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FLOODING RISK IN BELÉM (PA) CITY: THE TECHNICAL AND SOCIAL PERCEPTION OF RISK

RISCO DE INUNDAÇÃO NA CIDADE DE BELÉM (PA): A PERCEPÇÃO TÉCNICA E SOCIAL DO RISCO

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Abstract

Increasingly, a diversity of natural events such as floods has been more present in cities, causing numerous disasters, and besides that, the world's population is living in increasingly vulnerable urban centers. Belém (PA) is an example of a city that has flooding records due to the frequent climatic events (high tides and increased rainfall), added to the fact that 54% of its population live in subnormal agglomerations (slums). Thus, this research aims to identify the flood risk in Belém. The method has a premise on the combination of technical parameters and social judgments in identifying the risk. On the technical aspect, a mathematical model is used to constitute the risk, exposure, and vulnerability indexes based on social, economic, and environmental indicators, having as results cartographic maps developed using Geographic Information System (GIS). On the social view, a questionnaire is applied to identify common thinking based on the population's experience living with floods, resulting in percentage data on the frequency of floods and the losses experienced. The analyses identified four distinct risk areas divided by the districts of Belém; Sacramenta and Guamá; Entroncamento, Benguí and Icoaraci; Outeiro and Mosqueiro. The results show a spatial heterogeneity with a strong influence on the historical urbanization process of the city of Belém.

Keywords: Flooding. Risk. Exposure. Vulnerability. Disaster.

Resumo

Crescentemente, uma diversidade de fenômenos naturais como inundações estão se manifestando nas cidades provocando vários desastres, além de metade da população mundial estar vivendo em centros urbanos cada vez mais vulneráveis. A cidade de Belém (PA) é um exemplo de cidade que

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apresenta histórico de inundações em decorrência de eventos climáticos frequentes como fenômenos de maré alta e aumento da precipitação pluviométrica, além de 54% da sua população residir em aglomerados subnormais (favelas). Assim, o objetivo desta pesquisa é identificar o risco de inundação em Belém. O método utilizado tem como premissa a combinação de parâmetros técnicos e julgamentos sociais na identificação do risco. Pelo lado técnico, utiliza-se um modelo matemático para constituir os índices de risco, exposição e vulnerabilidade a partir de indicadores sociais, econômicos e ambientais, resultando em mapas cartográficos através de um Sistema de Informação Geográfica (SIG). Pelo lado social, aplica-se um questionário com o intuito de identificar o pensamento comum a partir da convivência da população com os episódios de inundação, resultando em dados percentuais de frequência das inundações e os prejuízos experimentados. As análises resultaram na identificação de quatro áreas distintas de risco divididas pelos distritos de: Belém; Sacramenta e Guamá; Entroncamento, Benguí e Icoaraci; Outeiro e Mosqueiro. Os resultados mostram uma heterogeneidade espacial com forte influência do processo histórico de urbanização do município de Belém.

Palavras-chave: Inundação. Risco. Exposição. Vulnerabilidade. Desastre.

Introduction

Fast urbanization has brought prosperity and opportunity to people, cities have become the economic engines as well as centers of technology and innovation in their countries, but this is the case for well-planned and managed cities. On the other hand, cities have become major risk-generating centers when growth is combined with the impacts of extreme weather events and the increase in poverty (UNISDR, 2012).

In 2016, worldwide, 569.4 million people were affected by natural disasters, the largest number ever measured since 2006. Also, approximately one billion people are living in urban slums (CRED, 2016; UNISDR, 2010). Thus, it is clear that there are two worrying situations: numerous people are vulnerable and occurrences of natural disasters are growing.

In Belém, flooding is understood as a hydrological process of overflowing water from drainage channels to marginal areas, submerging coastal areas due to the temporary rise in water level. The causes are frequent climatic events in the Amazonian winter period, usually beginning in December and ending in May, such as increased rainfall and high tides, enhanced by topographic conditions, soil waterproofing, and inefficient drainage infrastructure. (CAMPOS *et al*, 2014; CPRM, 2015; PINHEIRO, 2015; PONTES *et al*, 2017).

According to the last demographic census (IBGE, 2010), Belém has approximately 1.4 million inhabitants, with 758,524 thousand people living in subnormal agglomerations (see IPEA, 2014, p. 11), that is, 54% of the population lives in vulnerable conditions. This data becomes even more serious when compared to other important capitals, as Belém is ahead in this regard, for example: São Paulo 11%, Rio de Janeiro 22% and Salvador 33%.

Therefore, this research aims to identify flood risk in the city of Belém, so that greater understanding is obtained by integrating two paths of analysis: the technical and the social. This work gains more relevance due to this combination, not being restricted to only a perception of risk, and hence contributing to further research and discussions.

Risks e vulnerabilities

Studies on risks are individualized and fragmented for each area of knowledge according to their perspectives of understanding (MARANDOLA JR.; HOGAN, 2005 apud SANTOS *et al*, 2015), meaning they are produced from the perspectives of geography, geology, sociology, among other areas, bringing together a set of meanings.

For the French geographer, Veyret, the causes and consequences of risks must be known according to the diversity of classifications (VEYRET, 2007 apud SOUZA; LOURENÇO, 2015). Initially, damage and population exposure were considered in the approach to natural risks. Later, social and technological risks were incorporated, changing the nomenclature to environmental risks. Thus, risks are understood by the manifestation of nature together with how society has taken over the environment where it lives (EGLER, 1996 apud SOUZA; LOURENÇO, 2015).

In Geology, studies consider that the natural dynamics of the planet is comprised of processes that occur regardless of human activities, however, the action of man through to changes in land use and occupation can stimulate, streamline and increase many of those processes (CERRI; AMARAL, 1998; BARBOSA; FURRIER, 2017).

