

**ANALYZING SEGREGATION IN THE PERIPHERY OF LATIN AMERICAN CITIES
USING REMOTE SENSING**

A thesis presented to
the Faculty of the Department of Geography and Environmental Studies
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In Partial Fulfillment
of the Requirements for the Degree
Master of Geography and Environmental Studies

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Abstract:

The urban pattern in Latin American cities has changed significantly in the last decades. Historically, poor residents lived in the periphery of cities in a hierarchical structure. Since the 1980s, urban policies have increased the land value of the periphery and promoted formal development that restricted spaces for informal settlers, who were forced to move closer to environmental risk areas or areas with limited mobility. This study identified formal and informal settlements through satellite imagery, comparing urban growth of formal and informal settlements in Bogota, Colombia, from 2002 to 2018, and Sao Paulo, Brazil, from 2000 to 2017. The study also calculated the proximity of formal and informal settlements to hazardous environmental zones and public transportation access, respectively. The research showed that informal settlements occupied locations with better mobility over time, and formal developments used riskier areas in the periphery of Bogota and Sao Paulo. However, some areas showed segregation patterns. Locations in the north and south of Bogota and the north and east side of Sao Paulo showed that informal settlements were displaced by formal development. The study also showed that formal development settled in the expansion of cities according to preferences, different than the location of informal settlements that used the available land close to cities.

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1. INTRODUCTION

In Latin American cities, population size has increased significantly recently. The city fringe that Griffin and Ford (1980) described as ‘rings of poverty’ has been transformed into a more complex structure, modified by different socio-economic dynamics occurring in the periphery of cities. Neoliberal policies adopted in the 1980s shifted the socio-economic zoning of cities or ‘stratification’ to include diverse activities in the cities’ expansion that affected previous poor residents living in ‘rings of poverty.’

At the beginning of the 21st century, local governments promoted affordable housing macro-projects in areas beyond the urban boundaries. Then, developers, interested in lower cost land and supported by governments, constructed middle-class housing projects in isolated areas creating a fragmented expansion. Finally, suburban developments of high-class formed the leapfrog development in areas that were used primarily by informal settlers.

The change of urban policies to a neoliberal model was focused on increasing land value rather than improving the quality of living conditions. The new housing projects located in the city fringe jeopardized informal settlements in several ways. Initially, new constructions threatened the tenure security of informal housing. Further, informal settlements have not appropriated roads or provisioned adequate public services, making this population more fragile and less capable of responding to emergencies or environmental hazards (Wenzel et al., 2007; Hardoy and Pandiella, 2009). Finally, new suburban constructions for the middle and high-class occupied the best locations in the expansion area or changed the landscape to stabilize their locations, creating hazardous environments.

This study analyzed the changing settlement patterns in the periphery of Bogota, Colombia, and Sao Paulo, Brazil, in the last two decades. Additionally, the study compared the environmental risk and mobility of informal settlements after urban policies changed in 2000.

1.1 Statement of research questions

This study aims to contribute to a better understanding of the spatial segregation patterns in Latin American cities. The research evaluates the growing high and middle-class residential areas in the periphery affecting informal settlements due to urban policies adopted after 2000. Furthermore, the study identified how the change affects the informal settlements' mobility and exposure to environmental hazards.

1.2 Definition of terms

Administrative boundary:

The Strategic Urban Plan (*Plan de Ordenamiento Territorial-POT*) defines the boundaries of urban area, expansion or suburban areas, and cities' rural area.

The boundaries defined cannot be changed for the next ten years. The limit is controversial because it restricts the provision of urban service and urban road networks exclusively to zones designated as urban areas. When a zone is marked as rural, the area cannot be used for urban developments, only for agriculture purposes, until the administrative boundary is changed.

Bus rapid transit system (BRT):

The Bus Rapid Transit is a public system that unifies all bus routes into one system. The system is used in many Latin American cities. The infrastructure has dedicated lines and prioritized BRT in stops and intersections to reduce delays similar to a metro but with a lower cost.

Illegal settlement:

Land development without fulfilling the local requirements for subdivision or construction is considered illegal. In some cases, ‘pirate builders’ construct neighborhoods without fulfilling the provision of services or complete public infrastructure.

Informal settlements:

Poor inhabitants of the city have erected illegal construction because they cannot afford to rent or buy a legal house. Normally, poor people move to an empty lot and start to build houses over time. Neighborhoods of informal settlements have narrow and irregular streets, house plots with different sizes and shapes, generally with overcrowded conditions and poor structural quality. The infrastructure is deficient, and the location lacks essential public services such as water, sanitation, or paved roads.

