SURVEY OF SLUM HOUSING CHARACTERISTICS USING DRONES: AN EXPERIMENT IN THE ALTO DAS POMBAS COMMUNITY, SALVADOR DE BAHIA/BRAZIL

Joice Genaro Gomes [1], Julio Cesar Pedrassoli [2]

[1] Department of Architecture and Urbanism, University of São Paulo, São Paulo, Brazil
[2] Department of Transportation Engineering and Geodesy, Federal University of Bahia, Salvador, Brazil

Manuscript received: June 22, 2021
Revised version: August 31, 2021

Gomes J.G., Pedrassoli J.C., 2021. Survey of housing characteristics using drones: An experiment in the Alto das Pombas slum, Salvador de Bahia/Brazil. *Quaestiones Geographicae* 40(3), Bogucki Wydawnictwo Naukowe, Poznań, pp. 169–182. 2 tables, 10 figs.

Abstract: Since the approval of the Brazilian Federal Technical Assistance Law, whose objective is to guarantee adequate technical assistance to the residents of poor areas to improve their homes, several municipalities have implemented programs, not always successful, to improve housing in slums. Aiming to subsidize these programs implementation workflow, the present paper analyses use of drones as a tool to gather information about the physical characteristics slum households in Salvador de Bahia city, Brazil. As an experiment we flight over a single census sector within the Alto das Pombas slum, and after image processing we extracted and organized the collected data, extracting the possible information that could be applied to identify and quantify the most precarious houses that could be prioritized from a health improvement perspective. We conclude that many of the necessary data needed, on the urbanistic scale in Brazilian slums, can benefit from drone photogrammetry at low cost and fast execution.

Key words: slum upgrading, housing, drone, remote sensing

Corresponding author: Julio C. Pedrassoli, jpedrassoli@ufba.br

Introduction

The rapid growth of urban centres and difficult access to land and adequate housing are two of the main factors explaining the significant increase of people living in slums in developing countries. According to the Slum Almanac 2015/2016 produced by the United Nations (2016), one in eight people in the world live in slums and, although this number has been falling, the gross total number of people in slums continues to grow, passing the one billion mark in 2016.

In Brazil, referring to data from the Brazilian Institute of Geography and Statistics (IBGE), the slum population increased from 3.8% of the total population in 2000 to 6% in 2010, a growth rate of 74.9%, much higher than that of the total population (which was 12.3%), reflecting both methodological advances between censuses (which included more poverty typologies in 2010) and the increase in slums themselves.

Mation et al. (2014) developed a methodology for reclassifying census sectors for 2000 using the classification used by IBGE for the 2010 census. The authors concluded that the growth rate of the slum population in the country between 2000 and 2010 was 8.6%, a result more consistent with the observed improvement in socio-economic

https://doi.org/10.2478/quageo-2021-0031
ISSN 2082-2103, eISSN 2081-6383

indicators and poverty reduction across the country during this period. Nevertheless, according to the authors, the proportion of households in slums with an adequate sanitation system, either a general sewerage system or a septic tank, and receiving water through a general sewerage system increased, although it is still below the observed proportion, and the proportion of households in slums with two or more toilets in the dwelling increased from almost 7% of all slum dwellings to almost 15%. Although these indicators show an improvement in infrastructure conditions in the slums in 2010, housing in these settlements is still far from being classified as healthy.

Pasternak (2016) points to the improvement of sanitation in the slums of São Paulo, noting that: *If the policy of slum urbanisation was successful in providing water to almost all households in the subnormal settlements, sewage to >67% of them, and garbage collection (albeit with unknown frequency and with the help of containers), slum houses continue to show a strong precariousness: although mostly walled and with individual sanitation, poor ventilation, without sunlight, damp, poorly divided, with little insulation and with the possibility of water penetration, leading to the development of mould. Abandoned public spaces, frequently occupy piles of garbage and debris, attract arthropods, mosquitoes and rats, which are common. There are no green spaces or other recreational areas, and the streets are winding and confusing. Self-building combined with illegal land occupation has been the predominant form of access to housing for the poor and is usually carried out without technical supervision, and self-built houses can be hazardous to the health of their occupants*. According to the author, some of the diseases associated with poor housing are airborne or insect-borne diseases, cardiovascular and mental disorders, and household accidents.

Falls are examples of household accidents. A fall is defined as an event that results in a person coming to rest inadvertently on the ground or floor or other lower level, and when it happens because of an accident, can be called unintentional or accidental. According to Messias and Neves (2009), since younger children and the elderly spend a large part of the day at home, the home is considered a risk factor for falls in these two age groups. In Brazil, falls are the sixth cause of death in the population over 65 years of age, and about one-third of the elderly who do not live in nursing homes suffer one fall per year, and half of those who fall, fall again.

Self-build homes progress slowly. While waiting for construction to progress, the slabs are used in a variety of ways, from drying laundry on the clothesline, to providing a playground for children, to providing recreational activities for families during weekend barbecues. Without proper protection, they become risk areas for falls. There are few studies on unintentional falls in Brazil, but in some of them falls from slabs are considered a significant phenomenon, different from other types of falls.

Between the years 2000 and 2006, Campos et al. (2008) observed that >60% of spinal trauma admitted to Heliópolis Hospital, located near the second-largest slum in São Paulo, was due to unintentional falls, with falls from slabs accounting for almost one-third of these cases. Aranha et al. (2007) pointed out that in the hospital of the most populous district of the city of São Paulo, of the total hospital admissions for fall accidents in children under 13 years of age, falls from slabs accounted for almost 10%, which are more common on weekends when children spend more time at home. In another study conducted in the second-largest slum in São Paulo, Waksman et al. (2014) showed that of the total number of fall accidents among children up to 15 years of age, 55% were from families with more than six people living in dwellings with up to three rooms.

Housing conditions, then, are a factor that strongly affects people's health, and it is critical to have data to understand and improve housing conditions at an appropriate spatial and temporal scale. However, data on housing conditions and people's health at the housing level are not readily available and, in many cases, do not exist in a structured form.

There is evidence that inadequate housing conditions in slums, such as unprotected stairs and slabs, increase the number of falls with trauma among slum dwellers. Although there is insufficient data on this for Brazilian metropolitan areas, information from the Violence and Accident Surveillance Information System (SIVA), which exists in the city of São Paulo, may provide a good indication of the problem, as all 23 Brazilian metropolitan areas have many slums and, in some cases, very similar housing conditions.