To make understanding easier, risk analysis categories were established, followed by an adjective that qualifies them and with a clear determination of the threats that constitute them (VEYRET, 2007; CASTRO *et al*, 2005 apud ALMEIDA, 2012; CERRI; AMARAL, 1998 apud ROCHA, 2005 apud SANTOS *et al*, 2015):

- **Natural hazards**: Hurricanes, droughts, storms, hail, lightning, flooding, inundations, earthquakes, volcanic activities, tsunamis, landslides, erosion, diseases caused by viruses, bacteria, poisonous animal bites, etc.
- **Technological risks**: Leaks of toxic, flammable, radioactive products, accidental fires, vehicle collisions, aircraft crashes, etc.
- **Economic, geopolitical, and social risks**: Economic crises, insecurity and violence due to urban socio-spatial segregation, political-ideological conflicts, etc.

Environmental risks are considered the largest category of analysis, covering natural, technological, economic, geopolitical, and social risks. It is noteworthy that this classification is carried out to aid the reasoning of the types of existing risks, given that a phenomenon may be present in more than one of the groups. For example, urban flooding may have a purely natural cause, but it can also be influenced by human activities of soil impermeabilization, insufficient urban drainage, and housing in flooded areas.

When expanding the concept of risk in the light of Sociology, an important issue is the social perception of risk, which is understood as a social product that only exists because the society or individual can perceive it (constructivist perception). However, some defend the existence of an independent risk of being perceived, without interfering in the impact that can happen (objectivist or realistic perception). Thus, it is understood that the social perception is undeniable although it cannot be restricted in itself, so the analysis of risks in the urban space must embrace the combination of social judgments and scientific parameters (GUIVANT, 1998; VEYRET, 2007; TAVARES *et al*, 2017).

Another concept intrinsic to risk is vulnerability, that It can be defined by the characteristics of a society that enhance the susceptibility of negative consequences when a threat is manifested (UNISDR, 2009 apud KELMAN, 2018).

For authoress Cutter, the different approaches to existing vulnerability result in three main attitudes (CUTTER, 1996 apud MARANDOLA JR; HOGAN, 2005 apud SOUZA; LOURENÇO, 2015). The first vulnerability is premised on the spatial or geographical dimension, understood as a result of the physical aspects of a given region, designated by the extent to which an environment is susceptible to the occurrence of natural threats, in other words, it concerns the areas where the manifestation of a natural phenomenon occurs (TAGLIANI, 2003; ALVES, 2006 apud ESTEVES, 2011; PINHEIRO, 2015).

The second vulnerability is related to the characteristics of the community, contrasting the physical sense of the risks, taking into account economic issues, the offer and access to public services, the ways of life of the population living in risk areas, among others. In this thought, vulnerability concerns not only the populations that are exposed but also as a result of the social needs that affect them (CUTTER, 2006; 2010 apud MENDES *et al*, 2011; PINHEIRO, 2015).

The third one is the combination of social and environmental dimensions in the identification and analysis of the vulnerability. Thus, the use of the terminology "socio-environmental vulnerability" becomes relevant because environmental risks depend on social, economic, technological, cultural, environmental factors, etc. (ESTEVES, 2011; PINHEIRO, 2015).

Lastly, another relevant issue regarding threats and vulnerabilities is the possibility of all these elements being viewed through Geographic Information System (GIS) for the construction of physical and social indicators. GIS can integrate diversified data sources and assist in the understanding of risks as well as vulnerabilities, in addition to being able to assist in decision making to intervene in the territory (CUTTER, 2003 apud SOUZA; LOURENÇO, 2015).

According to Marcelino (2008), an indicator includes a diversity of data (maps, measurements in the field, satellite images, questionnaires, etc.) that enable the identification of the characteristics and the context of the environment. For the author, "whenever possible, quantitative data should be used from reliable sources, as well as long historical series and methods of analysis involving mathematical and physical models". The goal is that the risk assessment is as close to the reality of the place and not the perception of the technician responsible for the analysis. Also, this assessment has to be made possible for replication and comparison with other areas.

For KOBIYAMA (2004 apud MARCELINO *et al*, 2006), mapping risk areas is the objective of an analysis instrument since, based on a map, it is possible to elaborate a series of preventive, emergency, and joint actions between population and power public to provide a permanent defense of society against a natural disaster.

Method

This exploratory research is constituted by the method of mathematical modeling, survey, and case study according to theoretical reference, consisting of two stages of analysis. The first stage is related to the technical point of view with the use of a mathematical model that allows viewing and analyzing the different levels of exposure, vulnerability, and flood risk through the collection of social, economic and environmental indicators, resulting in the creation of cartographic maps using GIS.

The second stage approach is the social point of view through the application of a questionnaire to a portion of the population to build an understanding of how the population perceives the flood events, resulting in percentage data on the frequency of floods and the losses experienced.

Initially, an attempt is made to develop a flood risk index on a intra-municipal scale, adapted from the Disaster Risk Indicators in Brazil (DRIB) index, which is developed on a municipal scale. The DRIB index is based on the World Risk Index, whose theoretical concepts, in the context of natural disasters, state that the risk derives from a combination of physical factors and the vulnerability of exposed elements, having equation 1 as calculation premise (ALMEIDA *et al*, 2016; WRR, 2016):

$$R = E \times V \qquad \text{Eq. 1}$$

Where the risk index ($\boldsymbol{R}$) is the product between the exposure index ($\boldsymbol{E}$) and the vulnerability index ($\boldsymbol{V}$), with the numerical values of these components between zero and one: 0 (zero) indicates that there is no exposure, vulnerability or risk and 1 (one) indicates that these are maximum. To display the indexes, cartographic maps are elaborated on Quantum Geographic Information System (QGIS) and the numerical data are classified qualitatively into five classes: very low (0.00 - 0.20); low (0.21 - 0.40); medium (0.41 - 0.60); high (0.61 - 0.80); and very high (0.81 - 1.00).

