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GRADUATE PROGRAM IN HYDRAULIC ENGINEERING AND SANITATION

HAILTON CÉSAR PIMENTEL FIALHO

Socio-hydrological aspects of floods in commercial areas in two Brazilian basins.

Corrected Version

São Carlos - SP

2021

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Socio-hydrological aspects of floods in commercial areas in two Brazilian basins.

Original version

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ABSTRACT

Fialho, H. C. P. (2021). *Socio-hydrological aspects of floods in commercial areas in two Brazilian basins.* (Master Thesis). São Carlos School of Engineering, University of São Paulo, São Carlos.

The frequency of flood events has increased during the last decades in Brazil. Yet, there is a lack of studies investigating citizen adaptation measures. Therefore, we studied adaptation measures used by shopkeepers to protect themselves and their businesses against floods in two different basins to verify what drives the changes in protection. Both study areas are characterized as commercial areas with major flood problem. First, the Gregorio basin located in the city of São Carlos, south-eastern Brazil with an average annual total rain of 1,361.6 mm, and the second is the Tamandaré basin located in the city of Belém, north of Brazil, with average annual rainfall of 4,000 mm the Köppen climate classification system is Cwa and Af respectively. In Gregorio basin we conducted in person interviews with twenty-three (23) merchants to collect information about a flood occurred in January 12th, 2020, characterized by a return period of 103 years. Comparing our findings with previous work in the area, we found that people increased the flood gates' height more than 4-fold between 2015 to 2020. In Tamandaré basin we applied a questionnaire with forty-three (43) merchants to collect their viewpoints about the agents that cause the floods and what are the main implications of floods to their businesses. According to the merchants, the high tide is the main cause of flooding in the area, causing socioeconomic losses of up to 50% of their monthly income. Comparing the two basins, Gregorio suffers from floods caused by intense precipitation, the impermeabilization of the basin, and a high inclination of the land. The merchants then respond by improving their individual protection, by raising their floodgates, to prevent major damages. The Tamandaré basin, on the other hand, suffers from flooding from high tides, allowing the water to enter the drainage system, coupled with high precipitation rates which is very frequent in March and April. The merchants protect their merchandise from water but in general they don't use any structural protection to deal with the flood. The similarities stem from the fact that in neither of the basins the shopkeepers intend to move to a place with less risk because the areas are traditional commercial places since the foundation of the cities.

Keywords: socio-hydrology, flood risk, flood protection, economic loss, commercial properties.

RESUMO

Fialho, H. C. P. (2021). *Aspectos sócio-hidrológicos de enchentes em áreas comerciais em duas bacias Brasileiras.* (Dissertação de Mestrado). Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos.

A frequência de eventos de inundação aumentou durante as últimas décadas no Brasil. No entanto, faltam estudos que investiguem as medidas de adaptação dos cidadãos. Portanto, estudamos as medidas utilizadas pelos lojistas para se protegerem, e a seus negócios, contra enchentes em duas bacias diferentes para verificar o que impulsiona as mudanças na proteção. Ambas as áreas de estudo são caracterizadas como áreas comerciais com grande problema de inundação. Em primeiro lugar, a bacia do Gregório localizada na cidade de São Carlos, sudeste do Brasil com uma precipitação média anual total de 1.361,6 mm, e a segunda é a bacia do Tamandaré localizada na cidade de Belém, norte do Brasil, com precipitação média anual de 4.000 mm, o sistema de classificação climática de Köppen é Cwa e Af, respectivamente. Na bacia do Gregório realizamos entrevistas presenciais com vinte e três (23) comerciantes para coleta de informações sobre uma enchente ocorrida em 12 de janeiro de 2020, caracterizada por um período de retorno de 103 anos. Comparando nossas descobertas com trabalhos anteriores na área, descobrimos que as pessoas aumentaram a altura das comportas em mais de 4 vezes entre 2015 e 2020. Na bacia do Tamandaré aplicamos um questionário com quarenta e três (43) comerciantes para coletar seus pontos de vista sobre os agentes que causam as enchentes e quais são as principais implicações para seus negócios. Segundo os comerciantes, a maré alta é a principal causa das enchentes na região, causando perdas socioeconômicas de até 50% da renda mensal. Comparando as duas bacias, Gregório sofre com enchentes causadas por chuvas intensas, a impermeabilização da bacia e a alta inclinação do terreno. Os comerciantes, então, respondem melhorando sua proteção individual, levantando suas comportas para evitar danos maiores. A bacia do Tamandaré, por outro lado, sofre inundações com as marés altas, permitindo a entrada de água na rede de drenagem, associada a altas taxas de precipitação que são muito frequentes nos meses de março e abril. Os comerciantes protegem suas mercadorias da água, mas em geral não usam nenhuma proteção estrutural para lidar com a enchente. As semelhanças decorrem do fato de que em