In the city of São Paulo, where 65% of residents live in irregular structures, tenements, illegal subdivisions, or slums according to Kowarick (2009). Data from Municipal Health Department show that in 2017 there were 20.757 unintentional falls in the home (SMS 2018). The district of Grajaú, in the extreme south of the city, 30 km from the centre of the capital, where 6.74% of all housing in São Paulo slums was in 2010 (IBGE 2013), had a fall rate 15 times higher than the district of Alto de Pinheiro's, a noble region of the city without slum housing.

In the same year, in 14 out of the 96 districts of the capital city of São Paulo, in the eastern and southern regions of the municipality, a total of 2969 falls from steps and stairs inside dwellings were reported, representing 49% of the total reports for this type of fall in that year. There were also 422 falls from a slab in the home, and 12 precincts, all on the edges of the borough of Sao Paulo, had a total of 240 reports, according to SIVA data.

The number of slab falls seems negligible compared to the total number of falls reported in São Paulo this year, however, the severity of these types of falls can result in death or trauma, affecting the individual's potential productive life years and placing an excessive burden on health care and social security expenditures. As an example, Smith et al. (2015) argue that in the United Kingdom, the direct and indirect cost of treating a child who suffers head trauma at the age of three is £1.73 million, as the trauma affects the child's potential loss of productivity and the loss of the mother's job, who in most cases takes on the role of caregiver.

More than 15 years have passed since the first housing improvement programmes were implemented in Brazil. Physical interventions in housing are no longer one-off actions in slum upgrading programmes but have gained prominence in the design of local government's housing policies. The federal law 11.888, known as *Technical Assistance Law*, passed in December 2008, has helped to stimulate debate on the need for these interventions and to encourage the development of new initiatives. The Morar Melhor programme launched in 2015 by the Municipality of Salvador de Bahia, whose initial goal was to improve 100,000 homes over the next 5 years, is a good example, as described by Gomes (2017).

Although the criteria for selecting the communities and the specific households to receive improvements within the community vary from programme to programme, in many cases these decisions are guided by political issues rather than technical criteria. These interventions generally aim, at least in the discourse propagated, to eliminate risky situations and unhealthy housing conditions, such as opening windows to improve air circulation and coating the walls and floors of bathrooms and kitchens, protect slabs and stairways, among others.

The variety of these situations and the limited resources with which home improvement programmes operate is another problem. It is not possible to correct or compensate for all identified deficiencies when a home receives assistance from home improvement programmes. Sometimes this is due to the lack of dialogue between the technicians and the residents, who must ultimately approve and accept the interventions. However, in other situations, aimed at facilitating the implementation of the renovation and the budgeting of the interventions, the programmes pre-determine the planned services, so that even the demands that are more explicit and threaten the well-being of the residents are not prioritised or considered. An example of a risky situation is shown in Figure 1.

An example of this is the Better Housing Programme (Morar Melhor), conceived by the Municipal Government in Salvador de Bahia, which aimed to take care of 100,000 homes between 2015 and 2020, with a total cost of 500 million Brazilian Real (approximately 100 million

Fig. 1. Risky situations example.

US dollars at the June/2021 exchange rate), and whose practice has proven inefficient given the reality presented, where the households selected did not match the technical criteria defined by the programme regulations itself when you map it, according to Gomes (2017).

It is difficult to act in the face of the unknown: Housing built without technical support, failing to meet minimum specifications and construction parameters, apart from the speed of change in housing in slums, housing improvement programmes have not been feasible at a scale that responds effectively to the hardships that arise from unassisted self-build. The more knowledge and information that is available about the universe of slums, including housing and residents, the more planned and precise the intervention programmes can be in these areas.

Using unmanned aerial vehicles in data collection for housing improvement

Geospatial data are necessary for designing and planning the implementation and improvement of infrastructures, as well as for urban management (Fantin et al. 2018, Gevaert et al. 2018, Brito et al. 2020).

From geospatial data, we can extract information such as terrain elevation and topography, delineation of existing buildings, roads, drainage networks, power lines, water supply systems, classification of land use and settlement types, administrative boundaries, and additional information on risk areas such as geotechnical risks or flood-prone areas. However, consistent, up-to-date, and more accurate information is lacking in informal areas or precarious settlements, and this type of data is often overlooked in official data collection.

Data on the physical characteristics of housing in slums can contribute to the formulation of more comprehensive and effective planning of housing improvement interventions. The Levantamento de Informações Territoriais (LIT) (IBGE 2013), jointly conducted as part of the 2010 Census, expanded information on housing conditions in Brazilian slums. The LIT includes three data dimensions: location (topographic characteristics), urban patterns (types of internal and external transport routes) and occupancy density (distances between buildings and number of floors). The information is available in aggregated form by municipal boundaries and, in the case of capitals and larger cities, in aggregated form by districts or sub-districts. It is not possible to collect individual characteristics for census sectors in specific slums.

LIT uses high-resolution satellite imagery to produce information on the predominant physical characteristics of dwellings in census sectors classified as slums and links them to data collected on the ground and from municipal governments. Although remote sensing (RS), especially satellite imagery, appears as a free data source for collecting and organising information on informal settlements and their management, its limited spatial resolution can often be an obstacle given the complexity of precarious occupations, as it is not able to delineate buildings, capture verticalization processes, map internal infrastructure in detail, or describe local environmental conditions necessary for urbanisation projects.

In this context, Unmanned Aerial Vehicles (UAVs), or popularly known as drones, have recently been deployed around the world, especially in countries such as Asia and Africa where informal land occupation is much more pronounced and where there is little official information on settlements. Depending on their altitude,

Table 1. Examples of geo-data possible to get with UAVs (drones). Adapted from Gevaert et al. 2018.

Acquired directly from drone footage	Indirectly acquired from drone footage	Not captured with the drone – need for other sources
Road System	Land Use/Cover	Population counts and another census information
Building boundaries	Waste dumping sites	Income, etc.
Vegetation	Urban infrastructure	Administrative boundaries
Surface models (DSM)	Contextual Information	Security of tenure
Terrain models (DTM)	Attributes of the features, such as: roof type, number of floors, building material, etc.	Temperature of materials and surfaces (not with conventional cameras)

UAVs – unmanned aerial vehicles.

drones can capture imagery with great spatial detail, which after photogrammetric processing can provide georeferenced orthomosaics with information not visible on most freely available satellite imagery. The level of detail, low operational costs and relative positional accuracy are the real motivations for the use of drones in slum urbanisation, upgrading and land titling projects.

Gevaert et al. (2018) pointed to three levels of data needed for slum improvement projects, with the possibility that these are available directly, indirectly, or not at all through drone imagery (see Table 1).