That said, the first step is to know the exposure through the following georeferenced files: areas susceptible to flooding (CPRM, 2015; GEOFABRIK, 2018); territorial map and population data (IBGE, 2010). On QGIS, population data are linked to the territorial map to identify the different demographic densities. Thus, one can overlay the map of areas susceptible to flooding on the territorial map and apply the intersection between these two layers.

Subsequently, the different levels of exposure are identified at the district scale – a unitary element of the Municipal System of Urban Planning and Management (Sistema Municipal de Planejamento e Gestão Urbana) (BELÉM, 2012) – and then, the exposed population of a district is divided by the total population, resulting in cartography that represents the spatial dynamics of risk, see equation 1.1 shown below (adapted from ALMEIDA *et al*, 2016):

$$E = \frac{Exposed\ population}{Total\ population} \qquad \text{Eq. 1.1}$$

The second step is to know the vulnerability through thirty-two indicators that embrace the social, economic, and environmental conditions of the Brazilian territory, being divided into susceptibility ($\boldsymbol{S}$), coping capacity ($\boldsymbol{CC}$), and adaptive capacity ($\boldsymbol{AC}$). Socioeconomic and cultural conditions as well as the performance of public institutions in dealing with risks are strongly associated with vulnerability, taking into account that the series of inequalities and the inefficiency of the State result in barriers to risk reduction. The following are the vulnerability indicators divided into categories:

Table 1: Vulnerability indicators

Susceptibility	Coping capacity	Adaptive capacity
Public infrastructure	Government and authorities	Education and research
(a)% of people in households without water from the water supply network (b)% of people in households with a bathroom for the exclusive use of residents with a toilet without sewerage connected to the sewer network or rainwater network	(a) state government corruption index	(a)% of literate people aged 5 or over (b)% 15-17 years old who attended elementary school (c)% 18-24 years old with a high school diploma (d)% aged 25 or over who completed higher education
Housing conditions	Disaster preparedness and early warning	Gender equity
(c)% of the population in subnormal agglomerates (slums) (d)% of people in households with inadequate materials on the walls (e) Degree of urbanization	(b) Structural measures to reduce the risk of disasters (dams, channels, parks, reservoirs, etc.) (c) Flood disaster risk management (mapping and control to prevent occupation in susceptible areas, warning system, risk register, etc.) (d) Population vulnerable to floods who are signed up for housing public programs (e) Local structure for disaster response (firefighters, civil defense, community centers, etc.)	(e) Institution responsible for formulating, coordinating and implementing policies for women with specific budgets (f) The municipality has a policy plan for women (g) % of women who have been responsible for families/the providers for over 10 years
Poverty and dependence		Environmental conditions / Ecosystem protection
(f) Dependency ratio (g)% Vulnerable to poverty (% of persons responsible for families without monthly income)		(h) Policies and actions specific to the environment (i) Deforestation areas (j) Conservation areas (k) Fire spots
Economic capacity and income	Medical services	Adaptation strategies
(h) % of households with income of up to 1 minimum wage (i) Gini index (degree of inequality in the distribution of individuals according to per capita household income / per capita household income has the same value)	(f) Number of doctors for each inhabitant (g) Number of hospital beds for each inhabitant Material coverage (h) Level of coverage of the cash transfer program (Bolsa Família, 2012)	(l) Legislation and planning instruments (municipal laws, zoning, construction code, etc.) (m) Specific planning tools for disaster prevention (risk prevention laws, municipal risk reduction plan, geotechnical report for urbanization, etc.) (n) Public Administration adhered to the agenda for the millennium development goals Investments (o) Life expectancy at birth

Source: adapted from ALMEIDA *et al* (2016).

The selection of indicators is based on the World Risk Index, being related to the eight Millennium Development Goals and the United Nations Hyogo Board for Action on Disaster Risk Reduction (ALMEIDA *et al*, 2016). It is noteworthy that the indicators treated here refer to technical data collected from several official and publicly available sources, meaning that the exposure, vulnerability, and the risk itself are identified from numerical and georeferenced data.

Table 2 shows the categories, weights (weighting), databases, years of publication, scales, and units of the indicators that make up $\boldsymbol{S}$, $\boldsymbol{CE}$, and $\boldsymbol{CA}$.

Table 2: Information on vulnerability indicators

Categories	Weights	Indicators (Table 2)	Database	Year of publication	Scale	Unity
Susceptibility						
Public infrastructure	(0,22)	(a)	Population Census (IBGE)	2010	District	%
		(b)				
Housing conditions	(0,33)	(c)				
		(d)	Atlas of Human Development in Brazil (UNDP, IPEA and João Pinheiro Foundation)	2010	Municipality	%
		(e)				
Poverty and dependence	(0,22)	(f)				
		(g)	Population Census (IBGE)	2010	District	%
Economic capacity and income	(0,22)	(h)				
		(i)	Atlas of Human Development in Brazil (UNDP, IPEA and João Pinheiro Foundation)	2010	Municipality	Index
Coping capacity						
Government and authorities	(0,11)	(a)	Boll, 2010 (Master's thesis)	2010	State	Index
Disaster preparedness and early warning	(0,55)	(b)	Profile of Brazilian Municipalities - MUNIC (IBGE)	2013	Municipality	Ratio
		(c)				
		(d)				
		(e)				
Medical services	(0,22)	(f)	Medical Demographics in Brazil (FMUSP)	2015	Municipality	Ratio
		(g)	Medical-Sanitary Assistance research (IBGE)	2009	Municipality	Ratio
Material coverage	(0,11)	(h)	Social Information Report – Bolsa Família and Cadastro Único (Ministry of Social and Agrarian Development)	2018	Municipality	Ratio
Adaptive capacity						
Education and research	(0,26)	(a)	Population Census (IBGE)	2010	District	Ratio
		(b)	Atlas of Human Development in Brazil (UNDP, IPEA and João Pinheiro Foundation)	2010	Municipality	%
		(c)				
		(d)				
Gender equity	(0,20)	(e)	Profile of Brazilian Municipalities - MUNIC (IBGE)	2013	Municipality	Ratio
		(f)				
		(g)	Population Census (IBGE)	2010	District	Ratio
Environmental conditions / Ecosystem protection	(0,26)	(h)	Profile of Brazilian Municipalities - MUNIC (IBGE)	2013	Municipality	Ratio
		(i)	Deforestation Monitoring of Forest Formations in the Legal Amazon - PRODES (INPE)	2017	Municipality	Ratio
		(j)	Conservation Unit (Ministry of the Environment)	2018	State	Ratio
		(k)	Fires Program (INPE)	2016	State	Ratio
Adaptation strategies	(0,20)	(l)	Profile of Brazilian Municipalities - MUNIC (IBGE)	2013	Municipality	Ratio
		(m)				
		(n)				
Investments	(0,06)	(o)	Atlas of Human Development in Brazil (UNDP, IPEA and João Pinheiro Foundation)	2010	Municipality	%