nenhuma das bacias os lojistas pretendem se deslocar para um local de menor risco, pois as áreas são tradicionais locais de comércio desde a fundação das cidades.

Palavras chave: socio-hidrologia, risco de inundação, proteção contra inundação, perda econômica, propriedades comerciais.

LIST OF FIGURES

LIST OF CHARTS

LIST OF TABLES

TABLE OF CONTENTS

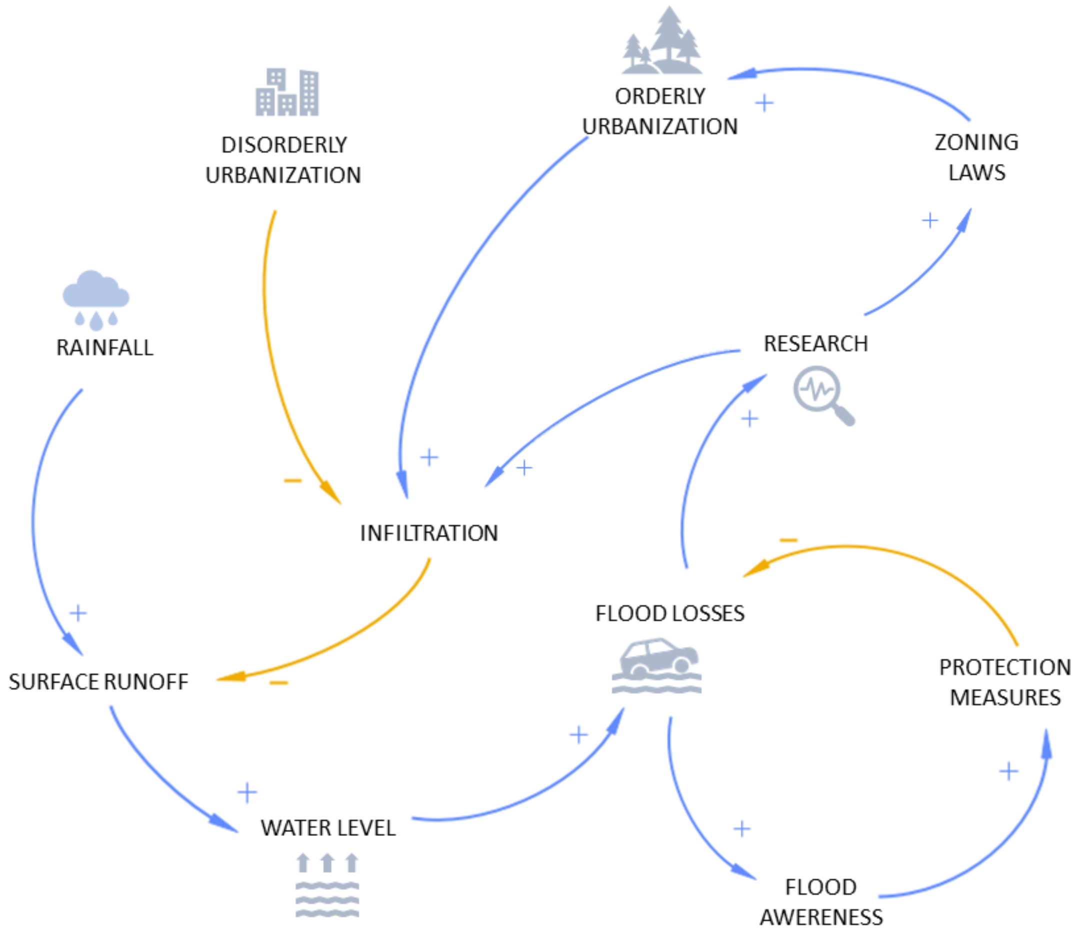
1 GENERAL INTRODUCTION

Due to the climate change scenario and the increase in extreme events such as floods and droughts, new technologies have been developed to obtain and manage hydrological data (MOSS et al., 2010). Despite technological advances, forecasting in basins with little or no measurement and measuring the damage caused by disasters are still major challenges (SIVAPALAN et al., 2003). Part of this problem can be solved by the population, through individual observation, transforming their experience into scientific data (BUYTAERT et al., 2014). Using volunteers to carry out a specific task, such as environmental monitoring, they become a Citizen Observatory, which is a platform to gather voluntary information on a specific topic (SOUZA, 2019).

In Brazil, around 60 million people deal with daily risks in more than 40,000 risk-prone Brazilian areas, and this number will increase in 2035, reaching 73 million people (PNSH. 2019).Floods represented 34.9% of disasters that happened between 2000 and 2015 followed by landslide. (DE FREITAS et al., 2020). In this scenario, social perception can help to improve resilience in risk areas, as citizen engagement plays an important role in decision-making (MCKINLEY et al., 2017). The commercial zones in Brazil are usually areas with high rates of soil sealing, rivers canalization and occupation of floodplains, which foment the generation of floods (CAMPOS et al. 2021).

Figure 1 shows the causal loop diagram of flood. Disorderly urbanization reduces the infiltration due to soil sealing. The precipitation and the reduced infiltration increase the surface runoff, which, increases the water level, promoting the occurrence of flood generating flood losses, whether by loss of products, suspension of activities or expenses