Informal Settlements and City Information Modeling

Producing data to inform land use regulation in Fortaleza-Brazil

Mariana Costa Lima[1], Daniel Cardoso[2], Clarissa Freitas[3]
[1] Centro Universitário Christus [2,3] Universidade Federal do Ceará
[1,3] {marianaqcl|urbcla}@gmail.com [2] daniel.br@mac.br

In recent years, several advances have occurred concerning the legitimacy of precarious informal settlements in Brazil. In spite of this progress in the legal dimension, little has been made concerning standards to ensure urban space quality. The difficulties of reversing this exclusionary logic are due to several complex factors. A factor less discussed, especially in the national literature, but that has begun to draw the attention of scholars, is the invisibility of the informal city. This research assumes that it is necessary to regulate the urban form of precarious informal settlements, in order to prevent the deterioration of urban environmental quality. We highlight the importance to compile data about their urban form and their built environment, in order to contribute to a reality-based regulatory policy for these settlements, and this is the primary purpose of this study. To address this question, we propose a method of measuring the settlements' urban form, based on the City Information Modeling's theorical and practical framework, which is applied to a case study in Fortaleza, Brazil.

Keywords: *Informal settlements, City Information Modeling, Urban regulation, ZEIS Bom Jardim*

Recent studies have established the role of urban planning policies in feeding the growth of informal settlements in Brazilian cities, through the socio-spatial exclusion of low-income residents (e.g. Rolnik, 2015). For these studies, housing informality is a by-product of restrictive urban regulations, which historically defined an ideal city model that ignores the needs and payment capacities of the majority of the population. When referring to the phenomenon of informality, we will adopt the definition of Castells and Portes (1989: 12), whom present informality is an activity that "[...] is unregulated by the institutions of society, in a legal and social environment in which similar activities are regulated". By this definition, informality is intrinsically related to regulation. This interpretation, while presenting the risk of naturalizing a dichotomy that does not exist between formality and informality, has the advantage of specifying precisely the regulatory apparatus in question (Kanbur, 2009). We understand urban regulations as the set of parceling norms, land use regulations and building standards, which are often applied in the form of zoning codes that are part of Brazilian urban comprehensive plans. These codes affect the social

distribution of developed territory, by defining the conditions and parameters that establish the threshold of what is considered a formal/legal urban settlement (Martins, 2006; Magalhães, 2013). Beyond this threshold, there are territories where the State's social protection is not guaranteed, especially with regards to access to urban services. Thus, the large number of informal settlements in Brazilian cities is caused not only by the poverty conditions of the inhabitants, but also, and specially, by a process of urban space production that is spatially exclusionary and has perverse social effects.

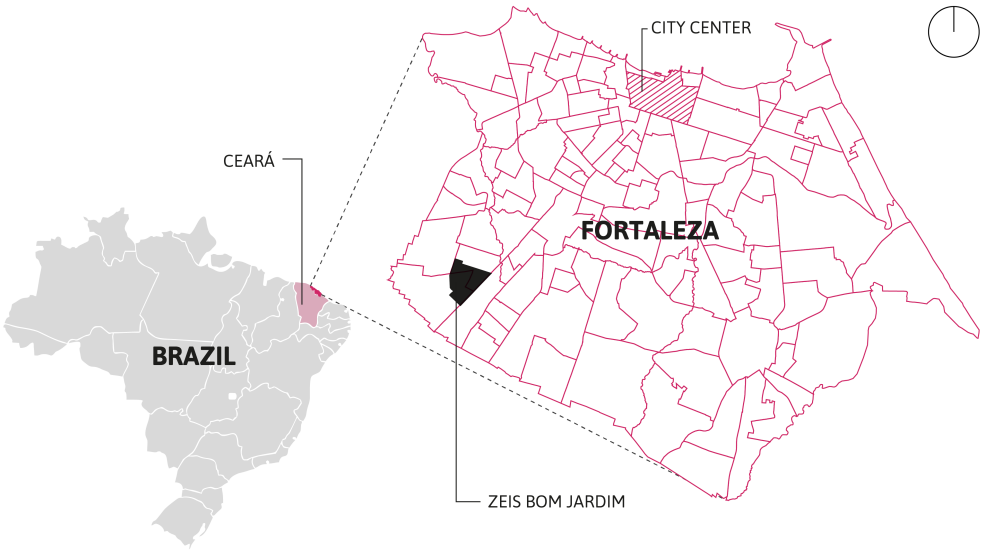
In recent years, several advances have occurred concerning the legitimacy of precarious informal settlements, which have enabled their provision of services and infrastructure through development projects. These advances constitute important steps towards the recognition of the rights of its residents. In spite of this progress in the legal dimension, little has been made concerning standards to ensure urban space quality. The difficulties of reversing the urban planning's exclusionary logic are due to several complex political, economic and cultural factors. A factor less discussed, especially in the national literature, but that has begun to draw the attention of scholars, is the invisibility of the informal city (Freitas, Gomes & Borges, 2013; Luque-Ayala & Maia, 2018).

