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The colonial and the porfiriato urbanization: inheritance of urban (un)sustainability in Mexico City La urbanización colonial y del porfiriato: herencia de la (in)sustentabilidad urbana en la Ciudad de México

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ABSTRACT Mexico City has experienced different periods of urban transformation, especially during the Colonial era and the Porfiriato. These periods have left a mark on urban (un)sustainability not only in Mexico City but also in other colonial cities. Using cartographic time series and the functional concept of neighborhoods, this study analyzes their influence on urban sustainability in the 21st century. We evaluate this sustainability through the environmental indicator of forest biomass. Our results suggest that colonial neighborhoods show a central concentration of forest biomass, decreasing as they move away from the colonial square (Zócalo). In contrast, during the Porfiriato, biomass is concentrated in the urbanization near the Zócalo, distributed in median strips and gardens. This study lays the groundwork for understanding the legacy of urban (un)sustainability throughout the periods of urbanization in Mexico.

RESUMEN La Ciudad de México ha experimentado distintos periodos de transformación urbana, destacando la Colonia y el Porfiriato. Estos han dejado una huella en la (in)sustentabilidad urbana no solo de la Ciudad de México, sino también de otras ciudades Coloniales. Utilizando series de tiempo cartográficas y el concepto funcional de Barrios, analizamos su influencia en la sustentabilidad urbana del siglo XXI. Evaluamos esta sustentabilidad mediante el indicador ambiental de biomasa forestal. Nuestros resultados sugieren que los barrios coloniales muestran una concentración central de biomasa forestal, disminuyendo conforme se alejan del casco Colonial (Zócalo). En contraste, durante el Porfiriato, la biomasa se concentra en la urbanización cercana al Zócalo, distribuida en camellones y jardines. Este estudio sienta las bases para comprender la herencia de la (in)sustentabilidad urbana a lo largo de los periodos de urbanización en México.

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1. Introduction

1.1. Colonial urbanization

Before the arrival of the Spanish, the landscape of Mexico City was characterized by a mosaic of towns of various sizes. The location of these towns was based on an understanding of the territory and the selection of land considering its environmental components, including access to resources (Christlieb and Urquijo-Torres, 2005). Tenochtitlán, now known as Zócalo, was the largest city in the Aztec Empire, with a population ranging from 200,000 to 400,000 at the time of the Spanish arrival (Denevan, 1992). Additionally, it was the cultural, religious, and economic centre of the entire Aztec Empire. This city was supported by smaller neighbouring towns (Tacuba, Texcoco, and Xochimilco), with which it exchanged goods.

The Colonial period spans 300 years and is usually divided into three phases: the first and oldest from 1521 to 1600, with the Viceroyalty being established in 1535. The second phase covers from 1601 to 1700, and the third from 1701 to 1821 (the year Mexico gained independence from Spain). By 1523, one of the first actions the Spanish took after the conquest was the reorganization of the populations in the Valley of Mexico. During this period, a central point was established, typically a quadrangular plaza. From this plaza, with the help of religious structures, the entire socio-spatial reorganization of the territory and the urbanization processes of New Spain were carried out (Toussaint, 1956). Additionally, populations were reclassified according to their number of inhabitants. The locations with the largest populations were designated as cities (Tenochtitlán, Texcoco, Xochimilco, Tlalpan, and Tacuba). Tenochtitlán remained the centre of power, now for New Spain, and was defined as the "Colonial Core," currently the Centre of Mexico City (Zócalo). Medium-sized population centres were designated as neighbourhoods. However, in some cases, settlements were classified as villas (Santa Catarina and Tacubaya). Villas were primarily used as rest areas, especially by economically privileged populations and members of the ruling classes.

In order to demonstrate colonial power, the colonizers significantly destroyed and modified the indigenous hydraulic system, introducing new techniques and practices for the management and exploitation of resources (Miranda Pacheco, 2019). These conditions led to structural changes in the society, economy, and natural resources of what was then Mexico City. Territorial transformation was also promoted through urbanization, with large buildings being constructed, the displacement of agricultural areas encouraged, and deforestation accelerated (Miranda Pacheco, 2019). At the same time, it is acknowledged that despite the prohibition of deforestation in the 16th century, this ban was ignored, and forests continued to be cleared (Musset, 1996).

1.2. Modernization of Mexico City

After the Colonial period, Mexico City did not experience significant urban transformations, even during the Viceroyalty period (Florescano Mayet, 2009). However, in the second half of the 19th century (1876-1911), President Porfirio Díaz promoted major reforms aimed at modernizing Mexico City (Escamilla Trejo, 2020) with a hygienist approach. The hygienist approach focuses on how to design the city by determining the features that homes, public and private buildings, as well as streets and avenues, should have to promote healthier environments (Sánchez Ruíz, 2020). Additionally, it advocated for the incorporation of avenues, parks, and tree-lined gardens to increase the green areas in Mexico City from 2% to 10%. However, this effort was mainly concentrated in neighbourhoods inhabited by the most privileged social classes (Meza Aguilar and Moncada Maya, 2009).

During the *Porfiriato*, there was a push for rapid expansion to consolidate Mexico City as the most important economic centre in the country (Ramírez, 2009). As a result, the city centre increased fivefold in size and more than doubled in population (Ramírez, 2009). However, overall, the expansion of Mexico City lacked a comprehensive urban zoning or land-use plan, as well as internal regulations to control urbanization (Huarte Trujillo, 1991; Urbina Martínez, 2015). Consequently, the accelerated growth favoured the transformation of the surrounding rural environment through the privatization of land, mainly agricultural areas, to create new subdivisions and promote the expansion of factories (Terrones, 2009), leading to the dissolution of the agricultural belt that bordered the city. The organization and planning of the territory mainly focused on some economically privileged populations (Acosta Sol, 2003), particularly those close to the Zócalo, promoting stark differences in urbanization processes within the city (Urbina Martínez, 2015).