Source: adapted from ALMEIDA *et al* (2016).

Concerning Table 2, the susceptibility refers to the population's predisposition to suffer damage, comprising nine indicators (a, b, c, d, e, f, g, h, i) divided into four categories (public infrastructure; housing conditions; poverty and dependence; economic capacity and income).

Coping capacity refers to the ability of the municipality to prepare before, endure during, and recover after flood impacts. Eight indicators are used (a, b, c, d, e, f, g, h) divided into four categories (government and authorities; disaster preparedness and early warning; medical services; material coverage).

Adaptive capacity concerns the capacity of the municipality and its population to self-transform as a society. For example, gender equity and the preservation of the environment are considered contemporary themes that may indicate the extent to which a society can adapt. Fifteen indicators are used (a, b, c, d, e, f, g, h, i, j, k, l, m, n, o) divided into five categories (education and research; gender equity; environmental conditions/ ecosystem protection; adaptation strategies; investments).

In the value of each indicator of coping capacity ($\boldsymbol{CC}$) and adaptive capacity ($\boldsymbol{AC}$) has been subtracted 1 (one) to compose the lack of these indicators ($\boldsymbol{LCC}$ **and** $\boldsymbol{LAC}$) since the global sum of the vulnerability components will be a measure of capacity deficiencies to deal with flood risk. The following equations show the vulnerability calculation sequence (adapted from ALMEIDA *et al*, 2016):

$$V = \mathbf{0,33} \times (\boldsymbol{S} + \boldsymbol{LCC} + \boldsymbol{LAC}) \qquad \text{Eq. 1.2}$$

$$S = \left(\mathbf{0,20} \times \left(\mathbf{0,50} \times (\boldsymbol{a} + \boldsymbol{b})\right)\right) + \left(\mathbf{0,30} \times \left(\mathbf{0,33} \times (\boldsymbol{c} + \boldsymbol{d} + \boldsymbol{e})\right)\right) + \left(\mathbf{0,25} \times \left(\mathbf{0,50} \times (\boldsymbol{f} + \boldsymbol{g})\right)\right) + \left(\mathbf{0,25} \times \left(\mathbf{0,50} \times (\boldsymbol{h} + \boldsymbol{i})\right)\right) \qquad \text{Eq. 1.2.1}$$

$$LCC = (\mathbf{0,11} \times \boldsymbol{a}) + \left(\mathbf{0,55} \times \left(\mathbf{0,25} \times (\boldsymbol{b} + \boldsymbol{c} + \boldsymbol{d} + \boldsymbol{e})\right)\right) + \left(\mathbf{0,22} \times \left(\mathbf{0,50} \times (\boldsymbol{f} + \boldsymbol{g})\right)\right) + (\mathbf{0,11} \times \boldsymbol{h}) \qquad \text{Eq. 1.2.2}$$

$$LAC = \left(\mathbf{0,26} \times \left(\mathbf{0,25} \times (\boldsymbol{a} + \boldsymbol{b} + \boldsymbol{c} + \boldsymbol{d})\right)\right) + \left(\mathbf{0,20} \times \left(\mathbf{0,33} \times (\boldsymbol{e} + \boldsymbol{f} + \boldsymbol{g})\right)\right) + \left(\mathbf{0,26} \times \left(\mathbf{0,25} \times (\boldsymbol{h} + \boldsymbol{i} + \boldsymbol{j} + \boldsymbol{k})\right)\right) + \left(\mathbf{0,20} \times \left(\mathbf{0,33} \times (\boldsymbol{l} + \boldsymbol{m} + \boldsymbol{n})\right)\right) + (\mathbf{0,06} \times \boldsymbol{o}) \qquad \text{Eq. 1.2.3}$$

Regarding the calculation adjustments, most indicators are in percentage, so has been divided by 100 (one hundred) to be in a range from 0 (zero) to 1 (one). Also, there is the "ratio" unit, which is the division of the indicator's value by its total. Thus, based on the census information, it is known how many measures have already been and should be implemented.

Lastly, for comparative analysis, indicators are sought on the smallest scale possible, with three scales being identified: district; municipality; and state. Despite that, this limitation does not prevent the analysis from being carried out; it only reduces a greater distinction between areas.

The social perception of flood risk is developed through the application of a questionnaire to survey how the population lives with flood events. Therefore, in the elaboration of the questionnaire, simple questions, which were easy to answer, were the focus to achieve faithful interpretations. It should also be noted that a representative sample of the population is used, free from any tendency or pre-judgment. The aim is really to collect the population's perception, without providing any prior information or selecting any group prone to risk and socially vulnerable. Hence, the questionnaire is applied by different means and locations to seek the largest and most diverse participation of the population.