The Slum Rehabilitation Authority (SRA), which is responsible for slum control and management in India, has launched a project to map all slum dwellings in the Mumbai metropolitan area using low-cost drones for urban rehabilitation and land titling purposes (The Times of India 2018). Other examples show collaboration between local governments, the third sector and Universities, such as the African slums of Agatare in Rwanda and Tandale in Tanzania, financed by the World Bank.

Objectives and study area

The present paper aims to identify the physical characteristics of the dwellings using drone

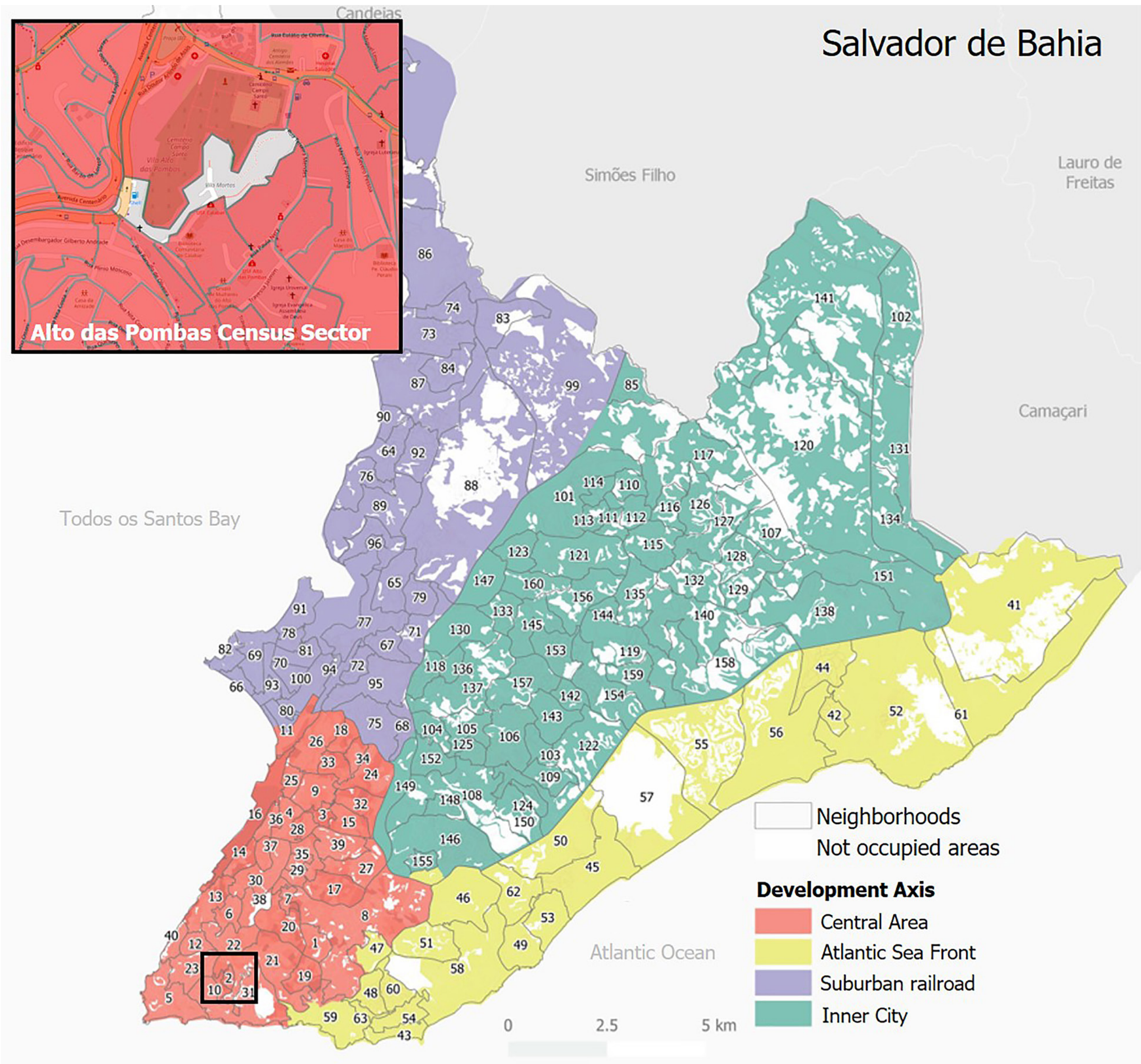

Fig. 2. Salvador de Bahia and the Alto das Pombas Census Sector.

imagery in one selected census sector classified as a slum in LIT and test the generated data and its feasibility to subsidise the planning of housing improvement programmes.

The city of Salvador, chosen as a case study, is a powerful example of how, in Brazilian cities, self-production of housing took place in slums and peripheral settlements as an urban survival strategy for a significant part of the working class (since almost 2/3 of the population lives in these areas).

Various authors have described the urban (con)formation of Salvador (and its segregation processes) from the point of view of housing (Brandão 1980, Mendonça 1989, de Carvalho 2002, Brito 2005, Fernandes, Regina 2005, Lima 2005, Soares, Espinheira 2006, Gordilho-Souza 2008, Santos 2012, Castro 2017), occupation and work (Carvalho, Pereira, 2018, Carvalho 2020), distribution of urban infrastructure (Silva 2015, 2019), mobility (Rocha 2014), provision of public spaces (Serpa 2006), environmental quality (Moraes et al. 2003, Santos et al. 2013) and health (Paim et al. 1987, Souza 2005, Antunes et al. 2013, Costa et al. 2021).

The history of urban development in this city is linked to the emergence of slums in the interior and, more recently, in the outskirts. The Alto das Pombas slum is an example of a very old settlement in the city, spontaneously created by workers who settled in this more central area of the city due to the proximity of their jobs to the local financial elite. The slum in question is in the vicinity of the Campo Santo cemetery, an institution that also owned the occupied area but donated the land to the community settled there.

The area was chosen for the experiment because it is easily accessible for field research and because it is representative of the types of housing problems in the city. Within the study area, a sub-selection of a single census sector was made to make an analytical comparison between the data obtained from the drone imagery and the Levantamento de Informações Territorais (LIT), of which this sector is the spatial aggregation unit. A census sector is the smallest unit of data aggregation available for the census results, a polygonal area covering about 270 households for research purposes. Figure 2 shows the location of the study area.

The experiment

In Salvador, people living on the margins of legality, together with people living in slums and illegal allotments, make up almost 2/3 of the total population, and together they occupy about 1/3 of the urban area (Gordilho-Souza 2008). In 2010, 1107 out of 3592 census sectors of the city were classified as slums, with a total of 275,593 households in them.