Additionally, from an aesthetic perspective, urbanization near the Zócalo incorporated French landscape concepts (Gaitán Ortíz, 1993). However, some subdivisions were influenced by the Garden City model, which gained popularity in Mexico in the 1920s. The Garden City aimed to recreate a rural atmosphere within the city to provide greater comfort to the population by improving the natural environment. In the specific case of Mexico City, the Garden City model was targeted at the emerging bourgeoisie (Winfield and Martí, 2013). All these actions have consolidated Mexico City as a wealth-generating centre with a high diversity of industrial, commercial, and cultural activities (Cruz-Bello, Galeana-Pizaña González-Arellano, 2023; Escamilla Trejo, 2020). However, there are still major questions regarding the relationship between historical urbanization processes and current urban sustainability.

1.3. Urban sustainability and its relationship with cities

Urban sustainability is understood as an adaptive process that addresses economic factors (economic equity), social factors (resilience to environmental impacts), environmental factors (pollution and degradation), and governance in an integrated manner (EEA, 2022; Perrotti, 2020), as well as the long-term viability of the system (Whitehead, 2009; Schirpke, Tscholl, and Tasser, 2020). Conversely, urban unsustainability is related to the inability of an urban environment to maintain a proper balance between population growth, economic development, and environmental preservation. Urban unsustainability is reflected in various issues, such as the depletion of natural resources, environmental pollution, the creation of heat islands, socioeconomic segregation, and other challenges that threaten the quality of life of city inhabitants in the medium and long term (James, 2014).

The reconfiguration of geographic space and (un)sustainability are closely related, as urbanization processes promote the creation, formation, and consolidation of cities (Henderson, 2003). Historically, all cities worldwide have functioned as territorial components with the ability to alter the territory (Cárdenas-Mamani and Perrotti, 2022). The constant expansion of cities drives the demand for goods and services from rural landscapes (Cárdenas-Mamani and Perrotti, 2022), within their regional (Ascher, 2007) and international contexts. In this context, the increase in the human population demands areas for housing, food, potable water, and energy (Maxwell and Slater, 2003; Vieira, Serrao-Neumann, Howes, and Mackey, 2018). Frequently, urban expansion occurs at the expense of the degradation of natural systems or rural landscapes (Corona, Galicia, Palacio-Prieto, Bürgi, and Hersperger, 2016; Mendoza-Ponce, Corona-Núnez, Galicia, and Kraxner, 2019). This condition promotes the loss of habitats and their ecosystem services (climate regulation, water infiltration, habitat fragmentation, etc.), as well as reduced access to goods and the benefits that these covers provide to humans (Corona-Núñez, Mendoza-Ponce, and Campo, 2021; Pearson et al., 2019), favouring the unsustainability of cities. Additionally, it is recognized that the lack of public policies to minimize and prevent the degradation of ecosystem services at multiple scales will reinforce urban unsustainability (Hatab, Cavinato, Lindemer, and Lagerkvist, 2019; Spiliotopoulou and Roseland, 2020).

Although the importance of understanding the cause-and-effect processes of urbanization is recognized (Dekolo, Oduwaye, and Nwokoro, 2014), there is little understanding of the historical interdependence and the biophysical and socioeconomic aspects, which limits the ability to design and implement applicable solutions to reduce adverse impacts (Perrotti, 2020). Therefore, it is essential to characterize and understand the drivers behind these conditions (Cárdenas-Mamani and Perrotti, 2022). However, understanding the spatiotemporal processes of urbanization and their relationship with urban sustainability remains underexplored. Additionally, the analysis of the legacy of historical urban landscapes as a guiding axis of urban (in)sustainability in modern cities has not been thoroughly explored, and significant questions remain.

Urban landscapes have a unique identity defined by their history, development, ideologies, policies, philosophies from different eras, among other territorial components (Escobar-Chanona, 2016). From a historical perspective, the urban landscape can be understood as the memory of the territory, with symbolic and visual order, where the actions of individuals and societies have materialized. Although understanding the conditions of the modern urban landscape and the impacts on ecosystem services should be recognized as the result of multiple interactions in space and time among various social and cultural actors (Schirpke, Tscholl, and Tasser, 2020), such studies are scarce. Specifically, Mexico City displays a structure defined by two significant historical periods: the colonial structure of New Spain and the Porfirio Díaz era, but its influence on urban sustainability is not well understood. Therefore, the objective of this research is to evaluate how the legacy of historical urbanization has influenced urban (in)sustainability in present-day Mexico City.

2. Methods

2.1. Territorial Nomenclature and Approaches

For this study, we adopted the definition of the historic urban landscape, recognizing the city as the result of natural, cultural, and socioeconomic processes that shape it spatially, temporally, and in terms of experiences (Bandarin and Van Oers, 2014). Additionally, the

historic urban landscape is recognized through the ensemble of buildings, structures, and open spaces (UNESCO, 2005). Specifically, for this study, the historic urban landscape was evaluated from the perspective of the functional unit of the neighbourhood (Castro Gutiérrez, 2010). Through the integration of this functional unit, the aim was to characterize the inherited territorial condition of the two dominant periods of urbanization in Mexico City: the colonial past and the Porfirio Díaz era.

The definition of neighbourhoods has colonial origins. This territorial unit was used during the colonial period to refer to indigenous settlements on the outer perimeter of cities (Castro Gutiérrez, 2010; Christlieb and Urquijo-Torres, 2005). In many cities of New Spain, neighbourhoods not only defined the boundaries of indigenous and Spanish territories but also the trades conducted in each area. Additionally, neighbourhoods did not include the central core where the Spanish built their houses and where political, religious, and commercial centres governing social and political life in New Spain were located (Toussaint, 1956). This condition highlights the historical sociocultural and socioeconomic separation defined by New Spain's state policy and serves to characterize the influence of colonial urbanization on present-day Mexico City, as the identity of the neighbourhood did not change throughout the city's history (Castro Gutiérrez, 2010). During the Porfirio Díaz era, the neighbourhoods from the colonial period formed what were called new subdivisions. These new subdivisions are comparable to the new neighbourhoods or Colonias of the 20th century. For this study, we considered both colonial neighbourhoods and new subdivisions as neighbourhoods. All the neighbourhoods selected for this study have remained and consolidated from their creation to modern Mexico. In the specific case of downtown Mexico City, it was delimited through the recognition of the Colonial Core. Given that the Zócalo has historically impacted the ordering and restructuring of the territory as a political and religious centre, it is important to assess its influence as a territorial unit on the space. To evaluate this influence, the Euclidean distance from the central portion of the Zócalo to each neighbourhood was calculated.