The questionnaire was designed to be applied using an electronic form (Google Forms) and printed on paper, having the data processed on Microsoft Office Excel 2016. The ideal sample size (n) was defined according to AYRES *et al* (2015), through equation 2:

$$\boldsymbol{n} = \frac{\boldsymbol{N} \, \boldsymbol{x} \, \boldsymbol{n_0}}{\boldsymbol{N} + \boldsymbol{n_0}} \qquad \text{Eq. 2}$$

In which $\boldsymbol{N}$ is the size of the population and $\boldsymbol{n_0}$ the size of the provisional sample that considers the margin of error (Er) in probabilistic terms of 5%. Thus, firstly, the calculation of $\boldsymbol{n_0}$ was done based on the margin of error to know the provisional sample size:

$$\boldsymbol{n_0} = \frac{\mathbf{1}}{\boldsymbol{Er^2}} = \frac{\mathbf{1}}{(0.05)^2} = 400 \qquad \text{Eq. 2.1}$$

Therefore, for a population size equal to 1,392,332 inhabitants (IBGE, 2010), the quantity for the questionnaire to be applied is given by the following calculation:

$$\boldsymbol{n} = \frac{\mathbf{1.392.332} \, \boldsymbol{x} \, \mathbf{400}}{\mathbf{1.392.332} + \mathbf{400}} = 400 \text{ questionnaires} \qquad \text{Eq. 2}$$

Initially, the questionnaire was validated through an experimental application to determine the quality of the questions, in other words, what they were proposed to measure.

With the necessary adjustments, the final application was done through a request for collaboration sent to the e-mails of students, employees, and teachers at the Faculty of Civil Engineering (FCE) of the Federal University of Pará (FUPA) including the link to the questionnaire in Google Forms and then, the questionnaire was randomly applied in-person to the students at FCE. The questionnaire (electronic one) was applied to people who attend FUPA due to the fact the authors had access to their e-mails. Nevertheless, they cover a large and representative sample of the city, as the interviewees live in different districts of the municipality targeted by the survey.

Finally, to diversify the public, the authors had assistance from the Civil Defense agents, who allowed that the interview was applied to the population in the social action promoted by the City of Belém in the neighborhood of Pedreira on April 4, 2018 (BELÉM, 2018).

In the first section of the questionnaire, through five questions such as gender, age, education, occupation, and district of residence, it is intended to characterize the interviewees. In the second section, the five questions aim to assess the awareness of risk, memory, frequency, and if they have already been affected as well as the damage experienced (Table 3).

Table 3: Questionnaire on social perception of flood risk

I – Sociodemographic characteristics	
Gender (Check only one answer):	( ) Male ( ) Female ( ) I prefer not to say
Age (Check only one answer)	( ) 15-19 ( ) 20-24 ( ) 25-29 ( ) 30-34 ( ) 35-39 ( ) 40-44 ( ) 45-49 ( ) 50-54 ( ) 55-59 ( ) 60-64 ( ) 65+
Education (Check only one answer)	( ) Illiterate ( ) Can read/write (no school) ( ) Elementary school ( ) High school ( ) Incomplete higher education ( ) Complete higher education ( ) Post-graduation (master's and / or doctorate)
What is your occupation? (Check only one answer)	( ) Student ( ) Student/Worker ( ) Self-employed ( ) Employee ( ) Unemployed ( ) Retired
Where do you live (district)? (Check only one answer)	( ) Belém ( ) Benguí ( ) Entroncamento ( ) Guamá ( ) Icoaraci ( ) Mosqueiro ( ) Outeiro ( ) Sacramenta
II – Living with floods	
Check the option that best reflects the feeling of risk (Check only one answer)	( ) Illness ( ) Unstable construction ( ) Flooding ( ) Corruption ( ) Terrorism ( ) Cybercrime ( ) Robbery ( ) Other:________
Do you remember any floods in your district of residence? (Check only one answer)	( ) Yes ( ) No ( ) I don't know If you checked the answer No or I don't know, do not answer the next questions.
On a range from 1 to 5, in which 1 means "Rarely" and 5 "Daily", check the option that best reflects the frequency of flood events in your district of residence. (Check only one answer)	( ) 1 – Rarely ( ) 2 – Annually ( ) 3 – Monthly ( ) 4 – Weekly ( ) 5 – Daily
Have you ever been directly affected by floods? (Check only one answer)	( ) Yes ( ) No ( ) I don't know
If "Yes" (9), what have you lost and got damaged in the flood events? (Check all the apply)	( ) Death of family members ( ) Wounds/illness ( ) Eviction ( ) Loss of furniture/equipment ( ) Loss of cars/motorcycle ( ) Other: ____________

It is noteworthy that question 5 allowed a comparative analysis among each district of the municipality, in addition to question 7, which intended to qualify interviewees to answer the following questions in the questionnaire, emphasizing that if the answer was negative to this question, the interviewee should discontinue the application of the questionnaire.

Results e discussions

It is known that cities are increasingly threatened by natural events, which have worried public managers to fight risks. In this regard, this research contributes to regional development in both planning and management. For example, the promotion of spatial planning that reduces exposure and population vulnerability or the adoption of management measures focused on building urban resilience.

