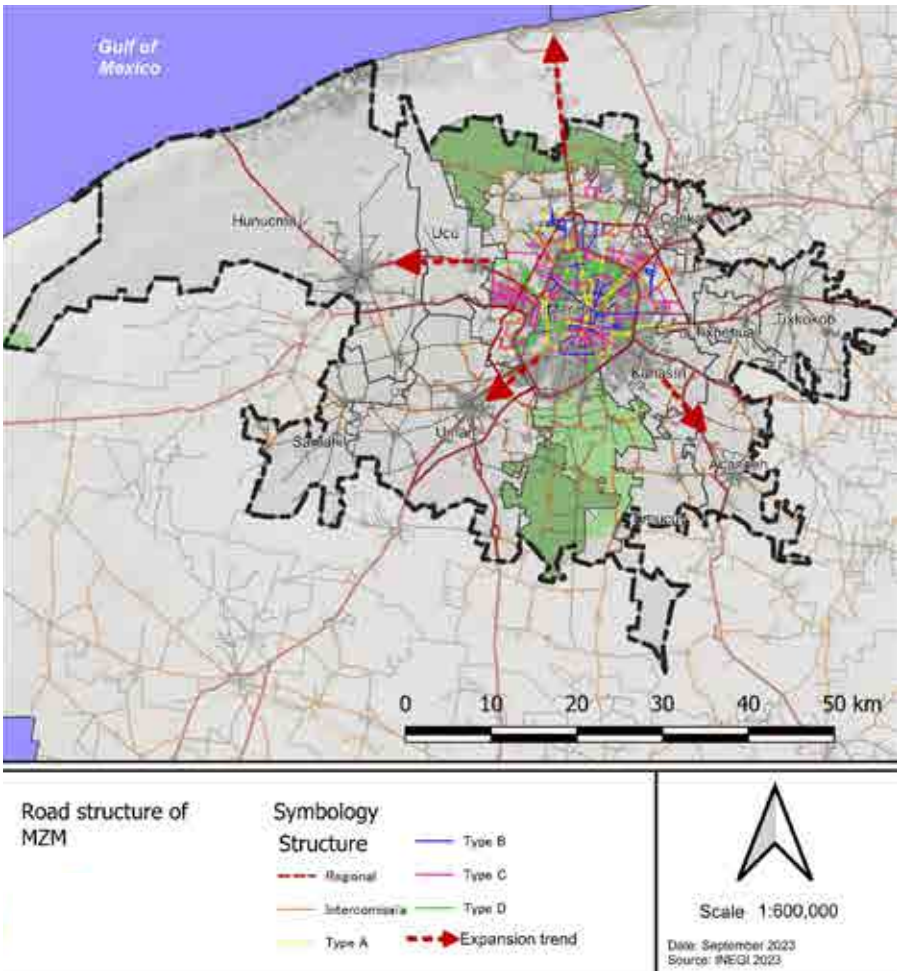


Figure 17: Mérida road network. Source: Own elaboration based on data from the National Institute of Statistics and Geography (INEGI), 2023.

Overall, urban planning instruments in Mérida often fail to adapt to changing circumstances. Processes for updating planning instruments are often long and disjointed, hampering effective responses to emerging urban problems. The absence of mechanisms for collaborative adjustments, productive dialogues between stakeholders, and the integration of novel solutions exacerbates the city's vulnerability to unplanned expansions and infrastructure gaps.

CONCLUSION

The urban development and expansion of Mérida presents a distinctive circular or concentric pattern, driven primarily by the absence of natural geographic limitations. Its expansive plain allows for relatively unimpeded outward growth. Thus, without a defined boundary imposed by nature, city expansion is largely determined by human decisions, land policies, and infrastructure developments.

Likewise, the territorial characteristics, politics and context have triggered various social, administrative, and legal aspects that largely explain the real estate and urban expansion phenomenon in Mérida. Mérida has expanded in all directions with a notable growth trend towards the north along the highway to Port Progreso, as well as to the east and west of the metropolis. The city is characterized by low efficiency in land use and, due to its configuration, by greater consumption of natural resources, in addition to a horizontal urban growth model that results in a low density.

Even though the legislation regarding urban planning and development is clear, the administrative and institutional arrangements that enforce such instruments depend entirely on the governance capacity of the municipal governments. In the case of the Mérida metropolitan area there are no institutional arrangements that would allow it to address territorial management on a metropolitan scale, beyond political coordination between municipalities. It is expected that the more urbanized a municipality is, the more capability it will have to produce resources that strengthen its institutionality. Hence, municipalities like Uman or Kanasín, much less populated and urbanized than Mérida, do not have municipal planning institutes and lack the technical tools to develop better planning instruments.

Moreover, the institutional challenges are also found in the distribution of competencies within authorities at the municipal level. Such distribution demands the establishment of coordinating mechanisms for the enforcement of planning instruments. In Mérida, the Municipal Planning Institute oversees the planning and monitoring of urban development, but the Urban Development Directorate oversees authorizing land use and construction permits with low to no intervention of the planning institute in the decision-making process. Therefore, despite the capability, coordination is hampered by institutional arrangements.

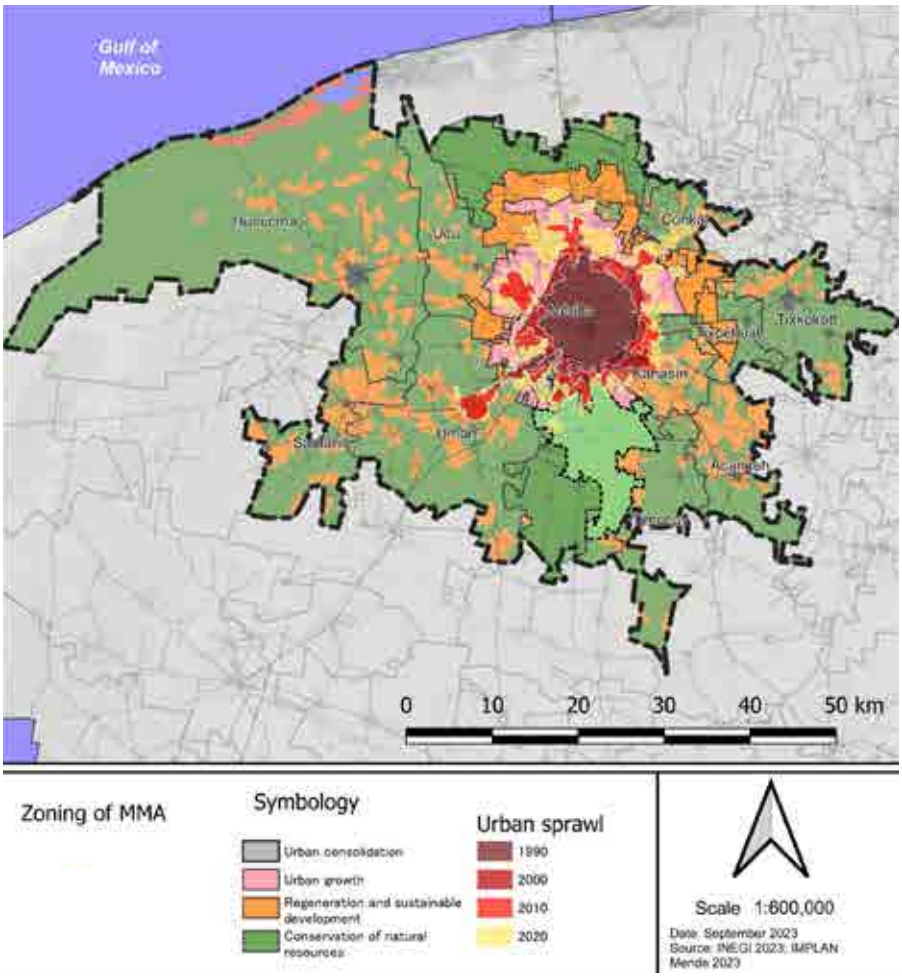


Figure 18: Territorial Policies in the 2018 Urban Development Program of Mérida Source: Own elaboration based on data from the National Institute of Statics and Geography (INEGI) and IMPLAN Mérida, 2023.

In all, a metropolitan area with few coordinating mechanisms between municipalities and different institutional arrangements has a low capacity to enforce planning instruments and promote a coherently planned urban expansion.

As it undergone decrease in its own compactness, in comparison to other LAC cities in this study, Mérida has lowered from 1st to 4th most compact city in the region14—these positions consider the difference in compactness from 1993 to 2000 and 2010 to 2019, respectively.

The spatial, regulatory, and institutional conditions have also been shaped by social and economic processes, resulting in Mérida's expansive model, as has occurred in other Mexican cities which, placed in the showcase of tourism and economic development, became a node that attracted national and foreign population. This, of course, has had notable effects on the recent expansion and urban structure of the metropolis. Through an attractive real estate market that offers homes and investment lots at very attractive prices, the city has continued to grow widely, with private developments in the northern area being a specific characteristic of this growth. While still undergoing meaningful urban extent expansion, when contrasting to other LAC cities in this study, Mérida has fallen from 10th highest increase in urban extent between 1993 and 2000 to 20th between 2010 and 2019.

Peripheral urban development based on housing demand drives the management of large extensions of land for urban use through strong negotiation between promoters and authorities, who generally disagree in their criteria. Rapid urbanization on the city's periphery has been driven by speculation and intense urban development, particularly due to mass housing projects. This housing model with megadevelopments did not foresee their integration with the existing urban fabric resulting in a confusing and dispersed urban layout that does not promote the formation of organized and compact urban centers.

This aggressive and accelerated expansion process is characterized by a lack of urban planning to structure expansion, and distribution of activities. As a result, the metropolis is growing in a fragmented way, full of social, economic, political, and environmental issues.

Endnotes

1. SEDATU, INEGI, & CONAPO. (2018). Delimitación de las zonas metropolitanas de México 2015. Obtenido de: https://www.gob.mx/cms/uploads/attachment/file/305634/*Delimitacion_Zonas_Metropolitanas_2015*.pdf

2. INEGI. (2023). *National Institute of Statistics Geography*. Obtenido de https://gaia.inegi.org.mx/scince2020/ - Batllori Sampedro, E., & Febles Patrón, J. (2002). El agua subterránea en el desarrollo regional de la península de Yucatán. *Avance y Perspectiva*, 67-77.

3. The data was provided by Shlomo Angel in May 2023.

4. For the definition of this index, see the Glossary in the Atlas.

5. Ibid.

6. Net urban density, considering just built area.

7. Built area added including urbanized open spaces.

8. "The built-up areas of cities were classified into three types: (1) urban cores, (2) suburban areas, and (3) rural areas. Urban core pixels were defined as built-up pixels surrounded by 50 percent of more built-up pixels in a 1 km^2 circle around them. Suburban pixels were defined as built-up pixels surrounded by 10 to 50 percent built-up pixels in a 1 km^2 circle around them. Rural pixels were defined as built-up pixels surrounded by less than 10 percent built-up pixels in a 1 km^2 circle around them." (Angel et al., 2010) https://www.lincolninst.edu/app/uploads/2024/04/1835_1086_angel_2_final.pdf

9. Map provided by Shlomo Angel in May 2023.

10. The henequen activity is the industrialization of the henequen agave for the manufacture of ropes, sacks, threads, among other products. This activity boomed in the mid-19th century and generated infrastructure for cultivation, transformation (haciendas and their surroundings as living areas for workers) and export to national, American, and European markets through the port of progress and the railroad network. In the 20th century, the activity suffered a hard blow with the invention of synthetic fibers. (https://www.gob.mx/firco/articulos/henequen-oro-verde-en-epoca-prehispanica?idiom=es)

11. Informal land subdivisions are areas that have been subdivided for urban use but lack visible evidence of compliance with land subdivision standards, such as regular parcel dimensions, paved streets, streetlights, or sidewalks. Formal land subdivisions are similar in design to informal subdivisions, but have a higher level of regularity, a higher level of infrastructure provision and better connections to existing roads. All roads must be paved for an area to be classified as a formal land subdivision. Sidewalks and streetlights are also usually visible.

12. National Housing Commission, CONAVI, National Housing Fund for Workers , INFONAVIT, National Housing Fund for Government Workers, FOVISSSTE, National Housing Fund for the People, FONHAPO, Federal Mortgage Society, SHF.

13. Programa Director de Desarrollo Urbano de Mérida, 2003.

14. Instituto Nacional de Estadística y Geografía, INEGI. Censo de Población y Vivienda 2020 (Censo 2020) - https://www.inegi.org.mx/programas/ccpv/2020/ - México, 2020

15. In Spanish: Constitución Política de los Estados Unidos Mexicanos (1917, latest reform June 2023).

16. In Spanish: Ley General de Asentamientos Humanos, Ordenamiento Territorial y Desarrollo Urbano (2016 latest reform June 2021). Further referred to as "General Law".

17. Mexico is a Federal State, as such each federative entity, also known as states, has its own Constitution, in this document the State Constitution refers to the State of Yucatán.

San Salvador Metropolitan Area, El Salvador

Salvador Herrera Montes

with contributions by Tania Romero López, Daniela Olivares Sánchez

INTRODUCTION

Located in a mountainous region surrounded by the Balsam Mountain range, the San Salvador Metropolitan Area (SSMA) has 14 municipalities. Twelve are from the department of San Salvador: Apopa, Ayutuxtepeque, Cuscatancingo, Delgado, Ilopango, Mejicanos, Nejapa, San Marcos, San Martín, Tonacatepeque, Soyapango, and the capital city of San Salvador. The other two are from the department of La Libertad: Antiguo Cuscatlán and Santa Tecla.

The SSMA accommodates approximately 1.9 million residents across 17,900 hectares. The area's economic activities are central to El Salvador's economy, contributing 33% of its GDP in 2019. Key sectors included commerce, services, manufacturing, and real estate. This economic vitality has also fueled urban expansion, predominantly towards the north and west, guided by topographical features that influence land use and development patterns. It is remarkable that, in comparison to other LAC cities analyzed in this study, San Salvador has lowered its position in terms of increase in urban extent—from 33rd between 1991 and 1999, to 48th between 2014 and 2020.

Urban expansion in San Salvador has been shaped by the available flat land amidst mountainous terrain, driving development outward along gentler slopes. This pattern has led to significant changes in land use. It is replacing green and agricultural areas with urban infrastructure, and thus negatively impacting biodiversity and environmental quality. In addition, placement of urban infrastructure in vulnerable areas—such as rivers and steep slopes—increases the city's vulnerability to extreme weather events and natural disasters.

Since its early years, San Salvador has experienced various natural disasters, including earthquakes, hurricanes, and floods. These events have increased in recent years due to climate change, consequently requiring ever more frequent recovery efforts. Environmental risk in SSMA is aggravated by how the urbanized territory has been used and modified. Thus, the city demands adaptive urban planning strategies, influencing its spatial organization.

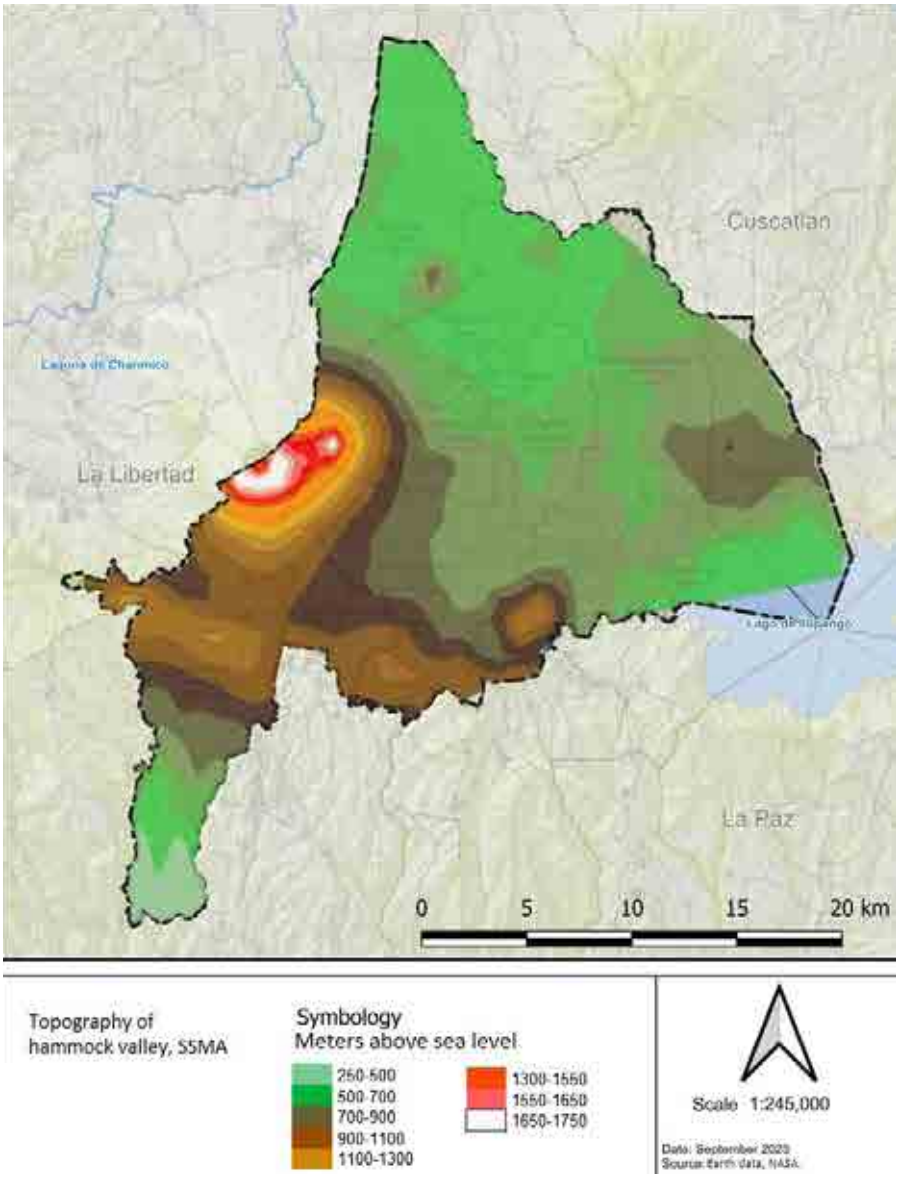


Figure 1: Delimitation and location of the SSMA. Source: OPAMSS, San Salvador.

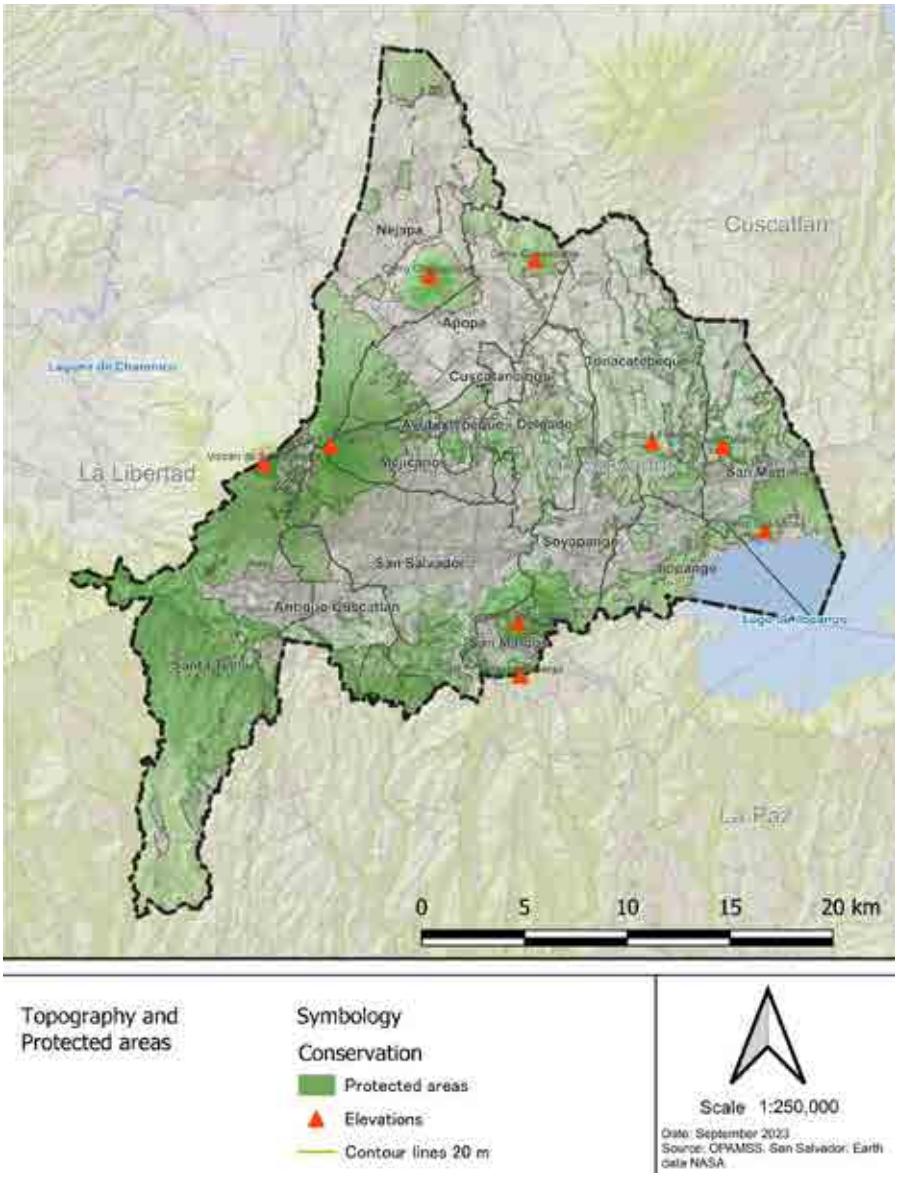


Figure 2: Topography of Valle de las Hamacas, San Salvador. Source: Own elaboration using Earth data, NASA.

The objective of this study is to analyze and describe the urban expansion of San Salvador over the past three decades (1990-2020), examining the growth models and resulting urban structures shaped by national and local policies. This research aims to understand the relationship between policies, legislation, and metropolitan development, exploring the impacts on expansion and densification processes in the SSMA. This study is based on the same data utilized in the Atlas of this book[1] and employs a mixed research approach, integrating quantitative metrics and qualitative analysis.

The research seeks to answer the following questions: (1) What has been the urban growth of San Salvador in its territory? What urban growth model has the city followed and what is the resulting urban structure? How has the metropolitan phenomenon been related to the process of expansion and densification? (2) What policies and other elements have driven expansion and enabled densification at the local level? What are the national and subnational policies related to the process of expansion and densification of the city and to what extent are they coherent? What have been the positive and negative impacts of these policies in this case study?

ASSESSMENT OF URBAN GROWTH

Population Change

The metropolis concentrates a total of 1,892,832 inhabitants. Population increased between 1990 and 2010, but has remained stable since.

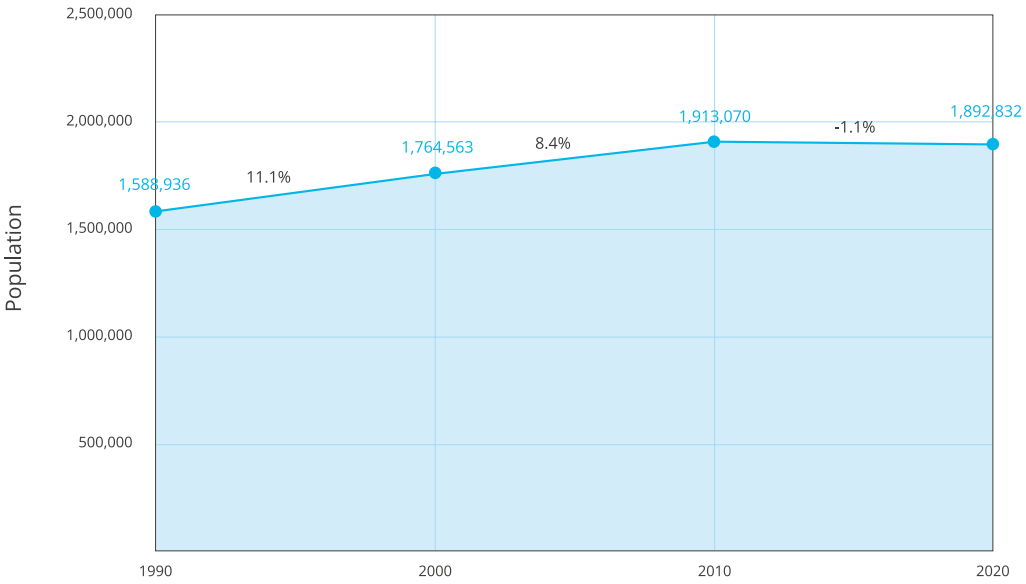
Urban density in 1990 was 130 inhabitants per hectare. Three decades later, it had declined to 74 inhabitants per hectare—considered high for the Latin American and Caribbean context. This suggests that, despite the population growth stability during the last decade, territorial expansion is still increasing.

Expansion of the Urban Footprint

Urban expansion can be investigated by comparing urban extent in different periods. The proximity and cohesion[2] indexes show that SSMA presents a less regular urban form, estimated at around 70% during the period analyzed. This situation is likely related to the topographic factor.

To analyze the urban footprint and its expansion process, surface and perimeter of the urban extent perimeter measurements were compared with the minimum optimal circumference. This exercise was conducted for all analyzed years to understand the growth pattern compared to the compactness index.

Figure 7 expresses that the urban perimeter (115.8 km) in 1991 was 2.8 times larger than the optimal circumference. Eight years later, this proportion



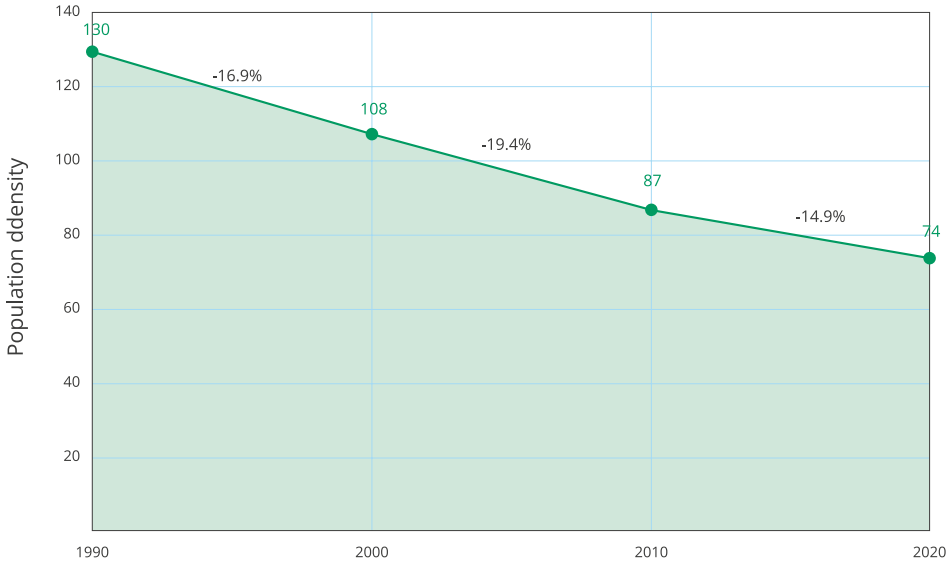


Figure 3: Population growth graph.
Source: Own elaboration based on data from Angel, 2023.

Figure 4: Population density decrease graph.
Source: Own elaboration based on data from Angel, 2023.

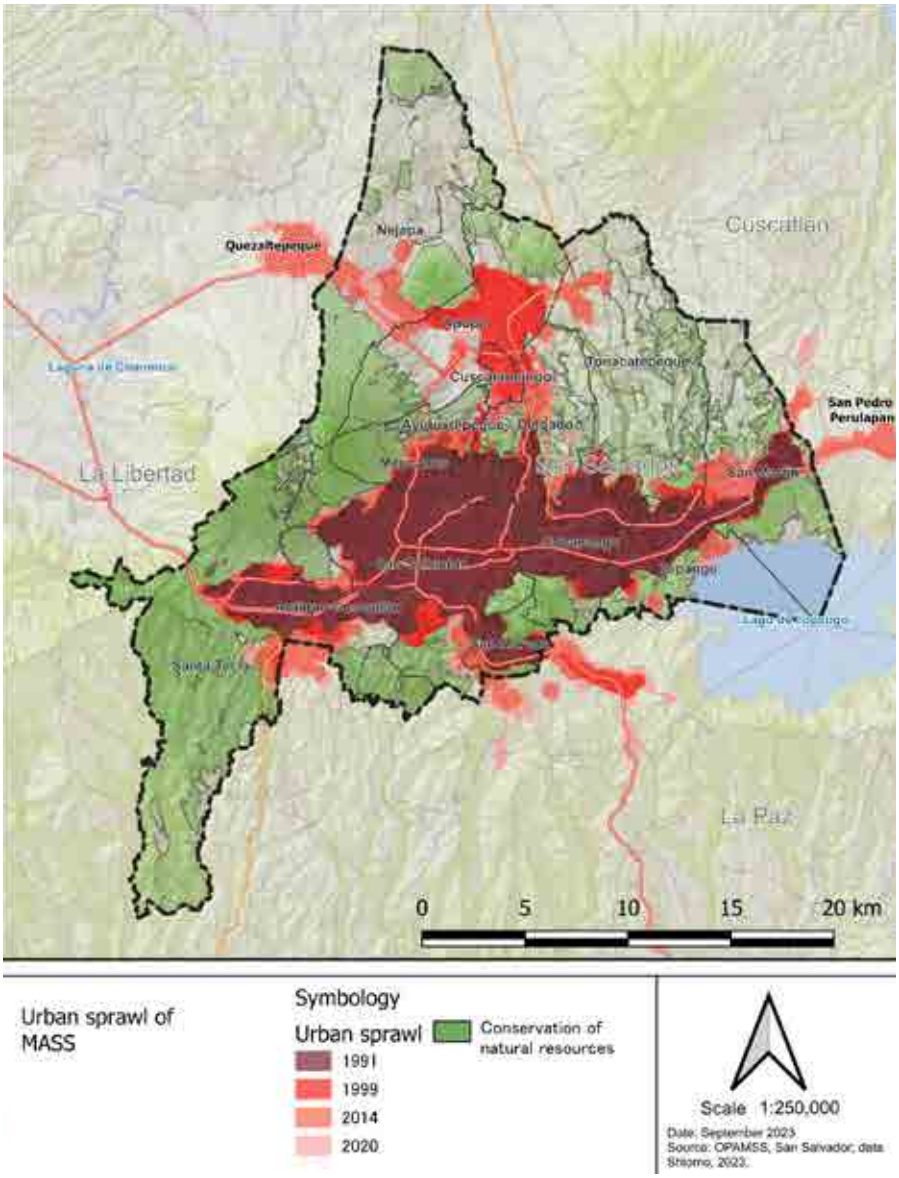


Figure 5: Expansion of the urban footprint of the SSMA. Source: Own elaboration based on data from Angel, 2023.

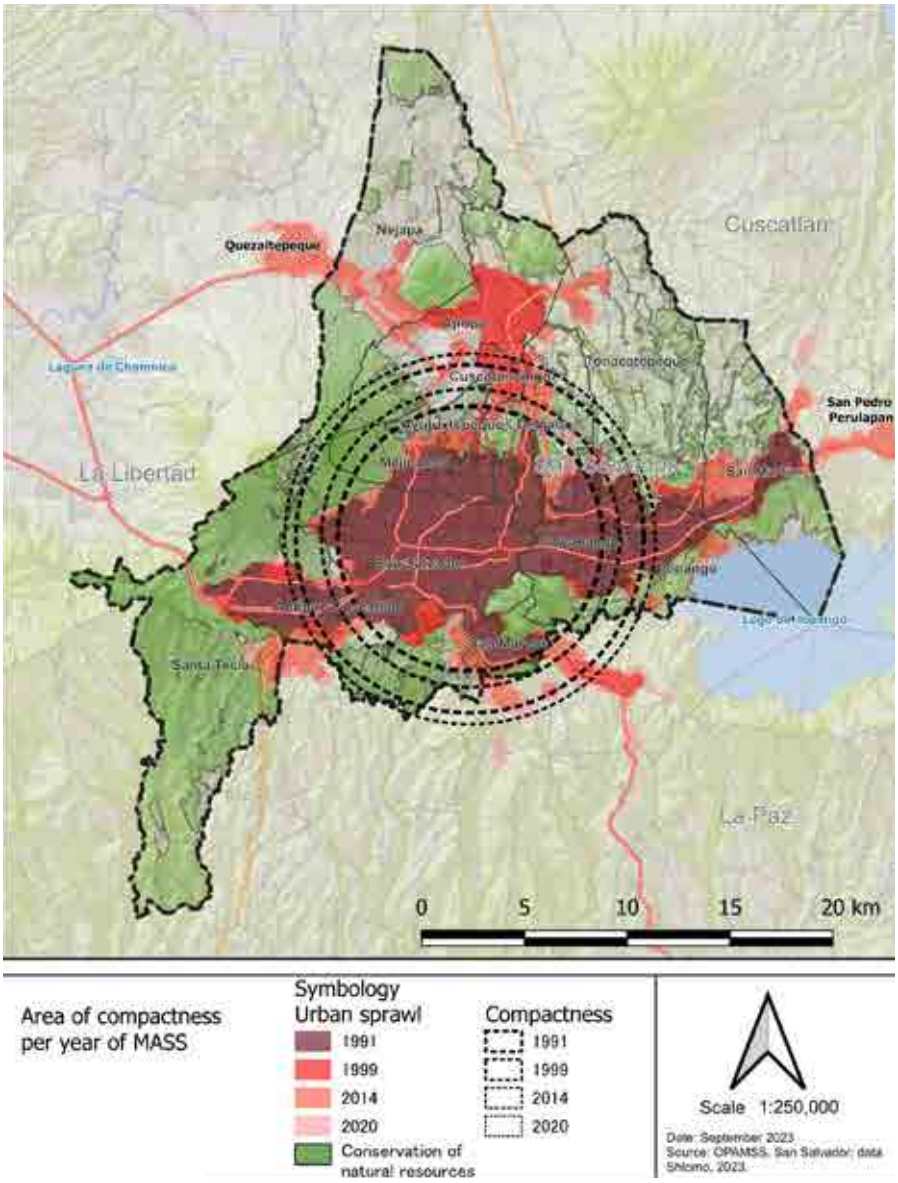


Figure 6:. Comparison of the historical surface area of the SSMA urban footprint and its compactness. Source: Own elaboration based on data of OPAMSS, San Salvador, 2023.

increased to 5.65 times. Fifteen years later, it continued to increase, resulting in a perimeter 10.7 times larger than that of a circle of the same area in 2014. By 2020, the surface of the urban area had reached 255.1 km^2 with a perimeter of 820 km, 14.5 times larger than that of a circle. In the SSMA, natural physical limitations induced elongated extensions of the metropolitan area, particularly in the northern area of San Salvador.

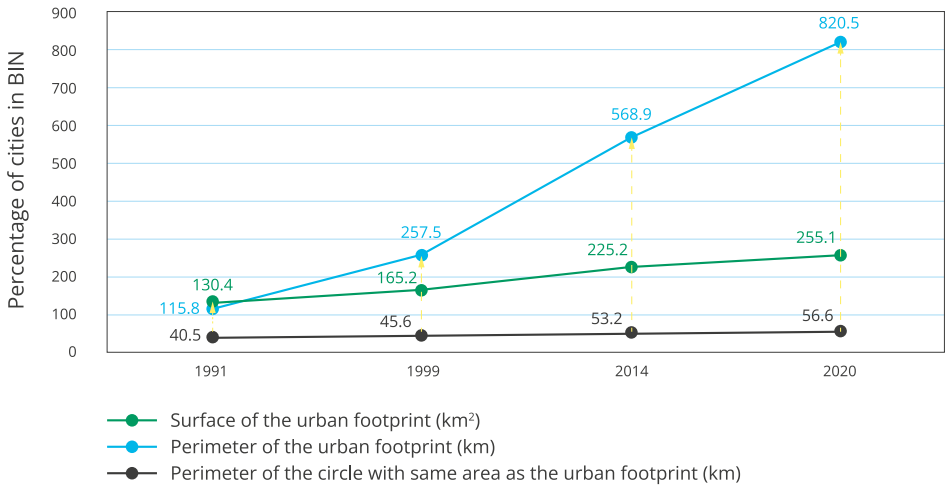
Historically, the expansion of San Salvador has been directed to the north and west, following the gentler slopes of the mountains. This direction of expansion has been driven by the availability of relatively flat land and the need for space to accommodate the growing population. In addition to topographic constraints, the city is vulnerable to natural disasters due to its geographic location in a seismically active region.

Territorial regulation, which includes the delimitation of growth areas, had a significant impact on the urban configuration of the SSMA. It has aimed to balance geographic and topographic elements with the urban sprawl, while also considering environmental factors and benefits. These efforts focus on the consolidation of irregular areas, rendering ineffective actions aimed at generating social housing. In this sense, it is recognized that the growth of the urban area has occurred without the accompaniment of national government actions. Due to high costs in the central areas and an absence of affordable housing supply, this has led to growth in the periphery, as will be analyzed below.

As shown in Figure 8, there has been an evident and sustained reduction in population density[3] in the urbanized area: it went from 193 to 106 inhabitants per hectare (net urban density) in 30 years. Density in the extended urban area also shows reduction, going from 130 to 74 inhabitants per hectare in the same period (gross urban density). Between 1990 and 2020, occupied indoor open space made up 39% of the total area added to the city, while outdoor open space was responsible for 21%, and rural open space for 11%. Whereas the densest areas are found in the peripheral municipalities—to the north and east of the SSMA—the central, southern, and western areas are characterized by low densities.