with cleaning. After a flood there is an increasing in flood awareness and protection measures to reduce flood losses. Those flood losses increase the research for effective solutions to this problem, either through compensatory techniques, for urban drainage, which increases the infiltration, or through new zoning laws promoting an orderly urbanization in order to increase the infiltration decreasing the surface runoff and preventing flood.

Figure 1 - Causal loop diagram



Source: Prepared by the author (2021)

1.1 Text Organization

Four chapters compose this master thesis. Chapter 1 is dedicated to a general overview of the study. It presents the study's hypothesis, goals and objectives. In chapter 2 was presented the study case of a flood happened on January 12th 2020 in São Carlos municipality that caused great damage to the commercial area of the city where 23 shopkeepers shared their experience of dealing with floods. In chapter 3 we carried out a socio-hydrological study in the commercial area of the city of Belém applying a questionnaire to the shopkeepers and street vendors to check their perception about floods. Finally, chapter 4 brings the general conclusions of this study and recommendations for future works.

1.2 Research Problem

The social perception of floods can shape the behavior and protection measures for different types of society?

1.3 Goals and Objectives

1.3.1 Goal

To classify type of society and its perception of floods in basins with different physical and hydrological characteristics.

1.3.2 Objectives

- Analyze flood risk reduction measures related to social aspects;
- Characterize the basins according to their memory acquisition through protective measures against floods applied to reduce damage.

1.4 References

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2 ANTICIPATED MEMORIES AND ADAPTATION FROM PAST FLOOD EVENTS IN GREGORIO BASIN, BRAZIL.

A modified version of this chapter will be submitted to Water as: FIALHO, H. C. P.; ABREU, F. G.; SOUSA, B. J. DE O.; SOUZA, F. A. A.; MIS, N. B.; MENDIONDO, E. M.; DE OLIVEIRA, P. T. S. Anticipated memories and adaptation from past flood events in Gregorio basin, Brazil.