This research aligns with the claim that invisibility is a structural component in understanding the limits of urban planning policies in major cities of the Global South, as suggested by Roy (2005). Solutions are usually pointed out without spatially understanding the alleged problem and the access to information about informal areas is not placed as an obstacle. Therefore, we focus on spatial issues and on techniques for collecting and systematizing data on the informal city, an approach very little discussed by this literature, which usually directs its efforts to the political and legal challenges (e.g. Fernandes, 2011). In the few instances where we find the relation between political-economic and spatial issues (e.g. Maricato, 2013), there are no analysis of specific case studies.

Although the search for spatially represented information is not a contemporary exclusivity, considering the use of maps since antiquity, city representation has improved through the various technological advances in recent years. However, technology advances faster than its application in real problems of the city (Pereira & Silva, 2009), as the problem of invisibility of the informal city has a greater political than technological nature. Historically, maps were designed by dominant groups and for dominant groups, showing and hiding aspects of reality according to the involved interests. The use of these cartographies have been modified over time and accompanied the technological development of other areas of science, notably by military and environmental needs (Pereira & Silva, 2009). This development is viewed with suspicion by some authors who see technology as a reinforcing concentration of media power. Indeed, digital visibility initiatives presented as empowerers and promoters of urban inclusion are usually part of a much more complex network of power, as pointed out by Luque-Ayala and Maia (2018). However, one can affirm the potential of new information technologies to positively impact the contents, forms, and means of control over cartographic representation. These technologies constitute a great opportunity not to focus only on the formal, previously designed city portions of cities. Freitas et al. (2013) contribute to this discussion arguing that, although far from solving socio-spatial exclusion, access to information can be a powerful instrument in the fight against exclusionary urban policies.

We acknowledge the latest advances in the visibility of informal settlements in Brazil, with emphasis on the operationalization of the concept, the definition of its limits and the quantification of its inhabitants in some major cities (Ancona, 2010). This research assumes that it is necessary to regulate (establish rules for) the urban form of precarious informal settlements, in order to prevent the deterioration of urban environmental quality. Taking this into account, our research highlights the importance of gauging indicators and establishing parameters that

Figure 1
ZEIS Bom Jardim in Fortaleza. Source: own construction.



adequately measure the specificities of each settlement: it is not sufficient to know how many people live in such settlements and their boundaries. It is necessary to compile data about their urban form and their built environment, and this is the primary purpose of this study.

It relies on a series of articles developed under the research project called City Induction (Duarte, Beirão, Montenegro, & Gil, 2012), which present the City Information Modeling (CIM) as a new paradigm not only to represent the city but also to inform urban policies and visualize future scenarios. Nevertheless, the knowledge on the measurement of urban form (Berghauser Pont & Haupt, 2010), often concentrates in the context of developed countries, at most in the formal city of developing countries. In order to unite these dimensions - the invisibility of the informal city and the potentialities of the City Information Modeling - we inquire: how can City Information Modeling contribute to a reality-based regulatory policy for precarious informal settlements?

In order to answer this question, we propose a new method of measuring the urban form in order to address the specificities of the informal city, which is discussed in the first section of this paper. This method, which combines geoprocessing and parametric and algorithmic design, is applied to a case study, described in the second session, regarding a group of settlements assigned as Zona Especial de Interesse Social (Special Area of Social Importance, or ZEIS in the Portuguese acronym) in Fortaleza - ZEIS Bom Jardim (see Figure 1). Finally, we discuss the method's contributions to a data driven regulation.