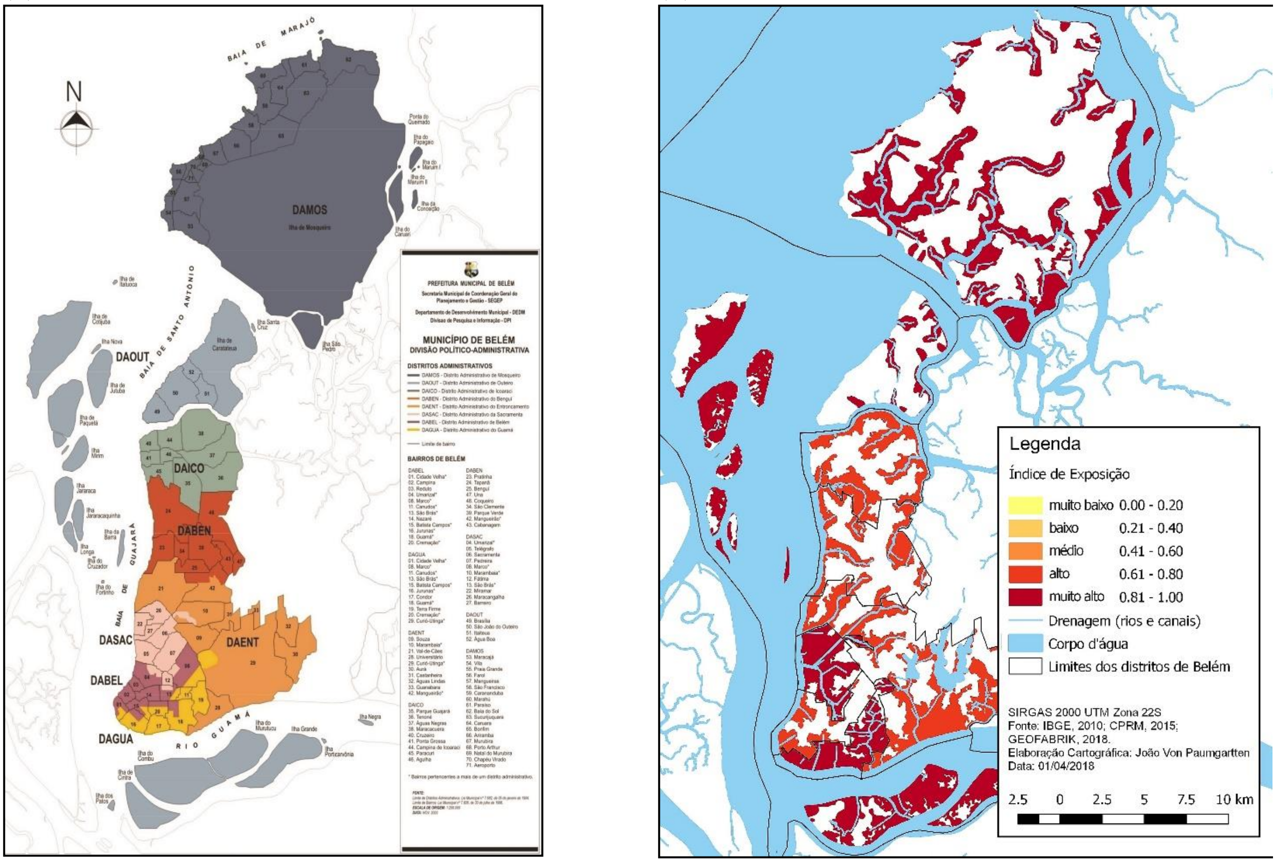
The matter is that urban risks need to be taken seriously through a holistic view, for a comprehensive understanding of the phenomena be sought. It is in this perspective that the object of this study is explored, by combining technical and social perception, contributing to future research and discussions on regional development.

At this moment, the results of the technical perception will be presented according to the official district division of the municipality: Belém, Benguí, Guamá, Entroncamento, Icoaraci, Mosqueiro, Outeiro, and Sacramenta (BELÉM, 2012).

The exposure index found is between 0.61 to 1.00, representing a worrying situation, as the numbers are high: Benguí (0.637), Belém (0.659), Entroncamento (0.665), and Icoaraci (0.721) presented high indexes whereas Outeiro (0.829), Mosqueiro (0.935), Sacramenta (0.946), and Guamá (0.994) presented very high indexes. Bellow, it is shown the official division map of the municipality, as well as the exposure indexes found for each district.

Figure 1: (a) Map of the political-administrative division; (b) Map of the exposure index

(a) (b)



Source: (a) BELÉM (2012); (b) developed by the authors.

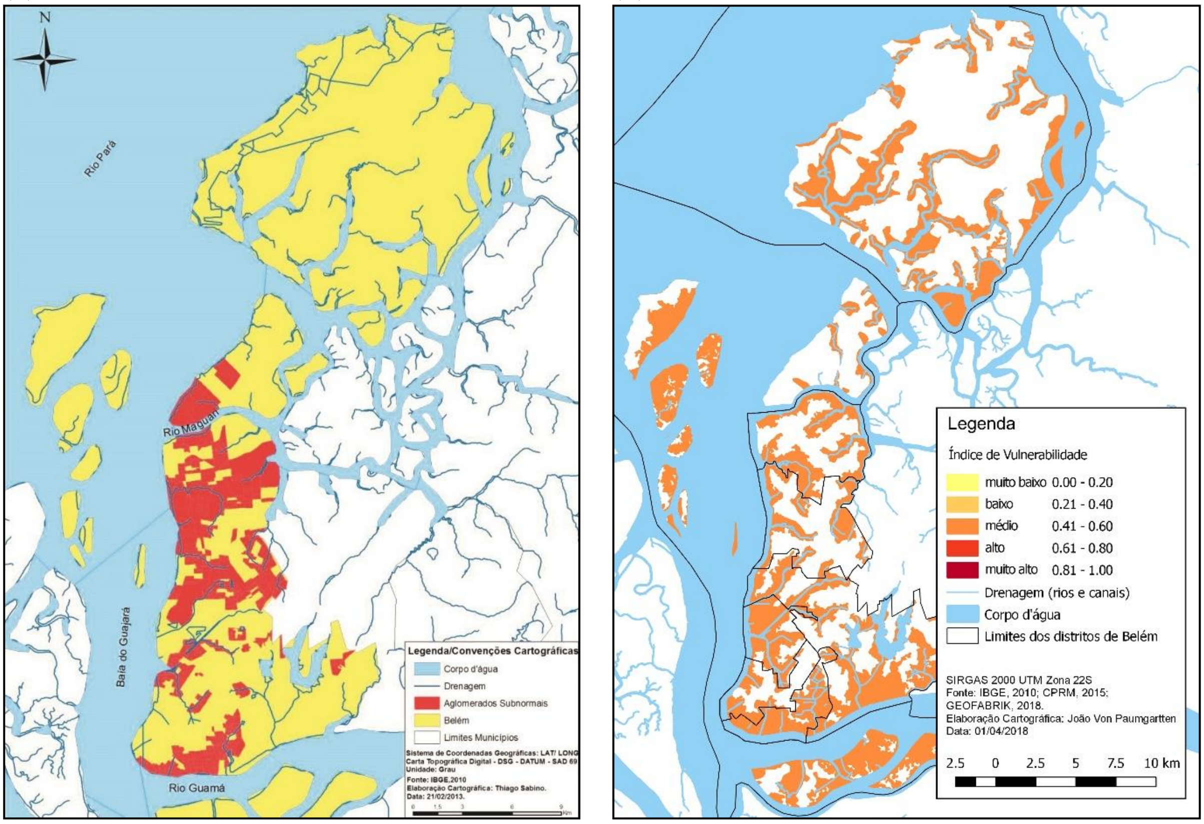
According to the figure above, it can be seen that the population exposure occurs along the adjacent drainage channels that cut through the territory, in addition to large coastal areas prone to flooding. A strong feature is the occupation of areas that are susceptible to flooding as well as unsuitable for housing by irregular housing.