In Brazil, informal settlements, slums, or shantytowns are named ‘*favelas*’ and are located within or on large cities’ outskirts, especially Rio de Janeiro and São Paulo.

Mobility:

Cities have transportation networks that allow people to travel from one place to another. Mobility is a location’s capacity to connect or commute the population through different modes and forms of collective or individual transportation systems. Collective transportation provides mobility for a group of people; it has a defined route, a regular schedule, and stops along the route. It includes modes such as railways, buses, trolleybuses, and subways. Individual transportation includes any mode where origin, route, and destination are personal choices; that includes automobile, walking, cycling, or motorcycle.

Mobility is measured by the transportation system’s access, quality, and travel time (Rodriguez, 2020).

Partial plan:

Urban policies created in Colombia and Mexico allow private investors to create or change municipal zone regulations and permit construction beyond urban boundaries. Partial plans are planning and land management instruments for regional or city sectors without infrastructure. It requires a proposal for future development regulating density, land cover, housing, roads, and community facilities.

Peripheralization:

The concentric urban pattern in Latin American cities locates the lower economic strata population in cities' periphery. Researchers like Bernt and Colini (2013) define peripheralization as a process in which poor people living in urban peripheries experience disconnection due to economic, social, and political marginalization.

The most critical features of peripheralization are fragmentation, segregation, and the creation of exclusionary neighborhoods such as gated communities.

Regularization of informal settlements:

In Latin American cities, informality is a social problem. Thus, governments search for alternatives to legalize property tenure and improve those neighborhoods' urban conditions, e.g., paved streets, provision of sewerage, and street lighting.

Segregation:

In Latin America, class segregation is more visible than racial segregation. middle- and high-class residents live in clustered neighborhoods, while poor people have been excluded by stratified regulations that define housing costs, education costs, and city subsidies.

Lots in the periphery of cities have a low cost. For that reason, poor residents live in those areas.

In the center of cities, lots, public services, and taxes are expensive (according to the socio-

economic stratification), and only rich inhabitants can afford it. The strata division of cities create barriers for people, separating them according to their economic capacity.

Self-constructed housing:

Several Latin American countries performed housing condition assessments or censuses at the beginning of the century; most studies showed that cities have deficits in housing supply. After that, national governments started to subsidize affordable housing projects like “*Minha Casa, Minha Vida*” in Brazil, “*Solución Casa Propia*” in Argentina, and “*Mi Casa Ya*” in Colombia. However, the private market, which provides housing options, adjust the housing quality to a lower-cost to get a high profit.

The affordable or social housing project included the installation of public services and the basic construction of houses without an internal division of spaces. For that reason, people have to complete, improve, or extend housing over time with self-construction.

Socio-spatial stratification:

In Latin America, the socio-economic classes have a historical origin from the Colonial period, based on excluding population by family origin or income, normalizing a social stratification.

Cities have geographical areas defined by zoning (number) according to the social stratum, based on several characteristics: income, house quality, proximity from the central district or central activities, and quality and cost in services provision. People pay different rates for public services according to this classification.

Social class divides the population by high-class (strata 6 or higher), middle-class (strata 3-5), and lower-class (strata 1-2). The socio-economic stratification is used also to calculate the base appraisal cost for land, public services charges, or public subsidy access.

Strategic urban plans (POT):

The Strategic Urban Plan (*Plan de Ordenamiento Territorial- POT*) or Master Plan permits public and private stakeholders to associate and develop cities (Steinberg, 2005). The comprehensive plan projects the city's long-term vision sets the limit for public institutions to supply public services, proposes zoning plan and land cover regulation, and regulates urban construction within the administrative boundary for 5-10 years.

In the framework of Strategic Urban Plans, countries like Colombia and Mexico implemented additionally sectorized strategic urban plans named **Partial Plans or Special Zones of social interest**, in Brazil, to create or change regulations for specific areas in the city.

Special zones of social interest (ZEIS):

ZEIS is a special designation for some areas in the city that have a potential for development or renewal due to blight conditions. The ZEIS demarcation creates the framework to establish a specific plan changing regulations, occupation, typology, and taxation similar to Partial Plans. The ZEIS designation is regularly used to upgrade informal settlements in Brazil, allowing governments to invest in service infrastructure, housing tenure, and public spaces improvement.