2.2. Cartographic data sources

For this study, it was necessary to conduct research using primary sources, including cartographic and bibliographic materials from archives and map libraries, concerning the historic urban landscape of present-day Mexico City. This review yielded maps of the urban and territorial structures of Colonial Mexico City and the Porfirio Díaz era. All cartographic information was scanned and georeferenced within the same coordinate system. The georeferencing of cartographic information followed the generic procedure of orthorectification, starting with the most recent cartography and working backward to the oldest. The georeferencing process included control points for distinguishable territorial attributes across the cartographies (intersections between streets, roundabouts, railway tracks, rivers, mountain peaks, etc.). A "spline" transformation was used to reduce cartographic distortions, particularly in areas of the territory far from the urbanized zones of downtown Mexico City. All neighbourhoods were georeferenced with at least one control point. This procedure ensures consistency in cartographic information across the different maps.

Within a Geographic Information System, manual digitization of the neighbourhoods was carried out. The entire 100% of colonial neighbourhoods were digitized when they had a minimum area of 2 hectares. Additionally, 100% of the neighbourhoods from the Porfirio Díaz era were digitized regardless of their size. In total, 36 Colonial neighbourhoods and 49 from the Porfirio Díaz era were identified. The colonial neighbourhoods were entirely established from the pre-Colonial era, were subjected to and reorganized during the colonial period of New Spain and are now consolidated within Mexico City. For their delimitation, the oldest maps to which we had access were used, including (1) the "*Mapa de la muy noble, leal e imperial Ciudad de México*" from 1753, created for D. Josepho António del Villaseñor Sánchez, and (2) the map titled "Map of the Valley of Mexico with a plan of defences of the Capital and the line of operations of the United States Army under Major Gen. Scott" from 1847, produced by M.L. Smith and E.L.F. Hard Castle.

The nomenclature of neighbourhoods was also used to define the functional units of the Porfirio Díaz era. For this period, two maps were employed, both from the year 1899. This year was chosen because it coincides with the peak of the Porfirio Díaz era. One map corresponds to the cartography of downtown Mexico City, and the second covers the

entire territory of Mexico City. The downtown map was created by the Interior Division of the Federal District, by Israel Gutiérrez. The map of Mexico City was created by the Department of Development under the direction of the Secretary, Manuel Fernández Leal. Both maps have a scale of 1:50,000. The 3D rendered images were created using Google Earth Pro.

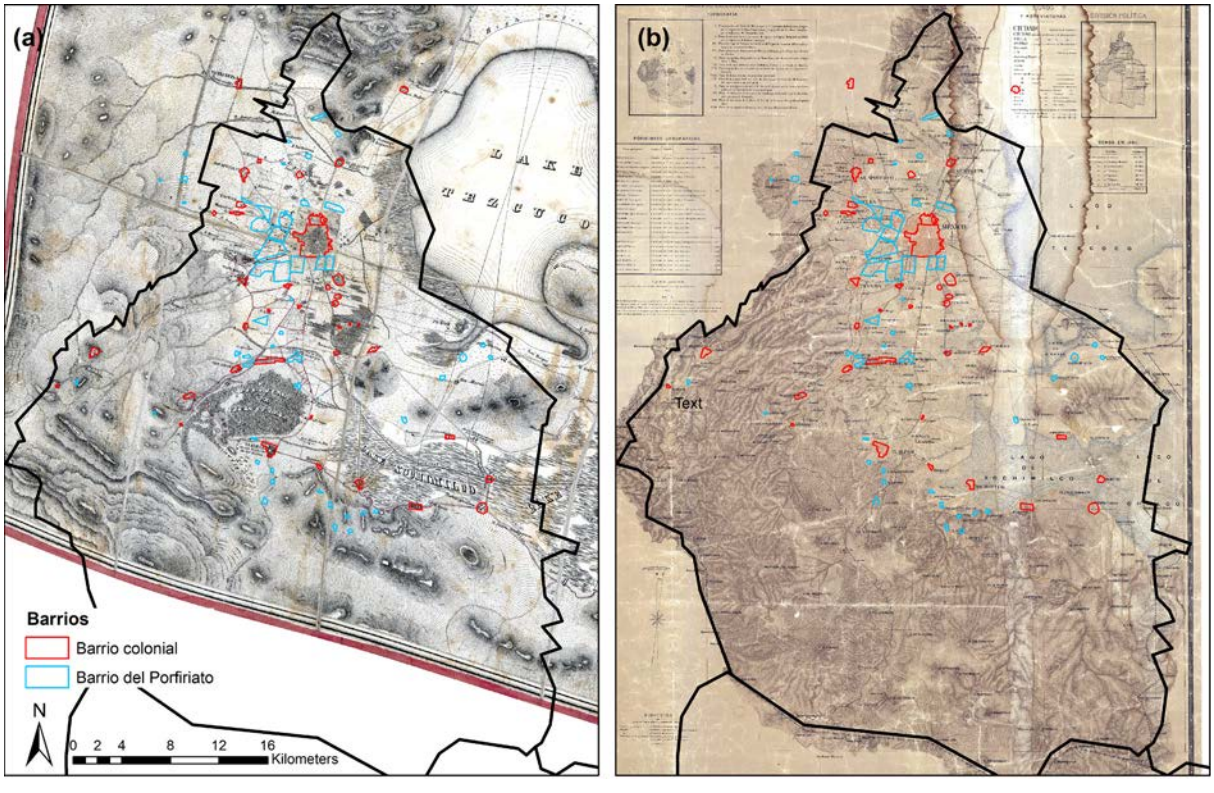
2.3. Data analysis

To understand the level of urban (in)sustainability, it is necessary to use environmental performance indicators within a territorial analysis. To address this, we identified the current green areas in Mexico City by estimating forest biomass. The use of forest biomass as an indicator of sustainability is justified because it has a direct relationship with other ecosystem services such as water infiltration, microclimate regulation, biological biodiversity conservation, and scenic beauty, among others. Therefore, values close to zero for forest biomass indicate unsustainable neighbourhoods, while higher values correspond to neighbourhoods with greater sustainability.