1 THE METHOD: CITY INFORMATION MODELING

The objective of the proposed method is to measure the informal settlements' urban form to subsidize the regulation of these settlements, focusing on the reduction of some of the spatial problems faced by the residents and taking into account the specificities of each situation. The proposed method does not demand a survey of each dwelling, allowing to uncover

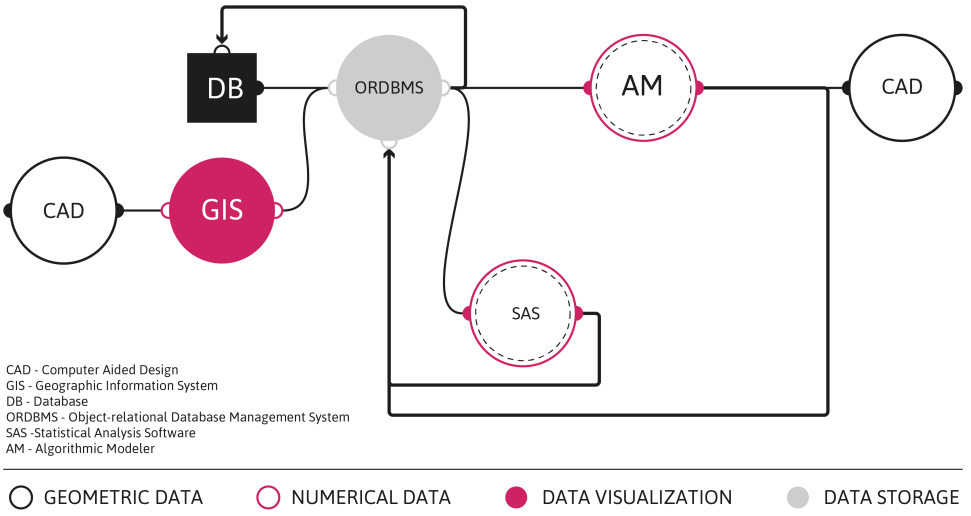


Figure 2
Adopted system. Source: own construction based on Sousa (2018).

the urban form of the settlements using simple geometric data. From simple geometric data, taken from an official aerial photogrammetric survey, we suggest measuring the urban form of the settlements notably through density indicators, such as those proposed by Berghauser Pont and Haupt (2010). The work of Berghauser Pont and Haupt (2010), titled "Space, Density and Urban Form", has stood out for its innovative and rigorous approach to the question of density. The Dutch researchers argue that density contains valuable information about spatial properties, with the potential to be a method capable of articulating quantitative and qualitative aspects of the urban form, provided that it has well-defined indicators. One of the reasons for using this theoretical apparatus was the correspondence of many of the indicators defined by them with urban planning parameters present in Brazilian legislation, such as Coverage, Building Intensity and Building height. We have studied and adopted their approach in order to adapt it to the particularities of the informal city in Fortaleza. The proposed methodology will be divided into scales, adapted from those applied by Berghauser Pont and Haupt (2010). The Lot scale is analogous to the one defined by the Dutch authors, the Fabric scale will correspond to portions of the territory that have relative homogeneity internally, that sometimes will coincide with the delimitation of precarious settlements and the District scale will correspond to the limits of the Zeis. Although didactically classified, these scales are intrinsically connected. This method was designed as part of a broader research (Costa Lima, 2017), which among other things, stablished ways of measuring different aspects of the urban form. Here we will focus on the measurements that are directly related to private areas' forms of occupation, such as lot size, coverage and building height.