To conduct the flight, we selected a census sector in the Alto das Pombas slum, an adjacent area to the Campo Santo cemetery in Salvador (Fig. 4). The cemetery was established in 1836, and the surrounding development, originally formed by cemetery workers, has existed for over 70 years (Santos et al. 2013). This sector is not only mainly residential but also includes some local businesses. In 2010, according to the municipality data, the Alto das Pombas community had 1486 houses and a population of 4604, with an average of 3.1 inhabitants/household (IBGE 2013). The territory occupied by the community was recently donated from Santa Casa da Bahia to the Association of Alto das Pombas Residents.

The experiment took place on June 20, 2018. Two consecutive flights were performed, starting at 2 p.m. (local time) and lasting 13 min each, flying at an altitude of 80 m. The flight tracks had 80% coverage, both in length and width. The sensor used had 12.71 megapixels at a size equivalent to 35 mm format and produced RGB images with a spatial resolution of 2.9 cm per pixel in this flight condition.

After the flight, the images were processed using the Structure from Motion (SfM) algorithm. In this method, the image blocks are used to identify homologous points in the scenes, which is possible due to the longitudinal and transverse overlap of the images during the flight. From the identification of homologous points, a three-dimensional point cloud was generated and condensed in the processing sequence. This three-dimensional point cloud is used to generate the three-dimensional (3D) model by triangulation. Using the 3D model, it is possible to create the digital surface model (DSM), which in turn allows the orthorectification of the image mosaic (Fig. 3).

AgiSoft PhotoScan Pro software was used for this processing part. The three final products generated were the orthomosaics, the DSM and the Digital Terrain Model (DTM). In addition to the data generated by the drone, we also used contour lines from Conder – Urban Development Company of the state of Bahia – from 2004 with a vertical spacing of 1 m.

The first step was to create a DTM from the Conder elevation contours of the study area. This process was carried out using the Topo To Raster tool available in ArcMap 10.1 software, in a 1 m spatial resolution. The DTM was then used to fit and calibrate the DSM created from the dense point cloud extracted from the drone imagery.

In the overlap of the two layers, 20 points of contact between bare soil (points free of construction) were identified in the DSM and the elevation values from the DTM were sampled. The mean value of the differences between the numbers recorded in the DSM and the DTM, 20 cm, was then applied to the DSM as an altitude correction factor:

$$(\text{DSMconder} - \text{DTMdrone}) / 20$$

The boundaries of the buildings and households were visually identified and manually reconstructed from the drone orthomosaics, using them as a base map in QGIS within the analysed census sector. These polygonal boundaries formed the minimum unit of analysis used to capture information from the sampled households in the study area. All these layers were, then, manipulated in QGIS, to make the spatial analysis required.

The LIT pointed out that in 2010, almost half of the households in the slums of Salvador were on land with a slope of 30% or more (IBGE 2013). With the DSM and DTM (drone derived), the DTM (Conder derived) and the calculated slope from it, was possible to calculate the specific situation for the households inside the sector analysed in the Alto das Pombas.

Albeit with less accuracy, it was possible to derive a DTM from the point cloud generated by the drone in the Agisoft PhotoScan software. This was done by automatically selecting the low points, then excluding the model constructions and interpolating the local values. The product was also fitted to the Conder reference datum using the same method as the DSM.

This allowed the average height of the buildings to be estimated by subtraction between the DSM and the DTM derived from drone imagery, and the occurrence of sloping terrain beneath the buildings (which could lead to an underestimation of the number of storeys of the buildings).

Because the Conder DTM was derived from contour lines obtained through traditional topography in 2014, the interpolated values tend to represent the natural terrain, with a slope under

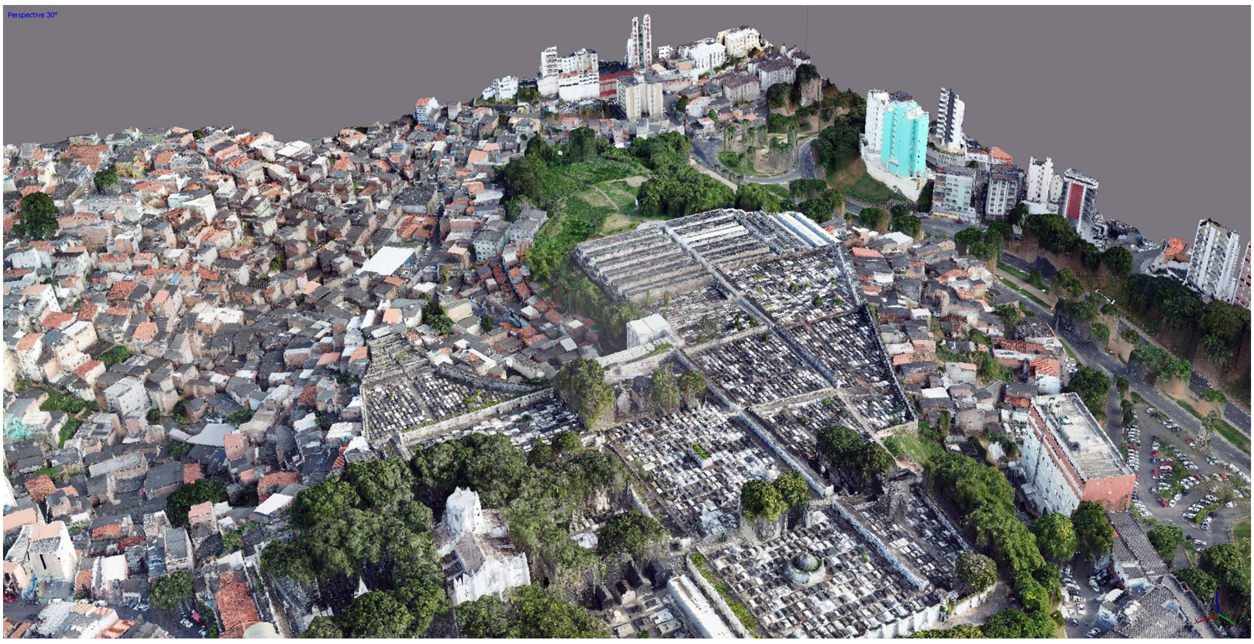

Fig. 3. 3D model of the study generated by drone: Alto das Pombas Community.

the buildings that estimates the situation before the anthropogenic occupation of the site. In this way, the Conder DTM served as the basis for calculating the average local slope, instead of using the drone DTM. In both cases, the polygonal aggregate statistics were derived using the zonal statistics tools of the QGIS software.