For this characterization, Landsat satellite images from 2014 and forest sampling were integrated. The forest sampling was conducted by the Forest Commission of Mexico as part of the National Forest Inventory of Mexico (CONAFOR, 2012). The satellite information was processed to calculate the Normalized Difference Vegetation Index (NDVI). The integration of satellite information and the forest inventory was carried out within a geostatistical modelling framework to reconstruct the vegetation conditions of the landscape, similar to other studies (Corona-Núñez, Mendoza-Ponce, and López-Martínez, 2017). Forest biomass was evaluated in two ways: (1) average forest biomass per neighbourhood; and (2) maximum forest biomass per neighbourhood. The first indicator helps understand the proportion of vegetation cover within the neighbourhood, while the second indicator helps identify neighbourhoods with the highest forest densities and the largest trees, which are often related to tree age and canopy.

The statistical characterization and comparison of neighbourhood conditions were conducted using the Wilcoxon statistical test and graphical representations with linear regressions.

Figure 1. Distribution of the barrios and the Zócalo within the context of the extension of present-day Mexico City. The background maps in panel (a) correspond to the year 1753 for the Zócalo and 1847 for the rest of the city (Colonial period); and panel (b) refers to the year 1899 (Porfiriato period). Own elaboration, for more details refer to the methods section



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3. Results

3.1. Neighbourhood characterization

The characterization of the neighbourhoods was carried out using four maps. The maps used correspond to the years 1753, 1847, and 1899. The cartographic information provides both a regional representation of Mexico City and a local representation of the Zócalo. The selection of the maps used for neighbourhood delimitation was based on identifying the best working scale and the level of detail of the cartography. This approach reduced the uncertainty in the cartographic representation of each neighbourhood polygon (Figures 1 and 2).

The characteristics of neighbourhood size and distance to the Zócalo are similar in both periods ($p>0.55$). The average size of neighbourhoods in both periods is 16.5±3.2 hectares. The size range varies from 2.2 hectares in the smallest neighbourhoods to 516 hectares for the Zócalo. The average distance of neighbourhoods to the Zócalo is 8.2±2.1 kilometres. The distance range varies from 400 meters to 23.3 kilometres (Table 1).

3.2. Influence of the Zócalo on Neighbourhood Structure

Our results show that in both periods, neighbourhoods exhibit an inverse relationship between distance from the Zócalo and their size (Figure 3). The neighbourhoods farther from the Zócalo are smaller in size (Figure 3). The minimum distance at which neighbourhood size stabilizes is 5 km. Neighbourhoods more than 5 km away show little variability in size. However, five neighbourhoods deviate from this pattern. Despite being far from the Zócalo, their size exceeds the average. Three of these neighbourhoods correspond to the colonial period (Azcapotzalco, Santa Catarina, and Tlalpam), while two are from the Porfiriato period (Churubusco and Tlacoquemecatl) (Table 1).

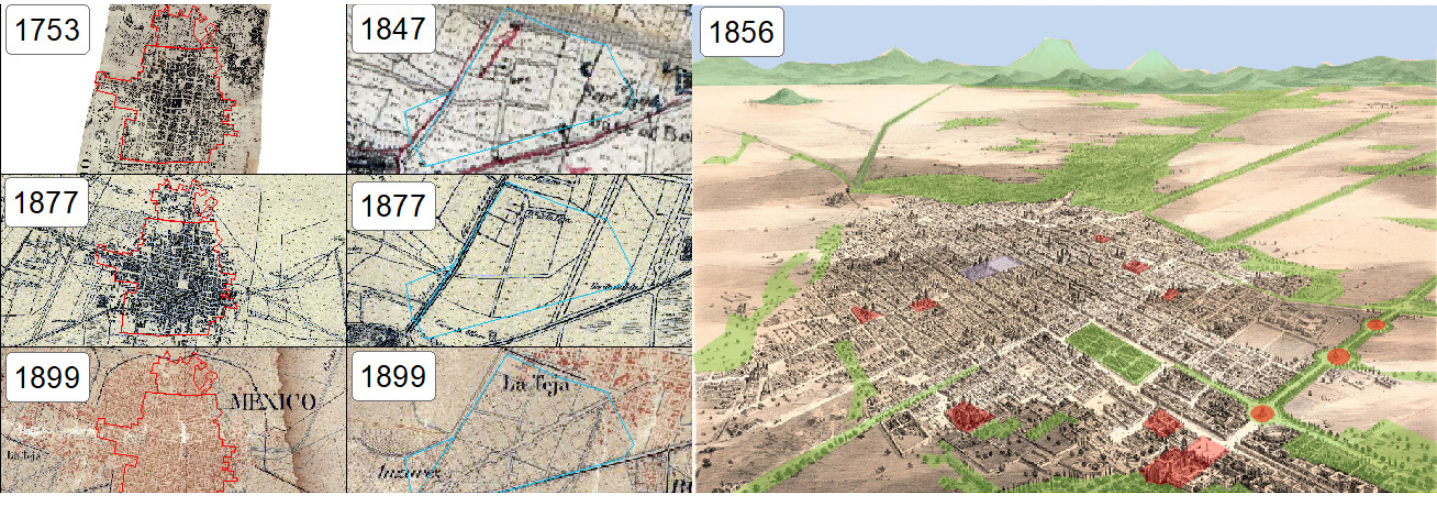
3.3. Legacy of urbanization on the (un)sustainability of modern Mexico City

The urbanization structure designed and implemented during the Colonial and Porfiriato periods exhibits differential gradients of (un)sustainability (Figures 2 and 4). On one hand, the colonial neighbourhoods show that the further they are from the Zócalo, the slightly higher the forest biomass content (Figure 4a, solid black line). On the other hand, the neighbourhoods from the Porfiriato period do not show significant changes in biomass based on their distance from the Zócalo (Figure 4a, solid red line; $p>0.05$).