The method relies empirically on the system developed by Sousa (2018), called the Integrated City Information Modeling System (Simic, in Portuguese) and which, in its turn, was based on the system cre-

ated by Beirao (2012), called CItyMaker. The adopted system (see Figure 2) has as its centerpiece a remote database (DB), which stores both the secondary data obtained and the data produced throughout the process. A Simic uses PostgreSQL as the object-relational database management system (ORDBMS), which has a large storage capacity and the possibility of accessing portions of the database and/or modifying it through queries with the Structured Query Language (SQL). The system is able to store and manipulate georeferenced spatial data thanks to its PostGIS extension, which also allows a direct connection to GIS software, such as Qgis. Qgis was used to import the secondary data in shapefile format for the DB as well as its editing and manipulation in real time, through the PostGIS extension. Qgis was also used for two-dimensional visualization and data analysis. However, not all the necessary analysis was possible to do in Qgis. For these analysis, it was necessary to use an algorithmic modeler (AM), Grasshopper 3D. Grasshopper is a plug-in of the chosen CAD platform (Rhinoceros 3D), where the urban form can be visualized, and it is connected to the ORDBMS via Slingshot, an add-on.

The data contained in the DB are queried via Slingshot!, which is a plug-in that connects Grasshopper 3D to the relational database and enables DB queries using SQL language. Using an algorithm developed by Sousa (2018) using some components of Slingshot!, which interprets the text string stored in the database, extracts information from Cartesian coordinates of the points forming the geometry and constructs its visualization. We combined the resulting lists into a table to attach it to the original shapefile in QGis. Regarding statistical analysis software (SAE), although some simple statistics can be generated with Qgis, for more complex statistical analyzes, SPSS Statistics was used.

For the lot scale analysis (see Figure 3), the geometries of lots and buildings must be imported into Grasshopper. Our algorithm allows first to identify the centroids, that is, the geometric centroid of each building. Then, it analyzes spatially in each lot which centroids - and the corresponding buildings - are internal to the lot delimitation curve, which generates a location filter for the buildings. It is then possible to calculate the occupied area in each lot. However, in order to calculate the constructed area, it is necessary to know the number of floors, which is estimated by dividing the attribute column with heights

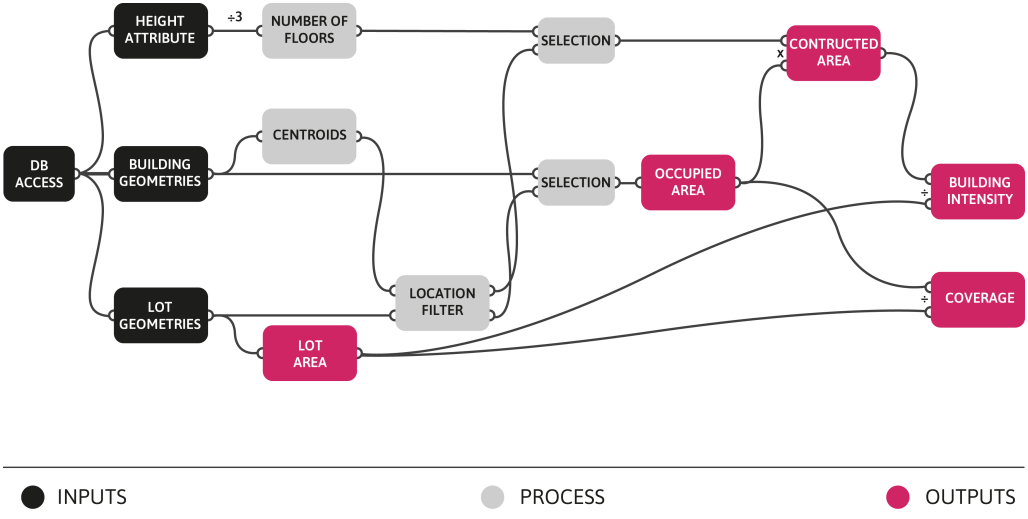


Figure 3
Algorithm for lot indicators calculations. Source: own construction.

(in meters) by three meters - an approximation of the floor's height - and rounding the result. The list with the number of floors is submitted to the location filter of the buildings, allowing the calculation of the constructed area and the maximum height in each lot. With the results of the occupied area and constructed area, it is possible to calculate - by dividing the results by the respective areas of the lots - the building coverage (GSI) and the building intensity (FSI), respectively. Although calculations are done at the lot scale, there is no need or feasibility to perform a lot-to-lot analysis. The results obtained should be used to provide a general and comparative overview of the characteristics of each lot on the District scale and also to ground the delimitation of fabrics.