Regarding the saturation of the urban area, evidence indicates that the saturation index in 1990 had a value of 0.67. Open spaces within urbanized areas have increased at a 2% annual rate over the past 30 years. In absolute terms, from 4 thousand hectares to almost 8 thousand hectares. The percentage of open spaces within the urbanized area increased from 31% to 60% between 1990 and 2020. In contrast, the proportion represented by the built-up area decreased significantly in the last 30 years, from 69% to 40%. Considering all the above, the SSMA shows a pattern of urban expansion with saturation and significant underuse of land.

The total built area[4] grew at a rate close to 3% per year over a 30-year course, in contrast to the slight increase in population. It went from 8,250 to almost 18,000 hectares. The gap between population growth and built-up area growth is evident. Between 1990 and 2020, what is defined as a built-up urban



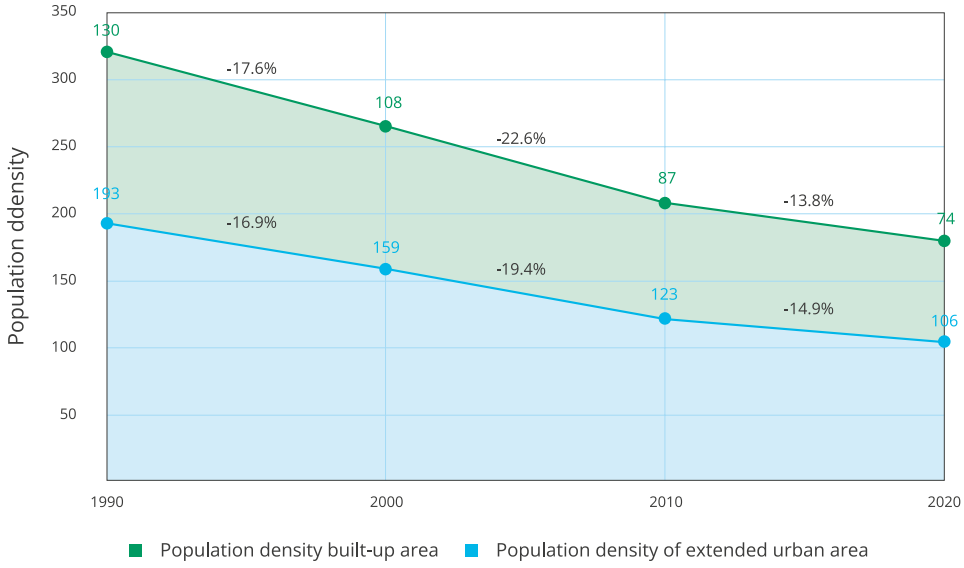


Figure 7: Comparison of the historical surface area of San Salvador's urban footprint and its loss in compactness. Source: Own elaboration based on data of OPAMSS, San Salvador, 2023.

Figure 8: Urban density. Source: Own elaboration based on data from Angel, 2023.

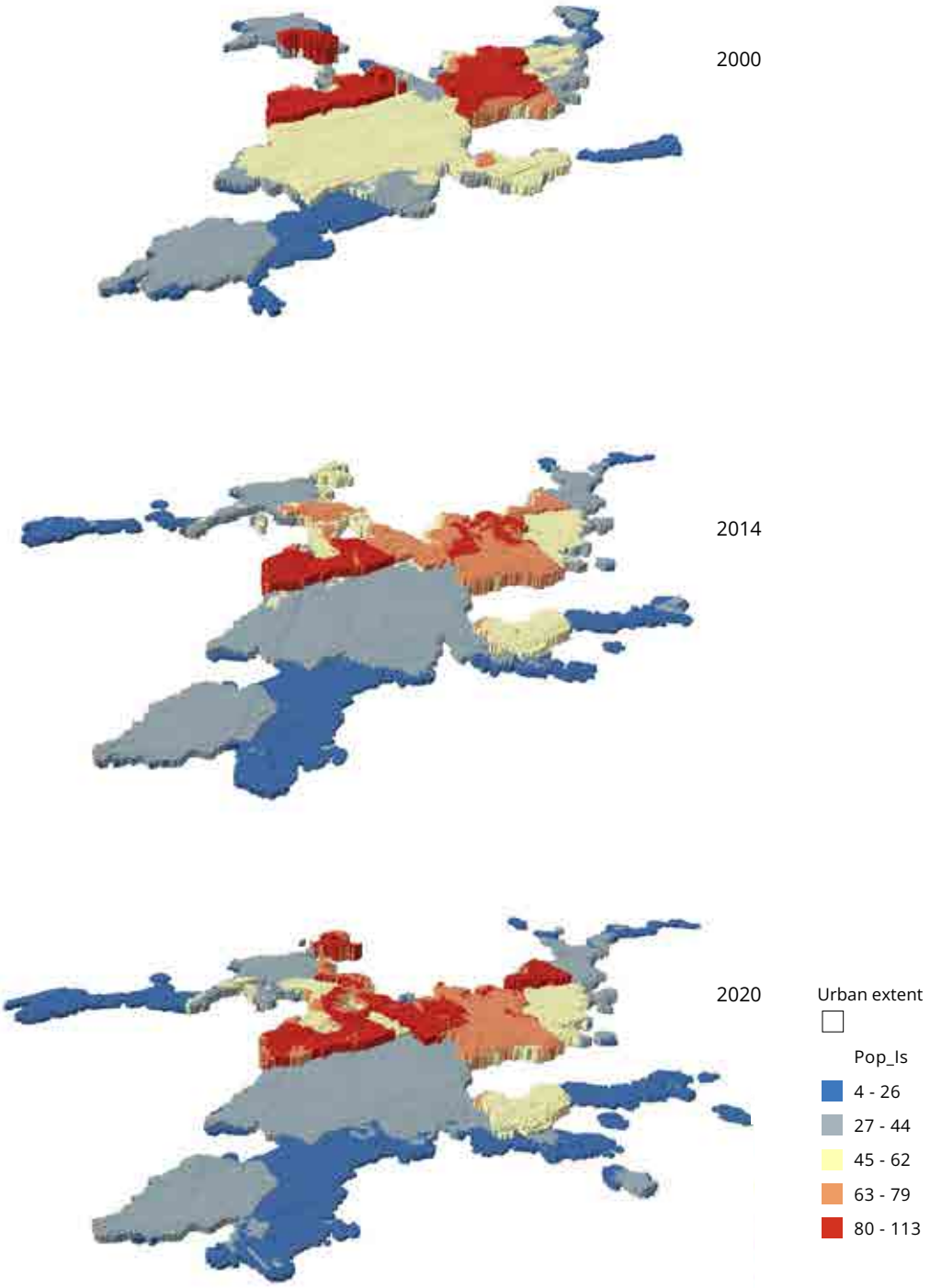


Figure 9: SSMA, Isometric Density Source: Angel, 2023.[5]

Saturation of the built area

1990	2000	2010	2020
67%	68%	71%	70%

Total population and urbanized area in hectares by area, 1990-2020

	1990	2000	2010	2020
Population	1,588,936	1,764,563	1,913,070	1,892,832
Total built area	8,250 ha	11,086 ha	15,592 ha	17,939 ha
Built-up urban area	6,688 ha	8,924 ha	12,577 ha	14,183 ha
Suburban area	1,450 ha	1985 ha	2,790 ha	3,478 ha
Urbanized rural area	112 ha	177 ha	225 ha	279 ha

Figure 10: Saturation of the built area. Source: Own elaboration based on data from Angel, 2023.

Figure 11: Total population and urbanized area in hectares by area, 1990-2020 Source: Own elaboration based on data from Angel, 2023.

area, increased by 2.5% annually, going from almost 7,000 hectares to a total of 14,183 hectares. It is also important to note that the largest increase in this area took place between 1990 and 2010, at 3.4% annually.

In 30 years (1990-2020), the suburban built-up area practically doubled. It grew at a 3% annual rate, slightly higher than that of the urban area, from 1,450 ha to almost 3,000 ha. It is worth noting that between 2000 and 2010, the percentage change fell to 2.4% per year, and then increased again in the following decade. The rural urbanized area shows a similar behavior to that of the suburban area. Between 1990 and 2020, it grew at an annual rate of 3.1%—although in absolute terms the area is not significant.

Considering the composition of the urban expansion of the SSMA (Figure 13), it is noteworthy that inclusion makes up for an average of 30%. This means that a significant amount of the added area is accounted for the connection of existing urban areas to the main urban footprint. Moreover, the most significant composition of added urban area happened with the infill of the existent urban extent. Thus, effectively new developed land (extension and leapfrog) account for a smaller makeup of the urban expansion.

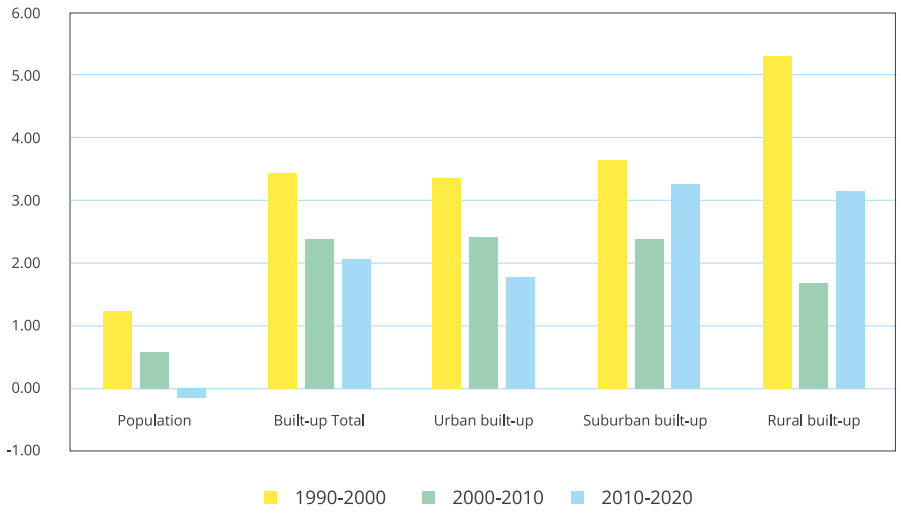
Housing Dynamics

Metropolitan San Salvador has experienced significant changes concerning housing dynamics over the last 30 years. As presented in Figure 15, the proportion of urbanized land used for housing decreased: between 1990 and 2000, it was 57%, while for the most recent period (2010-2020), 41%. On the contrary, built-up area destined for non-residential uses went from representing 29% (between 1990 and 2000) to 35% between 2010 and 2020.

The percentage of land built in irregular and/or non-conforming areas has increased slightly in the last 30 years: it went from 29% between 1990 and 2000 to 31% between 2010 and 2020. In contrast, the percentage of land built in areas that have been regularly subdivided has decreased significantly: from 28% between 1990 and 2000 to 10% in 2010-2020.

Urban areas have responded largely to the current zoning, since it has adhered to the natural elements that the same zoning has sought to protect. Even though there are areas currently settled as land for development, this development did not occurred as planned. A possible explanation for this primarily linear development is the lack of integration of a solid road strategy within urban planning instruments, which is largely related to the constant increase in urbanized land destined for road infrastructure.

Moreover, the considerable number of precarious or irregular human settlements, derived from the security conditions the country has faced in recent years, cannot be ignored. People seeking protection from the influence and violence exerted by war and gangs have been displaced and settled in



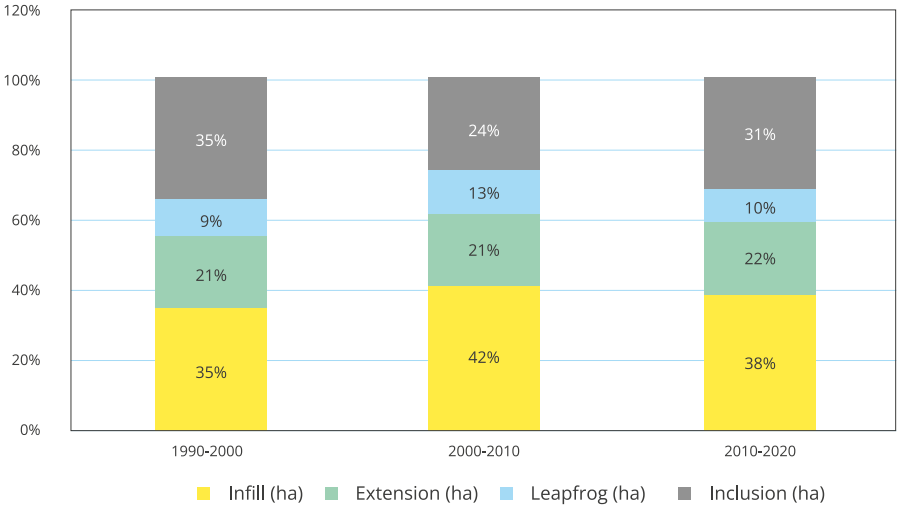


Figure 12. Population growth versus urban expansion Source: Own elaboration based on data from Angel, 2023.

Figure 13. The four types of new construction areas; SSMA Source: Own elaboration based on data from Angel, 2023.

the SSMA, fueling uncontrolled urban expansion or fragmented urban development. Another consequence was the rise of private and closed real estate developments that project a perception of greater security.

Several planning efforts focus on the consolidation of irregular areas, though render ineffective actions aimed at generating social housing. Thus, the growth of the urban area has occurred without the accompaniment of national government actions since, resulting in high costs of land in the central areas, the absence of affordable housing supply, and urban expansion in the peripheries.

At the national level, after the peace agreements[6] and the economic reforms of the 90´s, low-income housing policies were designed. These were oriented to stimulate private market through direct subsidies for families, requirements of savings according to housing prices, and the development of financing mechanisms to facilitate access and reduce risk in terms of the paying capacity of buyers. Moreover, in 2013 there were 28 companies dedicated to the subdivision of rural lands for urban development. This situation prompted the approval of the Special Law for rural subdivisions for residential use by the National Vice Ministry of Housing and Urban Development, as an instrument to tend to legal, business, environmental, and urban irregularities. The goal of the instrument was to legalize 300,000 lots which in 2012 represented 22% of the total housing stock.[7]

Nevertheless, El Salvador developed a Housing and Habitat Policy in 2015,[8] which acknowledges that there have been inadequate attempts to address the lack of provision of the right to housing at a national level. In recent years, different initiatives have been developed by the state, private enterprises, and non-governmental organizations to improve the housing and habitat situation; however, there are still challenges as overcoming institutional weakness, as well as dispersion and disarticulation in the state.

The national policy of El Salvador recognizes housing as a fundamental land use that largely determines the way in which the country's territory is organized and used, particularly in urban areas. It also underscores the importance of the participation of local governments in the design and implementation of the national policy, as these are the main regulators of the use and occupation of their territories. Given this, the housing policy includes a strategic planning axis of land use planning, in which actions are competencies of the municipal governments and links planned development with the provision of housing solutions.

In the financing chapter, actions are oriented towards design and implementation of a public and private financing system that offers multiple options for developers. In doing so, aiming the promotion and strengthening of permanent financing mechanisms that ensure resources for implementation of the policy. These actions show little specificity regarding financing mechanisms available at the national level for the provision of low-income housing solutions—there is

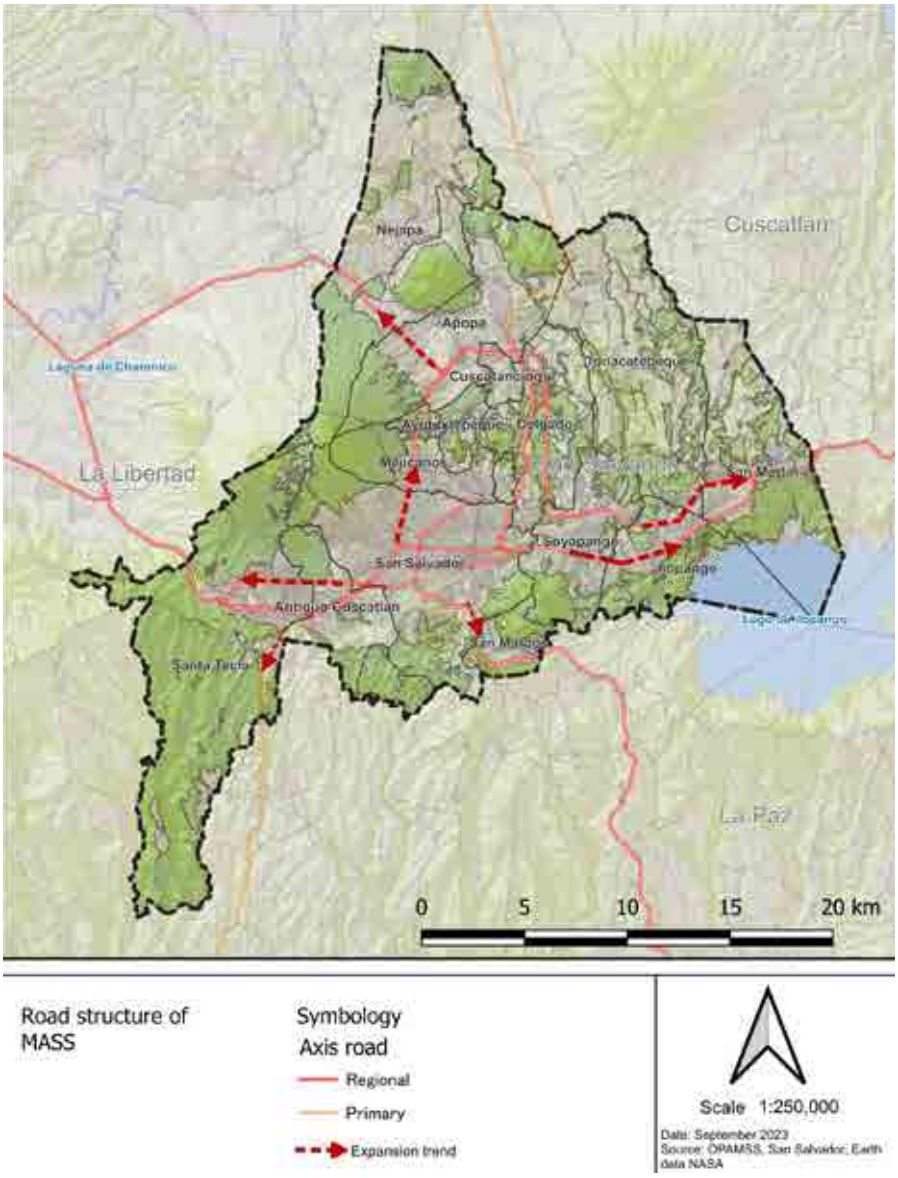


Figure 14: SSMA road structure. Source: Prepared from information from OPAMSS.

only the identification of the Salvadorian Housing Fund, and the National Popular Housing Fund as well as BANDESAL (El Salvador Central Bank).

There are several constraints on the affordability aspect of housing, which restrict financing for the acquisition or improvement of housing, thus impacting the housing stock. Therefore, there is difficulty in credit access through formal channels, which is highly related to income levels, informality, and underemployment. Data from 2010 showed that 26% of economically active population in El Salvador are underemployed in urban areas.[9] According to the OPAMSS database, the average price of registrations in the SSMA increased from US$112.50/sqm in 2007 to US$126.75/sqm in 2009, representing a 12.5% growth in two years, while inflation averaged 2.5% in 2009.

Differences in land value are evident in the SSMA. The highest average prices are registered in the municipality of Antiguo Cuscatlán (US$174.00/m²), followed by San Salvador (US$155.00/m²), Mejicanos ($150.00/m²), and Santa Tecla ($127.00/ m²). The average price in the rest of the metropolitan municipalities is quite homogeneous, ranging from US$50.00/m² in San Martin to US$97.00/m² in Ayacucho indicating two categories of municipalities: four "expensive" in the west of the city, and ten "expensive" in the south.[10]

Concerning housing policies, it was noted that, in 1997, the national government, based on PLAMADUR, introduced Neighborhood Improvement Plans (PMB, for its Spanish initials). In 2010, the PDT-SRMSS included "urban renewal" sectors with Precarious Urban Settlements (PUA), recognizing the precarious situation. The 2017 Master Plan recognizes precarious areas and establishes financial mechanisms based on urban compensation.

Urban Infrastructure

As previously mentioned, the road network infrastructure in the SSMA is conditioned by the topography of the valley. The most accessible roads are the ones that have been consolidated as structuring axis, integrating the Pan-American Highway along an east-west direction.

In terms of regional economic dynamics, San Salvador structures the country through the Pan-American Highway, with the city of Santa Ana to the west and San Miguel to the east. It communicates the center of El Salvador with the Port of La Libertad to the south, the main maritime access point through the Port of La Libertad Highway. Finally, the Quezaltepeque and Nejapa roads structure the northern expansion of the SSMA and form commercial and service corridors, in addition to surrounding the volcano and providing greater accessibility.

Such condition of high economic regional importance impacts the urban structure of the San Salvador Metropolitan Area by expanding the urban extent along these axes. This happens throughout the east-west highway in the municipalities of San Martín and Lolopango to the east of the SSMA; while



Network-driven growth

Predominant Land Use	Arterial	Collector	Local
Undeveloped Land	7%	5%	0.6%
Rural Land	2%	1%	2.9%
Land for development	6%	2%	0.2%
Urban Land	50%	23%	0.2%
Total	65%	31%	4%

Figure 15: Proportion of built area in informal residential, formal residential, non-residential, and road areas. Source: Own elaboration based on data from Angel, 2023.

Figure 16: Network-driven growth. Source: Prepared from information from OPAMSS.

the highway to the port of La Libertad structures the peripheral growth south of the municipalities of Santa Tecla and Nuevo Cuscatlán.

Moreover, the proportion of urbanized land destined for road infrastructure has increased: while between 1990 and 2000 the proportion was 14%, for the period 2010 to 2020 it is 24%. This coincides with statements made by OPAMSS officials themselves, who referred to the central role of roads in the urban expansion process.

The relationship between land-use planning regulations and road hierarchy has been studied to evaluate which roads favor urban expansion. In this context, it can be observed that arterial roads are mostly allocated in urban lands, whereas the land use presenting the highest number of roads is urban, while the other land uses do not even account for 10% in the other two hierarchies. The recently created land regulation mechanism in the SSMA is reactive, allowing for future urban expansion evaluation but limiting previous understanding of metropolitan planning and coordination instruments in San Salvador.

Regarding the economic activities present in the territory, the World Bank[11] reports that the GDP El Salvador was US$34.02 million. Approximately one third of the GDP is concentrated in the metropolitan region of San Salvador, which could be explained by the concentration of 40 percent of the country's economic establishments and 93 percent of microenterprises in the SSMA. While most workers are engaged in commercial, hotel, and restaurant activities, the second most important sector is manufacturing and financial intermediation, then followed by real estate.

Most of the companies are in commerce (56.5%), secondly in services (30.5%), and lastly in industry (10.9%). Hence, the economic vocation of the SSMA is directed to the tertiary sector. In the labor market, though the employment rate is high (93.4% of the EAP), 33% of the economically active population is in the informal sector and 30% remains underemployed. The average wage is low compared to the cost of the expanded basket of necessities, which represents 85% of the average wage. Women face the least favorable conditions in the labor market, constituting most of the invisible underemployed segment and receive the lowest average wages.

The following map shows the concentration of economic units of the SSMA. Two are located within the municipality of San Salvador and represent the historic downtown España Avenue corridor, and Escalon neighborhood. A second concentration is in the center of the municipality of Santa Tecla, southwest of the SSMA. Other centers of economic activity are in the center of the municipality of Apopa to the north and Soyapango to the east, along with the boulevard of the national army, responding to the logic of locating areas of greater transit of people and accessibility for the use of trade and services.

Industrial activities are mainly present in four points of the SSMA: Antiguo Cuscatlán, San Marcos, Soyapango and Apopa, which are in the limits of the

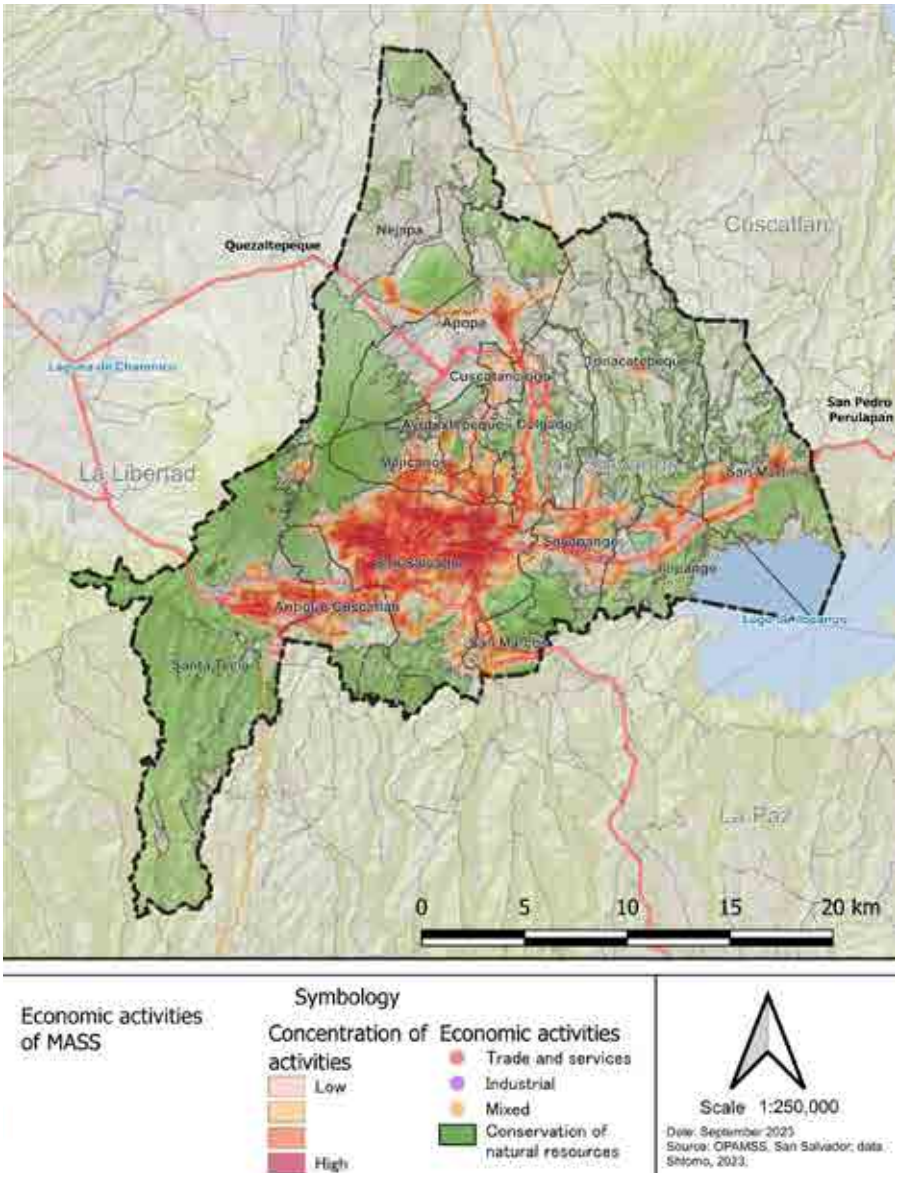


Figure 17: Economic corridors. Source: OPAMSS, San Salvador, 2023.

urban area. This is in line with the need to promote polluting activities away from the central areas, which present a higher residential density.

The previous map shows the hierarchy of economic nodes, referred to as centralities, located within the SSMA. It clearly shows that the capital has the greatest importance in contrast with municipalities located south of the SSMA, mainly with Soyapango and Antiguo Cuscatlán. This is because, in addition to comprising commercial and service activities, these locations also have a strong industrial vocation. Contrasting with the function that the Apopa centrality plays in the Metropolitan Area, where there is a prevalence of trade and services.

POLICY AND STRATEGIC RESPONSES TO URBAN GROWTH AND DENSIFICATION

Regarding climate change legislation and regulation, it is worth mentioning that the Environmental Law (1998, reformed in 2012) is developed along provisions of the country's Constitution. These refer to the protection, conservation, and restoration of the environment; the sustainable use of natural resources to improve the quality of life of present and future generations. They also say that environmental regulation, public and private management, and environmental protection are a basic obligation of the state, the municipalities, and the population in general. In doing so, it aims to ensure the application of international treaties or conventions concluded by El Salvador in this area.

Moreover, the National Environmental Policy (2012) establishes guidelines and strategies for environmental management in El Salvador, including measures to address climate change. Lastly, the National Climate Change Plan (2015) aims to build a society and an economy resilient to climate change. The plan seeks to promote a low-carbon economy, reduce greenhouse gas emissions, encourage the use of renewable energy, promote energy efficiency, and reduce deforestation. The plan seeks to integrate the climate change dimension into all government policies and actions.

Regarding private property, Article 103 recognizes and guarantees private property as a social function. Within Article 105, however, the state recognizes, promotes, and guarantees the right of private property over rural land, whether individual, cooperative, communal or in any other associative form, thus identifying that the figure of private property prevails over public interest.

Moreover, Article 106 of the El Salvador Constitution states that the main form of affectation of private property is through eminent domain. It must proceed for reasons of utility or legally proven social interest, as well as prior compensation. In certain cases, such as war, public calamity, or infrastructure implementation, compensation may not be prior. Likewise, the Law on Eminent Ownership of Real Estate for Municipal and Institutional Works establishes the procedure that the

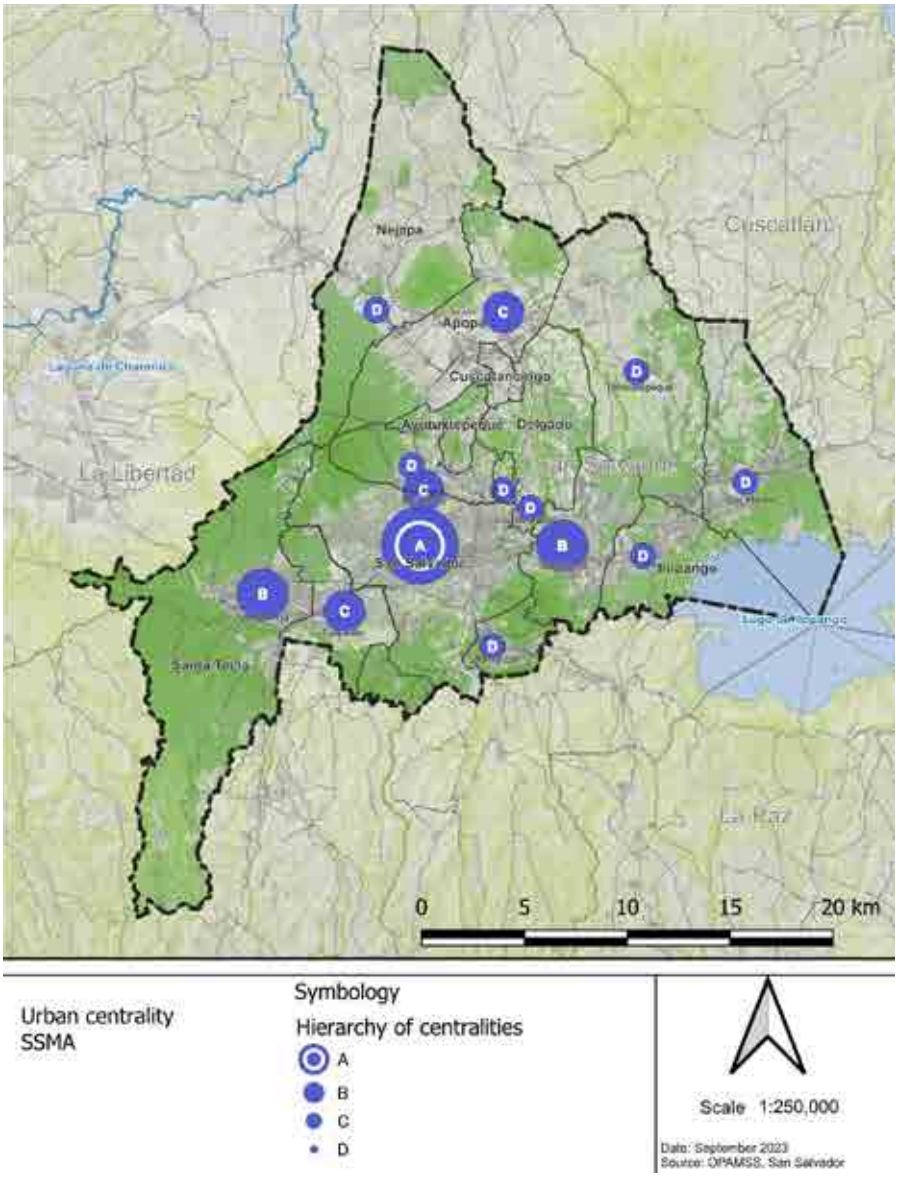


Figure 18: Centralities of the SSMA. Source: OPAMSS, San Salvador, 2023.

National Directorate of Municipal Works must follow in cases when it has not been possible to acquire the necessary land through direct negotiations with property owners or possessors.

Territorial regulation, which includes the delimitation of growth areas and other developing restrictions, is a strategy that has had an impact on the urban configuration of the SSMA. It has aimed to balance geographic and topographic elements with the urban sprawl, while also considering environmental factors and benefits. While topography plays a role in urban planning, other factors must be recognized: natural disasters, violence, and employment availability have also influenced the urban configuration of San Salvador.

The "Law of Territorial Development and Planning of the Metropolitan Area of San Salvador and the Surrounding Municipalities"—named on this paper as “the Law”—represents a comprehensive framework that combines regulatory mechanisms with principles of sustainable development. It not only emphasizes strategic planning and institutional coordination, but also prioritizes ecological balance. Thus, ensuring the growth of the SSMA while preserving its environmental and cultural heritage. Institutional coordination in urban planning can be broken down in a few key points, as follows.

Regarding institutional coordination, the Law establishes the planning committee COPLAMSS to coordinate planning in the SSMA. This committee enables collaboration between local and central governments, professional associations, and business entities related to construction. It streamlines consultations, facilitates efficient decision-making, and promotes a collective approach to urban and territorial planning challenges in the SSMA.

The Comprehensive Metropolitan Development and Territorial Plan begins with the Metropolitan Development Plan approved by the Metropolitan Council (COAMSS). This strategic plan outlines land use categories, including urban development, future urbanization, non-developable areas, and rural regions. It sets guidelines for permissible, conditional, and prohibited land uses, ensuring sustainable land management and controlled urbanization.

As part of the Metropolitan Development Plan, the Master Scheme (2017) provides a comprehensive diagnosis of land use and road networks. It addresses the organization of land uses, specifying urban, non-urbanized, and areas suitable for urbanization. The scheme outlines zoning regulations, detailing permissible, conditional, and prohibited activities within different zones, establishing a balanced framework for sustainable urban development.

Concerning environmental impact, the Law mandates environmental impact evaluations for proposed development projects in each sector plan. These assessments ensure that development aligns with sustainable practices, preserving ecological balance, biodiversity, and minimizing pollution. Policies integrate historical, architectural, and cultural landmarks with green spaces, promoting harmony between man-made structures and nature.

The Law designates specific areas as "restricted development zones" based on environmental criteria. These zones protect groundwater resources, conserve natural resources like forests, improve air quality, prevent soil erosion, and promote sustainable mobility options. This approach ensures development aligns with environmental priorities, reducing potential negative impacts on ecosystems and human communities.

Defined through technical evaluations, non-developable areas serve conservation purposes such as safeguarding groundwater resources, preserving biodiversity, controlling erosion, and managing risks. The law prohibits urban development in these zones, emphasizing long-term environmental sustainability and responsible land use practices.

Since one of the main problems in El Salvador has been violence, various security policies[12] have been implemented over time. Some of these policies have been linked to rehabilitation programs in degraded urban areas. These efforts have focused on the renovation and revitalization of areas with high rates of violence and crime through improvement of infrastructure, creation of safe public spaces, and implementation of social programs.

The SSMA stands out for the design and implementation of metropolitan planning since the late 1980s and early 1990s. It is the only metropolis in El Salvador and Central America that has institutional arrangements, legal framework, and planning instruments to address territorial management at a metropolitan scale. The Council of Mayors of the San Salvador Metropolitan Area (COAMSS, for its Spanish initials) is the main governing body, while the Planning Office (OPAMSS in Spanish) is established as the metropolitan technical authority.

Some of the pivotal planning instruments of the SSMA are:

1 Initial Climate Change Adaptation Plan for the San Salvador Metropolitan Area (PIACC-SSMA in Spanish): This plan is part of the Nationally Determined Contribution (NDC) under the Paris Agreements and was ratified by the Legislative Assembly in 2016.
2 SSMA Master Plan: it serves as the regulatory foundation for land planning across the fourteen municipalities of the SSMA. Formulated between 2013-2017 with European Union subsidies and technical support from institutions like FUNDAUNGO and Central American University José Simeón Cañas (UCA in Spanish), the plan incorporates citizen feedback to ensure it meets stakeholders' needs. It also includes strategies for promoting territorial economic growth.
3 Sustainable Urban Habitats Guide: Launched in June 2018 by COAMSS-OPAMSS, this guide envisions sustainable and resilient cities across the fourteen SSMA municipalities. It is the nation's first voluntary regulation for sustainable building practices.

4 Georeferenced Entrepreneurship Directory: Introduced by OPAMSS, this directory aims to promote territorial economic growth by highlighting entrepreneurial ventures and micro-businesses within the SSMA, fostering inclusive and sustainable economic development.

CONCLUSION

Natural conditions (rivers, bodies of water, volcanoes), as well as the availability of large rural areas, have promoted a horizontal expansion predominantly towards the northeast of the metropolis. In this process, demographic increase within the SSMA has occurred predominantly in the peripherical municipalities.

Thus, the SSMA was transformed into a complex and elongated metropolis with an irregular urban shape. Natural barriers guided expansion towards the periphery, creating an urban structure with a dominant centrality (municipalities of San Salvador, Santa Teca and Soyopango) and a series of municipalities with the character of dormitory cities. This configuration has given rise to municipalities such as San Marcos, Delgado, Ayutuxtepeque and Cuscatancingo—which have greater density and demand for pendulum mobility towards the central cities. Such trend of urban expansion rendering a more irregular shape was accompanied by an increase in compactness in comparison to other LAC cities in this study, as the SSMA's compactness rank rose from 51nd to 43th from 1991 to 1999 and from 2014 to 2020, respectively.