However, in both periods, there are neighbourhoods that deviate from the general trends. In the case of the colonial neighbourhoods, five stand out, ordered from highest to lowest biomass: San Gerónimo, Santa Catarina, San Angel, Tlalpam, and Tacubaya (Figure 4a, grey-filled circles; Table 1). As these neighbourhoods move further from the Zócalo, their average forest biomass density increases.

In contrast, for the Porfiriato period, seven neighbourhoods deviate from the general trends, ordered from highest to lowest biomass: Chimalistac, Anzures, Ahuayucan, Tlacoquemecatl, Zacatenco, Tlacopaque, and Los Remedios. These seven neighbourhoods exhibit a decrease in average forest biomass as they move away from the Zócalo (Figure 4a, red-filled circles, $p<0.05$; Table 1).

Figure 2: Historical transformation of colonial neighbourhoods (Zócalo and Peralvillo), from the Porfiriato period (Anzures and Chapultepec), and Mexico City. The images of Mexico City were edited to highlight characteristic features such as: in lilac, at the centre of the image, the Zócalo. Own elaboration, for more details refer to the methods section. The background images correspond to historical maps. The lithograph of Chapultepec is by Casimiro Castro, while the one of the Zócalo is by Cristóbal de Villalpando.



Our results show that the highest values of forest biomass were generally recorded in colonial neighbourhoods, while the lowest were found in those from the Porfiriato period. Additionally, the maximum forest biomass values decrease more significantly as the distance from the Zócalo increases (Figure 4b, solid red trend line).

The distribution patterns of forest biomass show significant contrasts between both periods (Figure 5). During the Colonial period, two distinct behaviours are observed. First, the colonial neighbourhoods of the upper social classes, such as the villas of San Ángel, Santa Catarina, San Gerónimo, and Tlalpam, stand out. These neighbourhoods show higher forest biomass values compared to other neighbourhoods and even the Zócalo. In the latter neighbourhoods and in the Zócalo, large areas with no forest biomass (bare land without vegetation) were estimated. Interestingly, there are concentrations of high forest density in isolated vegetation patches. Regarding the Porfirian period, two contrasting patterns concerning areas with forest biomass are observed. On the one hand, there are large areas with medium to high forest densities. On the other hand, forest biomass distribution follows well-defined geometric structures (medians and urban parks), accompanied by areas with almost no forest biomass.

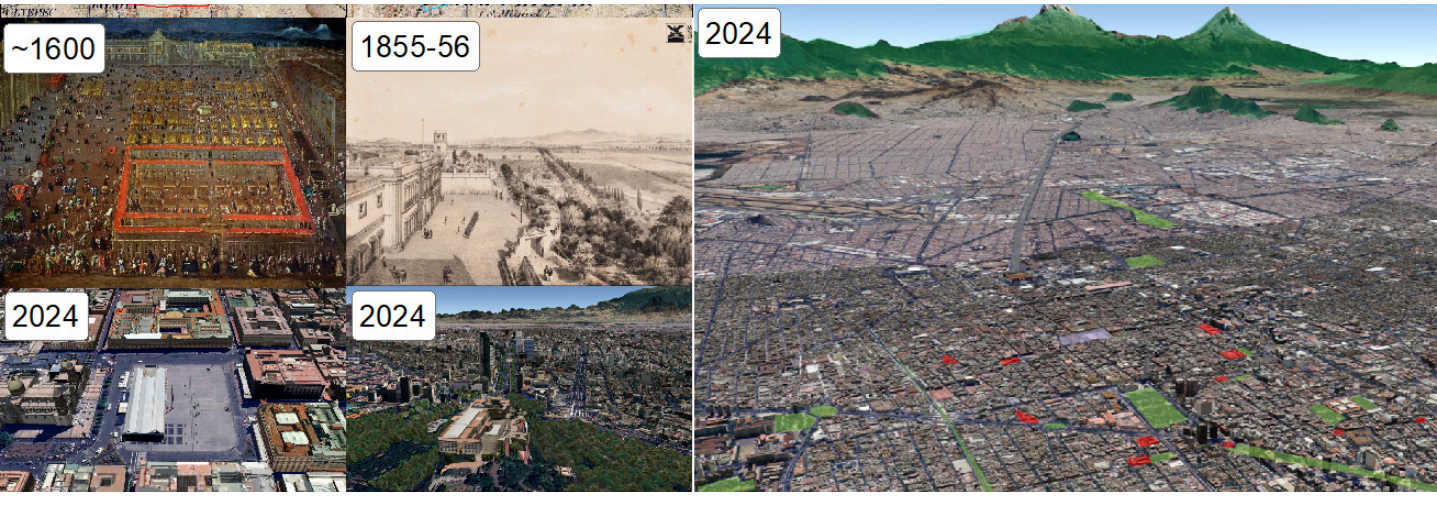
4. Discussion and conclusions

Historically, the organization and planning of the territory have been the result of reactive actions in response to social, economic, and political demands, rather than proactive efforts aimed at orderly and sustainable development. The proper design and implementation of territorial planning have been focused on economically privileged populations, thereby fostering contrasting differences in urbanization processes. These differences have led to mosaics of urban (un)sustainability. Our results show how the urbanization processes during the colonial period and the Porfiriato have contributed to the (un)sustainability of modern-day Mexico.

4.1. Historical dynamism of neighbourhoods in the colonial period

The segregation between the centrality of the colonial city and its neighbourhoods promoted the existence of consolidated buildings that gradually faded toward the periphery. This condition is still visible in the green spaces of 21st-century Mexico City, where the Zócalo remains densely built, containing only a few green spaces. The most notable example of this condition is the urban park La Alameda, constructed in 1529.

Figure 2: in red, the buildings and roundabouts present in both historical periods; and in green, areas with vegetation cover for each historical period. The aerial image is a lithograph by Casimiro Castro, taken by balloon from the northwest (1855-1856). The 3D renders from the year 2024 were developed in Google Earth Pro.