Abstract: In this research we used walking interviews as the method to investigate the measures used by shopkeepers as protection against floods. The concept of anticipated memory has been used to identify the relationship between their learning from previous events and the adaptive measures they have taken to reduce risk of flooding in the future in Gregorio basin. The area is affected by major flood problems in the city of São Carlos, southeastern Brazil. Twenty three (23) downtown merchants participated in the walking interview and shared their experience of the extreme rainfall that occurred on January 12th, 2020, characterized by a return period over 100 years with an observed intensity of 79.2 mm/hour. Comparing our findings with from November 2015 and March 2018 (Interviews 37 and 52 respectively) we noted that due to the enhanced level of threat people have increased the sum of flood gate's height more than 4-fold (870 cm to 3,830 cm) between 2015 to 2020. Our results showed that despite frequent flooding the shopkeepers downtown are reluctant to move away from the area rather they prefer to improve their individual protection. After 2020's flood, from a sample of 52 stores, only 6% moved to a new place, and 74% showed interest in getting flood insurance but their willingness to pay is much lower than (about 6%) their average loss. The substantial increase in the height of floodgates represents the population's feedback in face of a new threat's level. Therefore, it illustrates the interaction between society and floods in this catchment and the accumulation of memories from past events. Acknowledging the limitation of the sample size this study highlights the recurrent behavior of the commercial property owners that occupy the basin.

Keywords: Flood risk; Socio-Hydrology; Memory; Flood protection, commercial property

2.1 INTRODUCTION

Floods are the disasters that most cause material and human losses worldwide, even with billions of dollars of investments in disaster risk reduction, which have been being aggravated by urbanization and climate change (Aerts, 2020). In developing countries, the effects of floods are exacerbated due to unplanned urban growth, lack of public policies and risk management (Barros et al., 2021). In Brazil, according to the National Center for Monitoring and Alerts for Natural Disasters - CEMADEN, there are currently 40,000 mapped risk areas in the 958 monitored municipalities (about 20% of Brazilian municipalities), where 3,986 correspond to flood risk areas (Fava, 2019). Then, because of the impossibility of completely eliminating floods, many countries seek to devise ways to deal with losses (Leal et al., 2019).

Resilience is extremely important because delays increased social and economic pain (Dinh et al., 2021). Di Baldassare (2015) claims that, in flood risk assessment, there is an adaptive effect related to the observation that the higher frequency of floods is also associated with the decrease in vulnerability. The author found empirically that the impacts of a flood event are less when events of the same magnitude occur after short periods of time. For the author, this effect can be attributed to the ability to adapt acquired during such flood events. Thus, it is considered that future projections related to flood risk may bring unrealistic information about the situation.

Recent studies have shown that there are four expected types of society that deal with flood: i. risk neglecting it does not adopt protective measures because they believe it is impossible to manage risk; ii. risk monitoring, they use inclusive bottom-up strategies to address their risk; iii. risk downplaying, they underestimate environmental risk and do not see the need for collective actions; and iv. risk controlling, this society relies in protective measures system increasing its height after extreme events (Ridolfi et. al., 2020). It has been said that societies that rely on top-down hierarchies and structural measures as protection against flood, may still suffer high losses in extreme events. Meanwhile societies that invest in increasing awareness through inclusive and participatory approaches have flood losses reduced (Ridolfi, et. al., 2020). According to Garde-Hansen et al. (2017), for communities to be aware of flooding (prepare and take action) as a form of socio-ecological resilience, they need to record memories and remember events in some way. According to Folke (2006), memory is described as the accumulated experience based on the history of a system, which provides the basis for identifying sources of renewal, innovation, recombination, self-organization and innovation after stressful conditions.

The memory is a key point to improve resilience of a system, according to Wilkinson (2012), resilience is the capacity of the system to renew, reorganize and regenerate from the stress. It can encapsulate the process of response to challenges or adversity, positive outcome of coping, and the capacity to create adaptive responses to obtain desired outcomes (Liu et al., 2020). In order to collect data about resilience the use of interview, questionnaire and survey emerge as important methodologies.