Researcher assumptions

Mapping informal settlements is a challenging task. Their spatial appearance varies by geographical context (Barros and Sobreira, 2008). In Latin-American cities, informal settlements often use conventional construction materials (Rocco et al., 2019). However, some morphological features of the informal settlement remain, such as small building size, very high roof coverage (density), an organic layout breaking the reticular grid of the formal city (Kuffer et

al., 2014). The author assumes these informal housing characteristics to take samples and differentiate formal and informal urban areas in satellite images.

1.3 Significance of the study

1.3.1 The problem of peripheralization in Latin America

Several researchers have studied poverty as a social problem in Latin America (Gilbert, 1998; Codina, 2005; Foster, 2009; Klaufus, 2013; Rojas et al., 2013; Aguilar and Lopez, 2016). Others have studied the risks and disadvantages associated with their living conditions of informal settlements (Hardoy and Pandiella, 2009; De Bustillos et al., 2011). However, few studies have focused on the spatial dimension of peripheralization as a systematic problem, in which the state reproduces inequalities through urban regulations.

Segregation has been studied mainly in the inner city due to gentrification, e.g., segregation caused by historic centers' renewal in Mexico City, Panama City, Bogota, Cartagena, Quito Lima, São Paulo, Santiago, and Buenos Aires (Betancur, 2014). Governments have tried to control territorial expansion and promote urban densification through urban policies (Lungo, 2001). However, the cities' peripheries attracted developers, looking for a higher profit, investing in high and middle-class gated projects, and regulations such as partial plans and Special Zones of social interest permitted construction outside the urban perimeter, fragmenting city' fringe in the last decades. The phenomenon has affected previous inhabitants that are segregated to the disadvantageous locations in the periphery.

This study's timeline is associated with urban regulations endorsed at the beginning of the year 2000 that promoted formal development in cities' fringes. The study addresses the social problem of segregation of the poor, comparing informal settlements location with the new

suburbanization in cities periphery over the years. The methodology analyzes the changes of pattern and the consequences of the change to visualize segregation spatially. The study contributes to understanding long-term urban regulations in Latin America and shows spatially how local regulations impact social dynamics.

1.3.2 Mapping informal settlements with remote sensing

Latin American cities have widely implemented Geographic Information Systems (GIS) and census information for planning in Strategic Urban Plans. Public entities have open public access to an extensive database, e.g., permit zoning, roads, streets and public transportation networks, and environmental features such as rivers, wetlands, forests, and tectonic plates. However, all the information available is in vector format and for urban areas within an administrative boundary. The demographic information of informal settlements is scarce or without precise location, dimensions, structure, and morphology (Inostroza et al., 2010; Amaral, 2012; Hofmann et al., 2015; Duque et al., 2015). Inostroza (2016) indicated that cities do not have effective methods to monitor and quantify informal settlements.

Census data report population and their characteristics at the aggregated level within political boundaries. In Latin America, urban polygons are small compared with rural polygons, and the spatial distribution of population characteristics is not accurate. In the expansion area, polygons have a bigger size, and the population distribution is less accurate. Remote sensing has been proven to map urban development without administrative boundaries limitations (Taubenböck et al., 2018).

Not many researchers have explored remote sensing images to analyze informal settlements distribution in Latin America. The reason is mostly due to the high cost of very high

resolution (VHR) data and the spatial characteristics and materials of informal settlements that are not easily recognizable without high-quality images.

This study explores a methodology to substitute VHR images with publicly available pan-sharpened Landsat images and a stratified classification that improves image quality and brightens urban characteristics within satellite images to locate informal settlements at a low cost.

PREVIEW

2. REVIEW OF RELATED LITERATURE

This section explores urban patterns in Latin America and the compact city model. Additionally, the study in this section examines urban policies and the relationship between policies and pattern change. This section also shows the background on the conformation of informal settlements and their vulnerability in their current locations. It explores the evidence of displacement in Bogota, Colombia, and Sao Paulo, Brazil. Finally, a segment of the literature review shows the methodology used in previous studies to map Latin American cities' growth and informal settlements segregation.

2.1 Beyond the compact city model

In the 1960s, the urban population in Latin American increased significantly. The majority of the new population came from rural areas due to the armed conflict between guerrillas and the national army, and the increasing job opportunities of industries close to cities (Cubitt, 2014). Cities grew with a low-skilled population living in the periphery close to industrial developments (Barros, 2004).