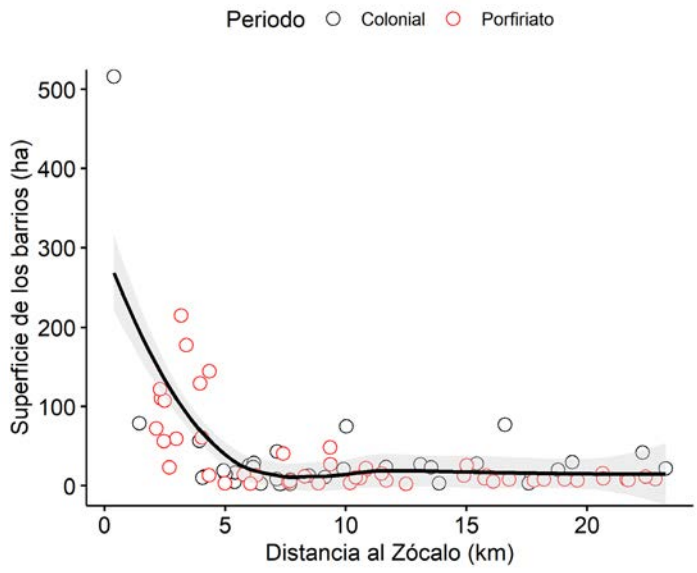


Figure 3: Influence of distance from the Zócalo on neighbourhood size. The solid line represents a smoothed curve for both periods. The shaded area corresponds to the 95% confidence interval. Own elaboration, for more details refer to the methods section

Additionally, isolated patches of vegetation within the Zócalo can be distinguished, including one inside the National Palace (Render in Figure 2), reflecting the Spanish heritage of Arab gardens (Caballero Deloya, 1986). Similar patterns are observed within colonial neighbourhoods. In these neighbourhoods, the central area of the population shows a higher concentration of trees compared to the rest of the settlement, leaving large expanses of bare soil and only a few remnants of vegetation patches in private gardens.

During this same period, the Villas stand out. In the Villas, summer homes were established for higher-income social classes, much like Hernán Cortés did around 1520 (Toussaint, 1956). These were grand houses situated amidst former fruit orchards, featuring large gardens, wooded areas, and springs—conditions that prevailed until the 18th century (Escobar-Chanona, 2016). It is in these locations where the highest levels of sustainability in present-day Mexico City are evident, both in terms of forest density, large and old trees, and green areas, including urban parks and private gardens.

4.2. Historical dynamics of the neighbourhoods during the Porfirio Díaz era

At the beginning of the 20th century, significant changes occurred in what is now Mexico City. During the Porfirio Díaz era, presidential decrees led to the expropriation of lands to facilitate urbanization and the growth of Mexico City. New neighbourhoods were created with planned access roads and organized lot distribution (General Bases of Layout and Hygiene to Which New Colonies of the Federal District, now Mexico City, Must Adhere) (Urbina Martínez, 2015). Neighbourhoods that had historically been inhabited by higher classes, a legacy of colonial urbanization, received more attention and remained as large properties with expansive gardens and tree-lined avenues (Huarte Trujillo, 1991). Additionally, some neighbourhoods defined during the Porfirio Díaz era were enhanced by the Garden City model by 1926, such as the eastern part of the Condesa neighbourhood, which gave rise to the Hipódromo-Condesa district, and the western part of Chapultepec, which led to the creation of the new Lomas de Chapultepec neighbourhood (Winfield and Martí, 2013). Similarly, popular neighbourhoods for the working class were created, though they did not enjoy the same privileges (Huarte Trujillo, 1991). These popular neighbourhoods received less attention, leading to population segregation (Safa, 2001), primarily due to inadequate urban planning policies. This situation encouraged the

Colonial neighbourhood	Size (ha)	Dist. to the Zócalo (km)	Forest biomass ($Mgha^{-1}$)	Porfiriato neighbourhood	Size (ha)	Dist. to the Zócalo (km)	Forest biomass ($Mgha^{-1}$)
Aculco	2,3	7,7	0,2	Agricultura	110	2,3	1,8
Azcapotzalco	43,3	7,1	2,3	Ahuayucan	8,3	22,8	22,1
Casco Colonial (Zócalo)	515,9	0,0	1,9	Anzures	13,2	4,3	34,8
Coapa	3,2	13,9	6,8	Balbuena	56,3	2,5	0,2
Contreras	3,0	17,6	1,7	Cadelaria	15,2	11,5	2,1
Guadalupe Hidalgo	29,0	6,2	6,4	Chapultepec	215,0	3,2	6,3
Ixtacalco	16,8	5,4	0,2	Chimalcoyotl	8,0	18,2	12
Ixtapalapa	21,1	9,9	3,1	Chimalistac	22,3	10,8	54,1
La Piedad	11,5	4,1	0,3	Churbusco	48,5	9,3	11,9
Los Reyes	10,3	4,1	0,2	Claveria	14,2	5,8	1
Magdalena sur	2,2	7,3	0,1	Consulado	59,4	3,0	0,3
Magdalena centro	19,4	4,9	0,8	Del Valle	177,8	3,4	7,5
Magdalena norte	56,7	3,9	1,1	Echegaray	6,5	11,7	2,8
Mexicalzingo	11,0	9,1	1,1	Guadalupe	10,6	10,4	12,9
Mixcoac	12,9	8,5	5,7	Haztahuacan	26,0	15,0	0,8
Nativitas	4,9	5,4	1.6	La Condesa	144,6	4,4	12
Peralvillo	78,8	1,5	4	La Palera	5,1	7,6	8,2
Popotla	19,6	6,1	0,4	Meyehualco	12,6	14,9	0,1
San Ángel	23,5	11,7	41,9	Narvarte	3,3	5,0	0,4
San Borja	2,8	6,5	3,4	Nativitas	7,2	21,7	5.3
San Gerónimo	27,8	15,4	53,6	Peña Pobre	5,3	16,1	3.8
San Gregorio	42,0	22,3	5,6	Remedios	2,5	12,5	18
San Joaquín	7,6	7,7	3,5	Romita	121,8	2,3	2,6
San Juanico	2,5	7,3	0,2	San Andrés Norte	15,9	20,7	0,7
San Marcos	8,6	7,1	2,6	San Andrés Sur	2,7	6,1	3,3
San Pedro	23,1	13,5	0,4	San Bartolo Oriente	19,9	10,8	0,3
Santa Catarina	74,9	10,0	45,4	San Bartolo Norte	13,3	6,3	0,5
Sta. María	14,5	5,0	0,2	San Esteban	3,7	10,2	2,2
Tacuba	26,0	6,0	3,6	San Jacint	60,9	4,0	8,2
Tacubaya	23,6	6,2	16,7	San Lorenzo	7,8	21,6	7,2
Tanepantla	26,9	13,1	1,5	San Pedro	7,8	19,1	0,9
Tepepan	9,2	17,7	6,3	San Rafael	107,6	2,5	0,9
Tlahuac	21,7	23,3	6,4	San Simón	23,3	2,7	2,4
Tlalpam	77,0	16,6	25,7	Santa Cruz	5,8	7,7	0,6
Xochimilco	29,7	19,4	7,8	Santa Marta	9,4	15,8	1,4
Zapotitlán	20,3	18,8	0,4	Santa Úrsula	6,7	17,8	9,2
				Santiago	7,8	16,8	0,2
				Tacuba	129,5	4,0	1,9
				Tepalcotlalpam	9,4	20,7	0,5
				Tezonco	12,6	15,8	0,1
				Ticoman	27,2	9,4	2,4
				Tlacopaque	9,5	10,6	18,1
				Tlacoquemecatl	40,4	7,4	21,2
				Vigna	72,4	2,1	0,6
				Xalpa	11,6	22,4	1,6
				Xochimanca	7,0	21,7	3,6
				Xochitepec	6,6	19,6	0,9
				Xoco	3,2	8,9	9,1
				Zacatenco	12,1	8,3	19,1