In order to carry out the analysis on the fabric scale, it is necessary, first of all, to divide the territory to be studied in areas with relative homogeneity internally, in terms of urban form. Once the fabrics have been delimited, they must be numbered, and that number should be assigned to the lots of each of the fabrics. Then, we used the SPSS Statistics, for which we imported the lot attributes table, which must already be filled with the values ⊠obtained in the Grasshopper algorithms for the lot scale and the classification in fabrics. With SPSS Statistics, it is possible to generate tables and graphs with the frequencies and percentages of each indicator, according to pre-established categories. With the same software (or even with the Qgis statistical tools), it is possible to analyze the data for the District scale.

2 THE CASE STUDY: ZEIS BOM JARDIM

Choosing a set of settlements assigned as ZEIS means choosing an area with greater potential to make possible the regulation of the precarious informal settlements and to promote an integration with development, housing supply, labor and income generation, and democratic management and community participation. Moreover, when they were included in city zoning, ZEIS had an important role in making visible informal settlements that were historically invisible in the laws and maps of Brazilian cities. The option for a peripheral ZEIS has important advantages in the application of this case study. In a peripheral region, the threats of eviction or displacement are less common and the urban problems, as results of the lack of investment and protection of the State are evident. On the other hand, the fact that it is a peripheral area also contributes so that the chosen ZEIS has not yet reached a critical level of consolidation before which the preventive nature of regulation seems innocuous. At ZEIS Bom Jardim, a considerable amount of free area per block is still preserved, which can be seen as an opportunity. The choice of ZEIS Bom Jardim, specifically, was given a priori due to the partnership, which has been developing since 2013, between the researchers and a very important local NGO (Centro de defesa da Vida Hebert de Souza - CDVHS).

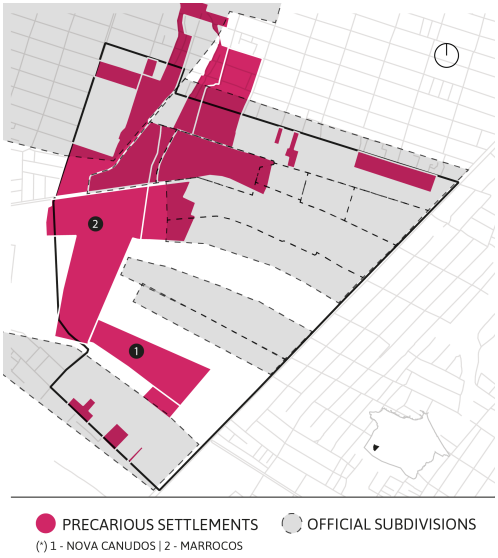


Figure 4
Official subdivisions and Precarious settlements in ZEIS Bom Jardim. Source: own construction based on official data (Fortaleza, 2012).

The main sources of the geometric data used in the case study were an aerophotogrammetric survey done by the municipality in 2010 and shapefiles produced by the municipal authorities. It should be mentioned that public authorities only had urban planning information on the approved land subdi-

Figure 5
Comparison of the lot shapefile before and after drawing missing lots. Source: own construction based on official data (Fortaleza, 2010).

visions, which corresponds to less than 30% of the whole area (see Figure 4). Due to the lack of governmental control, spaces destined for green areas and public squares or institutions had been occupied by the population, which explains the absence of community shared areas. From approximately 7,500 total plots of land estimated in the research, only 2,107 are actually present in Fortaleza's official plot database. The delimitation of the lots thus demanded, in the case studied, an extensive process of geometry manipulation (see Figure 5). This process was necessary since the lot would be the starting point for the measurement of the various density indicators. Here we highlight the lot area and building coverage measurements (see Figure 6).

From the ZEIS Bom Jardim's data of lots and buildings, the algorithms were applied, generating maps of the density indicators. By analysing these maps, 14 fabrics were identified. Unlike the examples presented by Berghauser Pont and Haupt (2010), practically none of the ZEIS Bom Jardim's fabrics can be considered totally homogeneous. In figure 7, two fabrics, that correspond to two precarious settlements with great difference of level of consolidation area, are compared with regard, in the example, to the lot area statistical frequency.