Moreover, recent decades present increase in irregular residential areas in contrast to a decrease in regular residential areas, considering the urban extent's composition. Hence, there are still challenges for SSMA's urban planning implementation.

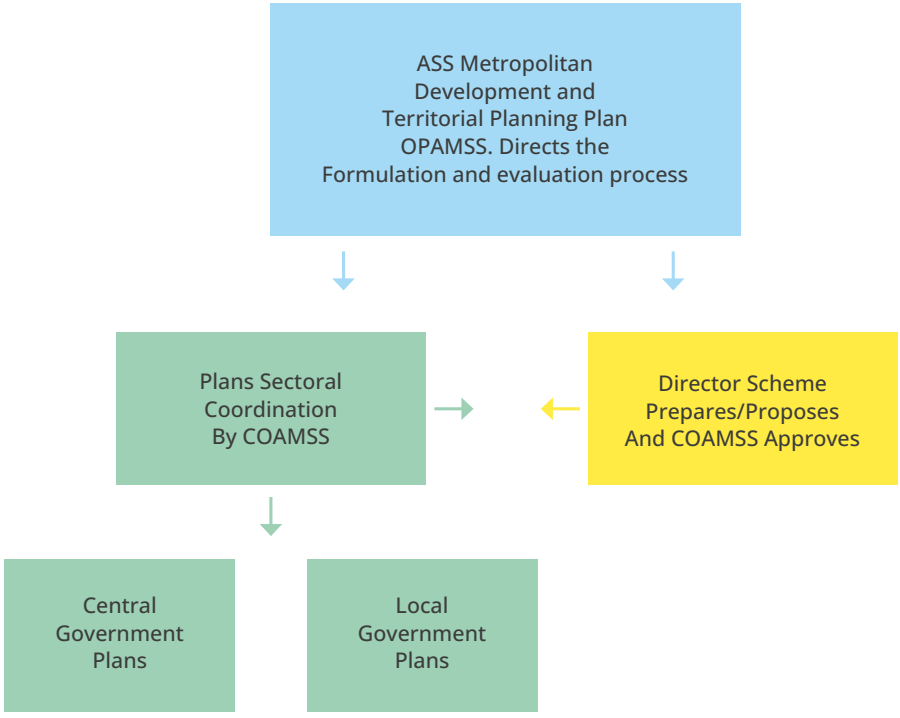


Figure 19: Main land management instruments used by the SSMA.
Source (own translation from Spanish): METROPOLIS INTERNATIONAL CONGRESS FOR GOVERNANCE, San Salvador, El Salvador, presentation “Metropolitan Institutionality and Policy of Public Spaces”. Provided by SSMA Authorities.

Endnotes

1. The data was provided by Shlomo Angel in May 2023.

2. For the definition of these indexes, please see the Glossary in the Atlas.

3. Population Density Built-up Area.

4. Including urban, suburban, and rural areas.

5. Map provided by Shlomo Angel in May 2023.

6. The peace agreements were signed in 1992 in México, between the Government of el Salvador and the Farabundo Martí National Liberation Front (in Spanish Frente Farabundo Martí para la Liberación Nacional).

7. ONU-Habitat (2013). Perfil del Sector Vivienda de El Salvador. See: https://unhabitat.org/perfil-del-sector-vivienda-de-el-salvador. Programa de las Naciones Unidas para los Asentamientos Humanos.

8. Vice Ministerio de Vivienda y Desarrollo Urbano. (2015).

9. ONU-Habitat (2013). Perfil del Sector Vivienda de El Salvador. See: https://unhabitat.org/perfil-del-sector-vivienda-de-el-salvador. Programa de las Naciones Unidas para los Asentamientos Humanos.

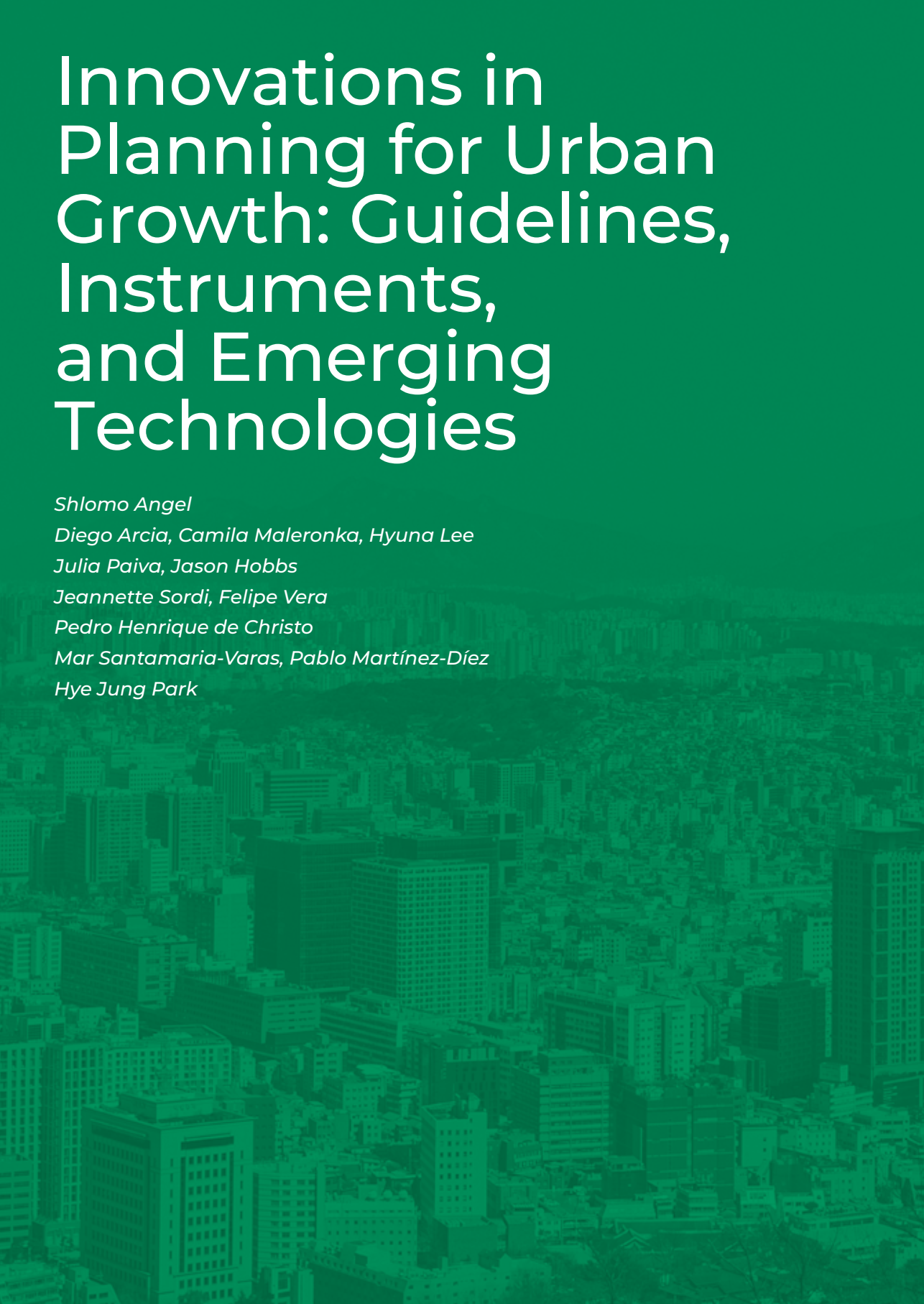
10. Ibid.

11. World Bank, 2023. See: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=SV.

12. Such as: Mano Dura – 2003; Super Mano Dura – 2004; Truce – 2012; Plan El Salvador Seguro – 2015; Territorial Control Plan – 2019.

Innovations in Planning for Urban Growth: Guidelines, Instruments, and Emerging Technologies

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PART THREE
STRATEGIES



Twelve Guidelines for Action on Urban Expansion **P.596** // Guidelines for Sustainable and Inclusive Urban Densification **P.638** // Transit Oriented Development in the Context of Accelerated Urban Growth in Latin America and the Caribbean **P.678** // Strategies for the Self-constructed City. Urban Expansion, Densification and Resilience **P.694** // Climate Urbanism **P.716** // Measuring Cities Together with their Citizens: Data and Algorithmic Transparency for Urban Planning **P.728** // Managing Urban Growth in South Korea **P.740**

Twelve Guidelines for Action on Urban Expansion

Shlomo Angel

In this final chapter, I summarize what I have learned over the years in twelve guidelines for action, actions that can be undertaken now, before urbanization largely comes to an end in the Global South as it already has, in large measure, in the Global North.

This evidence takes the form of both theoretical and empirical findings from past and more recent research, of successful examples—both recent and historical—of good practice, and of illustrative examples of bad practice as well, as presented in the previous chapters.

Here are the twelve guidelines:

01 Guideline 01: Come to an understanding that **urbanization results in urban expansion,** and that expansion is both global—namely that it happened and will happen in all cities in all countries—and local, namely that it has happened and will happen in your city as well.

02 Guideline 02: Understand and be able to explain that the two main forces that drive urban expansion are population growth and income growth, and that **urban expansion cannot be contained by policies and plans,** however well-meaning or draconian they may be.

03 Guideline 03: Come to terms with the fact that cities accommodate their added populations both by densification and by expansion, that the two are complementary, not exclusive, and that **most population growth is accommodated by expansion, not by densification.**

04 Guideline 04: Acknowledge, and convince others, that while densification is greener than expansion, the challenge is not to replace urban expansion by densification but to **make urban expansion green while ensuring that it is productive and inclusive as well.**

05 Guideline 05: Come to terms with the fact that **unplanned and disorderly expansion is undesirable**—it compromises city productivity, inclusiveness, sustainability, and resilience, making it more difficult and expensive to attend to these issues later.

06 Guideline 06: Understand that planned urban expansion can best be accomplished by **empowering local officials and stakeholders to plan and implement expansion** themselves, and not by plans made by outsiders and left for the locals to implement.

07 Guideline 07: Empower local officials and stakeholders to prepare for planned urban expansion by, first, **making realistic projections of the amount of land needed** to accommodate the growth in population and income in the coming decades, preferably for thirty years.

08 Guideline 08: Because projecting too little land will result in costly unplanned expansion while preparing too much land will cost little if preparations are minimal, **advocate for erring on the side of projecting more, rather than less, land for expansion.**

09 Guideline 09: Help the city **identify the lands on the urban periphery that are suitable for expansion,** ensuring that drainage channels, steep slopes, low-lying areas subject to sea level rise, and important environmental assets can be protected from development.

10 Guideline 10: Help **plan and mark the rights-of-way on the ground for an arterial road grid throughout the projected expansion area**—30-meter-wide roads one kilometer apart, that can carry public transport, are within women's walking distance, and connect workers to jobs.

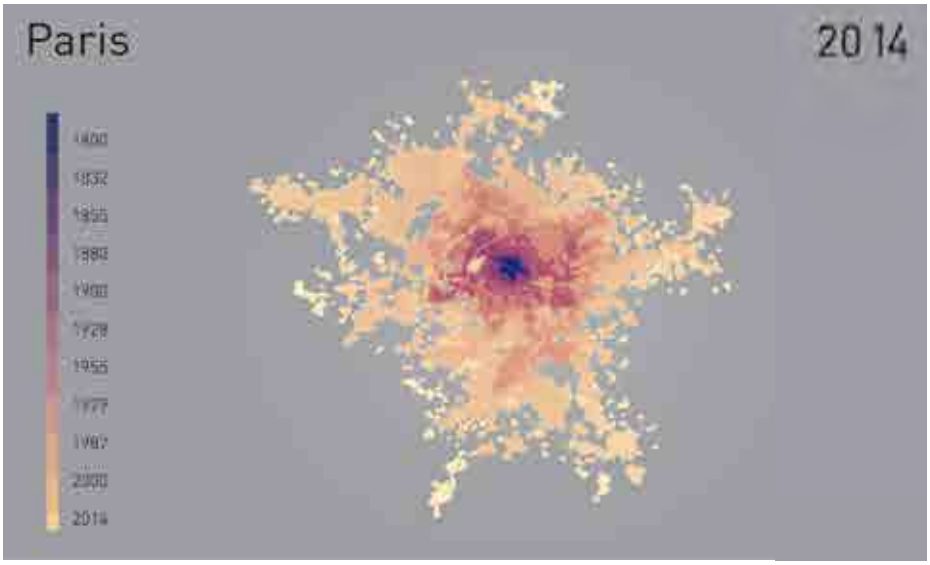
11 Guideline 11: **Reform zoning and land use regulations to allow for green urban expansion** permitting high-density transit-oriented corridors along arterial roads, mixed use within macroblocks, smaller plots, and higher plot coverage, and requiring neighborhood greens.

12 Guideline 12: Promote and empower rural councils and rural landowners to **implement land pooling and subdivision within the macroblocks** of the arterial road grid to reduce demand for informal settlement, capture the increased land value without compulsory acquisition, and provide large numbers of minimally serviced affordable plots.

01

Come to an understanding that **urbanization results in urban expansion,** and that expansion is both global—namely that it happened and will happen in all cities in all countries—and local, namely that it has happened and will happen in your city as well.

Together with colleagues, we studied the historical expansion of a group of 30 representative cities during the past two centuries, using historical maps for earlier periods and satellite imagery for later ones. In the case of Paris, for example, between 1800 and 2014, the population of Paris increased 22-fold, while its area expanded 220-fold.
In our study on Latin American cities, 69 out of the 70 cities of the sample, expanded their footprint between 1990 and 2020. In the image, we can see the urban expansion of Cuenca, Ecuador, between 1989 and 2021. Over the three decades of our study, the population of Cuenca, Ecuador, increased by a factor of 2.4, while its urban extent increased 5-fold.



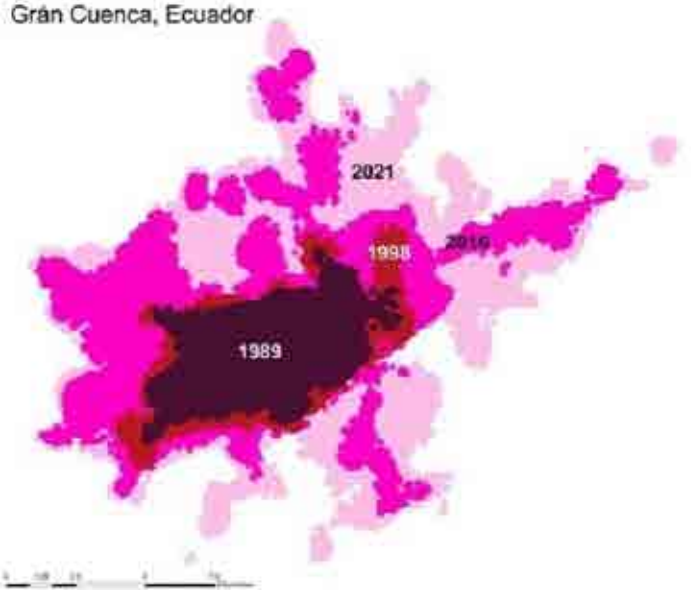


Figure 4.1: The expansion of Paris, France, 1800-2014.

Figure 4.2: Urban expansión of Gran Cuenca, Ecuador, 1989-2021.

02

Understand and be able to explain that the two main forces that drive urban expansion are population growth and income growth, and that **urban expansion cannot be contained by policies and plans,** however well-meaning or draconian they may be.

As introduced in chapter II, there is a long history of trying to contain outward urban expansion, starting with Queen Elizabeth the first, who banned construction within three miles of the City of London in 1580.
The three examples described in that chapter—the green belt defined by the greater London plan (1944), the deregulation of the Seoul, Korea, Green Belt (1998, 2000s), or the Urban Growth Boundary in Portland, Oregon, (1978)—are more recent examples of the risks involved with attempting to contain urban expansion.[1]



Figure 4.3: Queen Elizabeth I, 1580: Prohibit “any new building of any house or tenement within three miles of any of the gates of the said city of London.”

03

Come to terms with the fact that cities accommodate their added populations both by densification and by expansion, that the two are complementary, not exclusive, and that **most population growth is accommodated by expansion, not by densification.**

As we saw in the previous chapter, for the 69 cities in the region studied in our sample, the 1990 footprints accommodated less than one-fifth of the population added during the 1990-2020 period (18±5%), while their expansion areas accommodated more than four-fifths of this population (82±5%).[2]
In every decade, more than 60% of the added population was accommodated in expansion areas and less than 40% in the existing urban footprints at the beginning of the decade.

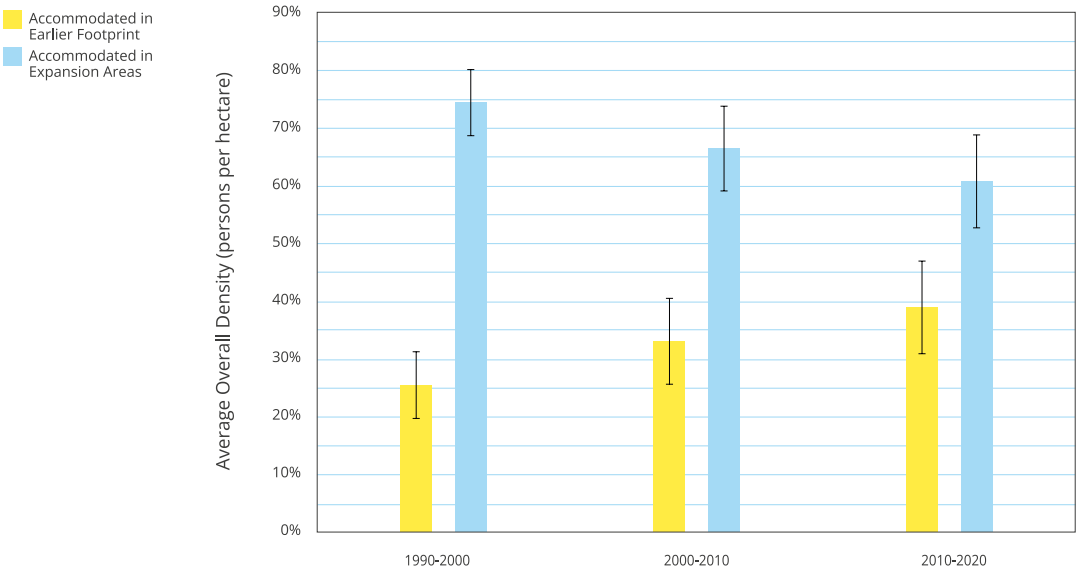


Figure 4.4: The respective shares of the added population accommodated by earlier footprints and by expansion areas in three time periods: 1990-2000, 2000-2010, and 2010-2020. Source: New York University, The Marron Institute of Urban Management.

04

Acknowledge, and convince others, that while densification is greener than expansion, the challenge is not to replace urban expansion by densification but to **make urban expansion green while ensuring that it is productive and inclusive as well.**

This can be accomplished, as we shall see later, by several means. I outline them here.
It can be accomplished by (1) connecting expansion areas to the urban labor market by a grid of arterial roads that can carry green public transport within the walking distance of women. (2) By enabling and encouraging high-density transit-oriented development along these arterial roads. (3) By promoting mixed land use. (4) By protecting drainage channels from development. (5) By guiding development away from flood-prone areas, steep slopes, sensitive natural habitats, and high value environmental assets. (6) By ensuring that neighborhoods contain adequate public open spaces; and (7) by planning for small blocks with four-way intersections that facilitate walking and biking.



Figure 4.5: Green open space in the Surco neighborhood in Lima, Peru.

05

Come to terms with the fact that **unplanned and disorderly expansion is undesirable**—it compromises city productivity, inclusiveness, sustainability, and resilience, making it more difficult and expensive to attend to these issues later.

Evidence is accumulating that the expansion areas of cities have worse urban fabrics than those in areas of the cities built earlier. In a global sample of cities, the share of the built-up area within walking distance of arterial roads decreased from 83% in areas built before 1990 to 69% in areas built between 1990 and 2015.[3] Average block sizes increased as well during the 1990-2015 period, in cities in the Global North from 4.2 to 6.2 hectares, and in cities in the Global South from 3.5 to 5.1 hectares. And the share of neighborhoods that are properly subdivided before they are built declined in all world regions.

This should be a cause for concern. Once an area is built-up, pushing an arterial road through it is both politically and economically infeasible, and therefore rarely happens.



Figure 4.6: Favela da Rocinha, a neighbouring community. Here we provided an option for each community.

06

Understand that planned urban expansion can best be accomplished by **empowering local officials and stakeholders to plan and implement expansion** themselves, and not by plans made by outsiders and left for the locals to implement.

There are two working models for making plans for urban expansion: the empowerment model and the consultancy model.
At New York University (NYU) we have been dedicated to making the empowerment model work since 2012, working with local officials in Colombia and Ethiopia, for example, who have made and implemented plans for their orderly expansion.
The picture below shows municipal officials from Bahir Dar, Ethiopia, drafting a long-term plan for the expansion of their city at a 2013 workshop organized by NYU in Addis Ababa. To assist officials, like those of Bahir Dar, in planning for accommodating growth—both by densification and by expansion—we have recently completed an online course in partnership with Urban Shift. The course, titled “Accommodating Urban Growth,” is presented in the form of some 120 short 3-to-4-minute videos or an accompanying text. It is now freely available online in six languages.
To conclude, empowerment has to do with what we call in architecture “who is holding the pencil?” Who should be making the plan? The foreign consultant armed with the latest globalized knowledge or local officials who understand the situation on the ground and, provided with simple tools they can master, can make the plans they really need?



Figure 4.7: Local officials drafting an expansion plan for Bahir Dar, Ethiopia, 2013.

07

Empower local officials and stakeholders to prepare for planned urban expansion by, first, making **realistic projections of the amount of land needed** to accommodate the growth in population and income in the coming decades, preferably for thirty years.

There are now, for the first time, global data sources for both population and built-up areas for all human settlements.
There are at least three global population grids with 100-meter resolution: LandScan, published by the Oak Ridge National Laboratory and shown here; GHS-POP, of the European Commission; and WorldPop, published by the University of Southampton.
There are at least two global built-up area grids: GHS-BUILT, of the European Commission
shown in this map; and the World Settlement Footprint (WSF) Evolution, of the German Space Agency (DLR). Both provide historical data; the former going back to 1975 and the latter to 2000.
There is also a comprehensive data set with census data from several periods for all cities at citypopulation.de, albeit without identifying their physical extent.
And finally, there is the UN Population Division's *World Urbanization Prospects*, with urban population for all countries from 1950 to 2050.
All of these global data sets still have serious issues that will need to be sorted out. But they are improving all the time.
These data sets already provide adequate information for projecting both populations and average urban densities into the future, making it possible to calculate

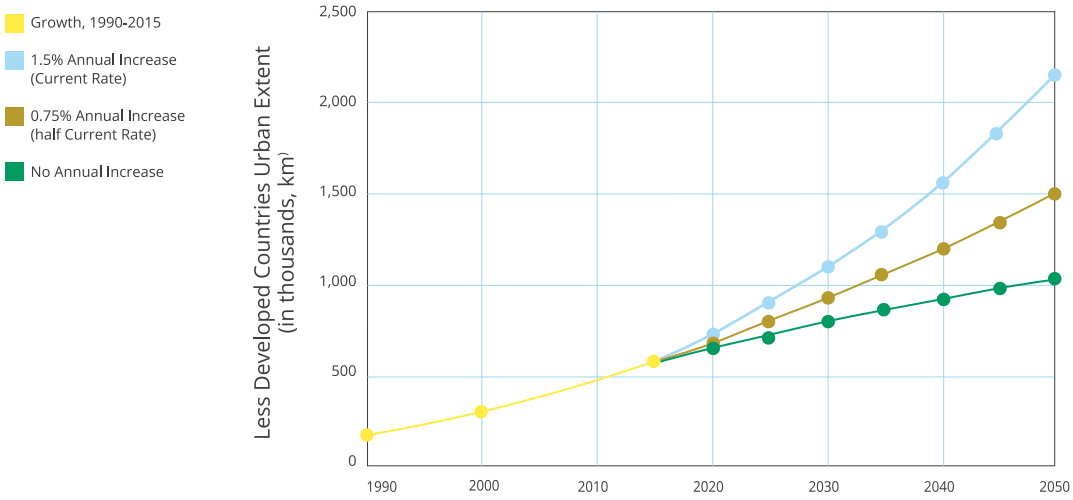


Figure 4.8: Less developed countries urban extent (in thousands, km^2). Source: New York University, The Marron Institute of Urban Management.

the amount of land needed for urban expansion for every city in the coming decades.

Going forward, together with partners from the World Resources Institute (WRI), we are now working to create the *Atlas of Urban Growth*, a complementary tool to the online course on *Accommodating Urban Growth* mentioned earlier.

The Atlas would provide easy access to free online maps and metrics of historical urban expansion, topography, and environmental hazards and environmental assets for all 50,000 cities that now have 10,000 people or more in as many as 50 languages.

The main function of the Atlas is to make data that is already available, but rather difficult to use globally, accessible to municipal officials in cities everywhere, so they can make their own urban expansion plans.

As presented in the introduction to chapter III, the urban population in the region is projected to grow by only 27% by 2050[4] and by a maximum of 32% by 2070 when it will have stopped growing (our own projection). In other words, the region's urban population will grow by less than one-third during the next 50 years before it stabilizes at 700-750 million people. However, some countries in the region, especially the poorer ones, are still urbanizing. And while no country in the region is expected to double its urban population by 2050, seven countries will increase it by over 50%: Haiti, Honduras, Guatemala, Bolivia, Paraguay, Ecuador and, surprisingly, Panama (figure 3.4). Guatemala, an outlier, is expected to almost double its urban population between 2020 and 2050.[5]

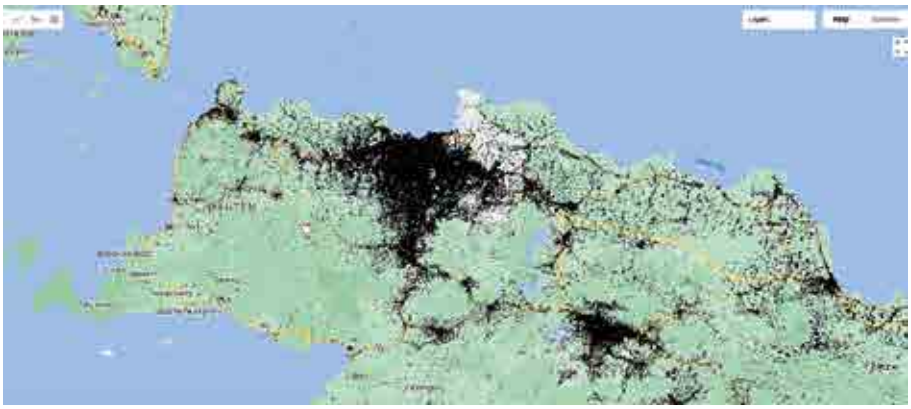


Figure 4.9: The Atlas of Urban Growth: Online maps and metrics of historical urban expansion, topography, and environmental hazards and environmental assets. Source: New York University.

08

Because projecting too little land will result in costly unplanned expansion while preparing too much land will cost little if preparations are minimal, **advocate for erring on the side of projecting more, rather than less, land for expansion.**

As seen in chapter II, there are three truly visionary plans for generous urban expansion at scale, all of them quite old: The 1811 Commissioners' Plan for New York City, Ildefons Cerdá's 1858 *Ensanche* Plan for Barcelona, and James Hobrecht's 1872 Expansion Plan for Berlin. The plans for all three cities were implemented on the ground and, ambitious as they were, all three cities grew far beyond them.
That said, these three classic plans provide ample evidence that planning for urban expansion at scale is both feasible and possible. More recently, visionary urban leaders in the Global South have taken those examples to heart. At an urban planning workshop recently organized by Cities Alliance, Dr. Sanya Wilson, the mayor of Koboko, Uganda, observed (and I quote): "In 2016, Koboko was 20 square kilometers. When I came back from the Urban Expansion Planning workshop in Addis Ababa, I said 'we are going to go the Ethiopian way, we are going to plan beyond, and I want to see the Koboko Municipality area expanded by 80 percent.' Now I have 108 square kilometers of Koboko which are planned, and we call it peri-urban planning. You will never stop urbanization. I am doing a favor to the leaders of Koboko that will come after me."



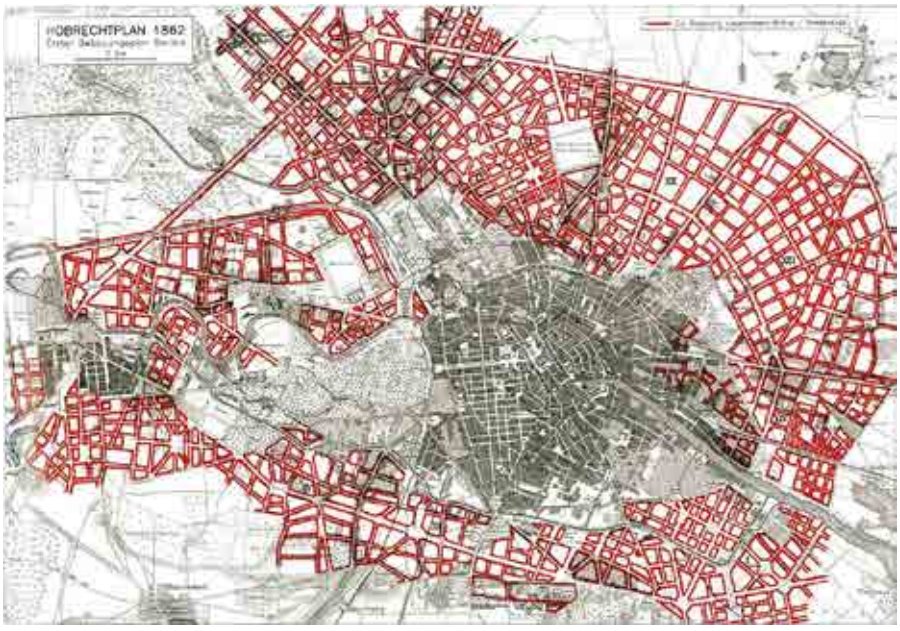


Figure 4.10: The expansion plan for Barcelona, Spain, prepared by Ildefonso Cerdá, 1859. See chapter 2.1, page 88 in this book.

Figure 4.11: James Hobrecht's 1872 plan for Berlin expanded the city at least fivefold in all directions. Its street grid was not orthogonal to better align streets with property lines.

09

Help the city **identify the lands on the urban periphery that are suitable for expansion**, ensuring that drainage channels, steep slopes, low-lying areas subject to sea level rise, and important environmental assets can be protected from development.

It is important to realize, at the outset, that simply mapping no-build zones on maps that decorate the walls of municipal offices is not enough. Here is one example, the 1999 zoning map for San Salvador.
By 2001, the new built-up area in the planning zones designated “maximum protection” and “unsafe to build” was more than twice the new built-up area in the zone designated “urban area.”
Similarly, protecting drainage channels, steep slopes, flood zones, or high- value environmental assets from urban development—and particularly from informal development—requires a more profound understanding of why such development happens.
In most cases, it happens because these areas are more accessible to the urban job market and because there is a shortage of affordable, yet green, formal plots with good access to the job market.
The key is to plan for an adequate supply of affordable, yet green, plots to reduce demand for informal plots, and to guide development there with arterial roads that carry public transport and provide good access to the urban job market.

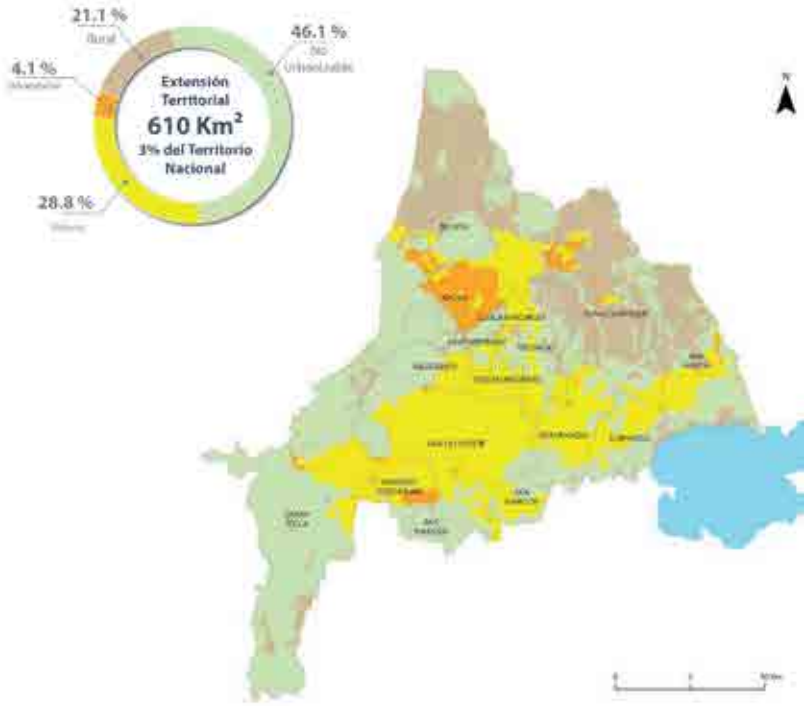


Figure 4.12: Zoning plan for the Metropolitan Area of San Salvador. Source: COAMSS/OPAMSS.

10 Help **plan and mark the rights-of-way on the ground for an arterial road grid throughout the projected expansion area**—30-meter-wide roads one kilometer apart, that can carry public transport, are within women's walking distance, and connect workers to jobs.

Look at this satellite map of Toronto. It has a grid of arterial roads one mile or half-a-mile apart.
Now look at this map. There is a transit line on every one of these arterial roads. Toronto has the third-largest transit system in North America, much facilitated by its arterial road grid.
An arterial road grid becomes more gender sensitive when roads are within walking distance of women, possibly carrying bags or caring for others. This is why we recommend arterial grids that are one kilometer apart, not one mile apart.
Local officials in Mekele, Ethiopia participated in an NYU workshop in 2013 where they prepared a draft arterial grid plan for their city. They later finalized the plan and implemented large parts of it.
This is an area in the southwest periphery of Mekele showing the development of macroblocks within its arterial road grid in 2024. In October 2023, high officials from Malawi participated in a workshop at New York University, where they prepared draft plans for the expansion of three of the largest cities in the country: Lilongwe, Blantyre, and Zomba.
The draft plan for Blantyre is shown in this map.
There are now plans in the making for a pilot project in Malawi aimed at finalizing one or more of these draft







Figure 4.13: Toronto, Canada's arterial road grid, spaced one-mile or half-a-mile apart is largely located on the rights-of-way of colonial concession roads, shown in light green.

Figure 4.14: Toronto's transit system map, showing that the majority of the arterial road segments are streetcar and bus lines.

Figure 4.15: Left. The arterial grid plan for the expansion area of Mekelle, Ethiopia, 2010-2040, prepared by municipal officials, 2014. Right. Newly opened sections of an arterial road grid on the southwest periphery of Mekele, Ethiopia.

plans into engineering plans, identifying the roads rights-of-way in high-resolution satellite imagery, surveying them on the ground, and marking them with beacons, spaced 100 meters apart on both sides.
In Valledupar, Colombia, parts of the future arterial road grid shown here were marked with trees along their future sidewalks.

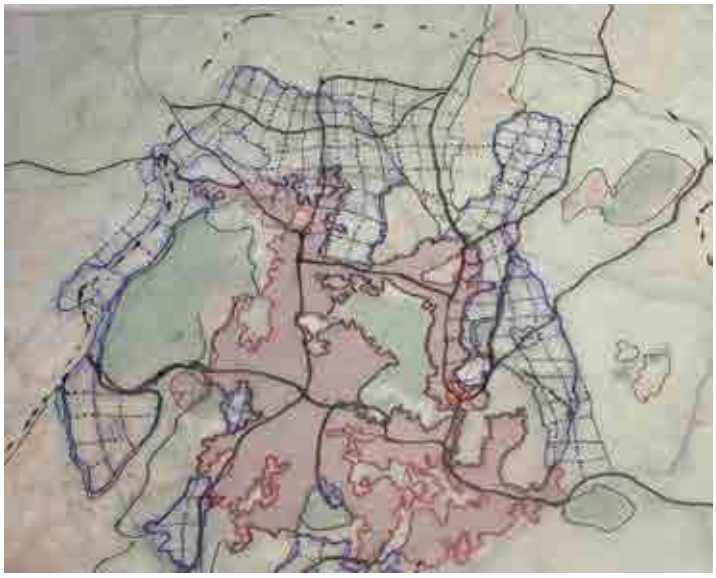




Figure 4.16: The draft expansion plan for Blantyre, Malawi, prepared by its Director of Planning and Development at a Workshop at NYU in 2023.

Figure 4.17: Children planting trees along the future sidewalks of an arterial road on the periphery of Valledupar, Colombia, 2017.

11

Reform zoning and land use regulations to allow for green urban expansion permitting high-density transit-oriented corridors along arterial roads, mixed use within macroblocks, smaller plots, and higher plot coverage, and requiring neighborhood greens.

The planning of an arterial road grid that can carry public transport—buses and later bus rapid transit as well—can help greening expansion if regulations are put in place that allow and encourage high-density mixed-use development along these arterial roads. This may require changing existing regulations to allow for higher floor area ratios, larger plots, higher plot coverage, or parking behind buildings to allow for the formation of walkable streets lined with shops. The zoning and land use regulations should aim at the proper layout and subdivision of macroblocks into streets and plots, allowing for and encouraging their conversion, one-by-one, from rural to urban use. These regulations need to be simple and transparent, and employed with affordability in mind.
They should aim to compete with informal settlements, offering an attractive alternative to persistent informality.
This slide shows a model macroblock developed for Ethiopian cities, based on a regulatory framework that allows high-density mixed use along its periphery, parking areas behind buildings, markets along the arterial roads, small blocks with a variety of residential plots, small public open spaces, and public facilities at the center.