Table 1: Characteristics of Colonial and Porfiriato neighbourhoods. The names correspond to the original name from the period in which the neighbourhood was established. When neighbourhoods had the same name, they were distinguished based on a spatial reference relative to the colonial core. Authors, for more details refer to the methods section.

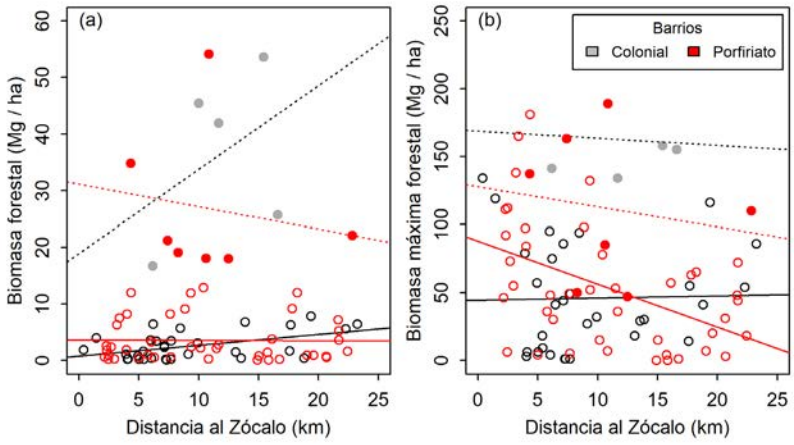


Figure 4. Forest Biomass of Each Neighbourhood as a Function of Distance from the Zócalo. Panel (a): Represents the average forest biomass within each neighbourhood Panel (b): Corresponds to the maximum forest biomass estimated within each neighbourhood. Solid-filled circles and dashed trend lines represent neighbourhoods with higher social classes. Hollow circles and solid trend lines represent the rest of the neighbourhoods. Own elaboration, for more details refer to the methods section

establishment of lots for agricultural use without urban or environmental awareness, resulting in the deterioration of the physical-natural environment. All these factors, combined with rapid population growth, contributed to the creation of differential mosaics of (in)sustainability in Mexico City.

4.3. Relationship between historical urbanization and urban sustainability

For over 400 years, the lack of a comprehensive urban planning strategy in Mexico City led to significant disparities within the city. Economically privileged populations benefited from organized and planned territorial development (Huarte Trujillo, 1991). However, areas inhabited by economically disadvantaged populations experienced urbanization processes that were governed largely by self-regulation and self-governance (Acosta Sol, 2003; Urbina Martínez, 2015). In these areas lacking structured planning, urbanization has primarily followed historical dynamics. This situation resulted in parts of the city with well-organized territorial structures that are currently reflected in high environmental sustainability (high forest density) and high living standards. Conversely, other parts of the city, particularly on its periphery, are segregated. In these areas, the absence of land use regulation is evident not only in environmental unsustainability but also in socioeconomic issues such as poverty, informal housing construction, lack of basic services (potable water and sewage), urbanization in biological conservation zones, and areas prone to risks, among other problems (Liano, 2017; Oehmichen, 2001). These conditions have contributed to the lowest forest densities being found in these peripheral areas of the city.

Additionally, the lack of planning for much of the city during the 19th and 20th centuries, particularly in terms of basic services (Urbina Martínez, 2015), exacerbated urban unsustainability, especially concerning water management. During this period, high levels of water pollution were recorded due to the discharge of residential and industrial wastewater. Furthermore, in the context of promoting accelerated urbanization in Mexico City, Porfirio Díaz's policies prioritized the construction of roadways (Acosta Sol, 2003) over many of the city's canals and rivers. This policy had an irreversible impact on the presence of rivers, streams, and springs, significantly affecting the city's hydrological resources.