One of the results of this study was the finding that while the Nova Canudos settlement (older, occupied in the early 1990s) had fewer problems regarding the availability of services and infrastructure (presence of a health facility, paving, garbage collection), it had little available free space, either on the scale of the lot or on the scale of the fabric. On the other hand, the Marrocos settlement (most recent, occupied in the 2000s) has no public facilities, no street paving, no garbage collection, but still has wide streets, large lots with low building coverage, and improvised recreation areas. This result shows that the implementation of infrastructure unaccompanied of urban regulation, can lead to more precarization. It also shows that there can be significant differences within the same ZEIS, especially regarding the lot area and the building coverage, revealing that it is impracticable to create general rules for all

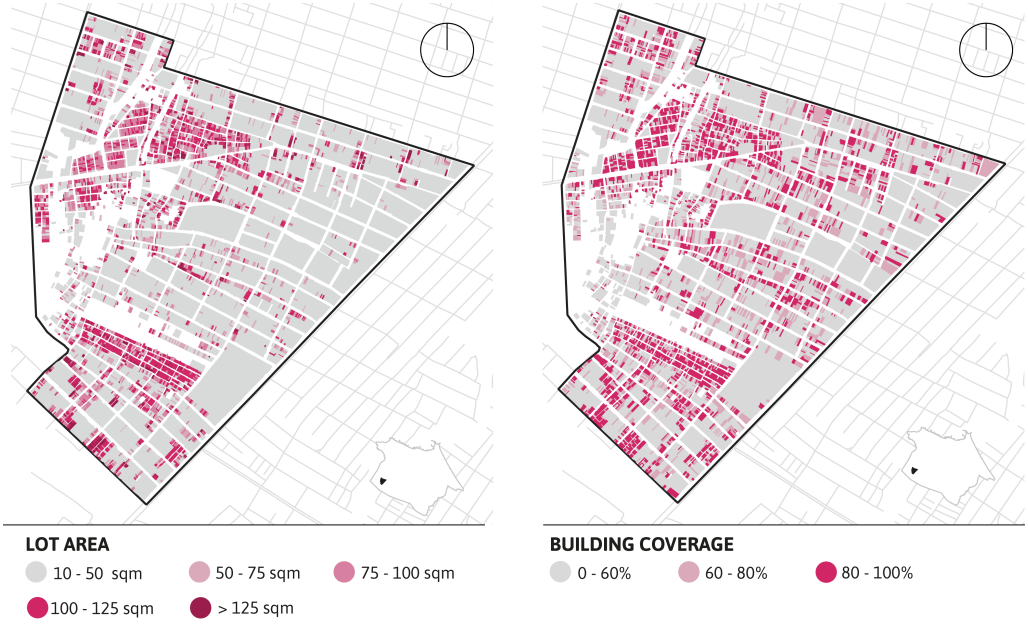


Figure 6
Lot area and Building coverage in ZEIS Bom Jardim. Source: own construction based on official data (Fortaleza, 2010).

settlements. These results demonstrate not only the relevance of urban regulation but also the need to know the urban form of the territory before proposing rules for it.

Besides that, in the ZEIS scale, in general, issues can be observed at a housing unit level: the plots of land's smaller size, for example. In fact, according to assessments, more than 60% of plots of land have a total area below the legal minimum of 125 square meters (not considering social housing zones). The smaller size generates problems in terms of occupancy rates: among plots with less than 125 square meters, 81% have an occupancy rate of above 60% - the legal maximum allowed by the Comprehensive Urban Plan (Table 1). Beyond affordability issues regarding the plot's size, existing housing is usually non-conforming to other urban legal parameters. Therefore, due to the small size, it is unfeasible to build houses with minimum living areas that meet legal requirements such as occupancy rate, what seems to be a decisive point for the plot's environmental quality. This finding can be observed once the number of plots with occupancy rates higher than allowed (bordering alarming 100% in some cases) is compared to plots with total area above or below 125 square meters.