Since 2000, Latin American cities have adopted Strategic Urban Plans (POT), which delineates urban and rural boundaries. From that point, cities imposed an urban boundary that limited sprawl and rural areas could not have urban development. Even with that, poor people settled illegally, either in areas extended beyond the urban fringe or unsuitable areas for settlement within the city, e.g., environmental risk zones. The socio-economic stratification pushed poor residents to the margin of cities. The tendency was reinforced by governments that have weak control in those areas, allowing them to establish and create extensive informal neighborhoods. Public entities preferred to ignore informal settlements and avoid the high cost of

managing poor people's social problems (Barros, 2004). The Economic Commission for Latin America and Caribe (CEPAL) informed in 2018 that 30.7% of the population live in poverty without adequate living conditions, or in the furthest places in cities (CEPAL, 2018).

Since the 1990s, urban policies in Latin America have had a higher economic impact, supported by changes in the political structure. Privatization of public agencies and public-private associations and economic decentralization showed more business interest than a social mission (Almandoz Marte, 2017). The administrative structure change has led to more poverty, public services deficiencies, market-oriented social housing, and increased land value over living conditions.

Governments' response to poverty was to create housing policies that moved informal settlements to high-rise buildings located in the periphery. Several housing projects have been criticized for the location being far from job markets and for socio-spatially excluding population (Magalhães, 2016; Castro-Correa et al., 2015). Another government approach was implementing upgrading agreements that improve the quality of living conditions in informal settlements and denominated settlements regularization. However, the strategy was less used because it required a high economic injection to produce large scale urban renewal.

The state's role in urban development and planning instruments has remained economic. Social factors that heighten poverty are not addressed. The 'barrios pobres' or informal settlements filled the fringe of cities in a disorganized structure and represented a growing problem of governability for Latin American cities (Betancur, 2007; Foster, 2009).

Governments indicated that they could not supply urban service infrastructure outside the urban boundary to support city needs. The urban boundary worsened informal settlements living

in the periphery outside the urban boundary that did not have access to sewage lines and transportation networks (Foster, 2009).

The compact city model and the limitations to sprawl imposed in Latin America for decades challenged megacities' constitution. Despite that, the increasing population migrating to cities connects several towns by road networks that mix urban and rural areas (Aguilar et al., 2003). In Latin America, megacities exhibit a fragmented development pattern (Figure 1). The periphery surpassing cities' urban boundary has disconnected clusters and a denser linear development close to highways (Inostroza and Tabbita, 2016).

The connection between cities in metropolitan areas attracts the middle-class population to new developments in the periphery. The city fringe is no longer the place for poor people to live but an opportunity for newly formed middle-class households who search for cheaper housing options, pushing away previous formal and informal low-income residents located in the fringe (Aguilar et al., 2003; Álvarez-Rivadulla, 2007). Some authors found that the new urban developments for the middle and high-class in the urban periphery are displacing poor and informal settlements towards specific areas in the periphery (Lungo and Baires, 2001; Rojas et al., 2005; Livertun de Duren, 2006; Álvarez-Rivadulla, 2007; Rodríguez Vignoli, 2009; Roitman and Giglio, 2010; Turgut et al., 2010; Klaufus, 2013; Molinati, 2018). The change in the urban pattern consolidates metropolitan areas as a fragmented urban structure different from the

traditional compact city model (Gilbert, 1998; Aguilar et al., 2003; Castro-Correa et al., 2015; Molinati, 2018).