The average slope value of the land under each delimited building was calculated (Fig. 4) using the data described before. The slope between the highest part of the census sector, on the edges of the keeping wall built around the cemetery, and the lowest part of this sector is almost 30 m high.

Two main information were produced from the DTM's and the DSM: The terrain slope above each building and the height (converted to the estimated number of floors for an average of 2.5 m on each floor). The slope at pixel level was calculated using the QGIS slope algorithm in the Conder DTM, and the transfer process of the results from the pixel level to the household level slope and the number of floors was made by calculating the zonal mean values for each building polygon following the scheme presented in Figure 5.

The buildings, in most of the sectors, are in lands of difficult occupation, areas of hillsides with slope equal or superior to 30%, being expressive of the number of buildings where the inclination of the land is >45%. To a lesser extent, some houses occupy land with moderate slope, between 5% and 30%, and only three buildings are on flat land with <5% slope. The average slope of the sector is between 40% and 45%.

According to LIT, the verticalization of housing in the slums of Salvador is a reality for 87% of all households that had two or more floors in 2010 (IBGE 2013). We expect that the expansion of housing will occur through verticalization since LIT also pointed out that 94% of homes in the slums of Salvador have no spacing between them. There are few free, unbuild areas found in the study sector, and this condition added to the high land SLOPE, as already showed, are factors that contribute to the verticalization. For

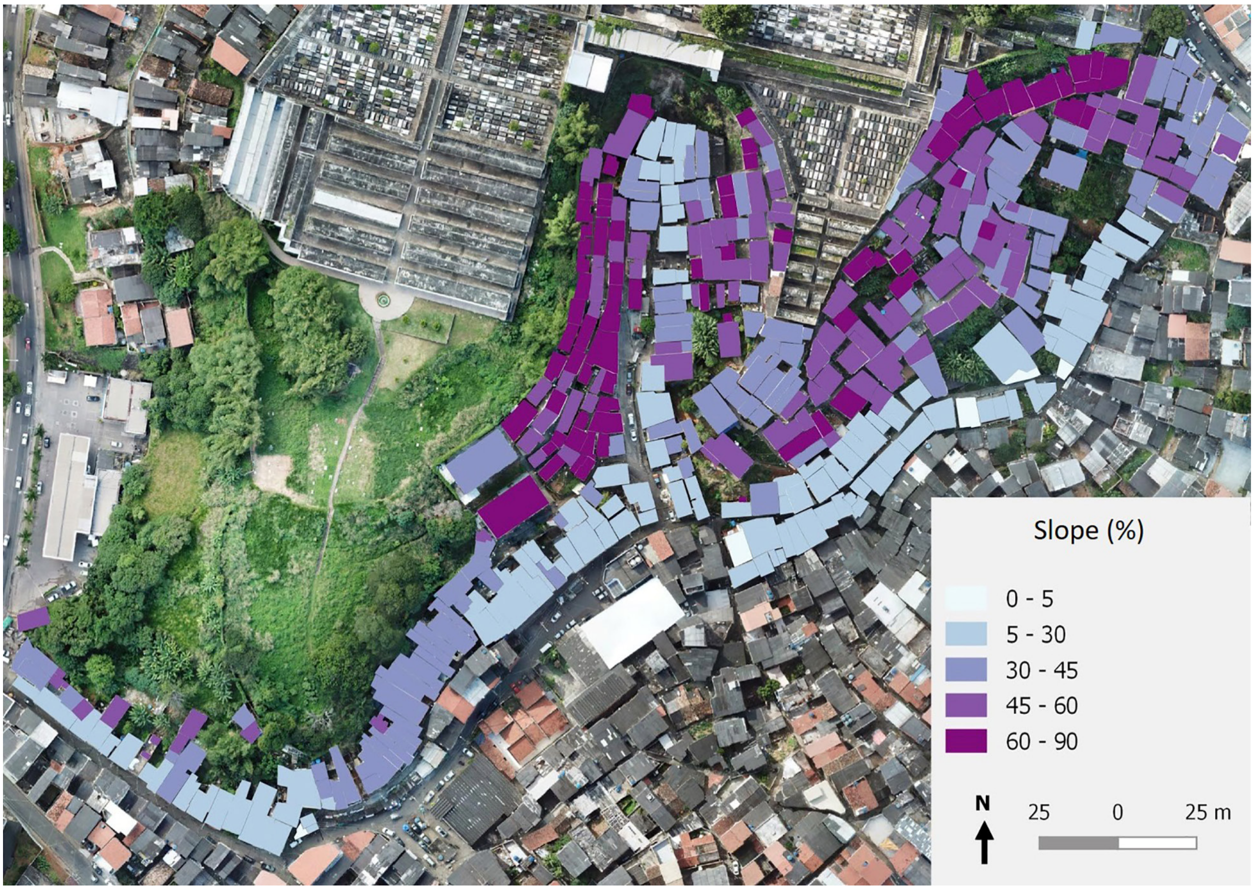

Fig. 4. Terrain slope below the houses in the study area of Alto das Pombas, in Salvador/Bahia.

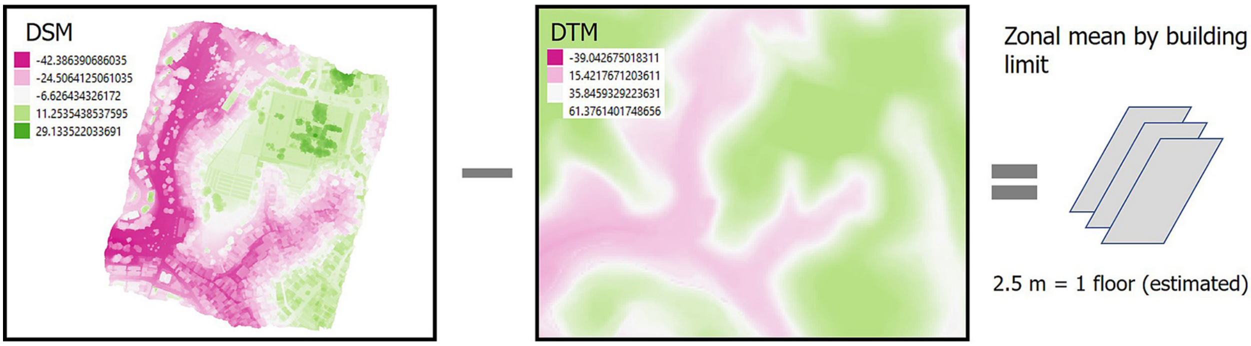

Fig. 5. The zonal mean calculation for slope and building height.

the estimation of the height of each delimited building, we estimated the difference between the zonal mean of the altitude value of the terrain (sampled via DTM) and the roof elevation (sampled via DSM), as presented in Figures 6 and 7. It is possible to observe the expressive number of houses that have three or more floors. The model also detected houses that were built below the ground level, pointing to situations where, possibly, intentional landmass movements occurred for the implantation of the building.