3 CONCLUSIONS

The findings reveal that regulation aimed at increasing the urban quality of informal settlements require, first and foremost, a good understanding of local reality - a goal to which a representation of this reality is fundamental. Information modeling contributes to this by enabling the generation of a wide gamut of urbanistic information from simple geometric data, making it possible to analyse informal settlements not as amorphous and opaque spots but as an urban form. Among the advantages of a predominantly

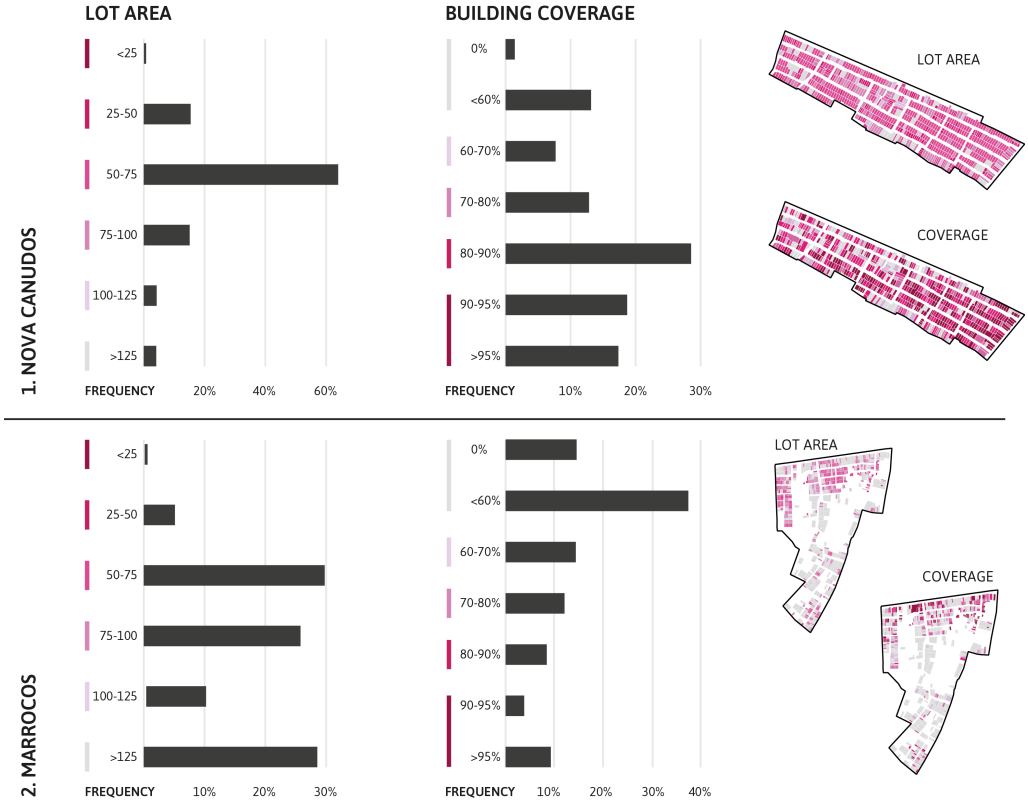


Figure 7
Lot area frequency comparison between "Marrocos" settlement and "Nova Canudos" settlement. Source: own construction.

parametric method, besides the automation of methods that would be extremely time-consuming or unviable, we highlight the "step-by-step" replicability for different inputs, such as different space and time delimitations.

The data produced highlights the enormous distance between urban regulations and the actual urban form, and can serve as a subsidy for the redefinition of urban rules for the informal settlements. With the proposed method, it was possible to measure the impacts of adopting each parameter, by mapping the cases that would comply with the proposed parameters and those that would be in disagreement, for example. By visualizing its consequences, one can make a more informed and reality-based decision. Moreover, the results contribute to give political visibility to low-income informal settlements, demonstrating in some cases precarious conditions that startle (tiny houses or without access) and, in other cases, situations that demystify preconceived notions about these settlements.

Taking into consideration the urban planning misinformation in informal settlements in Brazil, this paper's starting point, the State is not able to act on the territory and the residents are not able to fight for their rights. Different urban stakeholders must be aware of the dynamics present in building and rebuilding a city, as well as the legal mechanism in force

to influence those processes. In order to change the logic behind the production and reproduction of urban inequalities, it is imperative to change existing imbalances in the knowledge about different parts of the city. Only then would it be possible to consider effective participation: access to information to all stakeholders is a key requirement for the democratic process. Producing and spreading information on an urban peripheral area in Brazil points to a dialectic process: on the one hand, the technical aspect should be understood as also political; on the other, it is imperative that the political aspect of urbanization be informed by technical data.