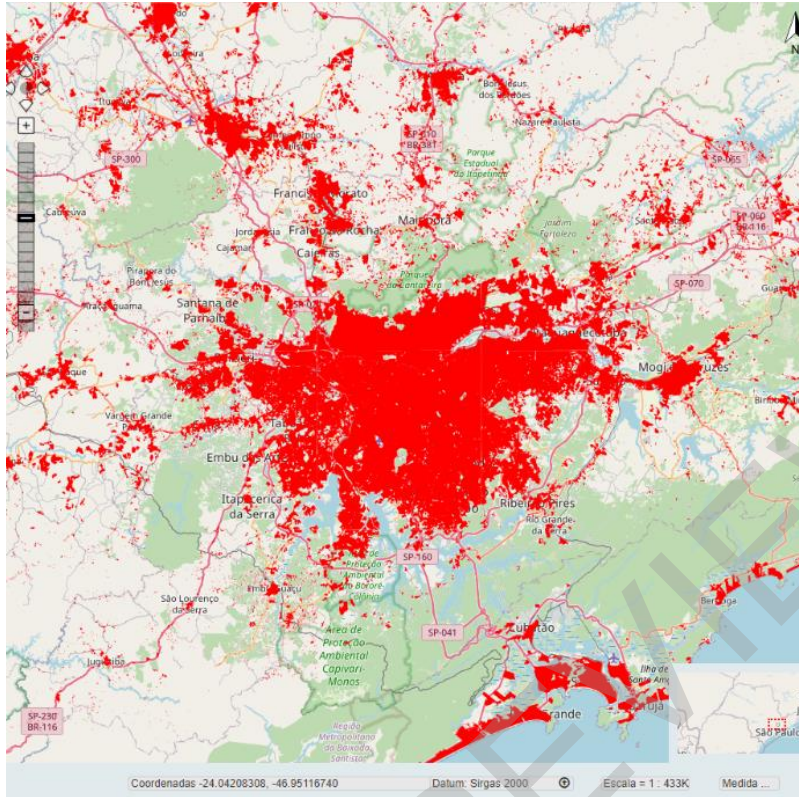


Figure 1. Datageo (2000) Urban areas state of Sao Paulo, 2004 retrieved from <http://datageo.ambiente.sp.gov.br/app/?ctx=DATAGEO#>.

The shift from hierarchical urban expansion to suburban development affects the most vulnerable population in cities' periphery. The growth of cities is inevitable; however, the unequal development of Latin American cities increases with the new division of cities beyond the compact city model. The compact city model and the hierarchical ring-based pattern defined by Griffin and Ford (1980) has transformed since 2000 to a complex, sprawled, and fragmented urban structure (Inostroza et al., 2010).

2.2 Urban policies in Latin America

In the 1980s, neoliberal urban policies in Latin America opened markets and changed conservative policies in countries. Before, policies protected national products; those were exchanged for export-oriented policies that worked in a globalized world. Several countries amended their constitutions, allowing political and administrative decentralization. The measure empowered local governments and gave them political authority and fiscal autonomy to control cities' urban development. Municipalities straightened their local instruments isolated from a regional strategy, creating limitations in how cities were connected.

Cities with new independence were not able to compete in the globalized economy. The low levels of local industries' development and limited budgets challenged the negotiation with private and multinational industries to develop cities towards sustainable development (Jenks and Burgess, 2003). In this way, the privatization of affordable housing provisioning allowed real estate developers to construct gated condominiums in former shanty areas (Lopez -Morales et al., 2016).

In the twenty-first century, Latin American governments introduced regulations to allow big housing projects to surpass the administrative boundary to accommodate the periphery's social housing demand, such as partial plans and the ZEIS program. Simultaneously, policies restricted low-income lot by lot developments surpassing the urban political boundary, limiting the city's expansion to realtors (Jenks and Burgess, 2003). Since public authorities did not have an appropriate infrastructure to serve new development outside the urban political boundary, several affordable housing projects lacked public services and appropriated transportation access (Codina, 2005; Klaufus, 2013).

Strategic Urban Plans, adopted by cities since the year 2000, allowed private industries to gain control over the city's sprawl. Developers were not interested in supplying housing needs but making a profit from the land low cost and benefits on taxes. Houses were not finished to keep a low cost, promoting self-construction as an alternative, but the housing size made expansions impossible (Rodriguez-Chumillas, 2006; Brites, 2015; Jaitman, 2015). Nevertheless, only the more profitable parts of the partial plans were executed. The plan's services provision was sometimes not executed (Montaña and Borrero, 2015).

In summary, neoliberal policies implemented in many Latin American countries at the beginning of the 21st century increased spatial segregation in many ways: first, the economic structure of cities increased class inequalities; second, the deregulation of the land market facilitated the periphery suburbanization; and third, service infrastructure in the periphery of cities was constructed to serve high and middle socio-economic classes. Therefore, urban policies implemented in cities since 2000 have had an economic interest that limited a continuous sprawl of cities and segregated poor residents.

2.3 Conformation of informal settlements in Latin America

The economic opening in the 1990s shifted the local production industry's economy to an economy based on import goods and services. The free market impacted local industries. Local businesses reduced job benefits for the working-class and decreased the number of employees to maintain a low cost. The economy's change forced low-skilled people to search for new income sources, increasing the informal economy in Latin American cities (Portes and Roberts, 2005).

The new economic trend also impacted housing for low-income people, who started to live in informal housing due to their economic needs (Riaño, 1991). Several local industries