Using the 2.9 cm/pixel spatial resolution image produced by the drone camera it was possible to identify and mark, through visual interpretation, within the studied census sector, houses containing apparent slabs and staircases without guardrails, representing a risk for falls, besides detailed data on dwellings in the expansion stage of construction.

Figures 8 and 9 show these situations and the difference between the spatial resolutions of the images got from Google Earth (2015) and those

Fig. 6. Spatial patterns of buildings distributed by the number of floors, Alto das Pombas Salvador/Bahia.

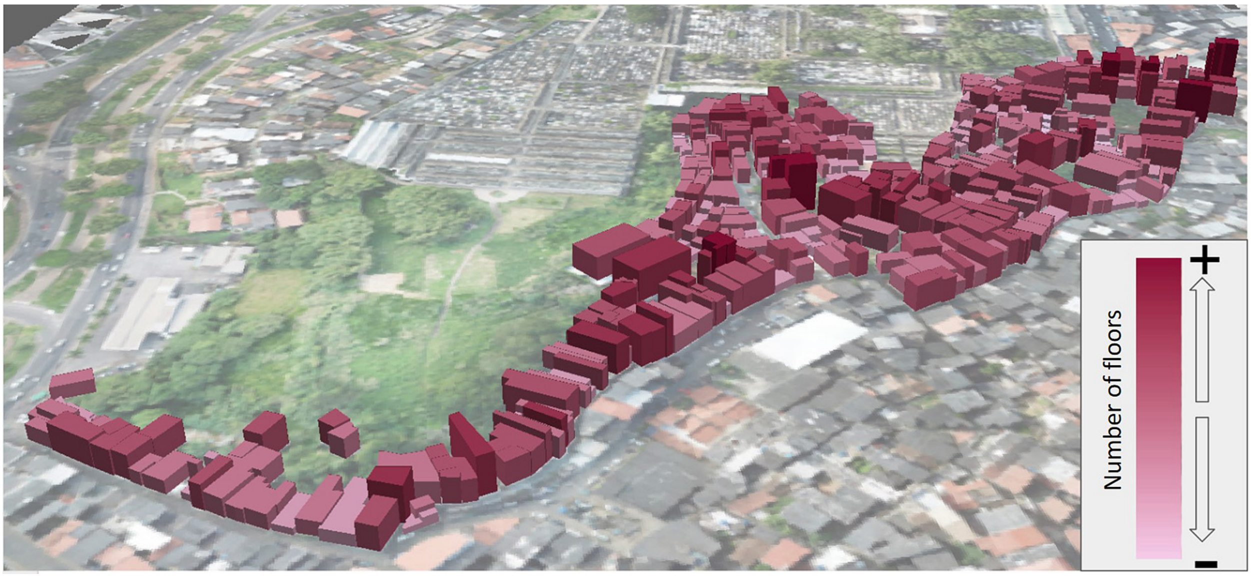

Fig. 7. 3D model with buildings distributed by the number of floors.

from the drone footage in 2018 over the same buildings with the same altitude of the point of view (27 m). It is noticeable that the gain in spatial resolution allowed to extract key information as the delimitation of the access routes, the calculation of the distance between the buildings,

Fig. 8. Google Earth a and drone b. Detailing the spacing between buildings, and roof cover type.

Fig. 9. Google Earth a drone b. Unprotected stairways and slabs became visible.

and the type of roof material (that could help to express the stage and quality of construction).

Considering the whole census sector in the drone imagery, we identified 45 situations associated with the potential risk of unintentional falls (apparent slabs and unprotected stairs) and 11 situations of houses being expanded (Fig. 10). It is necessary to note that this does not summarise the total number of houses under expansion, renovation, or those with a potential risk of falls in the study area because the covered (internal) part of the houses cannot be evaluated.

Regarding the external cladding of the houses, it was not possible to identify this characteristic in most of the buildings, and other flights with lower altitudes, oblique camera angles, and with the support of field visits are necessary. Table 2 summarises the possibilities and limitations found with the use of the drone and its derived products in this experiment.

Conclusions and discussion

Returning to the initial idea of comparability and compatibility between the data from LIT and the drone data, two important points can be emphasised:

1. There is a complementary scale of information between the two data sources. At LIT, the data are aggregated at the area level, with a single data set presented for each cluster boundary

(districts) in all three dimensions. Therefore, it is not possible to identify problems at the household level, although the source data used by LIT consider the average information about the situation of households in the area. In this way, the use of the drone allows the identification and mapping of the most problematic situations at the household level,

Fig. 10. Identification of dwellings been enlarged and with apparent unprotected slabs/stairs.

Table 2. Drone collected data during the flight above the census sector in Alto das Pombas, Salvador/Bahia.

Physical characteristics of the dwellings	Potentials and limitations of the drone imagery
Buildings' land slopes	Using the terrain model, generated from the image processing, a map was prepared that indicates the slope of the terrain where each building is located. Information is available on Figure 4.
Building floors	From the terrain and surface models, it was possible to identify the approximate number of floors of each dwelling. Information is available on Figure 6.
Spacing between buildings	It is possible to identify and measure approximate spacing between buildings, as shown in Figures 8.
Unprotected exposed slabs and stairs	It was possible to identify the dwellings that visually presented these characteristics. Information is present in Figure 9.
Width of internal roads	It is possible to delineate the width and type of internal roads (whether staircases or not), the type of paving, as per examples in Figures 3 and 4.
Type of roof covering	It is possible to identify the type of roof coverage of the buildings, as per examples in Figures 8 and 9.
Dwelling in expansion	It was possible to identify the dwellings that were visually enlarging. Information is present in Figure 10.
External coating of the dwellings	It was not possible to clearly identify the type of covering of the buildings. It is suggested to conduct new flights with different altitudes, and different camera angles on the drone.

which allows the selection of specific units for interventions.

2. Data collection with drones can be repeated (and thus have a higher temporal resolution) and adapted to local conditions. Thus, LIT plays a role in validating the process and, conversely, can benefit from drone data for updating between censuses.