Regarding the vulnerability indexes, all districts are between 0.41 and 0.60, so they have a medium vulnerability index. The results show that the population is more exposed than vulnerable, however, it is worth mentioning that most of the vulnerability indicators used are on a municipal or state scale, which influences less distinction among districts.

It cannot be overlooked that Belém has large areas of subnormal agglomerations and that these occupations influence the increase in vulnerability due to its characteristics. In Figure 2, the vulnerability index map is presented together with the map of the subnormal agglomerations.

Figure 2: (a) Map of subnormal agglomerations; (b) Map of the vulnerability index

(a) (b)

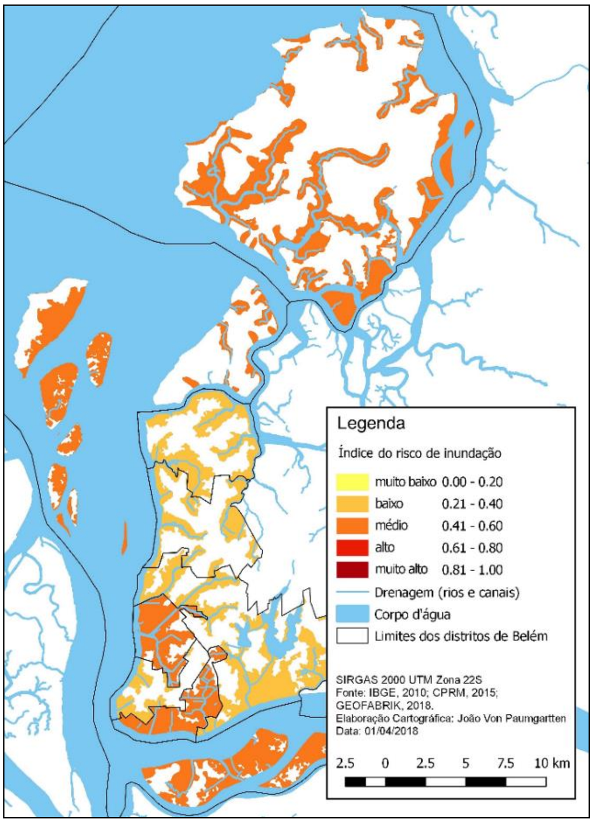


Source: (a) PINHEIRO (2015); (b) developed by the authors.

It can be seen in the above figure that Belém contains small areas of subnormal agglomerations and presents the lowest vulnerability index (0.450). Entroncamento (0.475), Sacramenta (0.479), Guamá (0.499), Outeiro (0.505), Icoaraci (0.507), and Benguí (0.517) have large areas of subnormal agglomerations and are also the ones with the highest vulnerability indexes. Mosqueiro (0.486) is historically known to have a predominance of the rural aspect and its peculiar deficiencies in both basic sanitation and urban infrastructure.

Therefore, at the end of the flood risk index calculation, Belém (0.297), Entroncamento (0.316), Benguí (0.329), and Icoaraci (0.366) had a low index rating, while Outeiro (0.418), Sacramenta (0.453), Mosqueiro (0.454), and Guamá (0.496) obtained medium indexes. In Figure 3, the map of the flood risk index of the municipality of Belém is presented.

Figure 3: Flood risk index



From this topic, the results of the social perception of risk are presented, starting with the profile of the interviewees. Gender, age, education, and occupation: **male (66.01%), 15 to 29 years (62.56%), incomplete higher education (50%), student (39.41%) or student/worker (26.60%)**. This profile can be justified by the large participation of students and employees of the Federal University of Pará.

When analyzing the answers about the district of residence, it is observed that a large portion lives in Belém (29.06%) and Sacramenta (23.40%). The percentages of Benguí (15.27%), Guamá (12.56 %), and Entroncamento (11.58%) are close, while the percentages of Icoaraci (3.45%), Mosqueiro (2.22%), and Outeiro (2.46%) are relatively low, considering that these districts are located at a much greater distance from the city center, making it more difficult to apply questionnaires in those areas. The results of the questions that involve the population living with floods are presented below, classified by district:

Table 4: Living with floods

Administrative District	6. (…) option that best reflects the feeling of risk:	7. Remembers flood events in the district of residence:	8. (…) option that best reflects the frequency of flood episodes in the district of residence:	9. Have been directly affected in any flood episode:	10. (…) which losses or damages were experienced in the flood episodes
Belém	Robbery 74% Flood 5%	Yes 59%	Annually 36%	No 35%; Yes 65%	Loss of automobiles / motorcycles 24%
Benguí	Robbery 74% Flood 7%	Yes 68%	Monthly 40%	Yes 100%	Other: interdiction on public roads to access my home 58%
Entroncamento	Robbery 76% Flood 6%	Yes 60%	Monthly 32%	Yes 100%	Other: traffic disorder 52%
Guamá	Robbery 77% Flood 6%	Yes 82%	Weekly 43%	Yes 100%	Loss of furniture / equipment 44%
Icoaraci	Robbery 79% Flood 0%	Yes 50%	Monthly 57%	Yes 100%	Other: interdiction on public roads to access my home 37%
Mosqueiro	Robbery 78% Flood 0%	No 67%	Monthly 67%	Yes 100%	Loss of furniture / equipment 67%
Outeiro	Robbery 100% Flood 0%	No 50%	Monthly 60%	Yes 100%	Loss of furniture / equipment 60%
Sacramenta	Robbery 79% Flood 4%	Yes 62%	Weekly 41%	Yes 100%	Loss of furniture / equipment 35%