Figure 4.18: Curitiba BRT.

In November 2023, Cities Alliance organized a high-level peer-learning event focused on learning about urban expansion planning from Mekele, Ethiopia.
The participants included state ministers from Ethiopia and Uganda, regional government representatives, mayors and municipal officials, and academics from Ethiopia, Uganda, and Somaliland.
At the completion of the high-level peer learning event, participants drafted and adopted the *Mekele Declaration of Cities*. The declaration resolves, among other things, “to put in place or review relevant legal and regulatory frameworks to facilitate preparation and implementation of urban expansion planning.”



Figure 4.19: Prototype Macroblock Layout for an Ethiopian city, showing high-density mixed use along its periphery, residential plots of different sizes, a hierarchy of public open spaces, markets and public facilities.

12

Promote and empower rural councils and rural landowners to **implement land pooling and subdivision within the macroblocks** of the arterial road grid to reduce demand for informal settlement, capture the increased land value without compulsory acquisition, and provide large numbers of minimally serviced affordable plots.

Converting macroblocks from rural to urban use, one macroblock at a time, provides a pragmatic way of implementing planned urban expansion at scale.
The key is to understand that proper streets and plots make all the difference between a place that develops as an irregular informal settlement and a place that develops into a regular urban neighborhood. In other words, land subdivision is an antidote to informality.
Most of the new construction on the periphery of cities in Sub-Saharan Africa, for example, is informal, where informality is characterized by rural land holders on the urban periphery breaking up their rural land holdings and selling them piece by piece to families who then build “starter houses” on them.
Basic amenities—such as streets, water supply, sewerage, drainage, and public open spaces—are not provided, sales lack a proper land survey as well as official documentation, and houses do not conform to the municipal building code.
Informality typically happens when rural land holders are not directly involved in the official conversion of lands from rural to urban use and are threatened by the prospect that their lands will be expropriated.
The resulting absence of proper street layouts greatly





Figure 4.20: A model land pooling and subdivision of a macroblock on the periphery of Lilongwe, Malawi.

Figure 4.21: The Comas squatter invasion on the outskirts of Lima, Peru, was laid out with 10-meter-wide streets and 10-by-20-meter plots before it was occupied.

increases the cost of the provision of infrastructure services later.

The absence of proper documentation increases the threat of eviction and the resulting insecurity of tenure delays investment of both savings and labor in house improvement.

What is more, the irregular layout of informal neighborhoods often imposes on them the stigma of being a “slum” which is difficult to shed over time.

The best counterexample I know is Comas, a 1960s squatter invasion on the periphery of Lima, Peru.

The only difference between Comas and other squatter settlements is that land was properly subdivided before it was occupied.

Each squatter family received a 10-by-20-meter plot along 10-meter-wide streets, while other plots were reserved for markets, parks, and schools.

Families built a shack in the middle of the plot overnight, immediately following the invasion, and then quickly dug channels along the plot boundaries to mark their territory. They then gradually built brick walls all around their plots and rooms facing inwards. In 2024, houses in Comas were selling for as much as $180,000.

In a proposed pilot project in Malawi, we are envisioning the development of three macroblocks, one after the other, using land pooling and subdivision—also called “land readjustment”—as the mechanism for converting rural land to urban use.

This mechanism has been used extensively in the past in Germany, Japan, and Australia, for example, and more recently in Ahmedabad in India.

In essence, the original owners get back a share of their



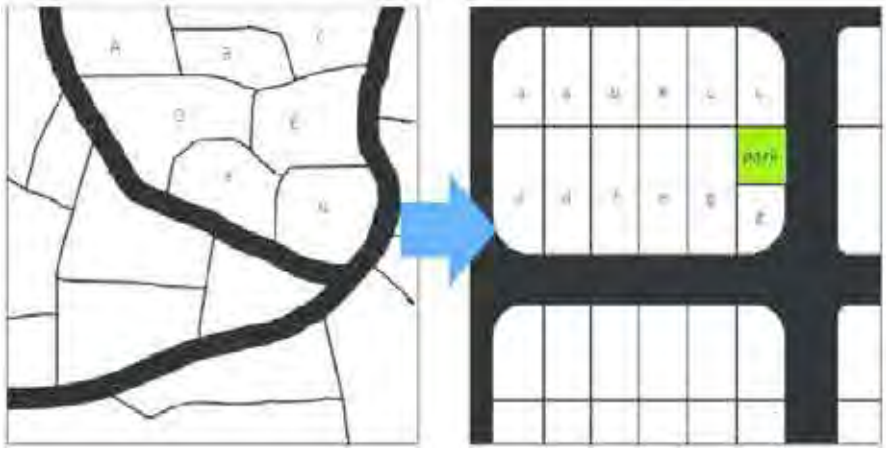


Figure 4.22: This house was for sale in Comas in 2024 for $188,000.

Figure 4.23: An illustration of the principle of land readjustment showing the conversion of rural land to urban use.

original lands in the form of salable plots with proper title documents, while the remaining land is used for streets and open spaces, as well as for funding basic infrastructure.
In Ahmedabad, 4.5 square kilometers of land for the 76-kilometers-long Sardar Patel Ring Road around the city were developed through land pooling and subdivision in four years.
This involved 47 Town Planning Schemes along the ring road alignment, each one involving land pooling and subdivision as shown in this map.
The 60-meter-wide right-of-way for the Sardar Patel Ring Road in Ahmedabad, India, was acquired through 47 Town Planning Schemes involving land pooling and subdivision, largely without compulsory acquisition and compensation.
It is envisioned that the Malawi pilot project will focus on developing 3 adjacent macroblocks in one of the larger cities in the country. This is expected to create 4,500 salable residential plots and 500 commercial plots.
At the conclusion of an October 2023 workshop for Malawi officials at NYU, Chief Kapecha Kalumbu, the chairperson of the Lilongwe Chiefs Council, commented that he originally was resistant to urban expansion as he thought it would just be used to take away the rights of traditional landowners.
He now understood that the cities are going to expand, whether the council plans for it or not, so that advance land subdivision would be the best method to get ahead of expansion.
He feels that he was now better able to explain to people in his community that cities can expand while still respecting local communities. I found this very encouraging and heartwarming.

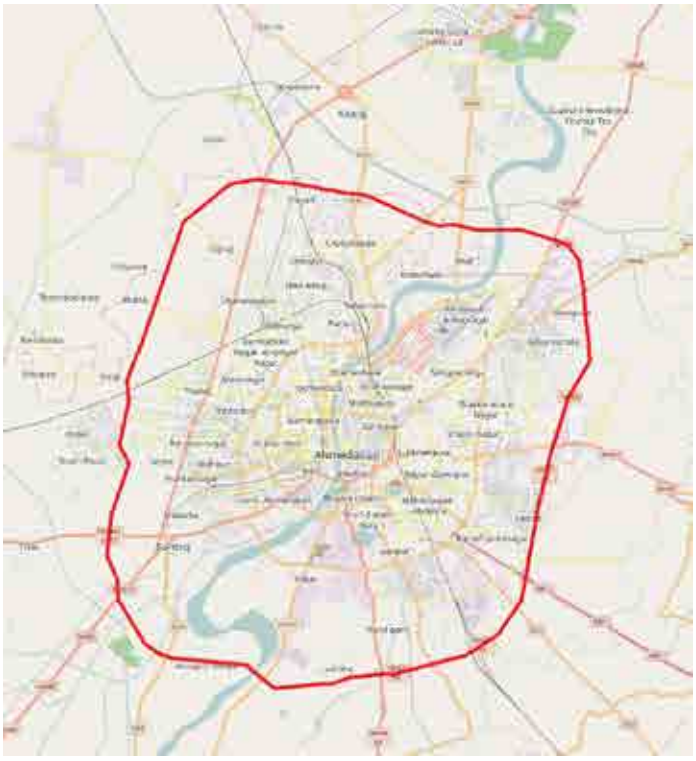


Figure 4.24: The 60-meter-wide right-of-way for the Sardar Patel Ring road in Ahmedabad, India, was acquired through 47 Town Planning Schemes involving land pooling and subdivision, largely without compulsory acquisition and compensation.

Endnotes

1. See the case studies included in the chapter 'Urban Containment: The State of the Art,' page 96 in this book.

2. See page 172 in this book.

3. New York University, The Marron Institute of Urban Management.

4. U.N. Population Division, 2018, file 3.

5. See Chapter 'Emerging Empirical Evidence for Territorial Planning in the LAC Region,' pages 131-157 in this book.

Guidelines for Sustainable and Inclusive Urban Densification

Diego Arcia, Camila Maleronka, Hyuna Lee

Cities are the mothers of economic development, not because people are smarter in cities, but **because of the conditions of density**. There is a concentration of need in cities, and a greater incentive to address problems in ways that haven't been addressed before. This is the essence of economic development. Without it, we'd all be poor.

Steve Proffit, "Jane Jacobs: Still Challenging the Way We Think About Cities", *Los Angeles Times* [Opinion], October 12, 1997 (emphasis added)[1]

Agglomeration economies are, at their root, advantages that come from reducing transportation costs. After all, **urban density is just the absence of physical space between people and firms**. Agglomeration economies can exist because of reduced transportation costs for goods: input suppliers and customers save on those costs if they locate near one another.

Glaeser & Gottileb. The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States, 2009 (emphasis added)[2]

This article offers a series of practical guidelines for (re)considering urban planning strategies that facilitate densification or re-densification in Latin American cities. We recognize that talking about "cities" in this context implies significant differences in geographical, institutional, historical, social, economic, and environmental aspects. Rather than proposing formulas, the aim is to provide guidance to governments, society, academia, and the private sector seeking to expand their options for reconfiguring urban space, taking advantage of the benefits of orderly, sustainable, and inclusive growth. The twelve proposed guidelines are:

1 Acknowledge that cities with **well-distributed population densities are more efficient**, since they optimize the use of transport networks, public services, and urban spaces, while also improving the quality of life. The concentration of people in compact urban areas reduces the need for long distances, favoring more sustainable modes of transport, such as public transport, walking, and cycling.

2 **Encourage demographic and economic growth in central areas**. Central areas are the symbolic, historical, and functional heart of cities, concentrating infrastructure and social capital. **By encouraging demographic and economic growth in central areas, their vitality is preserved or recovered**, allowing cities to (re)invent themselves and (re)adapt to contemporary uses without wasting their accumulated cultural value.

3 **Articulate densification with orderly expansion**, understanding that sustainable urban development requires both. Densification optimizes existing urban space, while planned expansion prevents uncontrolled growth and preserves strategic natural areas for cities.

4 **Promote Transit-Oriented Development (TOD) as a cost-effective and sustainable densification strategy**, by integrating land use with transportation systems, resulting in connected, efficient, and sustainable cities. This approach aligns urban growth with transport infrastructure, promoting development in high-capacity corridors (metro, BRT, and rail), improving accessibility and reducing dependence on individual transport and carbon emissions.

5 **Prioritize urban regeneration and heritage enhancement**. This is key to strengthening cultural identity and promoting inclusive and sustainable development. This preserves the collective memory and revitalizes the economy and the social fabric. The restoration and reuse of historic buildings turns underused spaces into vibrant centers of culture, commerce, and living, promoting social cohesion and attracting residents, visitors, and investors.

6 **Strengthening citizen and communal participation** is a key strategy for inclusive urban development, especially in built-up areas. Involving the community preserves local identity and strengthens social cohesion. Community workshops and public consultations help identify needs and create solutions based on local values. Diverse experiences show how participation revitalizes degraded areas, improves infrastructure, and strengthens the sense of belonging in the city.

7 **Making realistic projections of building and land demand** based on objective data is key to planning urban growth in an orderly and sustainable manner. Utilizing underused land within the urban perimeter optimizes resources, preserves natural spaces, and reduces uncontrolled expansion, promoting compact and efficient development.

8 **Planning for a controlled surplus of urban space** is key in order to avoid scarcity and property speculation, keeping the market stable and promoting more inclusive development. By anticipating this surplus, cities can adapt to future changes without disorderly expansion or high costs, ensuring that new spaces are strategically integrated into the urban fabric. This also helps mitigate spatial segregation and equitably distribute benefits for and opportunities of urban growth.

9 In dense cities, **identifying and protecting environmental areas and green spaces** is crucial to improve quality of life and increase climate resilience. Preserving and expanding well-distributed green spaces mitigates heat waves, improves air quality, and provides natural refuges in heavily populated areas. The inclusion of green areas in densification plans helps to absorb rainwater and reduce the risk of flooding, ensuring that urban growth is balanced and sustainable.

10 **Promoting residential inclusion is necessary** for urban densification to benefit everyone, avoiding segregation and fostering diverse communities. Inclusive zoning makes it possible to integrate social housing into consolidated and well-located areas, increasing access to services, employment, and transport without displacing low-income families to the outskirts. This optimizes the use of existing infrastructure and reduces expansion costs, promoting a compact and inclusive city.

11 **Combating speculative retention**, where land and buildings remain vacant awaiting for their value to rise, limits the supply of real estate, raises prices, and encourages disorderly expansion. Progressive regulations and taxes, which aim to develop underused land, encourage property owners to build or sell, ensuring the productive use of strategic areas. These measures promote a more compact, accessible city with a balanced offer of housing and commerce.

12 **Adjusting obsolete or excessively restrictive regulations**, and ensuring regulatory coherence, is key to avoiding disorderly growth. Land management tools make it possible to coordinate public and private participation to transform underused areas, finance infrastructure, and improve social housing supply in strategic zones.

THE CASE FOR URBAN DENSIFICATION

The research presented in this book analyzes the historical trajectories of urban growth in Latin American and Caribbean cities with rigor and empirical evidence. In addition to examining the pace, dimensions, and characteristics of this growth, the data invites us to reconsider the numerous activities that take place on urban land: industries, production systems, services, commerce, logistical infrastructure, recreational areas, and urban amenities. It especially highlights the urgent need for suitable soil for those living in unsuitable conditions and for future urban dwellers in the region. The proposal is clear: urban growth must be planned in an orderly and anticipatory manner, oriented towards sustainable development.

Cities in the contemporary world face the challenge of accommodating population and urban growth in a sustainable way. To meet this challenge, it is essential to provide strategies that integrate orderly expansion[3] as well as the densification of existing urban areas, promoting a compact city model: close, dense, mixed, diverse, continuous, and balanced.[4 5 6] Urban densification is key to increasing city efficiency, optimizing the use of existing infrastructure, and contributing to sustainability.[7 8 9]

Several authors have extensively addressed the positive and negative effects of urban agglomeration, and densification in particular, highlighting the correlation between density, economic progress, social interaction, opportunities, and innovation in urban environments.[10 11] Glaeser and Gottlieb[12] point out that, although in the past some manufacturing companies concentrated on reducing transport costs, urban success currently depends more on the capacity of density to accelerate the flow of ideas. This reflects the importance of proximity and face-to-face contact that dense and diverse areas provide, processes that are essential for innovation, productive diversification, and especially for social and interpersonal relationships.[13]

Impacts on the environment are evident in the analyses and inventories of CO_2 emissions in homes carried out by Glaeser and Kahn[14] in the United States, which revealed that the density of the area and proximity to the urban center significantly influence gas consumption: homes in dense areas (more than 10,000 people per square mile) consume an average of 687 gallons annually, while consumption in less dense areas (less than 1,000 people per square

mile) amounts to 1,164 gallons. This indicates that the chances of lessening the impact on the environment grow in line with density.

Other studies highlight the challenges and negative effects of uncontrolled densification such as pollution, congestion, and the negative impacts on social relationships — access to services, crime, contagion, and public health. These problems tend to worsen when density increases excessively without adequate territorial and urban structure.[15] [16] [17] In addition, public investment in built-up areas tends to be costly and difficult to manage, particularly due to the lack of resources from local governments and inefficiencies in management.[18]

In this context, the debate regarding disperse and dense models remains open, with a large body of literature supporting both approaches. The solution seems to lie in finding an appropriate balance, applying expansion and/or densification strategies according to the contextual factors of each urban area. Jan Gehl[19] explores this dilemma by asking whether a dense city is necessarily a vital city. According to Gehl, although the idea that a vital city requires high densities of buildings, people, and jobs has been widely extended, his practical experience shows that what is essential is "a combination of an urban space that is attractive to use and a certain mass of people who are willing to use it." Furthermore, he adds: "What we often observe is that a high-density sector, which has not been planned properly, actually obstructs the possibility of a vital urban space emerging."[20]

Evidence shows that planned expansion can be effective,[21] while densification is a viable opportunity in cities that still have space and favorable urban conditions such as the carrying capacity of the territory. However, urban densification requires a series of instruments and management that become more challenging, as it sometimes involves the reconfiguration of urban space and the provision of infrastructure in already built-up areas of the city. This creates a greater degree of complexity in negotiating with societal actors who inhabit and give life to these spaces, and who have historically turned these places into spaces for living, as well as productive development and social interaction between communities.

Historically, cities have not followed a single development path; many have combined different approaches to expansion and densification, even simultaneously. Disorderly expansion can result in problems such as a lack of adequate infrastructure, while unplanned densification can lead to congestion issues as well as social conflicts and loss of quality of life.[22] In their analysis of the Mexican context, Montejano and other authors[23] consider that accelerated urbanization, without the required investment in infrastructure, generates negative externalities such as pollution and social problems, while urban expansion is directly related to economic growth.

As presented in this publication, particularly in the contribution written by Professor Angel, it is clear that getting ahead of expansion is an urgent task. However, cities should also consider an integrated approach, combining

densification in central areas and existing neighborhoods with planned expansion on urban boundaries, aiming for more organized, accessible, and environmentally sustainable cities, as proposed by Ghel.[24] The key to success lies in implementing urban policies that balance these two strategies, ensuring that urban growth contributes to more inclusive, productive, and livable cities. The ability to actively plan and integrate these approaches should lead to positive results in urban development, towards the promotion of sustainable and resilient city growth.

The proposed guidelines for achieving sustainable and balanced urban densification are:

1. Recognize the Importance of Urban Densification

Cities with well-distributed population densities tend to be more efficient, making better use of transportation networks, public services, and urban spaces, while also offering a better quality of life. The concentration of people in compact urban areas reduces the need for long commutes, favoring more sustainable ways of transportation, such as public transport, walking, and cycling.

In addition, densifying existing urban areas promotes environmental sustainability by preventing the occupation of new green and agricultural areas, which preserves ecosystems and mitigates the impacts of climate change. Denser cities consume less energy and produce fewer carbon emissions per inhabitant, which contributes directly to global sustainability goals.[25]

Uncontrolled, market-driven urbanization tends to result in peripheral expansions disconnected from urban centers, leading to increased infrastructure costs and the creation of neighborhoods far from essential services and employment opportunities. Libertun and Guerrero[26] show that the relationship between density and costs for the provision of basic services is not linear. However, they have discovered that costs are minimized at an optimum density of around 90 inhabitants per hectare. Taking Brazil, Chile, Ecuador, and Mexico, 85% of municipalities have sub-optimal densities, which indicates that urban densification policies can reduce public spending.

The first stages of Brazil's *Minha Casa Minha Vida* program were widely questioned for making federal funds available for the construction of social housing without a direct link to local policies and municipal zoning. According to Kruger,[27] at least 12% of the housing produced by the program took place in territories that were disconnected from the urbanized area. As a result, public policy has driven peripheral urban sprawl. This type of expansive growth, rather than other development strategies, generates urban diseconomies, such as a lack of scale for the provision of certain public services, longer commuting times, greater dependence on individual transportation, and, in extreme cases, the abandonment of housing units.



Figure 1: Mexico's Federal District, Mexico. Source: Gabriel Benois. Unsplash. Creative Commons License.

Another clear example is Mexico, where around 6.1 million homes are unoccupied (approximately 14% of the country's housing stock), many of them located in peripheral areas with limited access to services and job opportunities.[28] This phenomenon, which has been extensively studied and documented,[29] [30] has largely been driven by public housing policies. It illustrates how unplanned urban sprawl can result in inefficient use of resources and greater economic and social challenges for municipalities, which must maintain services in disperse and often underutilized areas. In the case of Mexico, the OECD[31] highlights the need to align housing and urban development policies to avoid uncontrolled urban expansion that fosters spatial segregation in peripheral areas, where the most vulnerable groups are deprived of adequate access to jobs, transportation, services, and decent housing.[32]

OECD studies[33] indicate that Mexico has a high potential for increasing density in its cities, since the average height of buildings in large cities is below the OECD average. More dense development in areas with adequate infrastructure could help to reduce uncontrolled urban growth (sprawl). To this end, the OECD suggests strengthening urban planning tools by better integrating transport connectivity and infrastructure capacity. Although there are incentives to densify suitable areas, their application is still limited, and the design of urban growth perimeters could be optimized by considering geological barriers. The Mexican government is moving in this direction with significant advances and reforms in its urban and territorial policy.

2. Encourage Demographic and Economic Growth in Central Areas

Central areas play a fundamental role in urban life, being the symbolic, historical, and often functional core of cities, as they represent their economic, cultural, and social heart. These areas also concentrate the successive investments in infrastructure that cities have made throughout the urbanization process.[34] Maintaining the vitality of these areas is essential for preserving symbolic values. They also represent an opportunity for cities to reinvent themselves, adapting to contemporary uses and demands, without wasting the social capital they possess.

The lack of attention to the deterioration and abandonment of central areas implies high economic, social, and environmental costs for cities. According to Rojas,[35] this decline causes the disappearance of urban public assets, such as parks, squares, and heritage buildings, directly affecting their inhabitants and generating a spiral of decay characterized by crime, vandalism, and deterioration.[36] This leads to a gradual loss of urban services and the economic value of assets in these areas. Encouraging demographic and economic growth in central areas is a crucial strategy for maximizing the efficient use of urban land and promoting sustainability. By encouraging occupation and development in these spaces, cities can make better use of existing urban amenities, such as cultural spaces,





Figure 2: City Center of Sao Paulo, Brazil. Source: Lucas Marcomini. Flickr. Creative Commons License.

Figure 3: Commercial Street in Downtown Osaka (Japan). Source: Diego Arcia.

social facilities, and open areas, which are fundamental to the quality of life of their inhabitants. In addition, central areas are generally well served by public transport and can attract people who are less dependent on individual motorized transport, contributing to the reduction of carbon emissions.

Structured projects, such as mixed-use projects combining housing, commerce, and services, are an opportunity to redevelop central areas, optimizing land use and stimulating the local economy. These are projects developed in partnership with government, which can resolve regulatory and land issues that hinder private investment. The partnership also promotes the adoption of programs and initiatives in the public interest, such as heritage preservation and social housing. Adapting the built environment to meet contemporary demands must always respect historical heritage, creating a balance between preservation and innovation.

Valuing and fostering economic clusters in central areas is another powerful strategy for boosting urban development. Clusters are concentrations of companies and institutions from the same or related sectors, such as technology, finance, or health, which promote the exchange of knowledge, innovation, and competitiveness. In cities such as São Paulo and Santiago,[37] the presence of certain clusters has contributed to the vitality and appeal of central areas, attracting complementary uses and investments to these regions. For example, in São Paulo, the shopping circuit is an initiative to revitalize the central area, promoting the reoccupation and strengthening of local commerce, as well as tourism over an area of more than 18 km². Developed by the São Paulo Association of Shopping Circuit[38] Entrepreneurs (APECC, by its acronym in Portuguese), this "outdoor shopping" integrates public and private investments in security and maintenance, improving the shopping experience and fostering sales growth. As well as being a commercial area, it is a mixed zone with 157,066 properties, of which 96,000 are residential. The region is home to 44,446 companies, 36.5% of which are dedicated to commerce. Around 2 million people pass through the circuit every day.[39]

In Colombia, there are urban development agencies such as *Empresa de Renovación Urbana de Bogotá* (RENOBO, for its acronym in Spanish), which operate as urban managers and lead strategic projects in central areas of the city. Through *planes parciales* (partial plans), such as those for Calle 24[40] and Calle 26 Metro Station[41] in Bogotá, the city is seeking to revitalize the historical and urban value of the central area by improving public space, incorporating housing (including social housing), commerce, and services, as well as equipment of a metropolitan scope.

In the case of Brazil, national programs such as *Monumenta*[42] show the positive effects of a public policy aimed at restoring and preserving the central areas of cities. But it also highlighted the challenges and limitations that remain in the management of urban areas, particularly central zones with heritage value.[43] In addition to restoring historic buildings and sites, *Monumenta* has innovated preservation policies by upgrading public spaces and promoting economic, social, and cultural impacts. Its actions seek sustainable urban development that integrates and values historical heritage.

3. Articulate Densification with Orderly Expansion

To achieve sustainable urban development, it is essential to combine densification with orderly expansion. These two strategies, when well-integrated, are complementary and can create balanced, efficient, and inclusive urban environments. Densification optimizes the use of already occupied urban space, increasing the proximity of services, jobs, and public transport, while orderly expansion allows the city to grow in a planned way, avoiding the uncontrolled occupation of peripheral areas and preserving natural and agricultural spaces.

This integrated vision must be reflected in urban master plans or land use plans, which need to incorporate the demands and priorities of the city's various sectors. By integrating the needs of different areas, such as housing, transportation, infrastructure, and the environment, the link between densification and orderly expansion helps overcome the challenges of fragmented sectoral planning.

The complementarity between densification and orderly expansion is essential to promote a typological diversity of city uses and housing. By combining different housing typologies, such as high-density buildings in central areas and low-density neighborhoods in planned expansion zones, it is possible to meet a wider range of residents' needs and preferences. This contributes to the creation of more diverse and inclusive communities, offering housing options for different socio-economic groups.

A notable example of this approach is the metropolitan area of the Aburrá Valley, especially the city of Medellín, Colombia. Medellín has been an innovative model in articulating densification and orderly urban expansion, especially in a context of land scarcity. This has been possible thanks to urban planning and instrument-management, while also using funding resources that these instruments promote. The occupation model and objective vision of the city's land use planning has focused on densifying the central areas and the Aburrá-Medellín river corridor, using land management instruments such as partial plans,[44] land readjustment, and urban development units to direct growth in a controlled manner. These plans allow for a coordinated intervention that combines urban development with the preservation of public spaces and the improvement of infrastructure.

At the same time, Medellín has implemented orderly expansions in the areas fit for urbanization and classified as "urban expansion" lands through partial plans, seeking to ensure that urban growth is supported by adequate infrastructure and are in line with long-term planning guidelines. However, the need to expand mobility infrastructure has been one of the main challenges, due to the high costs and geographical complications involved in its implementation. Even so, innovation in mobility systems and urban integration in Medellín has yielded positive results in various dimensions, as recent impact assessments show.[45]

Medellín illustrates how the integration between densification and expansion can be used to tackle complex urban challenges, such as land scarcity and the need for affordable housing. The city has managed to revitalize central areas and densify strategic corridors such as the Medellín river corridor, while at the same time expanding its urban network in a planned way, promoting a more balanced and sustainable urban development. In addition, this development process relied on the active partnership and participation of public and private actors, enabling the use of investments that made it possible to regenerate former industrial areas close to the city's main mobility routes.[46]

4. Promote Transit-Oriented Development (TOD) as a Cost-Benefit Densification Strategy

Transit-Oriented Development (TOD) is a strategic approach that integrates land use with transportation systems to create more connected, efficient, and sustainable cities. This strategy seeks to align urban growth with transport infrastructure, promoting the development of areas along high-capacity public transport corridors, such as metro lines, BRTs (Bus Rapid Transit) and rail corridors. By focusing on the integration of land use and transportation, TOD improves accessibility, reduces dependence on individual transportation, and contributes to the reduction of carbon emissions.[47] [48]

Cities with greater urban compactness, such as Barcelona, which emits significantly less CO2 per capita compared to more dispersed cities, such as Atlanta, illustrate well the relationship between urban form and carbon emissions. While Atlanta occupies a vast area and emits 6.9 tons of CO2 per capita, Barcelona, with a much smaller area, emits only 1.11 tons per capita, despite both having similar populations. This demonstrates how the compact urban form promoted by the TOD can be an effective solution for reducing carbon emissions while improving quality of life.[49]

The integration of land use with the transport system allows for the creation of compact, connected neighborhoods where housing, commerce, and services are accessible on foot or by public transport. This model promotes urban efficiency, reducing the need for long commutes and encouraging sustainable modes of transport, such as walking, cycling, and the use of public transport. In addition, the TOD contributes to the revitalization of underused urban areas, stimulating investment in infrastructure and local economic development.

One of the main features of the TOD is the densification of transport corridors, which maximizes the use of existing infrastructure. TOD policies have been shown to significantly increase the number of passengers on public transport. For example, areas with TOD have seen passenger increases of up to 20-40% compared to areas without TOD.[50]



Figure 4: Parques del Río Medellín, Colombia. Source: Ministerio de Ambiente y Desarrollo Sostenible. Flickr.

By encouraging the construction of high-density buildings along these corridors, cities can accommodate a greater number of inhabitants and economic activities in areas with easy access to public transport. This transit-oriented densification not only increases the efficiency of the transport system, but also creates more vibrant and safer urban environments, with greater activity on the streets and a better quality of life for residents. TOD housing projects generate substantially fewer vehicle trips than estimated by traditional methods, with an average reduction of 44% in five US metropolitan areas.[51]

To implement the TOD effectively, it is crucial to adopt urban policies that encourage mixed land use and the creation of accessible, high-quality public transport infrastructure. Tools such as flexible zoning, tax incentives for development in priority areas, and the strategic allocation of public investment are essential for directing urban growth towards areas served by public transport. In addition, planning must consider universal accessibility, ensuring that everyone, including the elderly and people with reduced mobility, can benefit from transport services. In a recent study carried out in Brazil by the IADB, global tools for the design and implementation of TOD projects were improved, clearly presenting the different steps and stages.[52]

Cities such as Curitiba, in Brazil, are examples of successful TOD implementation in the region. Curitiba was a pioneer with its BRT system, which not only improved public transportation, but also shaped urban growth along its high-capacity corridors. Some agencies clearly highlight how, in the long term, the city of Curitiba has consolidated this type of strategy:

Curitiba's TOD is based on a phased approach to low-carbon urban development, emphasizing structured urban growth and a solid transport policy. This ensures compact, livable communities and allows the development of the infrastructure needed to support the system's growth over time.[53] [54]

Curitiba has managed to establish one of the most advanced public transport systems, combining high capacity and low cost, as a result of its innovative approach to transit-oriented development (TOD). The TOD approach in Curitiba has improved sustainable and low-emission mobility, reducing travel times and the use of private vehicles. The BRT system, used by 85% of the population, has a capacity of up to 40,000 passengers on the busiest routes. With 342 stations built between 1970 and 2016 and a system that covers 81.5 km daily through 6 corridors, the integrated transport network has contributed to raising the quality of life: the city's human development index (HDI) rose from 0.7 to 0.8 between 1970 and 2000. Currently, *Urbanização de Curitiba S/A* (URBS, for its acronym in Portuguese) operates 1,368 buses with biodiesel and hybrid options.[55]





Figure 5: Curitiba's public transport system, Brazil. Source: Whl.travel. Flickr. Creative Commons License'.

Figure 6: Use mix development in Shibuya Station–TOD strategy, Tokyo (Japan). Source: Diego Arcia.

5. Prioritize Urban Regeneration and Heritage Enhancement

Prioritizing urban regeneration and heritage enhancement is essential to strengthening the cultural identity of cities and promoting sustainable and inclusive urban development. Redeveloping degraded urban areas and enhancing historical and cultural heritage not only preserves collective memory and local identity, but also contributes to the economic and social revitalization of cities. By investing in the restoration and reuse of historic buildings and public spaces, cities can transform underused areas into vibrant hubs of culture, commerce, and housing.

Culture and memory play a crucial role in defining a city's character, influencing residents' sense of belonging and attractiveness to visitors and investors. The redevelopment of urban areas with historical value creates opportunities for the development of cultural and tourist activities, which in turn boost local economy. In addition, valuing urban heritage contributes to social cohesion by providing spaces that reflect a community's history and traditions, reinforcing citizens' bond with the city.

Urban redevelopment must go beyond the physical restoration of buildings: urban infrastructure must also be modernized to meet contemporary needs, such as accessibility, energy efficiency, and adaptation to climate change. This integrated approach ensures that the redeveloped spaces not only preserve their historical value, but also offer functionality and comfort for current users. It is essential that interventions respect the cultural value of the sites, incorporating elements of local architecture and history into new uses.

A notable example of success in integral rehabilitation and heritage enhancement is the historic center of Quito, Ecuador, with an area of 375 hectares. Declared a World Heritage Site by UNESCO in 1978, the central area has suffered from a continuous deterioration of its buildings since the mid-20th-century, causing a significant loss of population. From the 1990s, and with the support of the IADB, a revitalization process began through a comprehensive program that included the restoration of historic buildings, infrastructure modernization, and promotion of cultural tourism. The recovery of this central area was a pioneer endeavor in Latin America. In the 1990s, the municipality promoted private investment to revitalize the historic center: the public sector would implement regulation and improve infrastructure, while the private sector would lead medium-term profitable projects.[56] These initiatives have not only preserved the city's rich colonial heritage, but have also boosted the economic and social development of the central region, attracting residents, businesses, and visitors.

In Brazil, capital cities such as São Luís (MA) and Campo Grande (MS) have been working for more than a decade on the recovery of their central areas, promoting repopulation as a strategy to revitalize urban damage and reverse heritage deterioration of these areas. In the case of Campo Grande, this strategy also seeks to curb the disproportionate expansion[57] that negatively impacts the city's finances and service provision. The results, strategies, and impacts of these initiatives have recently been documented in IADB studies.[58] [59]



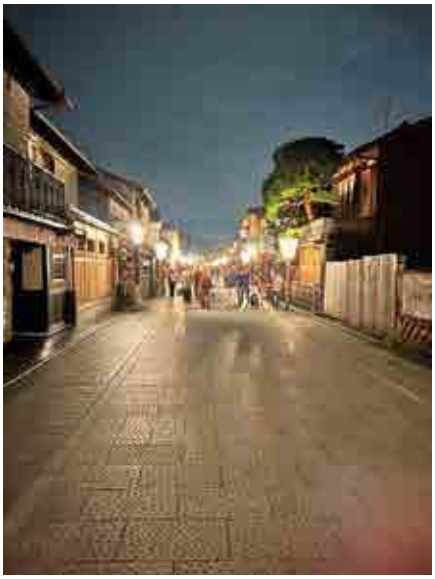


Figure 7: Historic Center of São Luís, Brazil. Source: Demetrio Jereissati. Flickr. Creative Commons License.

Figure 8: Heritage preservation and public space in Ginza District, Kyoto, Japan.Source: Diego Arcia.

6. Strengthen Citizen and Community Participation

Strengthening citizen and community participation is fundamental for inclusive and sustainable urban development, especially in the context of the compact city. A guideline that values the existing city strengthens the sense of community and social engagement, as it connects people to the places which they have historical and emotional ties, and life experiences. By respecting and revitalizing existing urban spaces, densification strategies can preserve local identity and strengthen social cohesion, promoting development that is felt and experienced by its own residents. Clark and Wise[60] offer a theoretical and practical overview of the relationship between urban renewal, communities, and social participation. In their compilation, they present international experiences that highlight how successful urban renewal requires the active involvement of the community in order to achieve inclusive development through case studies developed by various authors in cities such as Hong Kong, South Africa, and Korea. Their study also highlights the risks associated with gentrification and displacement, and proposes inclusive governance tools that facilitate the participation of traditionally excluded groups.

Empowering local residents and stakeholders to actively participate in the planning and implementation of these strategies ensures that the adopted solutions not only meet practical needs, but also value collective heritage and a sense of belonging. Active community participation in decision-making processes helps create more effective and fair urban policies that reflect local values and aspirations. This can be achieved through tools such as community workshops, public consultations, and digital platforms that facilitate dialog and co-creation. In this sense, Höflehner and Zimmermann (2018)[61] point out that urban laboratories and new models of participatory governance are key to addressing the complexity of "the great challenges" that the economy, society, and the environment pose on cities. Integrative, inclusive, and transdisciplinary approaches, such as urban laboratories, promote participation through experimental platforms (Living Labs and City Labs) that facilitate collaboration between science and society, overcome inequalities, and strengthen urban networks and capacities to face complex changes.

Incorporating residents into urban planning is particularly crucial in areas that already have a rich local history and culture. Revitalizing existing neighborhoods through respectful densification can prevent gentrification and promote inclusive development, where everyone feels part of the transformation. By including the community, it is possible to identify specific needs, such as the maintenance of public spaces, the preservation of local heritage, and the creation of services that directly meet the residents' wishes.

Medellín, in Colombia, is a striking example of how citizen participation can be a driving force for urban transformation. The city has actively involved its residents in the revitalization of degraded areas, promoting the redevelopment



Figure 9: Parque Biblioteca la Quintana Tomás Carrasquilla, Medellín, Colombia. Source: Guía de Viajes Oficial. Flickr. Creative Commons License.

of public spaces that value local history and culture, such as the Library Parks *(Parques-Biblioteca)*, as well as within the framework of the so-called "integral urban projects" (PUI, for its acronym in Spanish).[62] This approach not only improved urban infrastructure, but also reinforced the sense of community, strengthening social ties and increasing citizens' engagement with the city's future. In Colombia, the formulation and implementation of partial plans requires an extensive process of consultation and involvement with communities and owners of the intervention areas, an indispensable requirement for the approval. These processes are essential for areas of urban renewal and redevelopment and are also applied to the formulation of land use planning. Despite the existence of these mechanisms, challenges remain to increase the effective involvement of communities in these processes.

Another example is the participatory budgeting of Porto Alegre, in Brazil, where citizens have a direct say in the allocation of public resources for priority projects, including the improvement of urban infrastructure and the preservation of community spaces. This model not only increases transparency in public management, but also promotes a sense of ownership and shared responsibility among residents.