Currently, colonial neighbourhoods with tourist attractions exhibit a localized high concentration of forest biomass. This condition is primarily associated with the colonial historic centre. These public spaces are surrounded by large trees, as indicated by the maximum forest biomass measurements. The colonial neighbourhoods are scattered throughout present-day Mexico City, with those farther from the Zócalo having higher forest densities compared to those closer to it. This pattern is a result of competition for commercial and higher-value land uses, which threatens environmental conservation. In contrast, during the Porfirio Díaz era, the situation was different. Generally, neighbourhoods created during this period show similar values of forest densities. This reflects a new vision of urbanization in Mexico City. Furthermore, neighbourhoods close to the Zócalo were of particular interest, not only for accommodating populations with higher social and economic development but also as focal points for beautifying the city (Acosta Sol, 2003). This condition led to the design of tree-lined streets and the inclusion of large urban parks (Huarte Trujillo, 1991), as evidenced in the lithographs of Figure 2.

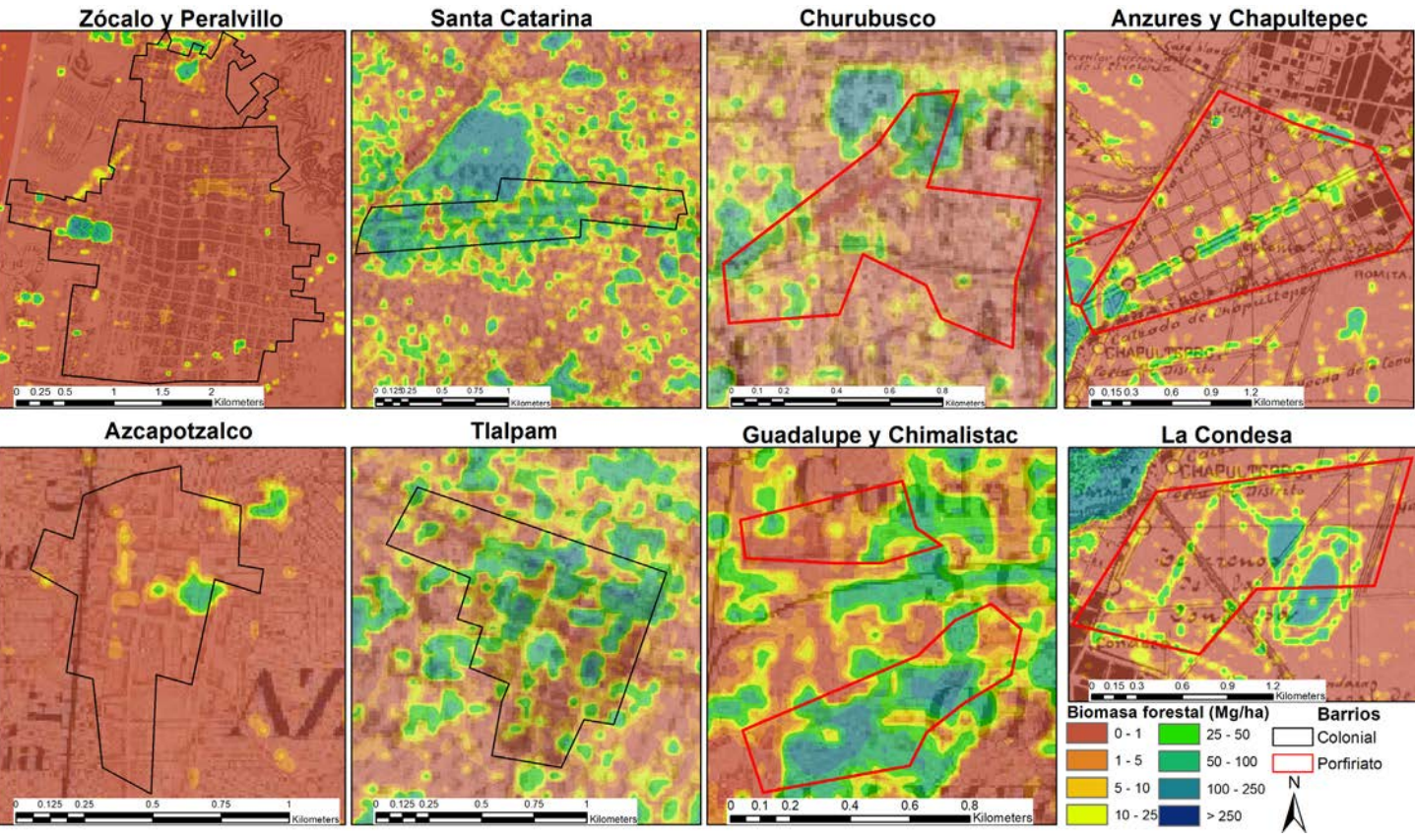


Figure 5. Distribution of forest biomass in various colonial neighbourhoods, the Zócalo, and neighbourhoods from the Porfiriato period. To aid in the representation of forest biomass distribution, historical maps were included as transparent overlays. Self-produced. For more details, refer to the methods section

4.4. Implications and alternatives

In light of the new challenges posed by global environmental change, territorial planning and the design of sustainable strategies are crucial to reducing the vulnerability of cities and their populations. Given the uncertainty surrounding the impacts and shared responsibilities for achieving sustainability in global climate scenarios, it is essential to address these challenges proactively.

Climate projections for Mexico indicate an increase in temperature and a reduction in precipitation across much of the territory (Mendoza-Ponce, Corona-Núñez, Kraxner, and Estrada, 2020). Furthermore, global environmental changes are expected not only to alter the climate but also to lead to significant shifts in local demographics and economies (Mendoza-Ponce, Corona-Núñez, Galicia, and García-Guerrero, 2019). These future conditions underscore the need for designing and implementing innovative and more integrated territorial planning measures to address current urban unsustainability.

5. Recommendations

Although this study focused on the first Colonial city of Mexico, and the urbanization processes in other colonial cities across the Americas followed similar patterns of organization, there may be specific characteristics affecting the level of urban (in) sustainability. These differences might be influenced by the sociocultural traits of the indigenous population or the physical-environmental conditions unique to each city.

Future research should aim to understand which socio-ecosystemic components reinforced or constrained the influence of colonial heritage within an urban (in) sustainability framework.

Nonetheless, this study highlights the intrinsic relevance of urbanization heritage for contemporary urbanism and architecture. It underscores the need to design innovative planning strategies and approaches based on a socio-environmental understanding within a territorial framework.

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