Besides, the successive budget cuts that the Brazilian federal government has made since 2018 in strategic areas for the country's development, such as reducing the number of questions in the census questionnaires and postponing them until 2022 (which should have happened in 2020), make it impossible to know the current living and housing conditions of the population. Given this, even the continuity of the data collection LIT is at risk, an important tool that allows a better characterisation of the living conditions of the poorest population in the country, especially in the big cities. In this sense, drone imagery is becoming a tool that allows us to identify in detail and at a low cost the living conditions of the population. New studies in Salvador de Bahia are carried out using drone imagery as one of the final steps in a methodology to identify the houses that should be prioritised.

We can conclude that the experiment made it possible to collect, gather and analyse the minimum information necessary for planning housing improvement interventions at the household level, detailing and updating the data coming from the LIT.

These results, although preliminary, lead us to a broader academic discussion on the subject today: there is no single solution to Brazil's housing problems. Programmes that promote both the construction of new housing and the improvement of existing houses, infrastructure, and physical conditions in slums must be part of the housing policy repertoire of all levels of government. Improving housing conditions in slums is a historic challenge and remains one of the greatest challenges for urban planning practice in Brazil today.

Given the current economic-political-institutional crisis, we expect that in the coming years there may be an increase in the densification of areas occupied by slums in large and medium-sized urban centres and the emergence of new occupations, possibly in environmentally sensitive areas. This will further worsen the living conditions of the poor and require authorities to respond more quickly and efficiently.

Drones are already a tool for collecting information in slums in poor countries in Africa and Asia that have little or no official data on their poor housing conditions. In the last 30 years, Brazil has made significant progress in terms of slum information. However, to act effectively and constructively in such dynamic and complex areas, it is necessary to introduce new technologies that cannot replace the forms of information collection in the field (demographic, socioeconomic data, health status, and others), but that can achieve more satisfactory results in the aggregate.

Time is an important factor in planning and implementing improvement activities in slums. The planning process takes too long, and often interventions never achieve their proposed goals. Unlike satellite imagery, when using drones, it is possible to control the origin (source) of the images, the homogeneity (use of the same sensor) and, above all, the periodicity of the flights, which makes it possible to follow dynamic processes as they occur in slums and to update them quickly during projects.

The use of drones is still new, especially in urban surveys, and needs to be tested in different ways. In addition, there are ethical issues that cannot be ignored, as the very high-resolution images reveal the intimacy of people's homes. Gevaert et al. (2018) address these issues in more detail. This paper, which falls far short of exhausting the topic, explores the contribution of drones in collecting information about housing conditions in slums to promote housing improvement programmes.

Although drones produce highly detailed images from a spatial resolution perspective, these may not be sufficient for the formulation of housing intervention projects that require a higher level of detail. In this work, we have shown that drone imagery can provide the necessary basic information for these projects, such as the slope of the terrain and dangerous structures in the houses, and it can also serve to analyse critical situations in areas considered homogeneous, such as slums, which we need to access and address individually.

Acknowledgements

The authors would like to thank the expert anonymous reviewers and the journal editor for their constructive comments and suggestions.

Author's contribution

Conceptualisation and design: JCP, JGG; Acquisition of data: JCP, JGG, Data analysis and interpretation: JCP, JGG; Manuscript writing and revision: JCP, JGG.

References

Antunes F.P., Costa M.C.N., Paim J.S., Vieira-da-Silva L.M., Cruz A.A., Natividade M., Barreto M.L., 2013. Desigualdades sociais na distribuição das hospitalizações por doenças respiratórias. *Cad Saúde Pública* 29(7): 1346–1356. DOI 10.1590/S0102-311´2013000700009.

Aranha S.C., da Costa F.M., Faustino L.R., Ichida M., Gouvêa L.C., Barattela J.R., 2007. Acidentes por queda de laje na infância registrados no Hospital Estadual do Grajaú em 2005. *Revista de Medicina* 86(2): 94–100. DOI 10.11606/issn.1679-9836.v86i2p94-100.

Brandão M.A., 1980. O último dia de criação: mercado, propriedade e uso do solo em Salvador. In: Valladares L.P. (ed.). *Habitação em questão*. Zahar Editores, Rio de Janeiro: 125–142.

Brito C., 2005. A estruturaçao do mercado de terra urbana e habitacao em Salvador-BA, a partir de 1970. *GeoTextos* 1(1): 51–80. DOI 10.9771/1984-5537geo.v1i1.3030.

Brito P.L., Kuffer M., Koeva M., Pedrassoli J.C., Wang J., Costa F., Freitas A.D., 2020. The spatial dimension of COVID-19: The potential of earth observation data in support of slum communities with evidence from Brazil. *International Journal of Geo-Information* 9(9): 557. DOI 10.3390/ijgi9090557.

Campos M.F., Ribeiro A.T., Listik S., Pereira C.A., Sobrinho J.A.D., Rapaport A., 2008. Epidemiologia do traumatismo dacoluna vertebral no serviço de neurocirurgia do hospital Heliópolis, São Paulo, Brasil. *Revista do Colégio Brasileiro de Cirurgiões* 35(2): 88–93. DOI 10.1590/S0100-69912008000200005.

Carvalho I.M., Pereira G.C., 2018. Salvador: Transformações de uma metrópole da periferia. In: de Queiroz Ribeiro L.C., Ribeiro M.G. *Metrópoles Brasileiras: Síntese da Transformação na Ordem Urbana 1980 a 2010*. 1ªed.Rio de Janeiro: Letra Capital: Observatório das Metrópoles, 1: 141–169.

Carvalho I.M.M., 2020. Segregação, vulnerabilidade e desigualdades sociais e urbanas. *Civitas* 20(2): 270–286. DOI 10.15448/1984-7289.2020.2.28393.

Castro C.G.M., 2017. PELAS MÃOS DO POVO: Um estudo sobre a circulação de saberes informais e formais na produção edilícia em ocupações urbanas. MS, *Master's dissertation*, PPG/AU Universidade Federal da Bahia UFBA.

Costa F., Zeppelini C.G., Ribeiro G.S., Santos N., Reis R.B., Martins R.D., Bittencourt D., Santana C., Brant J., Reis M.G., Ko A.I., 2021. Household rat infestation in urban slum populations: Development and validation of a predictive score for leptospirosis. *PLoS Neglected Tropical Diseases* 15(3): e0009154. DOI 10.1371/journal. pntd.0009154.

de Carvalho E.T., 2002. Os Alagados na Bahia: Intervenções Públicas e Apropriação Informal do Espaço Urbano. MS, *Master's dissertation* (Mestre em Arquitetura e Urbanismo) – Universidade Federal da Bahia – FAUFBA.