Lack of information on informal urban peripheral areas is not necessarily the result of public authority omission or inability, but can be considered an accomplishment, due to the fact that dominant classes are not inclined to consider the needs of peripheral area dwellers as a legitimate urban issue. Lack of visibility is in fact functional and serves as an important tool for the arbitrary use of power. Spreading information on these spaces, on the other hand, highlights inequalities and existing privileges, empowers the population, and provides arguments for an informed collective control. Though political challenges may seem unsurmountable and have to be discussed, it is imperative to produce accurate and quality data on urban territorial disputes. Technical hurdles for regulation and regularization of informal settlements might, to a great extent, be overcome with new media, such as Information and Communication Technologies (TIC), and more specifically CIM, which reveal, in particular, the need to better know and see the current situation in these informal settlements. Technical matters should be discussed and put into question, not only to inform a possible favorable political context, but also to create it.

REFERENCES

Ancona, AL 2010, *Guia para o Mapeamento e Caracterizacao de Assentamentos Precarios*, MCidades/SNH, Brasilia

Beirao, JN 2012, *CItyMaker: Designing Grammars for Urban Design*, ABE TU Delft, Delft

Berghauser-Pont, M and Haupt, P 2010, *Spacematrix: Space, Density and Urban Form*, NAi Publishers, Rotterdam

Castells, M and Portes, A 1989, 'World underneath: The origins, dynamics, and effects of the informal economy', in Portes, A (eds) 1989, *The informal economy: Studies in advanced and less developed countries*, Johns Hopkins University Press, Baltimore, MD

Costa-Lima, MQ 2017, *Ver a cidade: modelagem da informacao para regulacao de assentamentos informais*, Master's Thesis, Universidade Federal do Ceara

Duarte, JP, Beirao, JN, Montenegro, N and Gil, J 2012, 'City Induction: a model for formulating, generating, and evaluating urban designs', in Arisona, SM, Aschwanden, G, Halatsch, J and Wonka, P (eds) 2012, *Digital Urban Modeling and Simulation*, Springer, Berlin, p. 73–98

Fernandes, E 2011, *Regularization of Informal Settlements in Latin America*, Lincoln Institute of Land Policy

Freitas, CFS, Gomes, VG and Borges, M 2013, 'Planejamento urbano com uso de sistema de informacao geografica: o caso de Feira de Santana-BA', *Universitas: Arquitetura e Comunicacao Social*, 10(1), pp. 35-45

Kanbur, R 2009, 'Conceptualising Informality: Regulation and Enforcement', *Discussion Paper Series*, 4186, pp. 1-19

Luque-Ayala, A and Maia, FN 2018, 'Digital territories: Google maps as a political technique in the remaking of urban informality', *Environment and Planning D: Society and Space*, 37(3), pp. 1-19

Magalhaes, A 2013, *O direito das favelas*, Letra Capital, Sao Paulo

Maricato, E 2013, 'As ideias fora do lugar e o lugar fora das ideias', in Vainer, C, Arantes, O and Maricato, E (eds) 2013, *A cidade do pensamento unico: Desmanchando consensos*, Vozes, Petropolis, pp. 121-192

Martins, MLR 2006, 'Globalizacao, Informalidade e Regulacao em Cidades Latino-Americanas', *Cadernos PROLAM/USP*, 5(10), pp. 31-49

Pereira, GC and Silva, BCN 2009, 'Geoprocessamento e Urbanismo', in Gerardi, LH and Mendes, IA (eds) 2009, *Teoria, Tecnicas, Espaços e Atividades: Temas de Geografia contemporanea.*, UNESP/AGETEO, Rio Claro, pp. 97-137

Rolnik, R 2015, *Guerra dos Lugares*, Boitempo, Sao Paulo

Roy, A 2005, 'Urban Informality: Toward an Epistemology of Planning', *Journal of the American Planning Association*, 71(2), pp. 147-158

Sousa, CEM 2018, *Modelando a Percepcao: O ambiente do patrimonio cultural edificado na regulacao da forma urbana*, Master's Thesis, Universidade Federal do Ceara