7. Make Realistic Projections of the Demand for New Buildings and Land that can be Transformed

Realistic projections of demand for new buildings and land are a crucial step in effective and sustainable urban planning. Planning that adheres to reality, based on objective data and accurate projections, allows cities to direct their resources efficiently, avoiding both scarcity and oversupply of urban space. This is essential to ensure that urban growth takes place in an orderly manner, balancing the need for new construction with the preservation and transformation of existing land.

The use of objective data, such as demographic projections, economic trends, and market analysis, enables a clear understanding of future demand for housing, commercial, and industrial space. Planning based on this data helps avoid common mistakes, such as underutilization of land or disorderly development, which can lead to problems as increased infrastructure costs, pressure on public services, and environmental degradation. Accurate projections allow cities to accommodate growth in a sustainable way, ensuring that new developments are properly located and integrated into the existing urban fabric.

Realistic projections also imply considering the transformation of underused or degraded land, promoting the redevelopment of areas that already have infrastructure and a strategic location. Transforming land within the existing urban perimeter, rather than expanding into outlying areas, helps to preserve natural spaces and reduce cities' ecological footprint. It also promotes the revitalization of neighborhoods and the efficient use of urban resources, aligning growth with sustainable and compact development.



Figure 10: New densification of Amsterdam taking place in a ring around the historic city. Source: Productive Amsterdam, European 14, Netherlands, p. 12.

An example of urban planning based on realistic projections can be seen in cities like Singapore, where land scarcity has led to a rigorous approach to urban space management. Using modeling and simulation technologies, Singapore projects its future demand accurately, integrating housing, transport, and infrastructure in a cohesive way. This reality-based planning has allowed the city-state to grow in an organized and sustainable way, maximizing the use of its limited space.

Adopting planning based on objective data not only improves the efficiency of land use, but also promotes trust between the community and urban managers. When planning decisions are transparent and based on concrete data, it is easier to engage citizens and stakeholders, who come to see urban planning as a reliable process aligned with the real needs of the population.

Amsterdam's land use policy for urban development demonstrates a proactive strategy that promotes balanced growth while prioritizing sustainability. By leveraging realistic projection of housing demand and focusing on redevelopment within existing urban areas, the city effectively curbs urban sprawl. Initiatives like "Koers 2025," which aims to construct 50,000 new dwellings based on demographic and economic trends, align housing supply with anticipated demand.[63] Furthermore, the city leverages its land portfolio and organizational capacity to prepare land for development and open it to the market through innovative instruments like option contracts, which incentivize swift action by developers and discourage speculative landholding.[64] This reality-based approach enables Amsterdam to optimize its limited urban space, address housing needs, and establish a resilient framework for sustainable urbanization.

8. Plan for a Controlled Surplus of Space

Planning for a controlled surplus of space is a crucial strategy to avoid a shortage of land and buildings, which often leads to real estate speculation and rising prices, making the city less affordable for its residents. Urban planning that anticipates and accommodates a slight oversupply allows cities to maintain a more stable real estate market, reducing inflationary pressures and promoting more inclusive development.

Research on Brazil's 325 largest cities revealed that reducing the maximum permitted land use rate (coefficient of utilization) by one standard deviation can increase a city's urban area by 12.4%, which indicates how strict regulation can impact disorderly growth and increase the costs of infrastructure and public services.[65] In addition, estimates from the same study show that stricter building height regulations generate an annual cost of approximately US$ 9.58 million per average Brazilian city, which reinforces the importance of balancing regulations to allow for controlled expansion without overburdening the public budget.





Figure 11: Greenbelt zones in Seoul as of 2022. Source: hankyung.com

Figure 12: Aerial view of part of southern Portland metro area. Source: photo by Sam Beebe; Flickr creative Commons license.

The artificial scarcity of urban space can generate serious economic and social problems, such as the high prices of housing and the displacement of vulnerable populations to peripheral areas, which are less served by infrastructure and public services. By anticipating a controlled surplus of space, urban planners can create a more competitive and affordable environment, where the availability of land and buildings meets demand without the negative effects of speculation. This surplus must be planned carefully, avoiding the creation of unnecessary urban voids and ensuring that new spaces are strategically located and integrated into the urban fabric.

Planning that considers controlled surplus also makes it easier for cities to adapt to future changes, such as unexpected population growth, economic changes, or new demands for different types of land use. This offers a margin of flexibility that is essential for urban resilience, allowing for quick and effective adjustments without the need for disorderly or costly expansions in the future.

The South Korean government has implemented green belts in cities, including Seoul, since the 1970s with three objectives: preventing urban sprawl, preserving the natural environment surrounding cities, and securing strategic areas for national security.[66] This approach has yielded several benefits, including (1) enhanced amenities, such as scenic landscapes, recreational areas, and heritage preservation; (2) fiscal savings through more efficient public service and infrastructure delivery in compact urban spaces; and (3) ecosystem services, including air purification, biodiversity protection, flood control, and improved water quality.[67] However, the policy has also faced criticism due to challenges related to housing affordability, land use efficiency, and socio-economic equity.[68] This experience highlights a key implication that while positive allocative policies can yield benefits, they may also produce unintended negative consequences that require careful balancing and adaptive management.[69]

A similar approach, the urban growth boundary (UGB) in Portland, Oregon, has highlighted both its strengths and limitations. UGBs are effective in curbing urban sprawl by concentrating development within designated areas and preserving surrounding rural landscapes.[70] However, this containment policy has also led to unintended consequences, such as spillover development in adjacent regions like Washington State, where land-use regulations are less stringent, undermining the UGB's ability to manage regional growth effectively.[71]

Moreover, the restricted availability of land within the UGB has driven up housing prices, exacerbating affordability challenges, and underscoring the need for strategies that balance compact urban development with accessible housing solutions.[72] These dynamics reveal a critical need for holistic planning that transcends jurisdictional boundaries to address the interconnected challenges of urban growth, housing affordability, and labor market mobility. Effective regional planning must integrate policies across state lines and ensure that growth management strategies are equitable and inclusive, addressing the broader metropolitan area's needs comprehensively.[73]

Planning for a controlled space surplus also helps mitigate the risks of spatial segregation and promote a more equitable distribution of the benefits of urban growth. By ensuring that there is enough space for all the necessary uses — including affordable housing, public spaces, as well as commercial and industrial areas — cities can avoid the emergence of exclusive areas and encourage more inclusive and diverse development.

9. Identify and Protect Areas of Environmental Interest/Green Areas and Open Spaces Strategy

In the context of promoting dense and organized cities, the integration of green areas and open spaces is essential to guarantee a great urban environment and climate resilience. In a compact city, where densification is prioritized, the preservation and creation of well-distributed green areas become fundamental to balancing densification with quality of life. These spaces not only provide visual and physical relief in intensely built-up environments, but also play a crucial role in mitigating the effects of urban heat islands and promoting the well-being of residents.

As cities densify, it is vital that urban planning ensures that open spaces and green areas are preserved and expanded, making them accessible to all. These spaces act as green lungs in densely populated areas, improving air quality and offering refuge from excessive heat. The strategic distribution of parks, squares, and ecological corridors within compact areas helps maintain ecological balance and promotes the urban ambience necessary for healthy living in high-density contexts.

As well as contributing to the urban environment, the presence of green areas in densely urbanized zones also increases cities' climate resilience. In places where densification can result in greater soil sealing, the incorporation of green spaces and permeable areas is essential to absorb rainwater, reduce the risk of flooding, and create milder microclimates. By including green spaces as an integral part of densification plans, cities can mitigate the negative impacts of intense urbanization and ensure that growth is sustainable and balanced.

Medellín (Colombia) serves as an inspiring example of how the integration of green areas can be combined with urban densification. The city implemented the "green corridor" project, which transformed main roads and riverbanks into vegetated corridors, helping to reduce heat islands and improve air quality in densely populated areas. These initiatives have allowed Medellín to balance its urban growth with environmental preservation, becoming a model of a compact and sustainable city.

Copenhagen, Denmark serves as an exemplary case of integrating green areas and open spaces into urban planning through its cloudburst management plan, which emphasizes the adoption of green infrastructure solutions. This approach focuses on peri-urban areas and incorporates features such as parks, semi-natural urban green areas, blue areas, and green spaces designed for water

management. Additionally, urban green space is strategically connected to grey infrastructure elements, including permeable pavements and rain gardens, to effectively retain stormwater and reduce run off.[74] The Copenhagen's municipality cloudburst management strategy, initiated in 2013, aims to address both daily rainfall and extreme cloudburst events across the city's seven catchment areas.[75] The strategy includes 350 targeted projects to be implemented by 2035, supported by an investment of EUR 1.3 billion.[76] Annually, the city prioritizes projects based on risk assessments, ease of implementation, and opportunities to integrate measures with ongoing urban development, ensuring a strategic and impactful approach to urban resilience and sustainability.[77]

Chapultepec Park, the largest urban park in Latin America at 687 hectares, is a vital environmental and cultural asset for Mexico City, often referred to as the city's "lung" due to its critical role in urban sustainability.[78] Under Gabriel Orozco's master plan, the park is being reimagined as a bio-cultural forest guided by permaculture principles: care for the land, care for people, and equitable sharing of resources.[79] Since 2021, the Mexico City government and the federal culture ministry have implemented the master plan, including key projects, such as the *Calzada Flotante* pedestrian bridge, the *Cineteca Nacional de Chapultepec* cultural center, and *Cablebús Línea 3*, a cable car system improving connectivity.[80] These efforts aim to harmonize ecological restoration, cultural enrichment, and public accessibility, positioning Chapultepec as a global model for sustainable urban development.

10. Promote Residential Inclusion

Promoting residential inclusion is an essential strategy to ensure that urban densification benefits the whole population, especially in consolidated neighborhoods. Inclusionary zoning aims to integrate social housing within the existing urban fabric, avoiding spatial segregation, and promoting diverse and balanced communities. This approach ensures that urban growth and densification do not result in the exclusion of low-income groups, but instead create opportunities for everyone to live in areas well served by infrastructure, services, and public transport. Initiatives such as the partial plans for Bogotá presented above are heading in this direction.

Inclusionary zoning establishes rules that encourage or require the incorporation of affordable housing in new developments, especially in well-located and already consolidated areas. By doing so, cities can expand the supply of social housing close to jobs, schools, health services, and transportation, preventing low-income families from being pushed to distant outskirts. This not only improves the quality of life of residents, but also contributes to the creation of more cohesive and resilient communities, where social diversity is valued and promoted.



Figure 13: Aerial view of Chapultepec Park, Mexico City. Source: Courtesy Wikimedia Commons; Gobierno CDMX; Creative Commons.

One of the main advantages of inclusionary zoning is its ability to distribute social housing evenly throughout the city, avoiding concentration in ghettos or marginalized areas. By including affordable housing in consolidated neighborhoods, cities can take advantage of existing infrastructure, reducing urban expansion costs and promoting more efficient and sustainable land use. This integration strengthens the concept of a compact and inclusive city, where proximity between housing, work, and leisure is prioritized, and everyone has the opportunity to enjoy the benefits of urban life.

A significant example of this practice is the special zones of social interest (ZEIS, for its acronym in Portuguese), widely adopted in several Brazilian cities, such as Belo Horizonte, Recife, and São Paulo. The ZEIS are areas earmarked as priorities for social housing, where land use regulations can be adjusted to suit the reality of existing occupations and to make new projects feasible, both in new constructions and the renovation of existing buildings. In Recife, the ZEIS were regulated by Law 16.113/1995 to guarantee that popular settlements in well-located areas of the city remain. Moraes[81] shows that the ZEIS have promoted significant urban integration for their residents, connecting them to public transport networks, services, and urban opportunities, even in the face of persistent infrastructure challenges. For example, the *Coelhos* and *Brasília Teimosa* ZEIS stand out for their proximity to dynamic urban centers and their inclusion in the structural public transport system, favoring mobility and access to jobs and services. These examples illustrate how the application of inclusionary zoning can balance the demands for urban development with the protection of the rights of vulnerable populations, strengthening the concept of the right to the city and socio-spatial justice.

Another example is the Gunsan urban regeneration initiative[82] in South Korea, launched under the 2013 Special Act on Urban Regeneration[83] to address the challenges of a declining old city center while preserving its modern cultural heritage. With a budget of KRW 20 billion (~US$17 million), funded jointly by the central and local governments, the project prioritized affordable and inclusive revitalization. Key strategies included creating a pedestrian-friendly environment, restoring historic architecture, and developing cultural and commercial hubs, such as thematic street and art walls. Collaborative agreements with building owners and cultural groups ensured low rents, attracting startups and fostering local cultural programs. Initiatives like "Fun Village," a cooperative guesthouse program, enhanced tourist accommodation and accessibility, driving a fivefold increase in visitors from 220,000 to 1.02 million in just four years. The initiative also boosted local businesses, raising the number of stores by 11.5% and creating sustainable jobs.[84] This case shows how integrating heritage preservation, community collaboration, and economic revitalization can create sustainable and inclusive urban development while promoting socio-economic diversity and cohesion.



Figure 14: Housing in Plaza de la Libertad—Edificio Niemeyer (Belo Horizonte). Source: Diego Arcia.

11. Combat Speculative Property Retention

Combating the speculative retention of real estate is an essential measure to promote urban densification and avoid the underutilization of land in consolidated urban areas. Speculative retention — when land and buildings are kept vacant waiting for their value to rise — represents a significant obstacle to sustainable urban development since it limits the supply of housing and commercial spaces, raises real estate prices, and contributes to the disorderly expansion of cities. To meet this challenge, it is crucial to implement regulation and taxation instruments that encourage the productive use of urban land, promoting the development of idle and underutilized areas.

One of the main instruments for combating speculative retention is the use of fiscal policies, such as efficient taxation on real estate. Proper tax collection, with reasonable rates on periodically updated market values, discourages speculative retention and encourages owners to develop their properties or sell them to those who can. This is an extra-fiscal effect of property taxation, which also contributes to the fiscal health of cities.

In Colombia, the *declaratoria de desarrollo prioritario* (DDP) is an example of how the government can force the development of idle areas. The DDP allows the government to declare certain areas as priorities for development, obliging owners to develop their land within a set timeframe, under penalty of expropriation. This measure has been effective in combating speculation and ensuring that well-located land is put to productive use, contributing to urban densification.

In Brazil, the compulsory parceling, building, and utilization (PEUC, for its acronym in Portuguese) instrument provided for in the city statute is a powerful tool for combating speculative retention. The PEUC allows municipalities to require the development of idle urban land, imposing deadlines for subdivision, construction, or use. If owners do not comply with the requirements, they are subject to sanctions such as progressive urban property and land taxes (IPTU, for its acronym in Portuguese) and, eventually, expropriation with payment in public debt bonds. This approach seeks to increase the supply of opportunities for real estate development, taking advantage of existing urban infrastructure and promoting efficient land occupation.

India's rapidly urbanizing cities face challenges from speculative land retention, which limits housing supply and efficient land use. Tools like the vacant property tax discourage owners from holding unused plots by imposing financial penalties, promoting land utilization, and addressing urban sprawl.[85] Additionally, transferable development rights (TDRs) incentivize higher-density development by allowing property owners to sell unused development rights, fostering vertical growth and conserving open spaces or enabling slum redevelopment without extensive land acquisition.[86][87] In megacities like Mumbai, TDRs and vacant property taxes synergize to reduce speculative holding, encourage infrastructure and housing development, and align with broader goals of enhancing housing availability and urban livability.



Figure 15: Mumbai, India. Source: Simone D. McCourtie, World Bank.

These measures not only discourage speculative retention, but also increase the supply of real estate and opportunities for development, contributing to a more compact and accessible city. By combating real estate speculation, cities can ensure that strategic areas are developed in a way that meets the needs of the population, promoting orderly densification, and the provision of housing and commercial space in locations well served by infrastructure.

12. Adjust Land Use and Occupation Regulations

Adjusting land use and occupation regulations is a crucial guideline to ensure that urban densification takes place in a controlled manner and in line with a city's overall development strategy. Outdated or excessively restrictive urban regulations can hinder densification in areas where it is desirable and sustainable, while inconsistent regulations can result in disorderly and uneven growth. To promote a compact and efficient city, it is necessary urban regulations be reviewed and adjusted, ensuring that they are consistent with the goals of densification and rational land use.

Land management instruments, such as consortium urban operations in Brazil and *planes parciales* in Colombia, are powerful tools that can be applied to promote controlled densification in strategic areas. These instruments allow for a coordinated approach to urban development, involving both the public and private sectors in the transformation of underutilized areas and the creation of new housing and infrastructure opportunities. They are instruments for planning, management, and also for financing urban projects, since they contribute to land valorization in order to finance the intervention.

Consortium urban operations are public-private partnerships that allow the development of specific areas of the city through the negotiation and granting of benefits. These include an increase in coefficients of utilization or changes in land use, in exchange for investments in infrastructure and urban improvements. These projects are common in large Brazilian cities, such as Fortaleza, Curitiba, and São Paulo, making it possible to transform parts of these cities, with significant investments in public transport, public spaces, and social housing. One example is the *Riacho Maceió* consortium urban operation, in Fortaleza. Located in one of the city's most sought-after areas, Av. Beira-Mar, this operation allowed changes in urban parameters to make real estate developments viable in exchange for the construction of a public park and the environmental redevelopment of the creek.[88] The city of São Paulo has also applied the instrument and managed to mobilize important resources for investment in urban infrastructure based on the possibility of building densification.[89]

Planes parciales are another example of an effective tool for promoting urban renewal in consolidated areas. Widely used in Colombia, especially in Bogotá, these plans allow the reconfiguration of urban areas through the readjustment

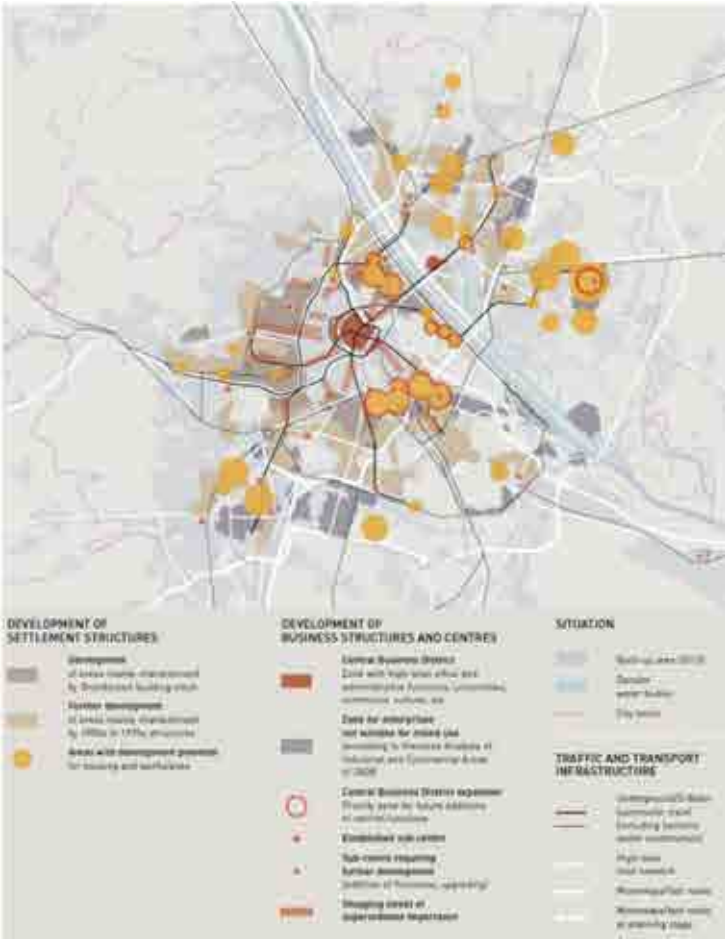


Figure 16: Development of settlement structures, business structures, centers, traffic and water infrastructure (STEP 2025). Source: Academy for Territorial Development in the Leibniz Association.

of land, where owners provide their plots to a collective development. This process makes it possible to create better-planned infrastructure and redistribute the benefits of urban development, increasing the efficiency of land use and ensuring that all property owners participate in and benefit from the process.

Vienna's land use regulations, guided by its Urban Development Plan (Stadtentwicklungsplan, STEP), integrate strategic planning with sustainable and inclusive development. Land acquisition aligns with STEP to ensure harmonious housing growth,[90] linking properties to robust public transit, such as a subsidized annual pass at €356 (€1/day) to enhance affordability. Limited-profit housing (LPH) associations can access subsidized land at capped prices (€188/m² of realized living space)[91] and apply for municipal schemes with strict rent controls and income eligibility standards, ensuring economic viability while meeting social housing goals. Since 1995, competitive mechanisms for allocating land and subsidies have fostered innovation in the LPH sector, balancing market dynamics with public objectives.[92]

In conclusion, building compact and sustainable cities requires urban planning that integrates densification with orderly expansion, while adapting to each urban context and integrating public-private collaboration and community participation. A city model that is close, diverse, and accessible fosters an efficient use of land and infrastructure, improving the quality of life, what Ghel calls a "vital city." This work offers guidelines for redesigning the urban structure of Latin American cities through tools and policies that promote inclusion, respect for heritage and citizen participation as pillars of resilient and equitable development. In a future set to present population growth and urban challenges in the context of crises such as climate change, it is essential that local governments, along with society and the private sector, implement sustainable strategies that maximize the economic potential of cities and transform them into spaces of opportunity and well-being for all.

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Transit Oriented Development in the Context of Accelerated Urban Growth in Latin America and the Caribbean

Julia Paiva, Jason Hobbs

Latin American and Caribbean (LAC) cities are experiencing accelerated growth, coupled with significant territorial planning challenges in an urban landscape characterized by inequality and informality. Further on, pressing sustainability challenges demand innovative urban planning tools to address issues derived from unplanned urban growth.

Transit-Oriented Development (TOD) emerges as a promising strategy for LAC cities within this context. TOD is a comprehensive approach that can be adapted to various realities and applied at different scales. It encompasses transportation planning alongside land use, housing, and sustainability. Despite its potential to tackle the challenges of rapid urban growth, TOD remains underutilized in LAC policies and projects. This piece focuses on how TOD can be effectively applied in LAC cities to inform policymakers.

DEFINITION AND PRINCIPLES

TOD was developed in the mid-20th century as a response to urban expansion challenges in cities worldwide. The term was coined by Peter Calthorpe, a leader in the New Urbanism movement. In his book *The New American Metropolis* (1993), Calthorpe introduced concepts aimed at optimizing urban land use, enhancing energy efficiency, and reducing congestion. His framework included long-term actions focused on: (i) preserving open spaces; (ii) improving air quality; (iii) promoting affordable housing within urban boundaries; (iv) reducing congestion; and (v) restructuring infrastructure costs (Calthorpe, 1993, apud Hobbs et al., 2021).

Subsequent authors expanded on these ideas, detailing how the ensemble of TOD strategies can be implemented. The Inter-American Development Bank (IDB) significantly contributed to this discourse in their publication Transit Oriented Development: How to Make Cities More Compact, Connected, and Coordinated. In this publication, the authors identified six key aspects for successful TOD implementation:[1]

1. **Land Use Optimization:** encouraging the integration of urban development and activities with the public transportation network.
2. **Land Value Capture opportunities:** using instruments such as land readjustment and other strategies to recover land value increases with the underlying goal of building a collaborative financing model for urban projects that supports financial sustainability and potential budgetary independence of public coffers.
3. **Coordination of public and private sector efforts throughout a project's lifecycle:** encouraging development of designated urban areas and re-balancing the costs and benefits of urbanization.
4. **New public transit infrastructure:** encouraging the use of clean and renewable energy in the transportation sector.
5. **Urban Regeneration:** achieving a better urban quality of life through the provision of housing, infrastructure, and public spaces for different socioeconomic strata.
6. **Diversification of economic activities:** Meeting market demand, adhering to planning strategies, generating jobs, and reducing travel times.

TOD prioritizes public transportation over private vehicles, emphasizing cleaner modes, including walking, cycling, and renewable energy-powered mass transit. Effective urban mobility planning must harmonize transportation systems with urban density, land use, and morphology.[2] Thus, sustainability is achieved through the strategic management of complementary instruments.

In this sense, understanding the spatial dimension of a TOD project is key in achieving sustainability and public policy coordination. Recently, Arcia

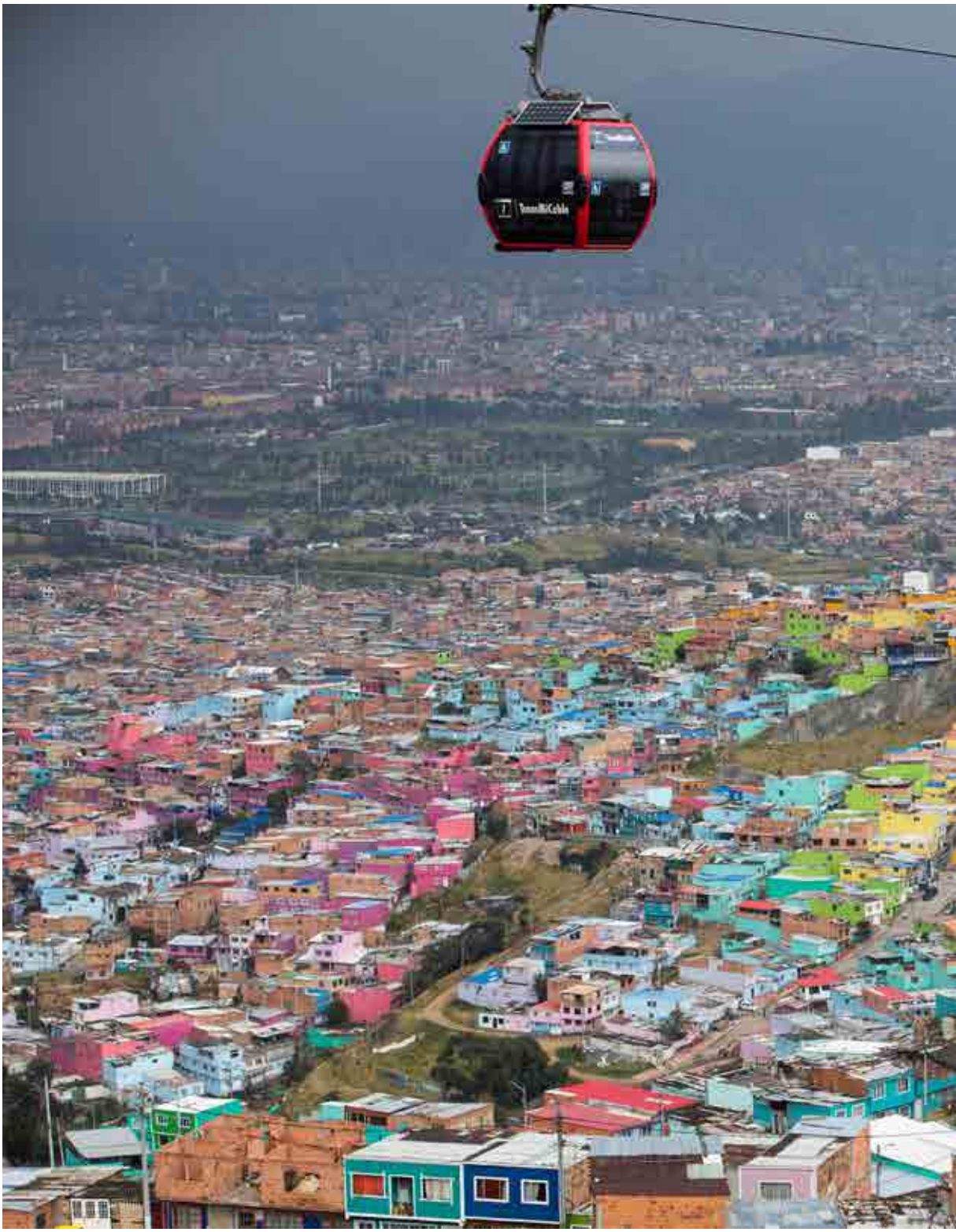
and other authors reviewed and compiled TOD implementation strategies designed to best accommodate the LAC urban context.[3] This framework focuses on quantifying a place's importance as (a) a node in the transportation network; (b) a potential site for placemaking, or quality of urban life; or (c) a location with potential market value. By comparing these three values for each place, the TOD strategy to be implemented is chosen based on the best fits to a location's needs and potentialities.

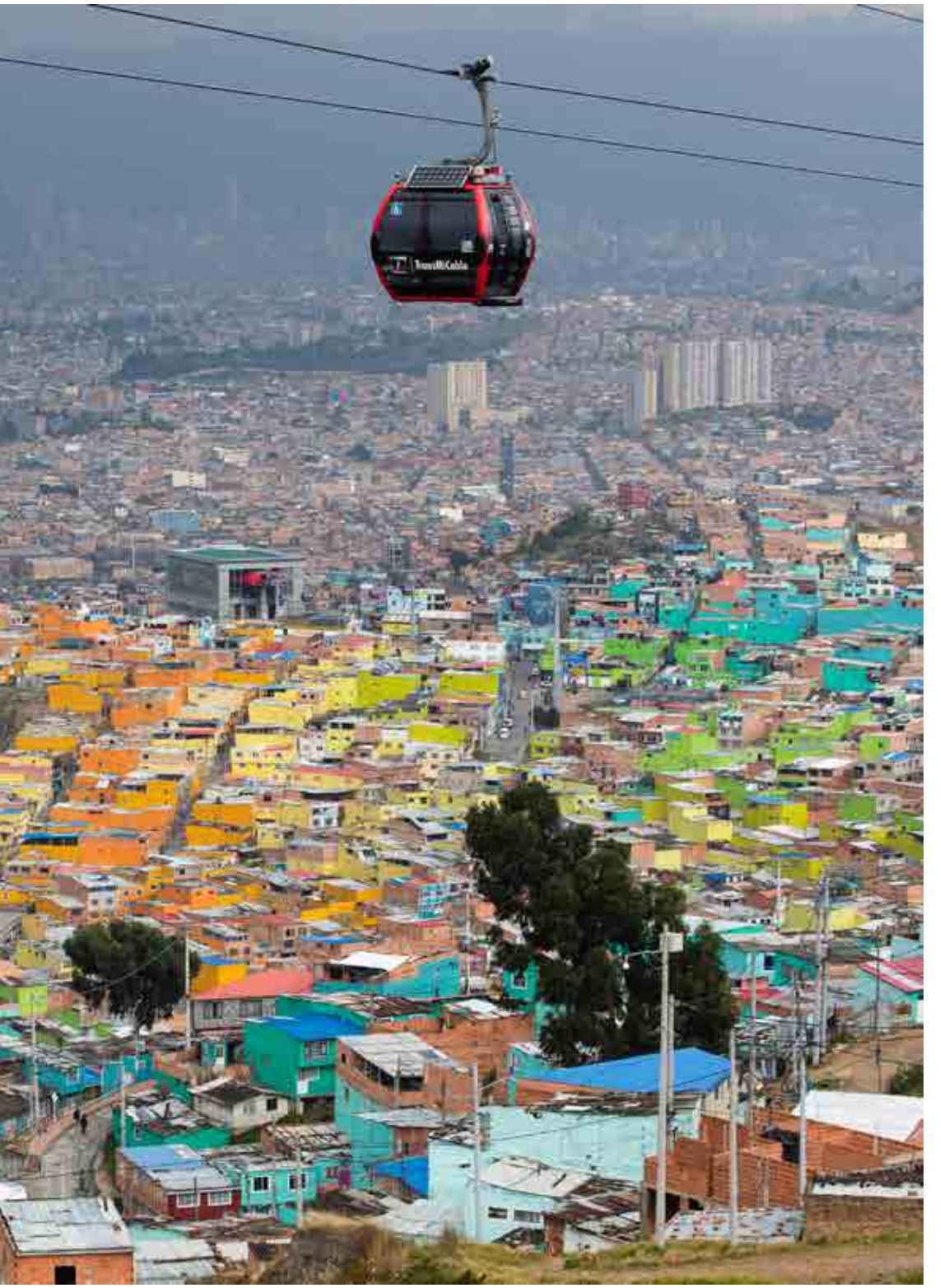
TOD strategies can be categorized as: (i) infill, as long-term revitalization of suburban nodes; (ii) intensification, as catalyzation of mixed-use and density around multimodal stations; and (iii) transformation, as concentration of jobs and market dynamic in major hubs.[4] Thus, TOD can help prepare for the growth of cities, promoting development within the urban tissue and increasing density where the available infrastructure can absorb it.

While analyzing mass transportation systems in Latin America, Alves & Souza found that several projects have adopted the Bus Rapid Transit (BRT) model as an intermediate solution for metropolitan mobility due to the cost and technical difficulties of implementing rail-based mass transit. BRT is an alternative that generally fits more easily to diverse urban shapes and routes can be adapted. Latin America represents 62% of global BRT ridership, serving over 20 million passengers a day in 57 cities.[5] This suggests that TOD strategies in the region should pay special attention to this transportation modal.

The effective application of the mentioned TOD principles result in an urban planning strategy that can yield significant socio-economic and environmental benefits. In the context of rapidly growing LAC cities, TOD has the potential to effectively manage urban sprawl and guide sustainable development, thereby enhancing resilience to climate change. Some of the key benefits include reducing carbon footprints, improving air quality, lowering infrastructure costs, and facilitating investments through the integration of TOD with land value capture strategies. Additionally, TOD improves access to employment opportunities, increases housing affordability, and promotes health benefits associated with active transportation modes, such as encouraging physical activity and alleviating traffic-related stress. For instance, the decrease in greenhouse gases emissions has already been mapped. The case of the Uptown District TOD in San Diego (U.S.) "was estimated to have 20% less emissions per household compared with households in nearby developments".[6]

While TOD offers numerous advantages, challenges cannot be overlooked. Some projects have been ineffective due to the contradictory application of guidelines. For instance, increased densification can reduce housing affordability, as rising land prices are often a negative consequence of improved infrastructure. Thus, attention must be paid to the context in which each TOD is being applied, and how the various guidelines and propositions are articulated in each particular city.





Cable cars in Bogota. Source: Mussi Katz, October 6th 2022. CC0 1.0.

MANAGING URBAN SPRAWL

TOD can effectively contain urban sprawl, directing growth and promoting adequate densities relative to urban infrastructure. The key factors influencing urban mobility, besides socioeconomics and demographics, are urban morphology and transportation.[7] By articulating these elements within a TOD policy, we can address the challenges of accelerated urban growth. To this end, it is important to clarify the scales to implement a project and the potential derived from each use of the strategy.

In Latin America, Alves & Souza indicate that TOD policy implementation in Brasilia and Teresina (Brazil) has yielded less growth than expected in commercial use and urban development along mass transit corridors. As the authors state, this might be due to the cities' low density and, above all, problems like lack of coordination between the timetables of feeder lines.[8] Thus, an important challenge for TOD strategies in LAC is its coordination with the city's mobility system.

Regarding LAC's social and economic scenery, it is essential that housing affordability and cost of living be taken into account when considering densification strategies that aim to counterweight sprawl. As stated by Turbay and others,[9] despite Curitiba's BRT being a remarkable example of TOD implementation, it should also be considered a cautionary tale. According to the authors, densification along BRT corridors had a direct effect in spiking land price and developing a premium real-estate market, whereas meaningful expansion of lower-income housing towards the periphery where real estate is more affordable has also been identified. TOD strategies can address the exclusionary effects of rising land prices when complemented by land policies like inclusionary zoning to equalize housing and accessibility opportunities.

This challenge is not unique to one region: despite differences in context, cities in both LAC and Asia are experiencing rapid urban growth and grappling with similar issues of affordability and accessibility. Korea underwent rapid urbanization, a situation in which planning had an important focus in transit coordination at macro and micro scales.[10] It ensured adequate densification along mass transit stations[11] and, more recently, that urban expansion developments public transportation policies be aligned as a measure to assure environmental sustainability for Sustainable New Towns.[12] Japanese cities can teach important lessons as some have historically expanded in accordance with major mobility plans that foresaw and explored the correlation of urban expansion and transit.[13] Tokyo is often regarded as an example for TOD development. Despite not completely preventing urban sprawl, Tokyo's capability of densification along transit corridors is admirable.[14]



Dense development along corridors in Curitiba. Source: Mario Roberto Durán Ortiz, February 23rd 2006. CC BY-SA 3.0.

SCALES AND IMPLEMENTATION AREAS

Evers and other authors[15] identified two primary frameworks for TOD application: as a master plan, outlining urban development guidelines that include zoning and urban instruments, and as specific projects that implement these guidelines.

Furthermore, TOD strategies can be implemented at various scales: regional, metropolitan, city, and local (neighborhood). Each scale has different objectives. At the metropolitan and regional levels, TOD strategies aim to facilitate efficient flows of goods and people, fostering interconnections between cities and minimizing issues arising from one region's influence over another—such as long commutes from dormitory cities lacking economic opportunities or adequate transportation networks.

At the city scale, the focus is on ensuring planning instruments align with TOD goals. At the local scale, and particularly in corridors, TOD can promote a network of locations oriented toward mass transportation. In areas around transit stations, TOD can be applied to enhance accessibility and micro-accessibility, which is vital to encourage mass public transport use over individual motorized transport.

In addition to considering various scales, the TOD strategy must also account for existing urbanization patterns, which significantly influence the transformations it aims to promote. The unique urban development context of each city is crucial for the viability of the TOD strategy. Patterns of urban growth are shaped by the type of land where TOD plans and projects are executed, allowing these strategies to guide both densification and overall city growth.

Opportunities for TOD can also be identified in urban voids or low-density areas close to existing or planned transit systems. Depending on their location within the city, these areas may necessitate varying implementation timelines. Such use of TOD presents the potential to develop land in vacant or underutilized land, to reduce urban sprawl, and direct development.

This strategy becomes effective if the difference between permission and promotion is well understood. Allowing densification along mass transit corridors is not equivalent to actively promoting it. While permission is a necessary condition, it is insufficient for true promotion. This process also entails curtailing undesirable dynamics that contradict TOD principles. For instance, managing dispersed urbanization—by defining urban perimeters or calibrating other urban parameters—is as crucial as enabling densification in targeted areas for effectively directing urban development.