Fantin M., Pedrassoli J.C., Zaratine G.N., Coelho I.L.F., 2018. The use of UAV for slums land regularization: Potentialities, hindrances, and challenges. In: XXII Congresso Internacional da Sociedade Iberoamericana de Gráfica Digital, *Blucher Blucher Design Proceedings* 5: 560–567. DOI 10.1016/sigradi 2018-1498.

Fernandes R.B., Regina M.E., 2005. A segregação residencial em salvador no contexto do miolo da cidade. *Cadernos do Logepa* 4(1): 39–46.

Gevaert C.M., Sliuzas R., Persello C., Vosselman G., 2018. Evaluating the societal impact of using drones to support urban upgrading projects. *International Journal of Geo-Information* 7(3): 91. DOI 10.3390/ijgi7030091.

Gomes J.G., 2017. Os (des)caminhos da assistência técnica para melhorias habitacionais: o programa morar melhor em Salvador. In*: II National Seminar in slum upgrading, Rio de Janeiro. Analls, II UrbFavelas*. Letra Capital, Rio de Janeiro.

Google Earth Pro., 2015. Coordinates: 552680.62 m E, 8562782.06 m S, 24L. Eye alt 80 m. Online: www.google.com/earth/index.html (accessed June 2020).

Gordilho-Souza A., 2008. Limites do habitar: segregação e exclusão na configuração urbana contemporânea de Salvador e perspectivas no final do século XX. EDUFBA, Salvador.

IBGE [Instituto Brasileiro de Geografia e Estatística], 2013. *Censo Demográfico 2010. Aglomerados Subnormais. Levantamento de Informações Territoriais* (LIT), Demographic Census. Rio de Janeiro.

Kowarick L., 2009. *Escritos urbanos*. Editora 34, São Paulo: 1–144.

Lima A.N., 2005. (In) segurança da posse: Regularização fundiária em Salvador e os Instrumentos do Estatuto da cidade. MS, *Master's dissertation*. Universidade Federal da Bahia.

Mation L.F., Nadalin V.G., Krause C., 2014. *Favelização no Brasil entre 2000 e 2010: Resultados de uma classificação comparável*. Texto para Discussão. Instituto de pesquisa econômica aplicada, Brasília.

Mendonça F.A., 1989. A estratégia de localização dos conjuntos habitacionais da Urbis em Salvador, entre 1964 e 1984. *Revista Rua* 2(2): 61–83.

Messias M.G., Neves R.D., 2009. A influência de fatores comportamentais e ambientais domésticos nas quedas em idosos. *Revista Brasileira de Geriatria e Gerontologia* 12(2): 275–282. DOI 10.1590/1809-9823.2009.120210.

Moraes L.T.S., Santos M.E., Sampaio R.M., 2003. Indicadores da qualidade Ambiental urbana: A experiencia do dique de Campinas em Salvador, Bahia. *Revista Rua* 9: 79–87.

Paim J.S., Costa M.D., Carvalho V., Motta I.A., Neves R.B., 1987. Spatial distribution of proportional infant mortality and certain socioeconomic variables in Salvador, Bahia, Brazil. *Pan American Health Organization Bulletin* 21(3): 225–239.

Pasternak S., 2016. Habitação e saúde. *Estudos Avançados* 30(86): 51–66. DOI 10.1590/S0103-40142016.00100004.

Rocha F.U., 2014. O perfil da mobilidade urbana em Salvador (1975 a 2012): A cidade dividida. MS, *Master's dissertation*. – PPG/AU Universidade Federal da Bahia UFBA.

Santos M., 2012. *O centro da cidade de Salvador: Estudo de geografia urbana*. 2. ed. Editora da Universidade de São Paulo, São Paulo: 1–208.

Santos M.E.P., Pinho J.A.G., Moraes L.R.S., Fischer T.D., 2013. *O Caminho das Águas em Salvador: Bacias Hidrográficas, Bairros e Fontes*. Second Edition, CIAGS/SEMA, Salvador.

Serpa A., 2006. Gestão territorial do Sistema de parques públicos em Salvador, Bahia: contradições e paradoxos. *Raega-O Espaco Geografico em Analise*, Curitiba 12: 7–19. DOI 10.5380/raega.v12i0.6208.

Silva H.S., 2015. Segregação socioespacial em Salvador – Bahia: Análise pela cartografia das redes de infraestrutura urbana. MS, *Master's dissertation* – Universidade Federal da Bahia, Faculdade de Arquitetura.

Silva H.S., 2019. Espaço metropolitano e justiça espacial [manuscrito]: Cartografia das diferenças espaciais em metrópoles nordestinas. MS, *PhD. Thesis* – Universidade Federal da Bahia, Faculdade de Arquitetura, Programa de Pós-Graduação em Arquitetura e Urbanismo, Doutorado em Arquitetura e Urbanismo.

Smith D., Kirkwood G., Pott J., Kourita L., Jessop V., Pollock A.M., 2015. Childhood injury in Tower Hamlets: Audit of children presenting with injury to an inner-city A&E department in London. *Injury* 46(6): 1131–1136. DOI 10.1016/j.injury.2014.12.029.

SMS [Secretaria Municipal de Saúde de São Paulo], 2018. *Sistema de Informações de Vigilância de Acidentes*.

Soares A.M.C., Espinheira C.G., 2006. Conjuntos habitacionais em Salvador-Ba e a transitória inserção social. *Revista Risco* 3(2): 57–65. DOI 10.11606/issn.1984-4506.v0i3p57-65.

Souza C.M.C., 2005. A gripe espanhola em Salvador, 1918: Cidade de becos e cortiços. História, Ciências, Saúde. *Manguinhos* 12(1): 71–99. DOI 10.1590/S0104-59702005000100005.

The Times of India, 2018. Slum Rehabilitation Authority to use drone tech to map slums. Online: timesofindia.indiatimes.com/city/mumbai/in-a-first-sra-to-use-drone-tech-to-map-slums/articleshow/62575273.cms (accessed 1 March 2021).

United Nations Habitat, 2016. Slum Almanac 2015/2016: Tracking Improvement in the Lives of Slum Dwellers. UNON, Publishing Services Section, Nairobi.

Waskaman R.D., Carrera R.M., Santos E., Abramovici S., Schvartsman C., 2014. Morbidade por trauma em crianças moradoras da comunidade de Paraisópolis, São Paulo, Brasil. *Einstein* 12(1): 1–5. DOI 10.1590/S1679-45082014AO2434.