The use of survey to acquire information about social response to extreme event is not new, McBean et al. (1988) applied a questionnaire to seven communities in the province of Ontario, Canada, which included registration information of the people affected, as well as the type of structure, description of the content of each part of the residences and costs of goods in a total of 287 interviews. Smith & Freedy, (2000) used a questionnaire to examine the role of psychosocial resource loss in the aftermath of floods of the 131 participants who lived in eight flooded communities along the Missouri and Mississippi rivers. Terpstra & Gutteling, (2008) applied an Internet survey in the province of Friesland in The Netherlands, to explore Dutch households' perceived responsibility for taking private protection measures against flood. A questionnaire survey of 719 randomly sampled respondents was conducted in 16 subdistricts of Jingdezhen to investigate the public flood risk perception by Wang (2018).

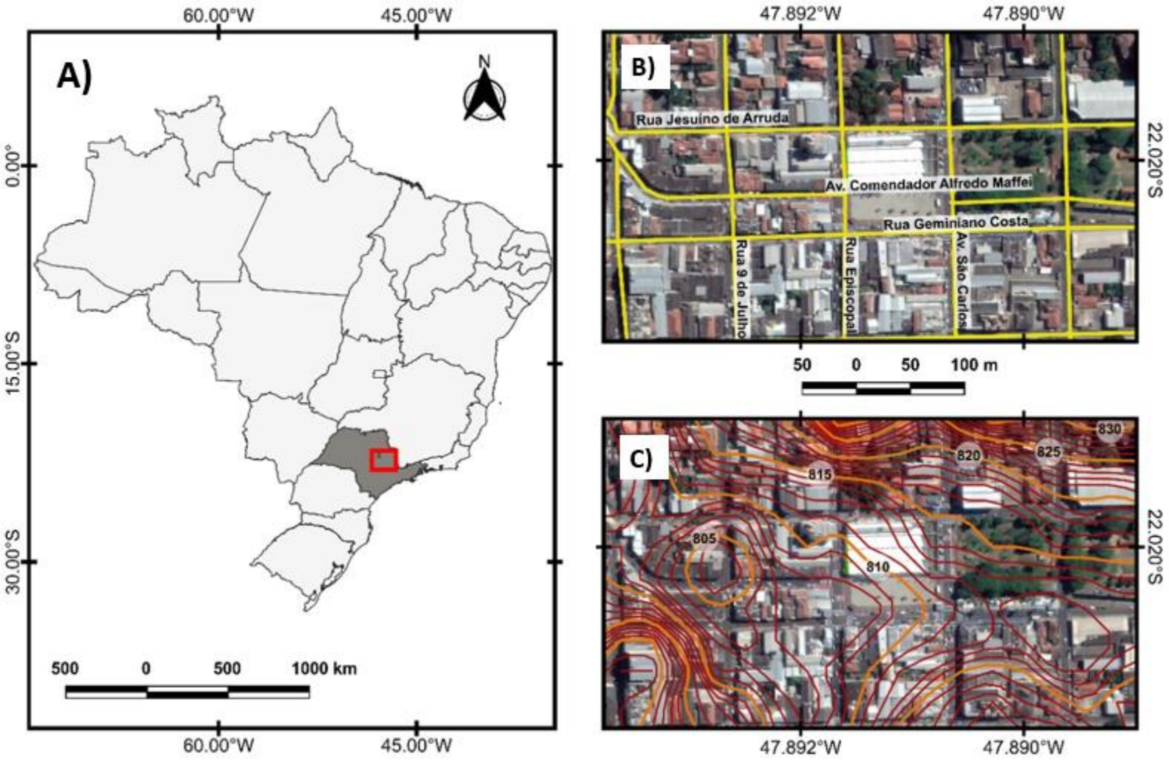
In Brazil, Lima (2003) constructed histograms through interviews with the affected population in the city of Itajubá, Brazil, the result was presented in terms of average values of flood damage as a function of submerged depth ranges. Righetto et al. (2004) carried out a survey of the damage after a flood recorded in the municipal market region (the same considered in the present study), located in the Gregório stream basin, in January 2004 (São Carlos - SP), through interviews with 14 shopkeepers. Although the frequency of flood events has increased during the last decades in Brazil, just a few measures have been done to address this hazard and only a few are effective.