Consolidated areas, such as traditional urban centers, often possess robust transport infrastructure but may have limited opportunities for urban transformation, primarily due to a scarcity of vacant or underutilized land. Transformations in these regions typically occur on "brownfields" or second and third-generation lands—sites in which the original use has become obsolete and are ripe for redevelopment. While there is generally strong market interest in

developing these areas, challenges such as high transaction costs—stemming from the need to acquire properties from multiple owners or address environmental liabilities—can hinder progress.

Conversely, "greenfields" usually involve lower transaction costs but are less appealing for development. These areas, characterized by minimal or no prior urbanization, often lack the necessary infrastructure, and their transformation can be a lengthy process. Typically situated on the outskirts of cities and disconnected from existing mobility systems, integrating them into a TOD strategy may require substantial upfront investments, although the long-term returns can be significant.

There is a potential to use TOD strategies between the two extremes of "brownfields" and "greenfields," particularly in urban voids or low-density areas adjacent to current or planned transit systems. A plan that permits densification can facilitate developments with TOD characteristics, such as mixed-use projects connected to the transit system. However, if TOD is not promoted throughout the city, the anticipated benefits—such as reduced pollution levels and increased mass transit ridership—will be limited. Thus, it is imperative to recognize the various scales of planning and understand the interrelationships among them.

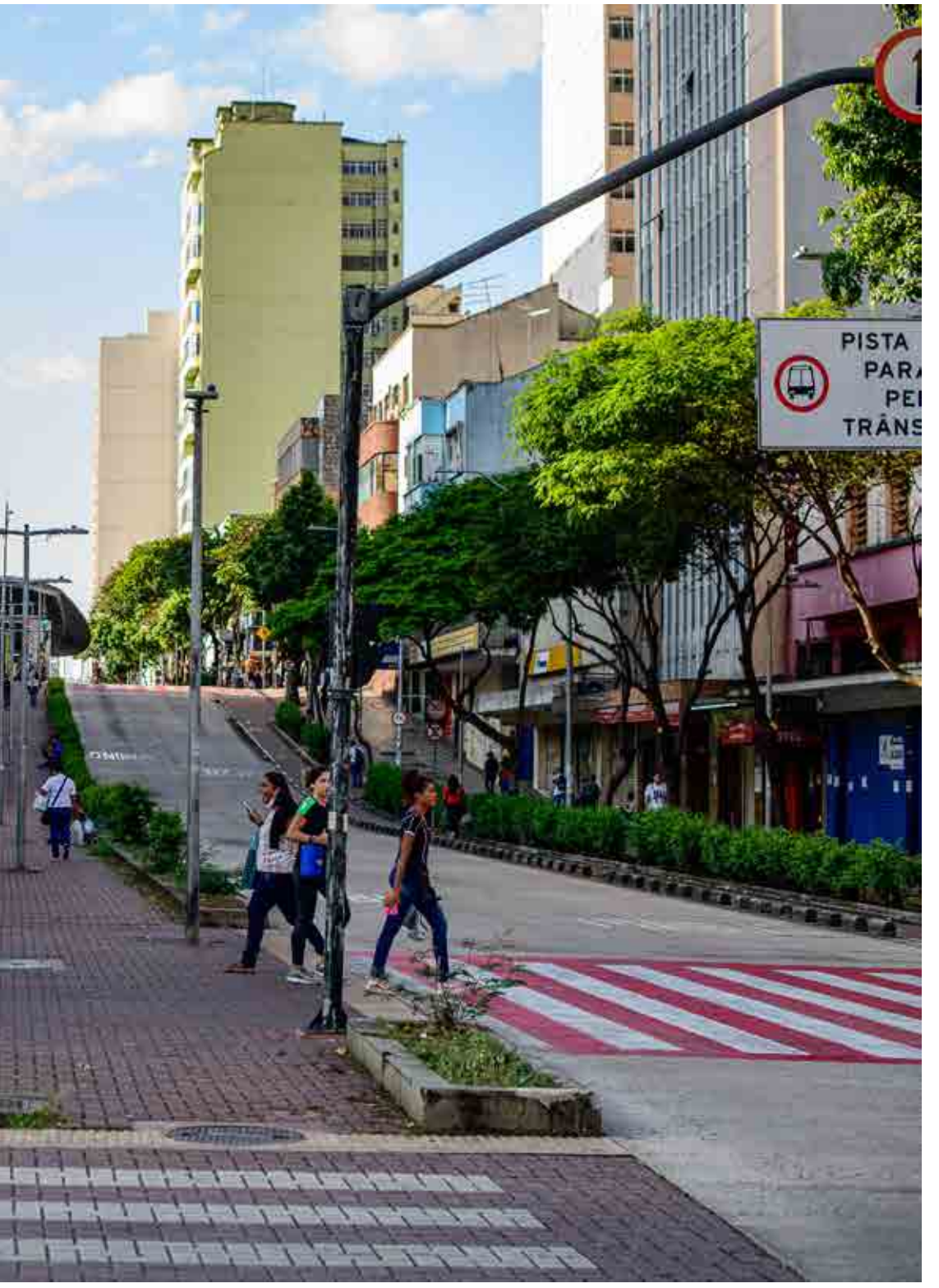
MIXED-USES AND COMMUTING TIME REDUCTION

TOD promotes a mix of residential, commercial, and recreational spaces, including parks, to reduce car dependency. This approach also encourages land development as infill, utilizing vacant or underutilized spaces within existing urban areas.

Studies by Rodriguez and Vergel-Tovar[16] analyzed several transit corridors in LAC cities and found that higher ridership is associated with mixed land use—particularly multifamily residential and institutional uses—while single-family residential developments tend to have lower ridership. Additionally, given the existing informality in LAC cities, special attention must be paid to low-income residents, who greatly benefit from relatively low-cost infrastructure improvements, such as adequate pedestrian infrastructure, mixed land use, and access to public facilities. The authors correlate these factors with increased public transportation usage. Sagawa and others[17] converge with this observation, given that, in Brasilia (Brazil), the authors observed the positive effect of BRT introduction on local economies, especially in lower-income areas and areas with high green levels.

As pointed by Alves and Souza, "neighborhoods serviced by BRT and Metro displayed commuting times to the city center 7 and 3.5 minutes lower than unserved neighborhoods, in average."[18] The authors point out how Belo Horizonte's (Brazil) higher density is an important factor for travel time reduction, as such travel time reduction was not assessed in less dense cities—Brasilia and Teresina (Brazil). The presence of multifamily housing was also indicated by the authors as contributing to travel time reduction.


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Urban mobility in Paraná Avenue, central area of Belo Horizonte, MG. Source: Nereu Jr/ WRI Brasil, April 2022. Attribution-NonCommercial-ShareAlike (CC BY-NC-SA 2.0)

Commuting time reduction and denser development correlation is better documented in Global North cities. Chan and Miranda-Moreno[19] suggest that a 10% increase in residents near mass transit stations may increase transportation demand by 7,4%. At the Randolph Towers near Arlington County's Ballston Station (Phoenix, USA), 69% of residents commuted to work via transit, compared with a region wide transit mode share of just 9%.[20] Moreover, in Washington D.C., near the Pleasant Hill BART station, 55% of those living in Wayside Plaza and 37% of those living in Park Regency regularly commuted via BART versus a citywide average of 16%.[21]

CONCLUSION

In conclusion, transport-oriented development holds significant potential for addressing the challenges faced by rapidly growing cities in the Latin American and Caribbean region. As a strategy that prioritizes public transportation and cleaner modes of transportation, TOD could contribute to further harmonizing LAC cities' mobility system with its urban density, land use, and morphology. BRT systems, being both flexible and a mass-transit mode, have proved to be well suited for cities in the region.

The management of urban sprawl is a key challenge and often a complex one. TOD presents high potential to deal with the negative externalities of rapid growth; however, its effectiveness relies on the coordination of mobility systems and land use policies with urban expansion planning. Moreover, as remote jobs become more common after the COVID-19 pandemic and business centers are more often underutilized,[22] less relevance of work-home dynamic is expected and identifying new mobility patterns is a fundamental task for TOD success.

Further on, LAC cities' urbanization patterns present a potential to implement TOD strategies as mixed-use developments along corridors and investments in urban infrastructure. Moreover, considering LAC's social and economic dynamics of spatial segregation, continuous housing affordability to low-income population pose a central aspect to be faced by TOD's implementation to ensure its positive effects for the city. In regards to accessibility, relatively low-cost improvements could significantly impact low-income neighborhoods in increase walkability and public transportation use.

TOD's effectiveness also lies on the comprehension of the scale it aims to impact. From regional to local developments, strategies must articulate existing policies at all pertinent levels of administration as to ease its viability. Existing urbanization patterns and local particularities must be taken into account, which directly shape densification and overall city growth.

TOD strategies and projects are strong tools to deal with the increasing challenges of 21st century cities, especially in the LAC region, which faces issues derived from rapid urban growth and exclusionary patterns. TOD as a comprehensive and interdisciplinary planning tool can positively impact the region and foster resilient and equitable urban environments.

Endnotes

Acknowledgement
We gratefully acknowledge the valuable contributions of Diego Arcia, Martim Furtado, and Camila Maleronka for their essential insights and support during the development of this text.

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Strategies for the Self-constructed City. Urban Expansion, Densification and Resilience

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One of main theses of this publication is that urban expansion is inevitable, driven by population and economic growth. Since 1950, Latin America and the Caribbean have experienced an accelerated urban growth. Urbanization grew from 26% in 1950 to approximately 81% today, making the region the second most urbanized in the world, with approximately 540 million people.[1] Poverty has also decreased in the region, albeit not at the same rate. Between 1981, when the measurement of poverty rates began, and 2021, total poverty decreased from 36.4% to 26.8%.[2] However, this drop has not been as significant as urban growth. In absolute terms, the number of people living in poverty in urban settings has increased. This excessive growth has turned self-construction into one of the main forms of access to urban land.[3] Nearly 60% of the poor in Latin America and the Caribbean live in urban environments, and most of them do so at the edge of the planned city.[4] The large cities of the region are a clear example of this phenomenon. As population grows, the number of self-built homes also increases, reflecting the inability of the formal market to absorb housing demand in urban environments.

SOCIAL AND CLIMATE VULNERABILITY ON THE EDGE OF THE PLANNED CITY

In Latin America, the increase in GDP per capita between 2000 and 2020, from US$4,462 to 7,386, has not managed to proportionally reduce the number of people living in self-built neighborhoods. Although productivity grew significantly, population in these neighborhoods[5] over this period of time only fell from 126 million to 95 million. Had it continued at the same pace as economic growth, this figure should have fallen to approximately 76 million.[6] This contradiction highlights the inability of economic growth alone to adequately improve housing conditions of the most vulnerable.

Currently, 14.2% of the Latin American and the Caribbean population lives in six cities with more than 10 million people, surrounded by peripheries with a high level of urban precariousness. In these areas, self-built neighborhoods are not only a by-product of the planned city, but also a fundamental part of its operation, since they offer essential services for it. Because of this, the planned and unplanned urban fabric in large cities grow jointly. For example, the Buenos Aires metropolitan area concentrates 38% of the total population of Argentina and has 2,066 self-built neighborhoods.[7] Montevideo, home to 49% of the Uruguayan population, has 330 self-built neighborhoods.[8] Santiago de Chile concentrates 40% of the national population, with 168 self-built neighborhoods,[9] while in Lima, 30% of the population lives in unplanned areas, which has 1,153 self-built neighborhoods and represents 54% of the city.[10] Economic and population growth have increased socio-spatial divisions, with millions of urban dwellers living in precarious housing and vulnerable urban conditions. These conditions are aggravated by the increasing risk posed by climate change.

By the end of the 21st century, according to the present and future Köppen-Geiger climate classification maps published in 2018, 596 out of the 727 mapped cities in the region will experience profound bioclimatic changes.[11] The main axis of change for existing urban settings will be desertification, savannization, and tropicalization: 261 cities will suffer desertification, 142 will endure tropicalization and 259 will become savannas.[12] This transformation will require a profound readaptation of urban infrastructure. The urgency of integrating climate strategies into self-constructed contexts becomes critical when considering the impacts of climate change in the region in light of adaptation challenges. These neighborhoods are particularly sensitive to desertification and the loss of biodiversity that global warming is accelerating. Furthermore, the rise in sea level, which has been faster in the region than the global average,[13] puts coastal areas at risk and seriously affects self-built neighborhoods, often located in low and exposed areas. Climate change aggravates already existing inequalities, deepening the development gap between formally planned areas and self-built neighborhoods.

One of the main risks affecting cities in the Latin American and Caribbean cities, and particularly self-constructed neighborhoods, is thermal risk. This means the impact caused by temperature rises generated by construction type, habitat degradation, changes in human-settlement microclimate, and the resulting consequences this has the well-being of citizens. This phenomenon is accentuated by the heat island effect, which generally produces higher temperatures in urban areas than in surrounding areas. Drought and flooding, caused by changes in rainfall patterns that can limit the capacity of drinking water supply and, in case of floods and extreme climatic conditions, also represent major risks for the region. They compromise the safety of urban infrastructures, housing, and commercial activities in precarious settlements, and are considered a health risk for the inhabitants.[14] The associated risks with rise in sea levels, erosion, and loss of biodiversity can also have a devastating effect on local economies and the lives of the most vulnerable, in addition to the ability of ecosystems to preserve their functionality over time and absorb extreme weather events.[15] These events can have very high human and economic costs.

In Latin America and the Caribbean, the number of people living in self-constructed neighborhoods is still growing. And although this growth is lower compared to a few decades ago, the accelerated impact of climate change is rapidly increasing their vulnerability.

GREEN INFRASTRUCTURE AND PUBLIC SPACE AS AGENTS FOR TRANSFORMATION

Our work over the past few years has focused on identifying best practices to prepare the most vulnerable settlements for the impact of climate change. In particular, we saw great potential in incorporating urban green infrastructure and nature-based solutions in precarious settlements as a strategy to enhance the resilience of existing precarious areas and future urban developments. Many cities in the world are now investing large monetary resources into building contemporary urban infrastructure and parks that will protect their centers from sea level rise, heavy rain, and rising temperatures, while providing respite from recurring heat waves and very much needed recreational spaces, as well as new opportunities for residents and visitors. These projects are considered urban green-infrastructure as they create a system of support focused on nature that can help respond to urban and climate challenges. The generation of permeable surfaces in public spaces like parks or building rooftops can contribute to increasing infiltration, decreasing the impacts of floods, reducing landslides, managing and cleaning water, and increasing availability of water for domestic use, while in the process reducing the risk of flooding as well as water shortages and poor water quality. They can also reduce heat island effect, increase biodiversity, produce edible food, and provide recreational spaces.[16]

Green infrastructure and nature-based solutions offer multiple benefits, are relatively low-cost, use common technologies and materials. Yet, they are rarely implemented in the most vulnerable communities. Green areas in general are a rare commodity. Looking at some of the important cities in Latin America —Sao Paulo, Santiago de Chile, Buenos Aires, Medellin, Bogota— one can see how the areas of lower income are those with less access to public space and urban green areas. Public space plays a fundamental role as a platform for civic action, exchange, and empowerment. Combined with green infrastructure, it can become a medium to improve social and environmental resilience in vulnerable neighborhoods. Parks, gardens, urban green corridors, and tree-lined streets can be combined with a series of activities such as trails, bike paths, public transit stations, markets, courts, lookouts, and playgrounds. These activities complement the ecosystem services offered by green infrastructures, such as improved air quality and more favorable temperatures, while improving physical well-being as well as social and mental health. In addition, green infrastructures have the capacity to increase their ecological value and functionality over time.[17] By increasing vegetation and stabilizing soil, green infrastructure increases its ability to absorb pollutants by filtering water, reducing the heat island effect and creating shaded areas. By comparison, gray infrastructure transitions into an immediate process of decay and depreciation. The frequency of maintenance can be higher for green infrastructure. Rain gardens and other green urban drainage solutions require more frequent cleaning compared to other water treatment solutions, and the soil has to be replaced periodically if subjected to contamination. However, these maintenance operations have a relatively low cost and generate jobs,[18] which can be an added benefit in the case of informal settlements.

THREE STRATEGIES FOR THE SELF-CONSTRUCTED CITY

We have studied over one hundred projects of green infrastructure on public space in precarious settlements around the world and selected thirty city interventions in Latin America and the Caribbean. These projects, which have proven to be successful in incorporating strategies and techniques of green infrastructure in vulnerable settlements, highlight different solutions and processes that can drive the transformation and growth of what are now some of the most vulnerable areas in the region. Learning from these projects, we have identified three strategies connecting climate resilience and urban aspirations that can drive the transformation of self-constructed neighborhoods: restore and upgrade, adapt and connect, mitigate and anticipate.[19]

1. Restore and upgrade - avoiding displacement and improving urban conditions

This strategy combines the need to remediate areas subject to landslides, abandonment, contamination, as well as other local social and environmental risks, with the opportunity to improve the quality of space and neighborhood life. The interventions are mostly site-specific and transform public spaces such as streets, squares, and buildings, adopting nature-based solutions to offer multiple benefits to the community: reduced maintenance costs, increased economic value of adjacent urban land, recreational, educational, and social activities within the neighborhoods.

For example, the project for Plaza Estacional in Caracas (Figure 1) implemented various techniques to stabilize and contain terrains vulnerable to landslides and hydrogeological risks, among them stabilization walls made of sandbags and the incorporation of a variety of vegetation strategies to contain the land. The intervention is part of a system of community facilities that included incorporating infrastructures for sewage and stormwater runoff, solar control devices, housing rehabilitation, and the stabilization of the land and common space in the most remote point of the community. The project, inserted in steep terrain that was vulnerable to erosion, capitalized on various planting strategies to stabilize the soil. A slope stabilization wall was also built with sandbags, which allowed a garden to be installed through permaculture techniques. The goal is to emulate nature, optimize natural resources without the use of chemical products, reduce the ecological footprint, restore soil and biodiversity, create community around nature-driven work, and provide organic and fresh food. This garden of deep-rooted plants transformed the square into a shared space for the development of training and productive practices. In addition, permeable cobblestones were incorporated during construction to encourage rainwater infiltration. All these techniques strengthen and consolidate the ground function as green infrastructure and enable the public space to be used as a workshop-training school, capitalizing on the agricultural tradition of the area.[20]

In other cases, recycling materials such as unused tires were leveraged to build embankments and contain earth in steep sites while incorporating vegetation. This technique was successfully implemented in Parque Fazendinha in Sao Paulo, where a landfill was transformed into a communal public space.[21] Another project in Brazil, the food garden in Manguinhos, developed by Hortas Cariocas in Rio de Janeiro, transformed an abandoned waste site into a large organic food garden, establishing a new public space capable of providing environmental, social, and economic services to neighbors through the garden.[22] Rochiña mas verde, in Rio de Janeiro, is also a productive garden developed by the non-profit Green My Favela to grow food and medicinal plants, promoting educational and artistic activities in the public realm. It is open to the public 24/7 and is visited





Figure 1: Plaza Estacional, Caracas.

daily by families and children. Throughout the year, the garden provides fresh produce for up to 400 people, contributing to reduce residents' monthly expenses up to 20%. Other ways in which the extensive food production can impact the low income population include the beneficiaries of food banks; children with their school lunches; and a few gardeners employed at the garden that receive a cash stipend plus compensation in the form of products.[23]

Infrastructures in disuse, such as roads, canals, bridges, or unused spaces –often sources of contamination and garbage– present another opportunity, as they can be transformed into public benefit with the incorporation of nature-based techniques and solutions. The Fresnillo Park in the Manuel M. Ponce Housing Unit in Zacatecas (Figure 2), developed by Rozana Montiel and Alin V. Wallach, in collaboration with INFONAVIT, was part of an urban regeneration program that repurposed a paved sewage canal and transformed it into a multifunctional playground. Prior to the intervention, the abandoned canal existed as an obsolete infrastructure that divided the neighborhood through two embankments approximately 1 km apart.[24] The project included the reconstruction of the canal slopes to function as a multifunctional rest area, and replicable modules were used to integrate games, stepped seating, lighting, furniture, and vegetation. In addition, universal-access bridges were built to facilitate crossings, children's games were painted on the ground, cellular pavements were incorporated to infiltrate water in previously impermeable areas, local vegetation was added, and trees were planted.[25]

2. Adapt and connect - rebalancing access to resources and allowing for higher density in areas of existing urban expansion

This strategy defines ambitious plans and projects that can improve the quality of life in vulnerable areas while having an impact on the larger metropolitan area. For cities to adapt to climate change, they require structural change and more ambitious projects that go beyond specific neighborhoods: increasing permeable surfaces, improving drainage systems, ensuring access to water, protecting biodiversity, etc, require a systemic integrated effort. Improving the quality of life in informal neighborhoods in the long-term also implies a systemic integrated effort, improving accessibility and connection to urban services and opportunities. A study in El Salvador of fifteen informal settlements subject to disasters showed that households spend an average of 9.2% of their income on reducing disaster risk (about US$26 out a monthly income average of US$284), not including building materials that are obtained for free, along with the free labor offered by family members.[26] These are significant expenses for vulnerable communities and, if the incremental development process of the marginal areas cannot keep up with the frequency of disaster impacts, the result may be greater insecurity and "poverty traps."[27] Given the increase in difficulties informal





Figure 2: Parque Fresnillo, Zacatecas.

communities face compared to the formal city, and despite the advantages of active stakeholder participation, it is problematic and contradictory to rely on purely ground-up efforts, without the support of public institutions for both implementation and project maintenance. Conversely, these projects can impact a much wider population.

The Social and Urban Integration Project of the *Barrio* Padre Carlos Mujica (Figure 3), known as *Barrio* 31 in Buenos Aires, is an example of the transformation and connection of an informal settlement to its surroundings. Although *Barrio* 31 is emblematic for its strategic location, it presented various barriers that excluded and segregated it from the rest of the city, as well as a lack of green and public spaces. The project, led by the Buenos Aires City government with the support of the IDB, was possible thanks to the approval of a law for the urbanization of the *barrio*. Interventions included a comprehensive infrastructure plan, construction of public spaces that connected it to the rest of the city, habitat improvements through adaptation of existing housing, and construction of new housing. Over 1,200 new apartments were built as part of a project to resettle families living in homes that could not be renovated, particularly those located under the elevated Illia Highway. In addition, new institutions, schools, and health centers were created to promote economic and social development. More than twenty-six public spaces totaling more than 12.8 acres of interventions were built and refurbished. Bicycle lanes and stations with free bicycles were incorporated, promoting sustainable mobility. A sustainable urban solid waste management program was also implemented, generating employment for *barrio* cooperatives. Throughout the process and to date, new projects have been developed with neighbors, consistently incorporating the community.[28]

Another example of projects developed close to vulnerable settlements which have the potential to benefit the larger urban community are water management initiatives. Self-constructed neighborhoods often lack appropriate water management infrastructure, or the natural runoff path is modified, preventing the historical flow of rainwater and its outlet. This creates a variety of negative consequences for the environment and people, including flooding, due to the low capacity for retention and filtration. The park in the Arroyo Xicoténcatl (Figure 4) is an example where water management, the study of both its conduction routes and retention, served as an essential component for the design of public space. This project, located in the periphery of Tijuana, was designed by Taller Capital to reclassify a water channel as the heart of an informal settlement. At project kickoff, the stream bed had disappeared, and in its place were mounds of infill material held back by two parallel, steep, and eroded dirt roads through which water drained. The operation consisted of nine new embankments, or platforms, built with the infill material in the streambed, to house recreational and sports activities. The slopes of the embankments were stabilized with walls made of unused tires made in the U.S., using traditional construction methods.



Figure 3: Barrio Padre Carlos Mujica, Buenos Aires.

The walls were then vegetated with endemic species. In addition, two canals running parallel to the riverbed were built of concrete and stone to direct water runoff and reduce its speed. The program included sports courts, playgrounds, and communal spaces, which were incorporated and are widely used by local children and youth. Despite the limited budget, the project provides many benefits to the neighborhood and the larger urban area.[29]

In Santiago de Chile, the project of the Parque Fluvial de la Familia (Figure 5), set the recovery of the Mapocho River bank in the western sector of the city as the main focus of the project, forming a body of calm water through the installation of collapsible locks. The project was located in a particularly vulnerable area, an industrially-contaminated site of 50 acres of public land on the outskirts of the metropolitan area with scarce presence of green areas, thus playing a critical role in the potential development of the involved communities and connection to central areas.[30] On one hand, the strategy consisted of building a new river bench, which included a large amount of excavation and removal. The adopted technology allowed development of nautical activities with small boats without motors such as kayaks, rowboats, and small sailboats. On the other hand, the surplus of excavated earth was used to generate an artificial topography and park, which was also used to contain the riverbed through a series of hills. The inclined planes of topography and manipulated surface were planted with a variety of native plant species to help stabilize the ground, featuring evergreen creeping succulents with low water consumption and long flowering periods. Various species of native trees were also planted, creating zones of fruit trees and shaded areas. The park works at the scale of the city, physically and visually connecting the communities in which it is inserted, controlling a stream and regulating its flow through advanced engineering, and transforming an abandoned dump into a public recreation space framed around water.[31]

3. Mitigate and anticipate - preparing for urban expansion and rebalancing access to resources

In order to address climate change and develop more sustainable cities, it is necessary to intervene in the causes. The third strategy, “mitigate and anticipate,” focuses on reducing the causes of climate change, meaning reducing the sources of greenhouse gas emissions or increasing carbon sinks to avoid an increase in average temperature. This means imagining new ecologies, economies, and societies to anticipate future conditions. However, from an urban perspective, anticipating future conditions in the region also requires considering self-constructed settlements as an evolving reality, acknowledging their possible transformations and mitigating related risks. As previously discussed, according to the United Nations, the percentage of people in Latin America and the Caribbean living in informal settlements is gradually declining.[32] However,



Figure 4: Arroyo Xicoténcatl, Tijuana.





Figure 5: Parque Fluvial de la Familia, Santiago de Chile.

in absolute terms, the number of dwellers living in self-constructed neighborhoods keeps increasing, albeit at a slower rate than before. Also, in 2018, 50% of the population in the region did not have access to public transportation, and 23% of the population did not have garbage collection (it was 20% in 2001-2010).[33] To "mitigate and anticipate," therefore, means to acknowledge the fact that self-constructed neighborhoods are still growing, and that green infrastructure can possibly drive their transformation, increase their resilience, and maintain their low carbon footprint, today as well as in the future.

A strategy to achieve climate mitigation and anticipate future expansion is to unify and connect separated, segregated, or inaccessible urban areas, facilitating mobility between the connected parts. Public space has the capacity to strengthen social and urban fabric through bike paths, linear parks, and green corridors. These provide alternative mobility systems in addition to offering socio-environmental benefits to the neighborhoods they pass through. For example, rivers can function as urban armatures,[34] linking dissimilar neighborhoods and areas and consolidating ecological corridors and linear green infrastructures throughout the city. Mapocho 42k (Figure 6), in Santiago de Chile, for example, seeks to build a green pedestrian —and bikeable— network at the metropolitan scale. The main objective is to achieve social and territorial connectivity, while reducing the urban inequality gap. The metropolitan-scale pathway highlights the landscape features and geography of Santiago, connecting eleven communes of different social strata and topography. Following the course of the river, the public corridor forms an east-west backbone, defining a green corridor that connects all of the existing and potential green spaces located along the banks of the river, linking these previously fragmented or inaccessible areas to other nearby parks and economic opportunities in the city center.[35]

Another strategy entails remediating some of the impact of urbanization by reestablishing biophysical processes that facilitate ecosystem balance. Remediation operations allow for the preservation of these resources and the landscapes and natural systems in which they exist, requiring the designation of protected areas. These protected areas can be active urban infrastructure, including not only nature-based solutions but also urban infrastructure and amenities. Projects like The Lake Texcoco Ecological Park (Parque Ecológico Lago Texcoco, Figure 7), by Inaki Echeverria, adopt ecological design strategies for environmental remediation. The project aims to preserve a large lake reserve on the outskirts of Mexico City and restore the bodies of water lost as a result of exponential population growth, unplanned urbanization, and environmental degradation. The ecological park reactivates the hydrological processes through actions that help direct the development process of the eastern zone of the Valley of Mexico. These actions include the introduction of designated areas for restoration and reforestation, reintroducing endangered species of the ecosystem to restore the native flora and fauna; the incorporation of productive landscapes for local





Figure 6: Mapocho 42k, Santiago de Chile.

Figure 7: Lake Texcoco Ecological Park, Mexico City.

agriculture in areas with great deficiencies; and the recovery and expansion of lagoon regulation. Along with the remediation process, new recreational activities are dispersed, including areas for sports, ecotourism structures, museums, and research centers, all capitalizing on a new renewable energy network that feeds the entire system. The proposal focuses on three principles: facilitating accessibility to the territory for public use, ensuring the environmental protection of the 30,150 acres of parkland, and implementing actions for environmental restoration. In other words, the project seeks to generat e greater resilience by agglomerating actions to mitigate environmental damage and climate change.[36]

BEYOND THE VULNERABLE CITY

These projects and this essay focus on strategies to improve the resilience of Latin American and Caribbean self-constructed settlements, the most vulnerable neighborhoods. They are often responsible for the least amount of greenhouse gasses emissions. If on the one hand it is urgent to improve the living conditions in these neighborhoods, the security of their inhabitants, and their work opportunities and economic development, it is also important to develop solutions that put the environment and efficient use of resources at the center of attention, creating a leap forward that would avoid repeating the destructive impacts of the traditional industrial model. The strategies and projects presented in this essay are examples of interventions that can improve the resilience of existing self-constructed neighborhoods, connect them to opportunities, and anticipate their transformation, accommodating future growth and needs. These projects can reduce the risk of displacement, create the conditions to improve density within neighborhoods, and allow further expansion. These projects often have a limited budget, need to achieve more than less, and prove that they can serve a larger community; all of which are key elements to be implemented beyond self-constructed neighborhoods in the years to come.

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Climate Urbanism

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The extreme events of the climate crisis are growing in scale and intensity, making the transformation of our cities and structures to achieve climate resilience a matter of survival. Recent examples include the floods in the state of Rio Gande do Sul and the heatwave, drought,and fires in the Amazon and across 80% of Brazil's territory in 2024 (INPE; et CEMADEN).[1]

Today, globally, our cities, which are home to 56% (4.2 billion) of our population (UN) and responsible for 70% of GHG —greenhouse gas emissions— (IPCC, UN)[2] and over 80% of GDP (World Bank),[3] are covered by concrete and asphalt. This not only creates heat island effects, which are even more intense when associated with continental-scale heat domes, but also impede water from penetrating the soil, increasing its accumulation and velocity during flash floods. As 26% of the world's urban population live in high-risk flood zones (World Bank; et UN)[4] and 24% are exposed to extreme heatwaves (NBER),[5] and counting, we cannot face the climate challenges of the 21st century with the urbanism and infrastructures of the 20th century that have truly become a double burden and a literal trap when to comes to climate.

It is urgent that climate adaptation be produced through the use of multifunctional urban resilience infrastructures (Figure 1) that use the natural elements of terrain, vegetation, and water as constructive technologies, combined with the precise application of hard materials, such as concrete. This allows water to penetrate soil, be absorbed by swelling vegetation, diminish its speed, and pool in areas designed to be flooded, together with built drainage networks, or protections against the rise of the sea level, as part of public green spaces while increasing the number of trees to decrease urban temperature and pollution. These same infrastructures have to also be capable of storing water, enabling it to be squeezed to the surface during droughts and coupled with investments in water reuse, sanitation, urban reforestation, and clean energy, integrating adaptation and mitigation.

This logic is already being applied in flood-prone Netherlands with its *Waternet*, and in tropical and water-scarce Singapore. It is also used in China's *sponge cities* and across American metropolises, such as New York and Los Angeles, through clever green urban design and regulations.

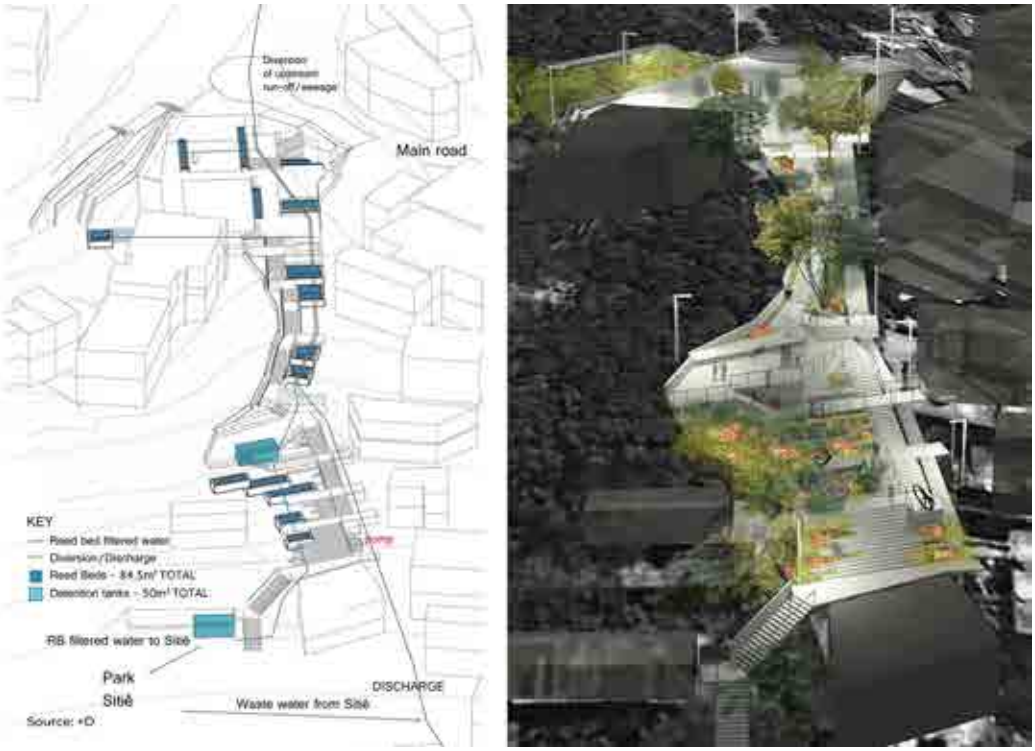
The synthesis of these practices, which include social urbanism from Medellín and new resilience technologies and solutions developed in Park Sitiê, as part of RioLab, by a team from Harvard and MIT with the community of Vidigal, Rio de Janeiro, in partnership with leaders from the Bloomberg mayoral terms in NYC, has been given the name of *climate urbanism*.[6]

This effort has progressed alongside the evolutive sequencing of Medellín's experience. Its proposal has been evidenced in urban transformation projects such as the Library Parks and in metropolitan plans such as Bio 2030, that reflect the central relevance of water among the population in a valley that has more than 300 streams, together with the innovative experience of communitary climate action allied to the effective use and creation of technological tools, urban design, and participatory processes in Vidigal (114 ha), Rio de Janeiro. An informal community located in the Atlantic Forest, the most overwhelmed and inhabited Brazilian ecosystem with 58% of the country's population (FSP).[7]

This same group developeda *4D Modeling* technology (Ds: x, y, z, and t for time) (Figure 2) in the Rio favela, where climate simulations in a digital twin of its built and natural spaces have been capable of predicting future scenarios with 95% accuracy (FSP),[8] including the 2019 landslide that closed Av. Niemeyer, it's only access to the rest of the city. This technology allows us to avoid disasters and test projects to achieve far greater effectiveness with much lower costs and then incorporate this anticipatory knowledge in multifunctional public spaces with drainage and structural reinforcement associated with relocation housing policies and successful urban integration such as in Medellín's social urbanism.

The coupling of anticipatory instruments with urban design solutions within climate urbanism is urgent. Due to extreme climate events, in addition to the catastrophic loss and devastation of human lives and biodiversity, economic damages are expected to reach US$38 trillion per year by 2050 without the proper investments in adaptation (resilience), resulting in a 19% decrease in global GDP (PIK - Potsdam Institute for Climate Impact Research).[9] At the same time, it is known that the cost of inaction is 7 times that of necessary investments (World Bank).[10] Last year alone, in addition to the human victims, the damage caused by extreme climate events was US$20 billion in Brazil, 1% of our GDP (CNM),[11] and this year it is already nearing 2%.

Cost estimates for adaptation are significant and varied. And, as much as inaction is simply not viable, resilience, too, will bring considerable fiscal pressure on national and local governments from now until 2050: US$520 billion globally and US$15.7 billion in Brazil annually as estimated by the UN,[12] totalling US$11.55 trillion and US$228 billion respectively, according to think tank CPI —Climate



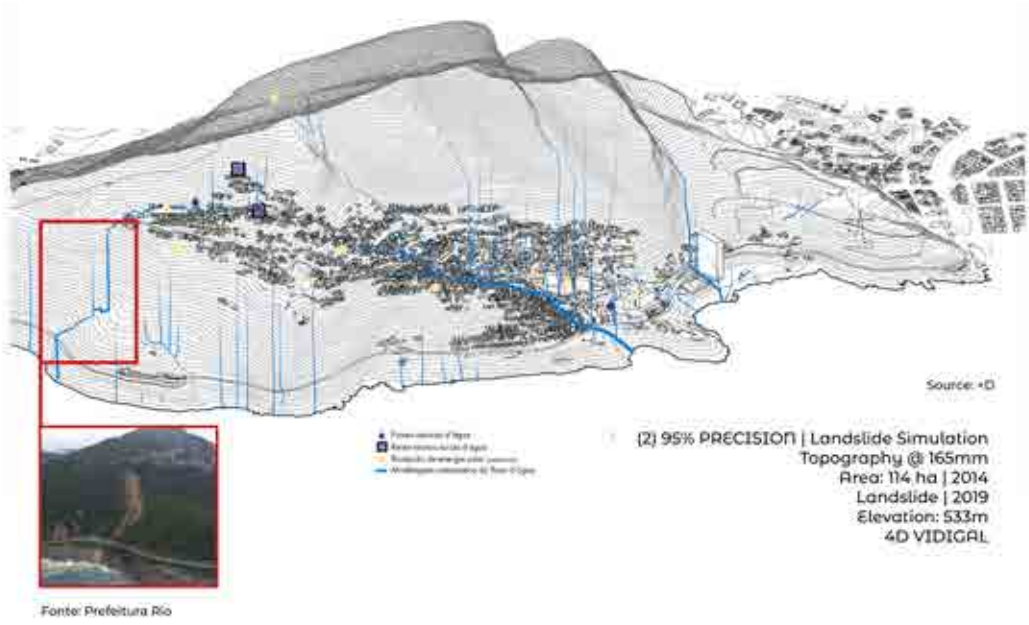


Figure 1: Multifunctional Resilience Structure: Sitiê Stairs+Square, Vidigal, RJ, 2015 SEED Design Awards; Source: +D.