Regarding awareness, the risk is best translated by the word robbery, chosen by the majority of interviewees in all districts (above 73% in each district). This data reveals that the population does not perceive flooding as the main risk and, in some districts, it is not even perceived as a risk. Instead, the risk of being robbed is what most concerns.

Regarding memory, interviewees were asked if they remember the occurrence of floods in the district of residence. Mosqueiro and Outeiro had higher percentages for the answer "No". All other districts had higher percentages for the answer "Yes" and those interviewees who answered "No" or "I don't know" did not answer the following questions. Consequently, it is understood that throughout the municipality, part of the population has already witnessed some flood events.

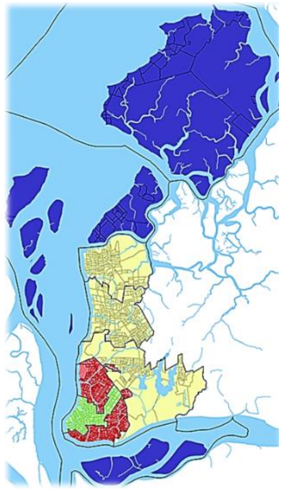
Regarding the frequency of flood events in the district of residence, the option "Monthly" is the most chosen among Benguí, Entroncamento, Icoaraci, Mosqueiro, and Outeiro. Belém presented the highest percentage for the answer "Annually", which can be considered the lowest frequency in the municipality. Guamá and Sacramenta had the worst ranking of interviewees who indicated the answer "Weekly".

The district of Belém had the highest percentage of interviewees whose cars or motorcycles have been damaged. In Benguí and Icoaraci, the interviewees suffered from interdiction on public roads to access their homes, similar to Entroncamento, where the interviewees suffered from traffic disorder. In Mosqueiro, Outeiro, Guamá, and Sacramenta, the interviewees had both their furniture and equipment damaged. In this way, it is noticed that the damages and losses are related to the means of transport and urban mobility or furniture and equipment.

Therefore, when completing the development of the analyses through the combination of technical and social perception, four areas of risk are identified according to the similarities and differences that characterize them. Certainly, these perceptions converge, making it possible to logically structure a table with the results obtained and consolidate the possibility of integrating them, as shown in Table 5:

Table 5: Technical and social perception of flood risk

Areas:		Belém	Entroncamento, Benguí, and Icoaraci	Outeiro and Mosqueiro	Guamá and Sacramenta
Technical perception	Flood risk index	Low	Low	Medium	Medium
	Exposure index	High	High	Very high	Very high
	Vulnerability index	Medium	Medium	Medium	Medium
Social perception	Flood frequency	Annually	Monthly	Monthly	Weekly
	Experienced losses or damages	Loss of cars /motorcycle	Other: traffic disorder; Other: interdiction on public roads to access my home	Loss of furniture / equipment	Loss of furniture / equipment



The spatial heterogeneity of risk is perceived on a direct link to the historical process of urbanization due to the dynamics of the city's development. The formation of the central area (green area) was configured on the high and sanitized lands, occupied by families of higher income while in its surroundings, low and floodable land (red area) became alternatives for poorer families (RODRIGUES *et al*, 2013).

In the expansion area (yellow area), the occupation had occurred spontaneously, in most cases with precarious urban infrastructure, having large land lots with physical configurations of areas prone to flooding (RODRIGUES *et al*, 2013). The districts of Outeiro and Mosqueiro (blue area), also part of the expansion area but formed by groups of islands, concentrate the lowest demographic densities and urban infrastructure (PEREIRA, 2009).

Conclusion

Firstly, the flood risk index was a useful tool for producing information, resulting in thematic maps of risk and vulnerability by the use of GIS. It is worth noting that there is a substantial generalization of vulnerability indicators, considering that they are available, in the vast majority, in numerical tables incompatible with the GIS format or solely in percentages. Therefore, it is interesting that these data are made available as georeferenced files.

Another issue is the lack of a probabilistic component, given that demographic information from the 2010 Census was used and also due to the difference in years among the indicators' databases.

Then, the social perception of flood risk was developed through a participatory process of the population, resulting in collected information that contributed to the characterization of the risk. The application of the questionnaire has become a challenge of communication and consultation to citizens, successfully overcome beyond expectations, given the production of information close to the reality of the municipality of Belém.

Concerning its limitations, the questionnaire presented a relative diversity of the interviewed public since each district showed a different percentage of responses, this would allow the analysis of the most reliable social perception for each area.

Therefore, it can be concluded that the quantitative survey of the exposure and vulnerability indicators, as well as popular participation, allowed a qualitative comparative assessment among the districts that compose the study area. The flood risk index is an essential spatial analysis tool to support decision making, especially because it considers indicators from different sorts for a global analysis of the real situations that the municipality has faced and, in the same way, the questionnaire was established as a tool for social analysis.

It is also recommended for future research to work together with experts from environmental, sanitary, and water resources engineering, among others, to enrich this study through a holistic view, by adding a greater amount of information from different points of view. Such a study would bring a greater understanding of the extent of flood risk by adopting a multifaceted approach, resulting in a document rich in details for flood equalization.

Lastly, it is recommended to carry out a comparative study between cities that present flood events and have implemented projects that have been successful in solving these problems.

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