Figure 2: 4D Modelling of Vidigal and Park: Sitiê, 2015; and, Landslide at Vidigal, RJ, 2019 SEED; Source: +D.

Policy Initiative.[13] The *BCG (Boston Consulting Group)*[14] predicts Brazil needs to invest US$150 billion in resilience per year during the same time period. For this great transformation to be viable it will have to be surgical, therefore, making it *sine que non* that we be capable of anticipation to avoid repeated massive costs due to project and policy failures. Thus, the importance of 4D modeling as an essential part of climate urbanism. A strategy that in addition to being more effective is, on average, 5-7 times cheaper (REA; et EU),[15] since concrete and other hard materials are what elevate the cost of construction.

A decisive example of this approach is the recent development of a 54 ha multifunctional resilience public space commissioned by the city hall of Cabrobó, in the state of Pernambuco, located in the semi-arid region of Brazil which is going through a desertification process and suffering recurrently stronger flash floods due to the combination of climate crisis and its geographical position in the São Francisco River Valley. The project was developed after the 4D modeling of its topography and built space, which guided its topological and urban design through several iterations until the most effective version in terms of performance and cost viability was achieved (Figure 3). Now, under its development process as part of the PAC federal government program, this project is set to propel a more resilient and inclusive future for this small city in the drylands as it embodies all aspects of climate urbanism, including green and blue infrastructures, public spaces, a water collection, treatment and reuse system, and a solar powerplant. However, what are climate urbanism processes and how can they be applied in different contexts?

Let's take the city of Belém, Pará, as na example. Located in the Amazon with 1.303.339 inhabitants and 2.249.405 in its metropolitan area, it is scheduled to host the UN COP 30 in 2025, the world's most important climate negotiations event. As in the entire Amazon region, where the urban population has grown 3.1 times over the last 40 years (IBGE; et MapBiomas),[16] Belém hás undergone an intense process of urbanization that saw its population more than double over the last 50 years (UFPA; et IBGE).[17] The urban growth in the Amazon and Belém has come with considerable environmental degradation, represented by the widespread decrease of green areas, from 65% to 28% in urban perimeters, and the rise societal vulnerability, with a fourfold increase in the overall slum areas of the region, between 1985 and 2022 (MapBiomas). Since the majority of the amazonian population is now urban, and close to 60% of the Belém population live in slums located in flood-prone áreas with a deficient sanitation coverage of under 10% (IBGE),[18] problems are mounting to face the climate crisis.

Not only that but Belém (2nd), the Amazon's other metropolis, Manaus (3rd), and cities of similar latitude worldwide such as Pekanbaru in Indonesia (1st), have the highest global risk of extreme climate events due to the intensifying occurrence of wetbulbs (CarbonPlan; et Washington Post),[19] in addition to historically recurring floods and now increasing droughts. Wetbulbs, the most

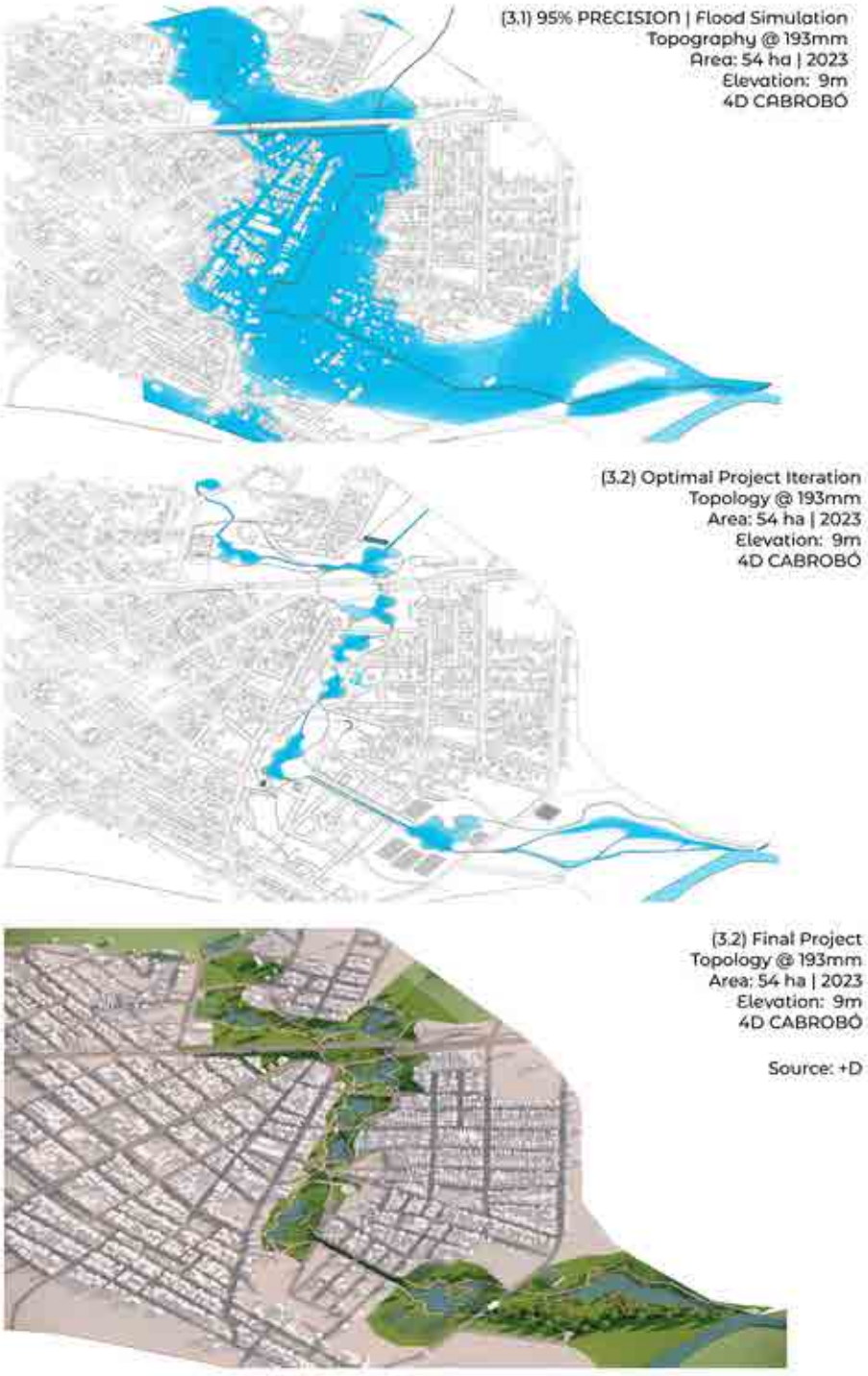


Figure 3: 4D Modelling of Cabrobó as current and of best performing project, plus Final Project 2023; Source: +D.

deadly climate extreme due to its combination of heat and humidity, do not allow for the human body to cool down through sweat, leading it vital functions to collapse due to overheating. As the Amazon is extremely humid—usually over 70%—there is a potentially deadly climate event everytime temperatures exceed 36C (97F). Therefore, as part of the urban legacy of UN's COP 30 in Belém, our team of collaborators has been developing a plan with its city hall within the framework of climate urbanism which consists of:

1 *City scan*: analysis of the (1.1) Natural: climate and environmental, (1.2) spatial, (1.3) policy, (1.4) socioeconomic and (1.5) cultural, and technological context of the city;
2 *PCP - popular climate plan* (Figure 4): a process to validate technical knowledge and the emergence of democratic propositions, with the population respecting undeniable scientific evidence but integrating the contextual knowledge of communities via the *digital agora*,[20] as well as building public equipment and conducting processes through physical and digital means of participatory democracy;
3 *4D modelling* of the city to assess and develop anticipatory interventions for different climate scenarios;
4 *Concept plan*: a unified urban design and policy plan for the city composed of *integrated urban plans (PUIs)* connected within a *great green grid (GGG)* at the scale of natural systems, communities, regions, cities, and metropolitan areas as the synthesis of the work of Singapore's *URA – Urban Redevelopment Authority*, Medellín's *EDU - Empresa de Desarrollo Urbano*, and Vidigal's *RioLab*, and;
5 *Live Belém*: a digital twin of the city that constantly updates visualized data regarding climate, risks, nature, population, infrastructure, and socioeconomic activities that is used, mastered, and updated through the participation of city population both as a means of resilience and development;

It is proposed that these efforts be developed within the establishment of a climate urbanism lab dependant on city hall that permanently share knowledge with other Amazonian and tropical cities, infrastructures, and territories in the process of scaling up developed solutions and absorbing/adapting external successful practices with the necessary urgency and effectiveness. For cities, infrastructures and territories in general, not just those from Amazonian and tropical regions, the main criteria for the development of climate urbanism are:

(I) The definition of the ecosystem in which it is going to be developed (eg: Amazonian, mediterranean, etc) together with the further understanding of its characteristics (eg: current and future climate, geology, water systems, vegetation, fauna, etc);

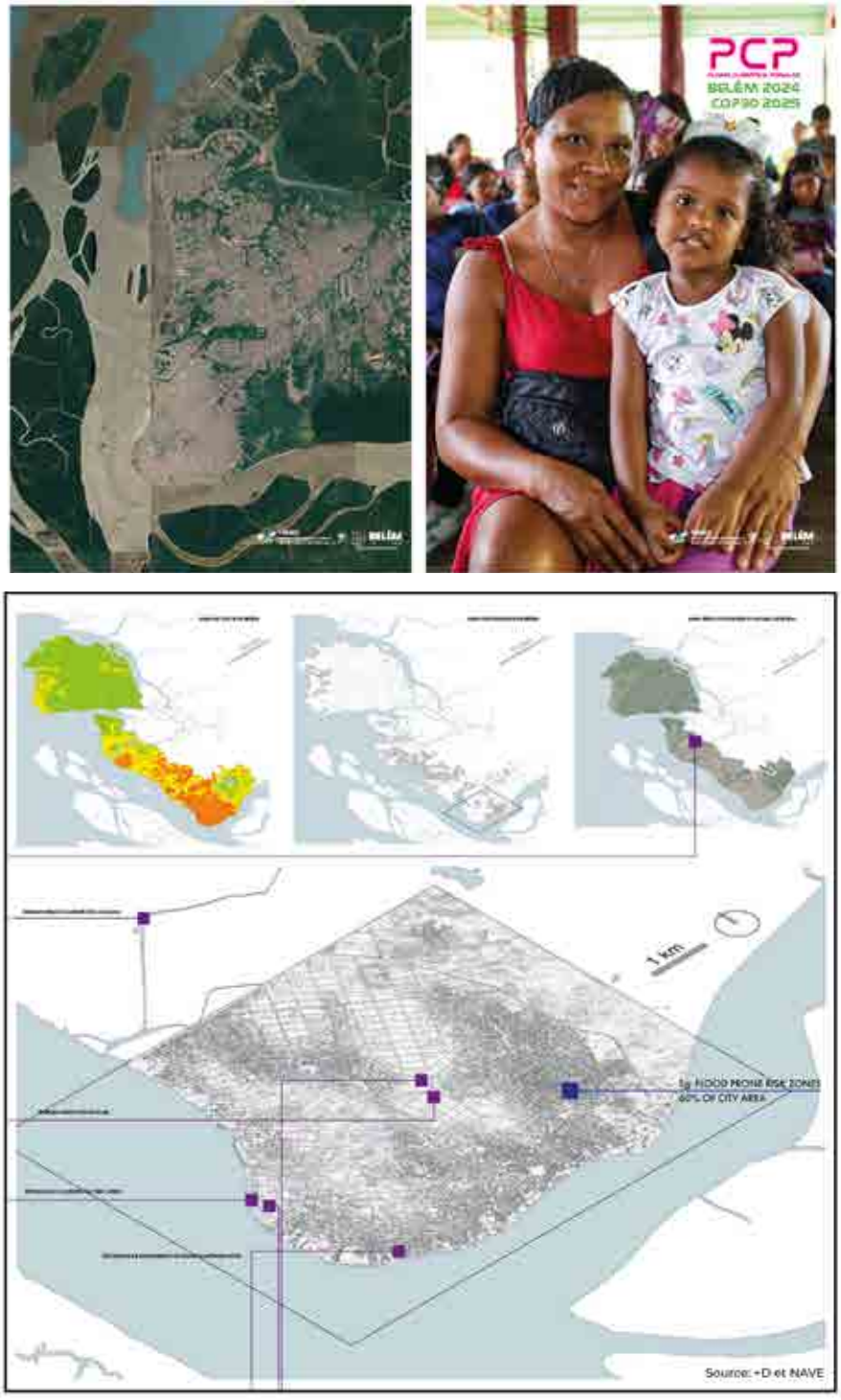


Figure 4: PCP - Popular Climate Plan, Belém, 2024; Source: City Hall of Belém, NAVE, Fervura no Clima and +D.

(II) Definition of a specific perimeter of action for interventions, measurement of results and governance of the commons (Ostrom, E);[21]
(III) The analysis of the cited human, natural and spatial factors in (1) and then the same steps cited from (2) to (5);

It is our goal to continue developing an effective application of climate urbanism together with the city hall of Belém and Pará State, as well as with the federal government as COP 30's legacy from Belém to the Amazon and tropical world: the development of a plan capable of uniting adaptation, mitigation, and integration, using this city as a lab.

The inevitable and urgent great climate transformation of our cities and structures in the Global South is simultaneously our only chance of survival, and the greatest opportunity for our nations to become developed. In this case, climate justice means achieving urban resilience and inclusion, environmental regeneration, and energy transition with public engagement, while removing the fewest people possible from their communities and making the territory and those most vulnerable more visible. For that, a series of *GNDs—green new deals*—will have to be realized across the world at all scales and they will have to occur under a cohesive strategy that is adaptable, scalable and anticipatory. Given that the climate crisis is our greatest existential threat, coupled with the fact that the majority of the population in the Amazon (75%), Brazil (84%), and Latin America (81%), as well as in the rest of the world, live in cities (IBGE; CEPAL; et UN),[22] climate urbanism is an immediate priority.

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Measuring Cities Together with their Citizens: Data and Algorithmic Transparency for Urban Planning

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Humanity must urgently address the upgrading of urban settlements. Better management and configuration of urbanization are essential to accommodate an expanding population. Indeed, this task must consider planetary boundaries and create efficient and sustainable habitats despite the climate crisis that could make our current built environment obsolete. Beyond functionality, we must also aspire to provide high levels of livability: to create attractive, desirable environments that we want to live in and live with—and that we want to be part of and care for.

Time is pressing. Therefore, actions to respond to this challenge must be precise and accurate. Fortunately, we have new data-driven technologies that allow us to build quantified descriptions of our settlements, speeding up and adding new nuances to this task. From satellites to mobile phones and autonomous vehicles (constantly mapping cities), these technologies have arrived to complement and overlap with the tasks we still solve today with spreadsheets or sometimes even simple paper sheets. On the one hand, data is currently a tool that supports the knowledge needed to analyze territories with a high level of expansion (which requires the velocity that these systems provide). On the other, it also allows the regeneration of consolidated urban settlements with precision and detail.

These descriptions create evidence and show irrefutably what we thought we knew. For the first time, they allow us to compare distant and distinct urban environments. Through data, we can observe them in the same way. Thus, it is possible to scale and improve the replicability of actions and policies thanks to the possibility of comparing settlements in significantly different contexts. Finally, and perhaps most fascinatingly, these descriptions can address the invisible dimensions of urban environments: from the confines of urbanization, to what happens inside each household or even inhabitants' affections towards their territory. This regard transits from Sennett's[1] (2019) *ville* to *cité*, from the city's physical reality to its daily and experiential functioning.

However, we must remain cautious while promoting the use of these tools, despite our optimism. The possibility of successfully overcoming these challenges is equal to the risks linked to improper use. Thus, it is essential to insist constantly on the governance of the data used. The data must be of high quality, accurately describing the phenomena, and for administrations to ensure autonomous and unbiased use.

As an illustration, the diagnosis conducted for Campo Grande in Brazil emphasizes the importance of supporting urban description with data that public administrations can validate and sustain.[2] Here, data came from existing infrastructure (municipal statistics, administrative records, or even citizens' digital footprints), partially latent, and previously unused. It is an amalgam of information with very different characteristics, disparate sampling frequencies and deviations, which requires a high level of complexity in harmonizing the various sources. As a result, this new municipality description covers urban sprawl, housing prices, household composition, accessibility to public services and supply, among many other aspects that can guide various strategies for sustainable urban development.

In Campo Grande, despite using local data, we used the same calculation methodologies as those used in Barcelona to assess the proximity of citizens to different public services and facilities.[3] We used a taxonomy of public services according to typology (health, education, etc.) and user profile (age, local/visitor) to determine a proximity degree (from 5 to 25 minutes) and develop an urban

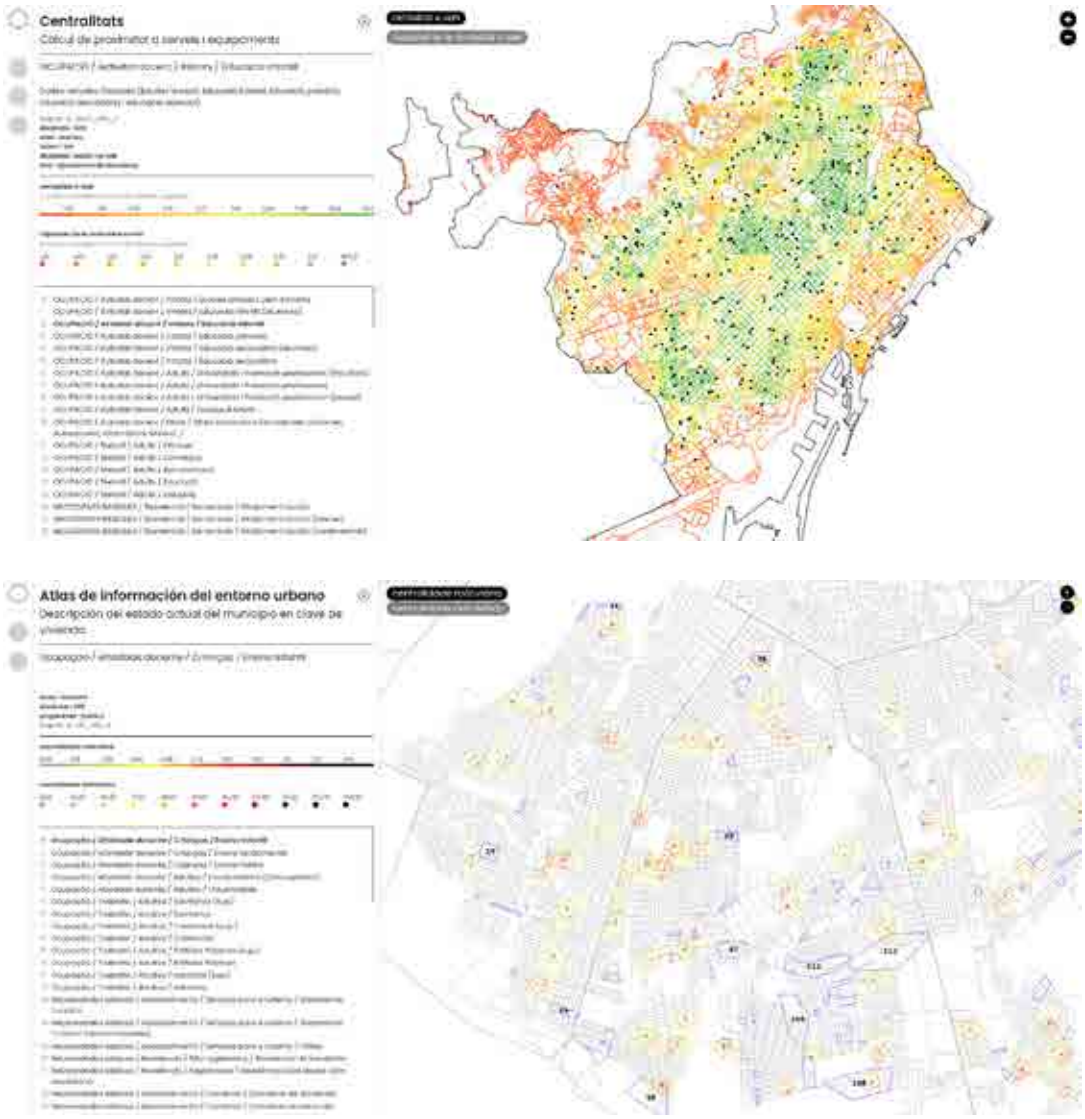


Figure 1: Comparative images of the centrality system of Campo Grande and Barcelona (accessibility to schools).

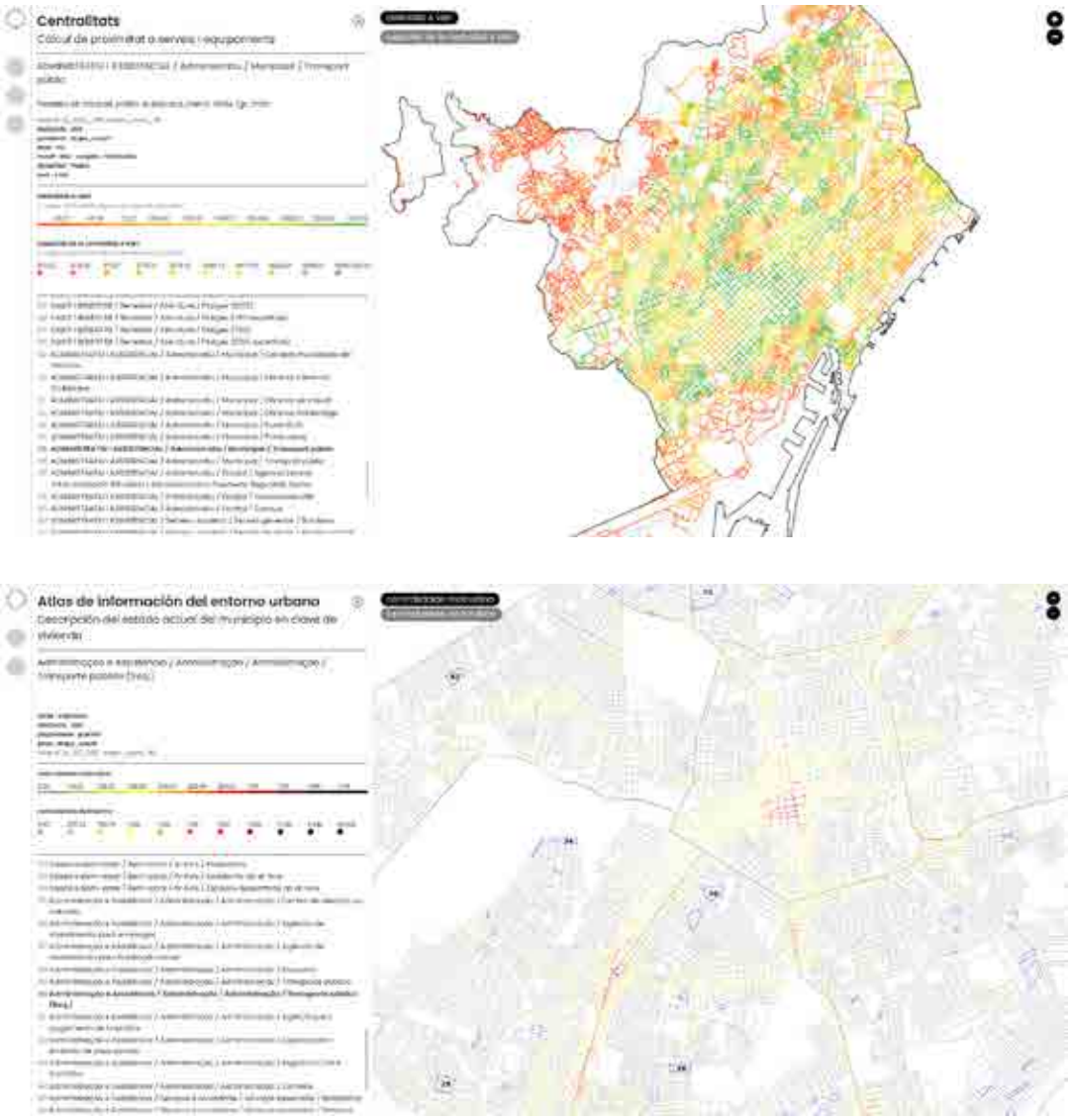
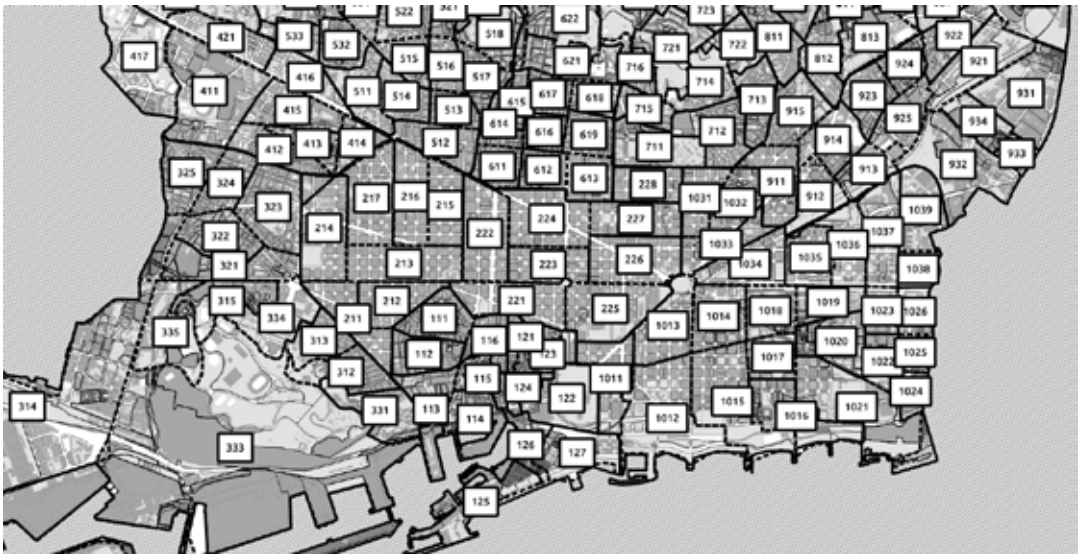
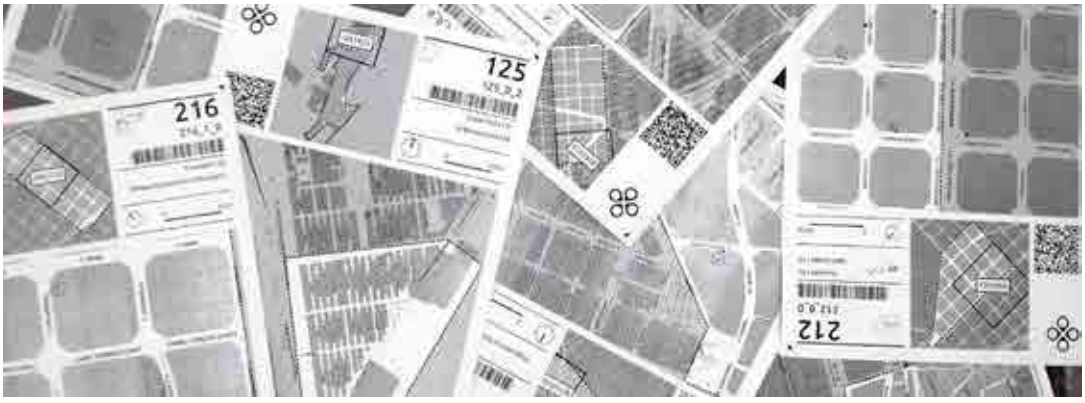


Figure 2: Comparative images of the centrality system of Campo Grande and Barcelona (accessibility to public transport).





Figures 3 and 4: Open Papers collaborative census system (Map of areas to be recognized and data collection sheets).

model that evaluated the level of accessibility at each point of the city in relation to the population. Two distinct locations, each with its unique information infrastructure, employ the same algorithms and analytical methodologies, enabling meaningful comparisons between them. Consequently, it is essential to prioritize public information sources to ensure the replicability and transparency of diagnoses that precede or assess planning processes and public policies. The data, along with the infrastructures to generate it, must be publicly accessible —ensuring that information is both reliable and verifiable.

However, not all the data required for pre-planning diagnostics either exists or is readily accessible. Certain fundamental aspects, such as demographic data, remain incomplete, particularly concerning vulnerable populations, such as the homeless. For instance, like many other cities, Barcelona lacks a comprehensive homeless population census, which makes it difficult to develop effective public policies. To address this challenge, the Arrels Foundation[4] has conducted censuses with the help of up to 900 volunteers, who canvassed the city on a single night to assess the extent and characteristics of this population. For many years, the foundation has employed the open-source tool Open Papers,[5] which has facilitated the creation of a cartographic system initially supported on paper (later digitized) for census campaign organization, as well as the automatic processing of resulting data.

As a result, citizens are not only beneficiaries of these processes. They play an active role in the creation and monitoring of the data. This is exemplified by Open Papers (where citizens themselves participate in the collection and validation of information) and, similarly, in Mercè[6] and Arturo,[7] two citizen-trained algorithms to measure the livability of the cities of Barcelona and Madrid, respectively.

Through a citizen science experiment, based on the possibility of constructing an urban model that contemplates a large volume of descriptive parameters of the environment, the citizen evaluates which of those parameters are most relevant and to what degree in order to define a livable environment. From the selection of pairs of city images, citizens create an order according to a collective consensus in their identification, which makes it possible to associate quantified values to each of the places that the photographs represent. In this way, it is possible to determine which variables (street width, number of trees, density, volume of traffic, and level of mix uses) contribute to generating a greater sense of comfort.

Through a citizen science experiment aimed at evaluating a data model incorporating a wide range of descriptive parameters of the urban milieu, citizens evaluate which factors are most relevant and in what proportion they contribute to defining a livable environment. By selecting pairs of city images, participants collectively rank them according to collective consensus, enabling the assignment of quantified values to the locations represented by the photographs. This process allows us to determine key factors—such as street width, number of

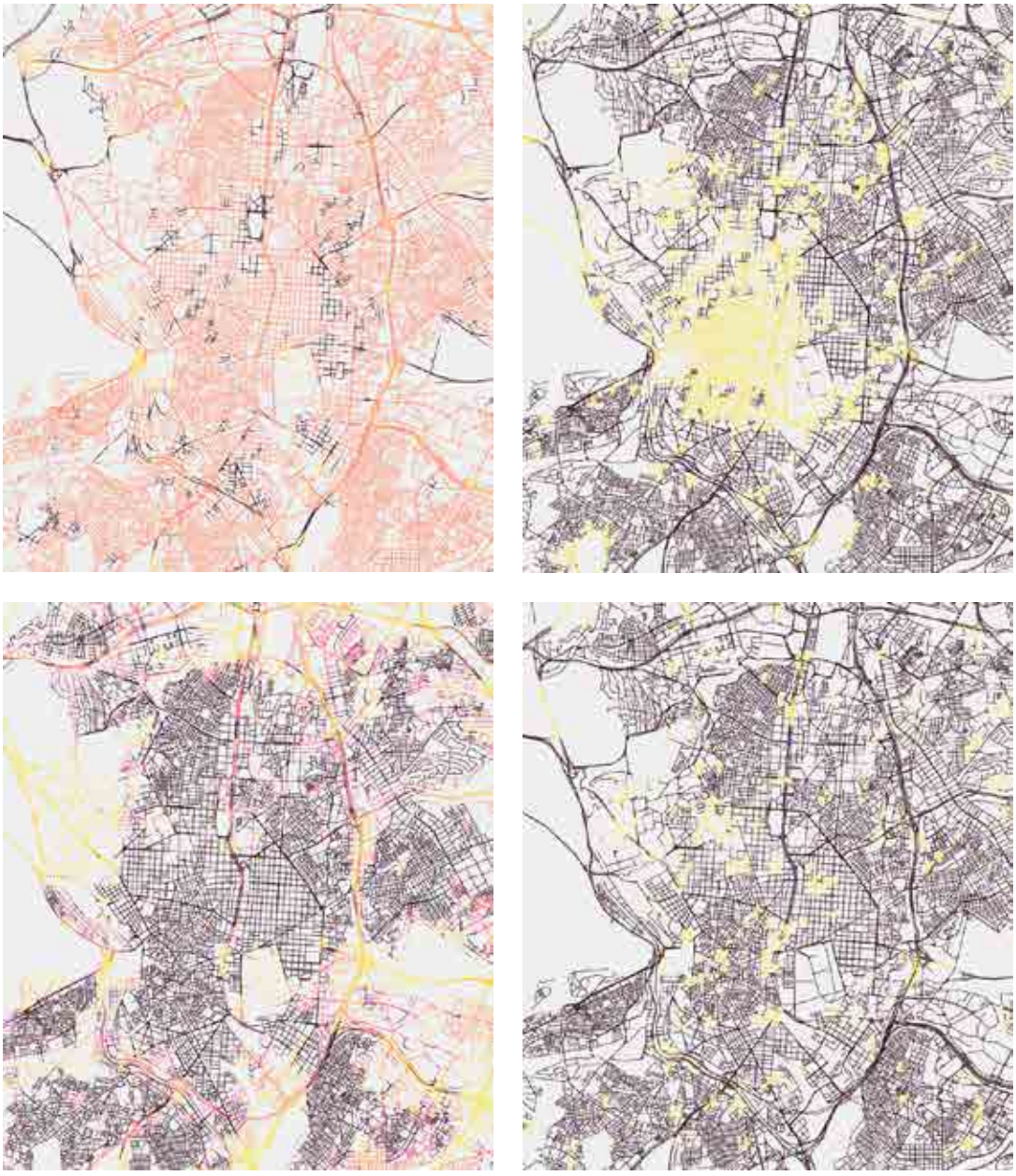


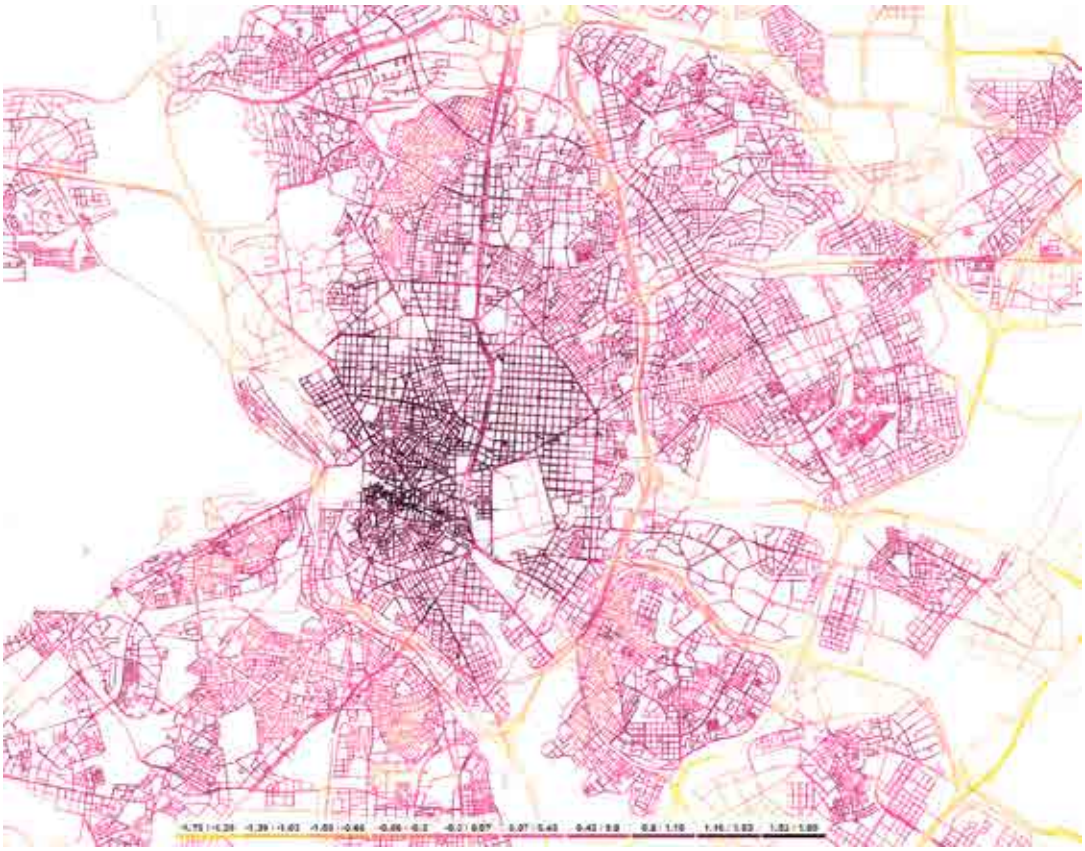
Figure 5: Layers of the urban data model, trained by citizens in the Arturo Project (built quality, age of buildings, mix of uses and proximity to nearby green spaces).

trees, population density, type of ground-floor activities, traffic volume, and mix of uses—that enhance a sense of comfort in the urban environment.

This approach enables the assessment of one part of the dataset to be extrapolated to other city areas or apply these evaluations to different urban settings. Essentially, the experiment distills the judgments and evaluations of a group of citizens on what constitutes a better or worse environment into an algorithm, allowing livability to become a measurable criterion. Although potentially subjective, this criterion becomes assessable and can be incorporated objectively into urban planning agendas and goals.

We have implemented the same experiment in various settlements in South Africa to evaluate the quality of informal settlements (slums).[8] While satellite imagery is relatively effective in identifying these areas, it has not yet advanced to the point of quantifying their level of precariousness. To address this, the residents themselves (who possess intimate knowledge of their surroundings and can recognize dimensions that even the most experienced urban planners might overlook) have trained the algorithm that analyzes the photographs. This project combines satellite imagery with the subjective assessments of residents, gathered via mobile phones, to inform urban decision-making processes. In this way, it places citizens at the core of the algorithmic calibration that processes this information.

All of the previous examples highlight the necessity of adopting a data-driven approach in the planning and transformation of urban settlements. It is crucial to integrate the data value chain—comprising data capture/creation, diagnosis, formulation, and evaluation—into public policy while simultaneously building governance capacities and strategies in the locations where these solutions are applied. Achieving the necessary pace for these initiatives will also require employing tools that enable the scalability and replicability of interventions. Data serves as a strategic asset, offering valuable insights, making it essential to establish public governance frameworks that ensure its availability, accessibility, and reliability for policymakers and the citizens they aim to serve. Equally important is ensuring that the algorithms processing this data are transparent and auditable, fostering credibility and autonomous, well-informed decision-making.



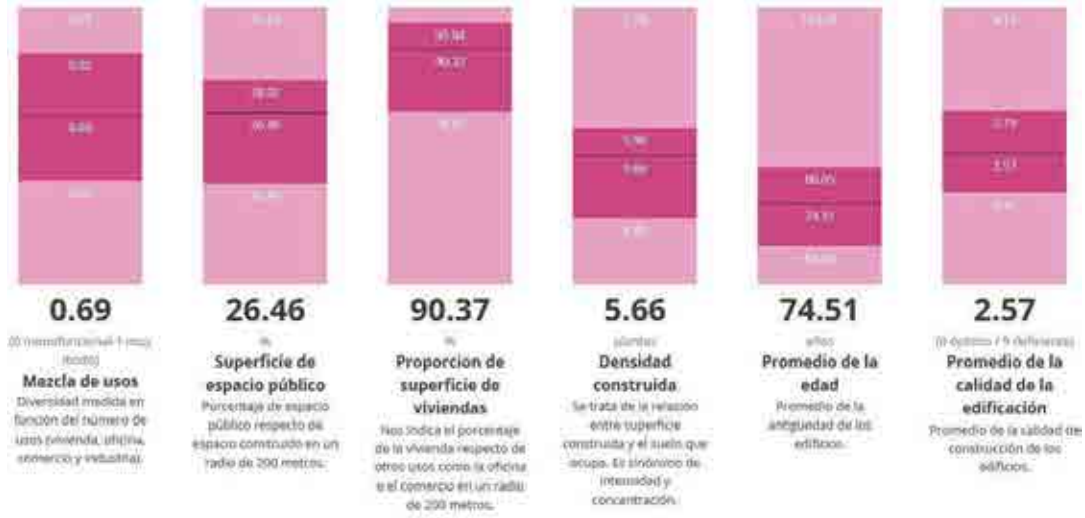


Figure 6: Map of the streets of Madrid according to their level of habitability defined by the inhabitants (Arturo Project).

Figure 7: Parameters of the urban model with the greatest influence on habitability (Arturo Project).

Endnotes

1. Richard Sennett. *Building and Dwelling: Ethics for the City.* Penguin Books, 2019

2. Developed with the support of the IBD and the consultant.

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Managing Urban Growth in South Korea

Hye Jung Park (KRIHS)

Korea has undergone a notable rural-to-urban migration process since the 1960s, precipitating rapid urbanization and population growth around major urban centers. Population in the Seoul region surged from 21% to 49% of the country over 61 years, signifying a substantial decline in population across other areas. For over five decades, the Comprehensive National Territorial Plan (CNTP) has represented the efforts of the Korean central government to regulate urban densification, particularly in the area surrounding the capital, adjusting to demographic shifts and directing urban trends across five successive phases, from 1972 to 2040.

The changes in population within South Korea can be tracked back to the inception of the Government of Republic of Korea. Since the establishment of the government in 1948, the first population and housing census was conducted in 1949, and it has been conducted every five years since 1955. Comparing census 1949 and 2010, total population nationwide has increased over 28.4 million including 19.7 million in capital area (Seoul and Gyeonggi-do) and 6.4 million in Gyeongsang area (including three metropolitans and two provinces in administrative division, in south-east side of peninsula). Ninety two percent of population increase has happened in those two areas. The phenomenon of urban densification is evident in the spatial distribution of population across administrative regions.[1] In 1949, 73% of the total population resided in *Myeon* areas, with only 18% (3.5 million) residing in *Dong* areas. Conversely, by the year 2010, the distribution had shifted significantly, with a mere 9% of the total population residing in *Myeon* areas, while 82% were concentrated in *Dong* areas.

This illustrates that since the conclusion of the war, Korea has undergone notable rural-to-urban migration, precipitating rapid urbanization and the concentration of population around major urban centers. Specifically, within the Seoul capital region, the population has surged from 21% to 49% over the span of 61 years, signifying a substantial decline in population across other areas.

The population cartogram, a cartographic representation resized according to statistical data, distinctly illustrates the pronounced population growth within the capital area. During the 1960s, the Seoul capital area, encompassing Incheon-si (city), accounted for 21% of the total population, a figure that surged to 49% by 2010, effectively expanding to occupy 139% of its original geographic extent on the map. Conversely, metropolitan areas outside the capital region, including Busan, Daegu, Gwangju, Daejeon, and Ulsan, collectively represent 20% of the population. Consequently, the Seoul capital area and its metropolitan counterparts account for a combined total of 70% of the nation's population.

During the 1970s, cities boasting populations exceeding 200,000 were predominantly situated in regions rather than the capital area. However, by 2010, a noteworthy shift occurred, with 31 out of 47 cities surpassing the 200,000-population threshold now clustered within the capital and Gyeongsang area. Presently, within the capital area, particularly in Gyeonggi-do (the province surrounding Seoul), there is a discernible trend of declining populations in rural areas, juxtaposed with an influx of residents into urban centers.

Although not visually depicted in the cartogram, as of 2020, the population of the capital area has reached 23 million out of a nationwide total of 51,829,136 individuals. This signifies an increase of 3 million residents compared to the 2010 figures, with nearly 2 million of this population growth attributed to the capital area alone. Such data underscores the persistent high level of population concentration within the Seoul capital area, suggesting a further expansion in its spatial occupation as anticipated in the cartographic representation.

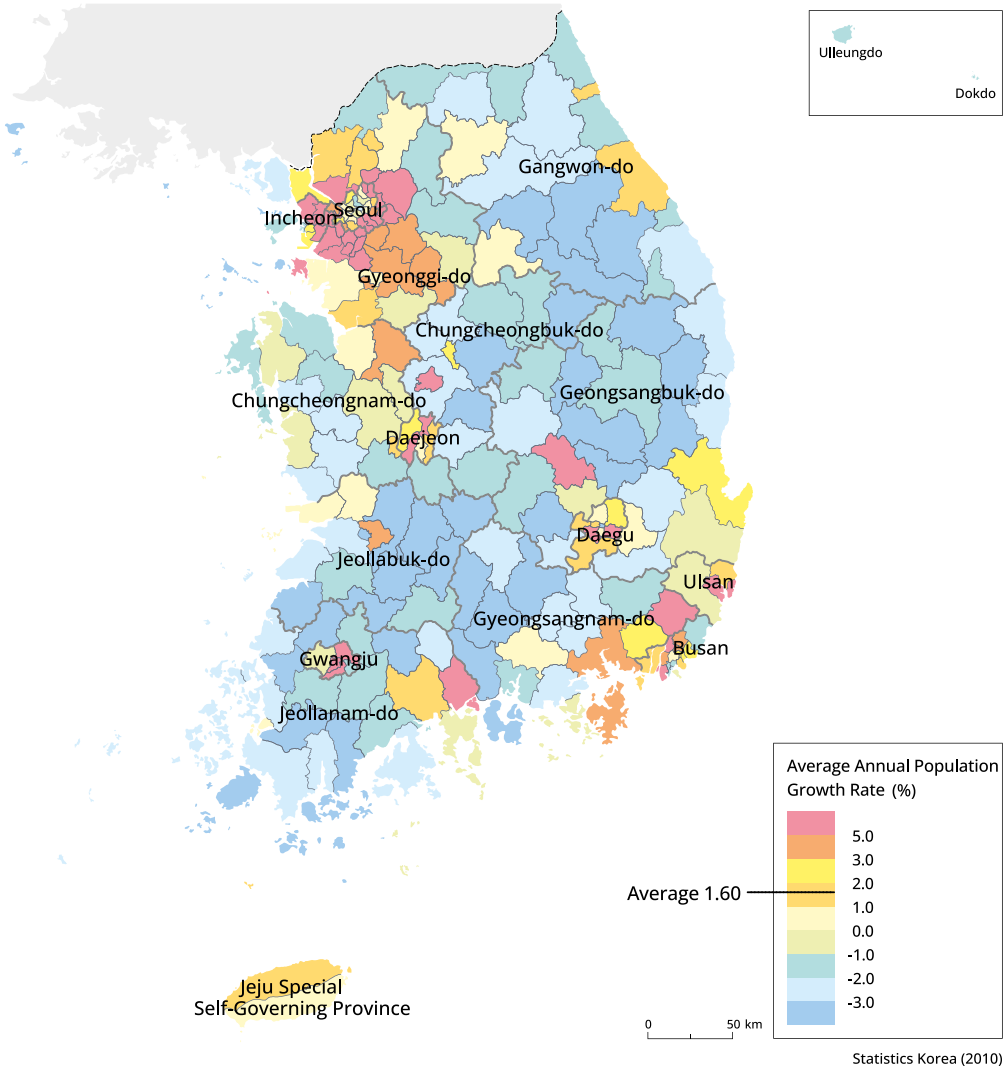


Figure 1: Population Growth Rates 2000 - 2010. Source: NGII 2016.

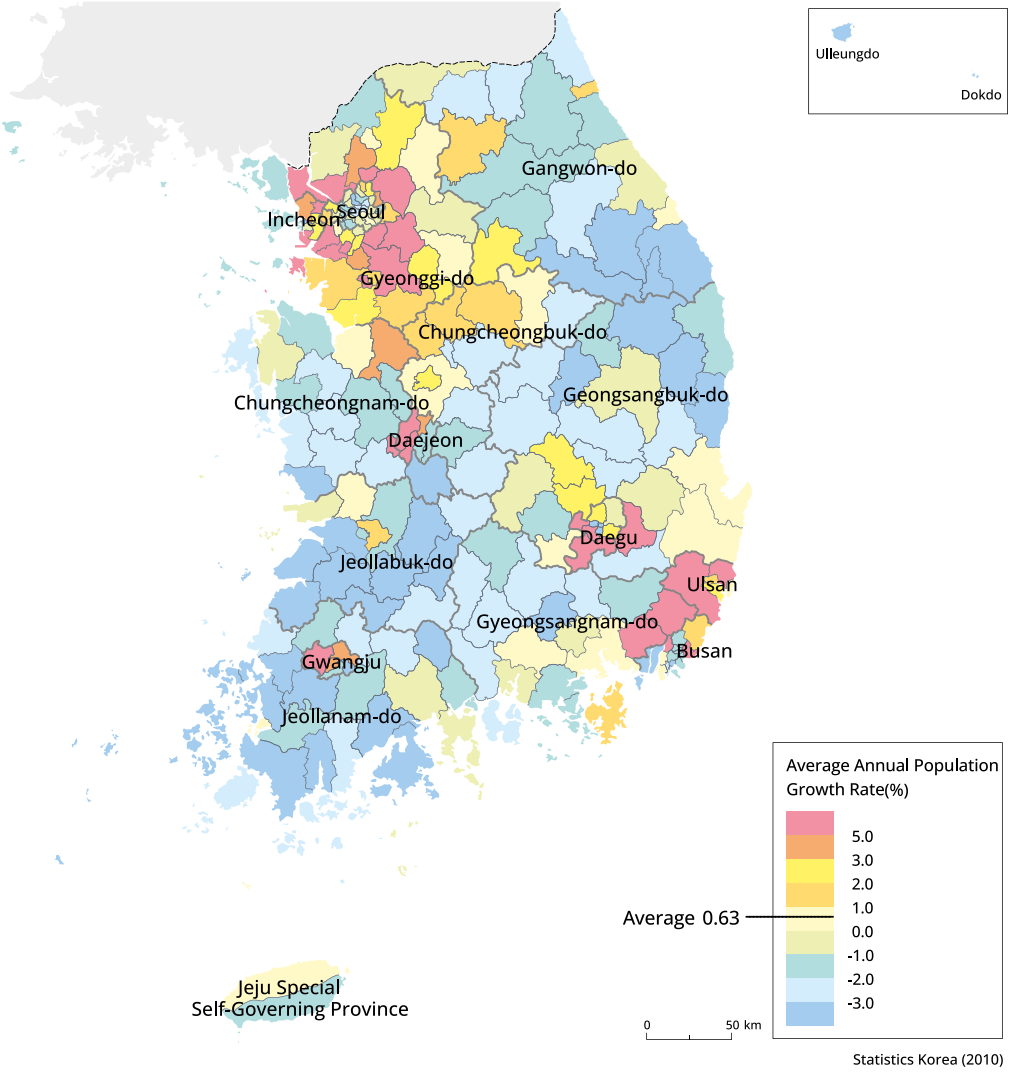


Figure 2: Population Growth Rates 2000 - 2010. Source: NGII 2016.

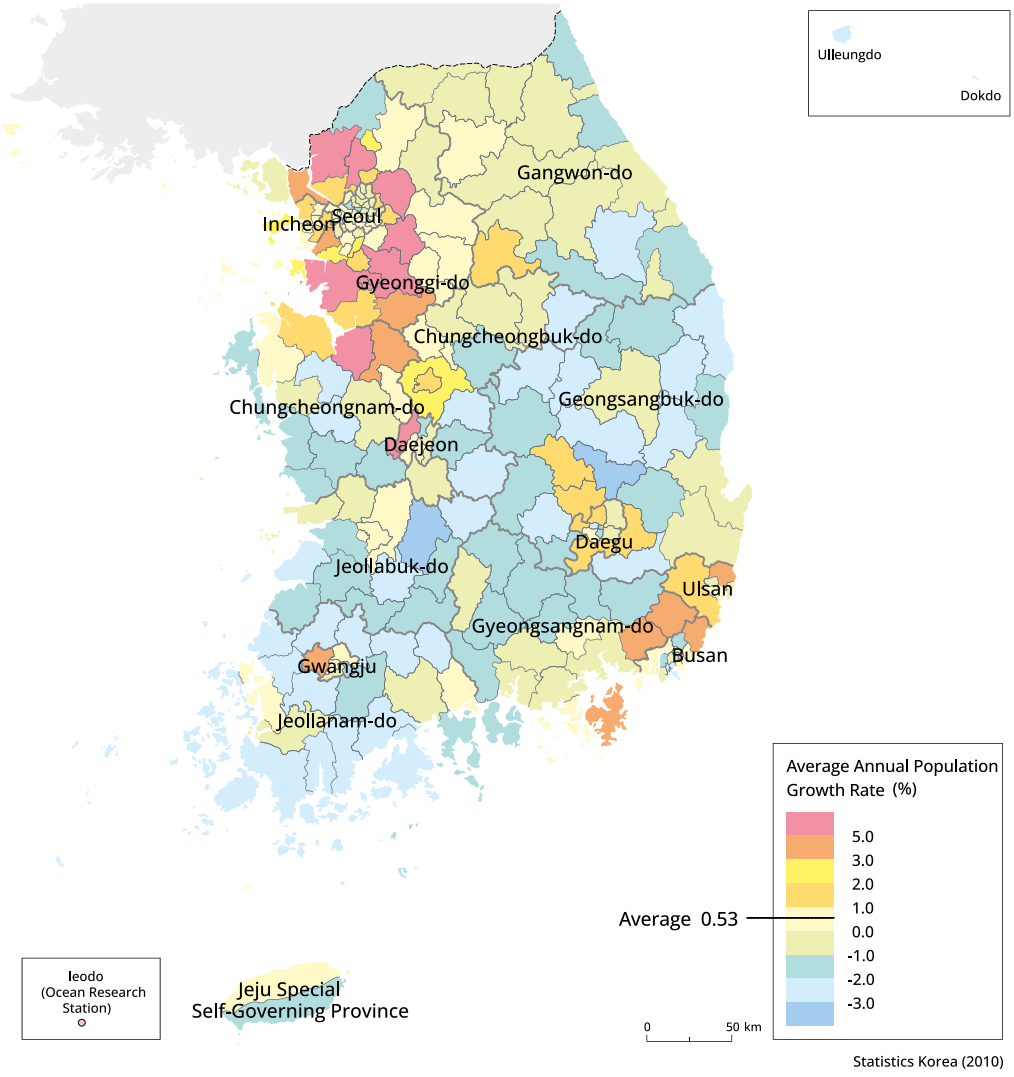


Figure 3: Population Growth Change. Source: NGII 2016.

Conversely, small and medium-sized cities situated in regional areas commenced a trend of contraction beginning in the 1990s. Typically, cities with populations falling below the 200,000 thresholds outside the capital area have been subject to this phenomenon. These shrinking cities have witnessed a reduction in population of approximately 30% over a span of two decades, despite certain urban development plans forecasting a surge in population ranging from 30% to 50%. This incongruity may stem from growth-oriented policies that inadequately anticipated demographic shifts.[2]

The examination of infrastructure and housing conditions concurrently elucidates the factors contributing to, and consequences of, urban concentration within the Seoul capital area. Seoul exhibits a notable prevalence of aging infrastructure alongside numerous redevelopment projects, both completed and ongoing. Regarding housing, structures surpassing the 30-year mark since their authorization for use comprise an average of 52 percent, with the capital area registering slightly lower at 43.3 percent, and other regions at 55.2 percent.[4] Notably, over the past decade, the capital area has witnessed a greater volume of housing units undergoing reconstruction compared to other regions, with exceptions occurring solely in 2019 and 2022. This discrepancy, juxtaposed against regional proportions, underscores the capital area's adeptness in promptly responding to housing reconstruction demands stemming from sustained housing needs, while regional locales contend with aging structures amidst diminished population pressures.

In the case of Gyeonggi-do, the province surrounding Seoul, has continuous development of public transportation infrastructure to widen the connectivity to the center of Seoul while the area is acting as a residential town as it was planned at the beginning of New Town phase 1 and 2. Regional polarization of transport service is getting severe since the local governments out of capital area could not follow the growth in capital area due to its decreasing population which is connected to feasibility of construct such infrastructure.[5]

In the context of Gyeonggi-do, the province encompassing Seoul, a concerted effort is underway to enhance public transportation infrastructure, aimed at bolstering connectivity with the central Seoul district.

Concurrently, the region serves as a residential hub, aligning with its original design objectives outlined during the inception of New Town phases 1 and 2. However, a notable trend of regional transport disparity is emerging, exacerbated by the challenges faced by local governments outside the capital area in keeping pace with the rapid development witnessed within the capital region.

The Comprehensive National Territorial Plan (CNTP) constitutes a principal national spatial strategy in accordance with the Constitution and the Framework Act on the National Land of the Republic of Korea. As delineated in Article 6 of the Framework Act, the national territorial plan is defined as "any strategy devised to establish developmental trajectories for the national land in response

Population changes by cities with different population scale (1970-2010)

Population scale	Number of cities			Population proportion			Increasing rate (%)	
	1970	1990	2010	1970	1990	2010	1970-1990	1990-2010
Over 1 million	3	6	8	27.0	47.6	48.3	147.6	13.6
0.5-1 million	1	5	11	2.1	7.0	16.1	381.5	156.4
0.2-0.5 million	3	15	30	3.7	10.3	18.7	284.9	103.4
50 thousand-0.2 million	35	47	37	8.3	9.5	9.2	60.6	7.4
Gun (under 20 thousand)	130	138	81	58.8	25.6	7.8	-16.1	-65.9
Total	172	211	167	100	100	100	-	-

Key purpose of Comprehensive National Territorial (Development) Plan

The Plan	Key purpose
The First (1972-1981)	Apply growth pole development by industrial belt around capital region and South-East coast to construct bases for rapid economic growth.
The Second (1982-1991)	Control the spatial concentration in capital region and promote regional development to settle local population and improve living environment.
The Third (1992-2001)	Propel decentralized national territorial development by promoting local cities including west-coast industrial area to improve national welfare and preserve environment.
The Fourth (2000-2020)	Propel open-integrated national territory with harmonization of development and environment, targeting interregional integration and integration with northeast Asia.
The Fifth (2020-2040)	Inter-regional alliance and cooperation for regional development Alliance for local development, balanced national development with highlighting regional characteristics.

Table 1: Population changes by cities with different population scale (1970~2010)
Source: Park, Sehoon, Kim, Dongju, Jeong, Yoon Hee, Park, Geunhyun & Lee, Eunyoung.[3]

Table 2: Key purpose of Comprehensive National Territorial (Development) Plan Source: Government of Korea, The Fifth Comprehensive National Territorial Plan (2020~2040), 2020.

to prospective economic and social transformations, aimed at realizing predetermined objectives through the utilization, development, and preservation of said national land" (Article 6, Framework Act on the National Land).

The endeavors of the central government of Korea to regulate urban densification, particularly within the capital area, are delineated across five successive phases of the CNTP. The primary objectives of each phase are outlined below.

THE FIRST COMPREHENSIVE NATIONAL TERRITORY DEVELOPMENT PLAN (1972-1981)

A rapid economic growth during the 1960s caused an enormous migration from rural to urban area, resulting in urban expansion in major cities including Seoul, while rural areas were suffering population outflow. Regulations such as a preventive for Population Concentration in Metropolitan (1964), Basic guidance for anti-concentration in Seoul Metropolitan Area (1970) were introduced to deal with such a phenomenon in SMA.[6] In the first CNTDP, the central government's intention to achieve balanced development was reflected, however, since economic development was a crucial goal of South Korea, it was hard to balance at the first phase.

THE SECOND COMPREHENSIVE NATIONAL TERRITORY DEVELOPMENT PLAN (1982-1991)

By the year 1981, the population of Seoul had surged to 8.5 million, exceeding the anticipated figure of 6.3 million. This demographic shift underscored a perceived failure in achieving regional equilibrium development as envisioned by the initial Comprehensive National Territorial Development Plan (CNTDP). Concurrently, populations in regional metropolitan areas, including Busan, the second largest city in South Korea, experienced growth, while other regions, barring major urban centers, witnessed population decline. In response to the unintended consequences of the first CNTDP, the government introduced the concept of the "Regional Living Zone," aiming to identify and cultivate growth centers that would function as central hubs, thereby facilitating the operation of these regional living zones and ensuring the efficacy of the plan. However, the objective of "settling the regional population" was ultimately constrained, as the second CNTDP failed to formally designate growth center cities or materialize the concept of Regional Economic Zones due to a lack of specific implementation mechanisms during this period.[7]

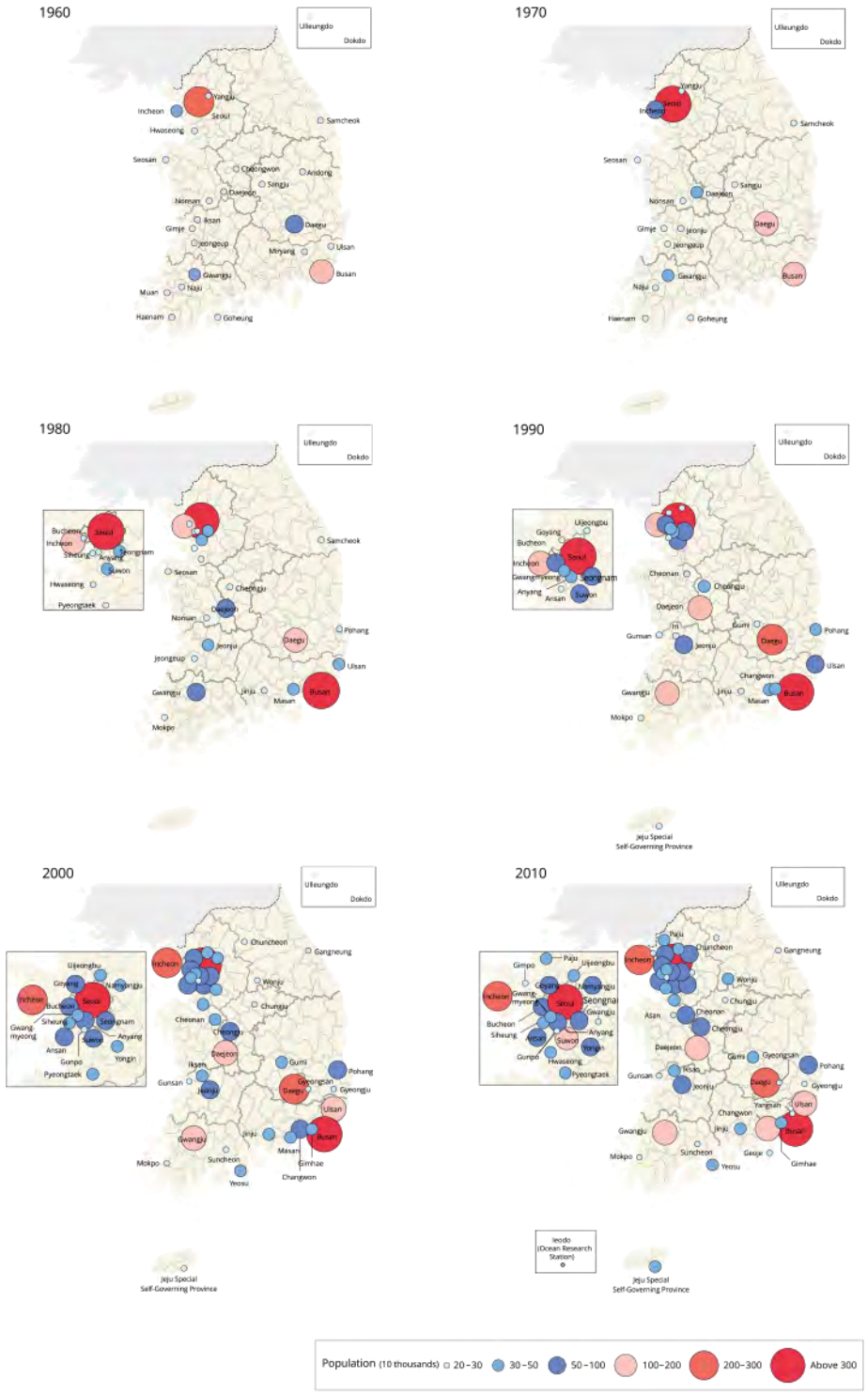


Figure 4: Cities with a Population over 200.000. Source: NGII 2016.

THE THIRD COMPREHENSIVE NATIONAL TERRITORIAL DEVELOPMENT PLAN (1992-2001)

Despite the implementation of the first two Comprehensive National Territorial Development Plans (CNTDP) and the enactment of robust policies aimed at mitigating population concentration in the capital area, such as the Capital Region Arrangement Plan,[8] nearly half of the nation's population aggregated in the capital area by 1990, constituting 42.7%.[9] This demographic concentration not only represented an imbalance in population distribution but also served as a catalyst for transportation, housing, and pollution challenges within the capital area. By 1990, 52.7% of vehicles and 95.5% of conglomerates' headquarters were situated in the capital area,[10] further exacerbating these issues. Consequently, the government anticipated continued population growth in the capital area until the culmination of the third CNTDP in 2001. Accordingly, the third CNTDP incorporated the objective of forming a decentralized territorial structure and emphasized the principle of achieving a balanced distribution of territorial space. Within its sectoral plans, strategies were delineated to promote provincial areas and mitigate concentration in the Seoul Capital Area, including measures such as the prioritization of tax incentives for industries in provincial regions and the relocation of public institutions. Additionally, the plan advocated for regional self-decentralization through the development of new industrial spaces and industrial complexes, as well as the cultivation of key industries in small and medium-sized cities, positioning these initiatives as core projects of the third plan (Government of the Republic of Korea, 1991, 144-145).[11]

THE FOURTH COMPREHENSIVE NATIONAL TERRITORIAL PLAN (2000-2020)

The inaugural Comprehensive National Territorial Plan (CNTP) in the 2000s, from the fourth iteration onward, notably excluded the term "development" from its official title. Instead, it embraced a strategic approach focused on the relocation of central government entities, including ministries, as a means of decentralization. In contrast to prior plans that predominantly employed the establishment of special economic zones and industrial belts in collaboration with the private sector to achieve balanced development, the Participatory Government actively orchestrated the migration of central government offices through legislative channels (Special Act On The Construction Of Administrative City In Yeongi-gongju Area For Follow-up Measures For New Administrative Capital, December 2005), thereby ensuring a deliberate pursuit of decentralization objectives. Concurrently, mounting concerns regarding urban densification within the capital area heightened the demand for policy alternatives. This climate of urgency precipitated

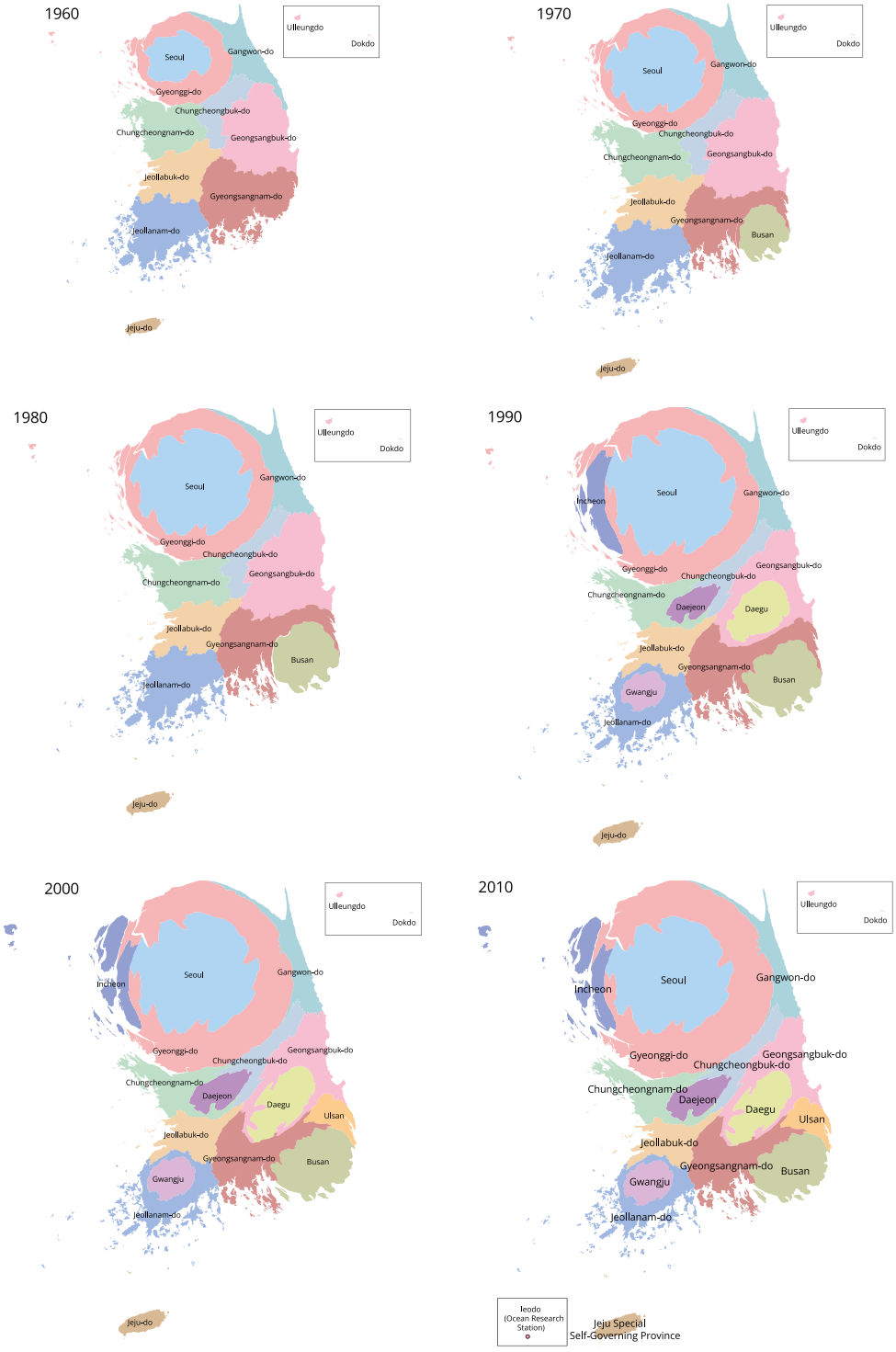


Figure 5: Population Growth Change. Source: NGII 2016.

the expedited announcement of strategies to enact decentralization, including initiatives tailored to specific industries. Nevertheless, the persistent gravitational pull toward clustering in the capital area persisted, compounded by the absence of adequate implementation mechanisms. Against this backdrop, the revision of the fourth plan was promulgated.

The primary aim of the revision of the fourth plan was to accommodate anticipated transformations stemming from the establishment of a regional innovation system and the decentralization of central functions, exemplified by initiatives such as the construction of a multifunctional administrative city.[12] This culminated in the formulation of the initial objective of the revision, namely the "balanced national territory of coexistence." The plan advocated for a multi-core territorial structure to foster regional hubs, alongside the establishment of specialized development bases tailored to each region, thereby facilitating the harmonization of territorial development and promoting cooperation in local development endeavors. Concurrently, there was an unprecedented national-level endeavor to facilitate the relocation of government ministries. However, public contention intensified until the finalization and subsequent implementation of regional decentralization policies pertaining to government ministries and national public institutions.

THE FIFTH COMPREHENSIVE NATIONAL TERRITORIAL PLAN (2020-2040)

Addressing the concentration of population in the capital area has remained a central objective spanning from the inception of the First Comprehensive National Territorial Development Plan (CNTDP) to the ongoing fifth iteration of the Comprehensive National Territorial Plan (CNTP). The current CNTP endeavors to devise strategies to confront the structural shifts in population dynamics attributed to low birth rates and an aging society, while concurrently grappling with the persistent issue of population concentration in the capital area. It places particular emphasis on regions where the prevalent trend of a diminishing domestic working-age population in provincial areas has resulted in a decline in economic vitality and exacerbated disparities in relation to the capital area. Accordingly, the fifth plan delineates the pursuit of a "balanced national territory" as one of its three overarching goals, alongside the aim of fostering "distinctive and decentralized regional development" and fortifying solidarity and collaboration among regions, articulated as one of its six core strategies.[13]

Considering the preceding discussion, South Korea has undertaken numerous policy initiatives within a national framework to address the importance of balanced development. However, it is challenging to assert that these initiatives have been sufficiently successful.

Additionally, the last five decades of the Korean case illustrate how the concentration and migration, as well as the growth and decline of the population, directly and significantly influence the nation's perception. While Seoul has attained the status of a global city with advanced infrastructure, its symbiotic relationship with other regions is comparatively less favorable.

Policy-making is increasingly challenging due to contemporary issues such as low birth rates and demographic crisis, which are leading to the decline of local towns in regions outside of Seoul and the capital area.

To address these changes in policy-making contexts, it is essential to review and reflect on past policy initiatives, and to manage the system for effective future implementation. One key implication from this chapter is that South Korea is prioritizing the 'population atlas' as a central element of its national territorial policy, recognizing that this agenda should not be neglected. Consequently, the rapid urbanization resulting from significant migration must be managed by both central and local governments through a consensus-driven approach to achieve systematic implementation of urban policy.

Endnotes

1. *Eup/Myeon/Dong*: submunicipal level division in Korea. *Eup* (town): division of a county (*gun*) or city (*si*) with a population of less than 500,000, minimum population required is 200,000; *Myeon* (township): has smaller population than *Eup*, mostly population around 2,000; *Dong* (neighborhood): sub-level of *Gu* (district or borough) which is subdivision of metropolitans or over medium sized cities in capital area.

2. Park, Sehoon, Kim, Dongju, Jeong, Yoon Hee, Park, Geunhyun & Lee, Eunyoung. "Demographic Change and Spatial Transformation in Korea: Recent development and policy directions." Anyang, Korea Research Institute for Human Settlements, 2012.

3. "Demographic Change and Spatial Transformation in Korea: Recent development and policy directions." Anyang, Korea Research Institute for Human Settlements, 2012.

4. Total 7,391,084 building units with 4,227 m^2 area nationwide. Ministry of Land, Infrastructure, and Transportation (MOLIT), 16 April 2024. Available online at: www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?lcmspage=1&id=95089658 [Accessed August 27, 2024]

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9. Government of Korea, The Third Comprehensive National Territorial Development Plan (1992~2001), 1991, p. 24.

10. Ibid.

11. Government of Korea, The Third Comprehensive National Territorial Development Plan (1992~2001), 1991, pp.144-145.

12. Sejong Special Self-Governing City is a tangible output outlining decentralization plan and strategy, around 170 km far from Seoul, has population of 392,311 as of 2023. By the official launch of the city, the population was 113,117 which is less than one-third of the current population. The target population by 2030, the completion of the city, is 695,000 (Sejong Basic Plan 2030).

13. Cha, Misook. (A Premier on Korean Planning and Policy) 50 Years Path of Comprehensive National Territorial Plan (2020-2024). Sejong, Korea Research Institute for Human Settlements, 30 Dec. 2022.



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Edited by
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Inter-American Development Bank

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ISBN 978-1-59782-580-1