The objective of this study is to investigate if the measures used by shopkeepers as protection against flood are related to acquired memories from previous events in a basin with major flood problems in São Carlos, southeastern Brazil. Urbanization started in the municipality in the 18th century at the western part of the Gregório Creek catchment. Mendes and Mendiondo (2007) divided the period after the first flood record into three stages related to the urbanization rate in the catchment. In the first stage, from 1950 to 1970, second from 1970 to 1980 and the third from 1980 to 2002. Sarmento (2020), introduced a fourth stage ranging from 2004 to 2018, where the urbanization rate nearly doubled. From the first stage until fourth, the urbanized area increased from three to fourteen square kilometers, approximately 75% of the total. The studied basin suffers with constant flood events. We address the population’s preparedness against these events and also show the measures shopkeepers have been taking as protection tools. Three events are used to build a scenario, 2015, 2018 and 2020 with 17, 8 and 103 years of return period respectively. Our study shows how people can respond to a new level of threat from flooding and how the accumulation of memories improves the individual protection.

2.2 MATERIALS AND METHODS

The Gregório Creek catchment is located in the city of Sao Carlos - SP, in Brazil's southeast region, and has a total area of 18.9 km² (Barros et al. 2007). Floods have a greater impact in the commercial area of the municipality of São Carlos (see Figure 2). According to the Köppen climate classification system, the climate in the studied watershed is Cwa, humid temperate, with a dry winter from June to September and a hot and rainy summer from December to March the predominant soil class is purple, dark red and yellow red latosol (Alvarez et al., 2014). It has an average annual total rain of 1361.6 mm, with the month of January being the rainiest, with 274.7 mm, on average, and August the least rainy, with 22.8 mm, on average (EMBRAPA, 2020).

Figure 2: Map of the case study. Part A) presents the location of the São Carlos city, and items B) and C) presents the region affected by the floods. Item B) presents the streets names surrounding the area, while item C) presents the topography of this region.



Source: Prepared by the author (2021)

A survey was created on the Google Forms © the platform was of great help, since it is capable of generating reports with the collected data, presenting predetermined automatic calculations, the possibility of including photographs of the location, as well as the collection of geographic coordinates and the ease exporting to Excel. The questionnaire applied to commercial properties' owners or managers was built using previous findings obtained by Abreu's (2019).

Abreu (2019) performed interviews in 52 stores (Figure 3) from April to May 2019 addressing the extreme events of November 23th 2015 and March 20th 2018, of which only 37 stores were located at the same spot in 2015. In January 2020 a new survey was applied in 23 stores about January 12th 2020's event. The 52 stores chosen by Abreu (2019) and the 23 of this work were chosen from 141 stores with potential of damage on the extension of the floodplain (based on observation data). The questions applied are shown in Chart 1.

Chart 1: Questionnaire of flood impacts in the commercial center of São Carlos/SP.

CHART 1 - QUESTIONNAIRE OF FLOOD IMPACTS IN THE COMMERCIAL CENTER OF SÃO CARLOS - SP.
1. NAME
2. ADDRESS
3. COMMERCIAL ACTIVITY
a. DEPARTMENT STORES, WAREHOUSE ITEMS, CLOTHING AND FABRICS, SHOE AND LEATHER PRODUCTS b. FURNITURE, ELECTRIC HOUSEHOLD APPLIANCES, COMPUTER EQUIPMENT c. PHARMACEUTICAL PRODUCTS, PERFUMERIES AND COSMETICS d. JEWELRY SHOPS, WATCHES AND OPTICS e. RESTAURANTS, SNACKS, BARS AND COFFEE f. NEWSSTAND AND STATIONERY
4. GROUND PLAN HEIGHT IN RELATION TO THE SIDEWALK (CM)
5. WATER LEVEL INSIDE THE ESTABLISHMENT (CM)
6. WATER LEVEL OUTSIDE THE ESTABLISHMENT (CM)
7. HOW LONG DOES THE ESTABLISHMENT EXIST AT THIS ADDRESS? (YEARS OLD)
8. DOES IT HAVE A FLOODGATE? a. YES b. NO
9. FLOODGATE HEIGHT (CM)
10. WILLINGNESS TO PAY FOR A FLOOD INSURANCE A YEAR (U$)
11. GENERAL OBSERVATIONS

Source: Prepared by the author (2021)

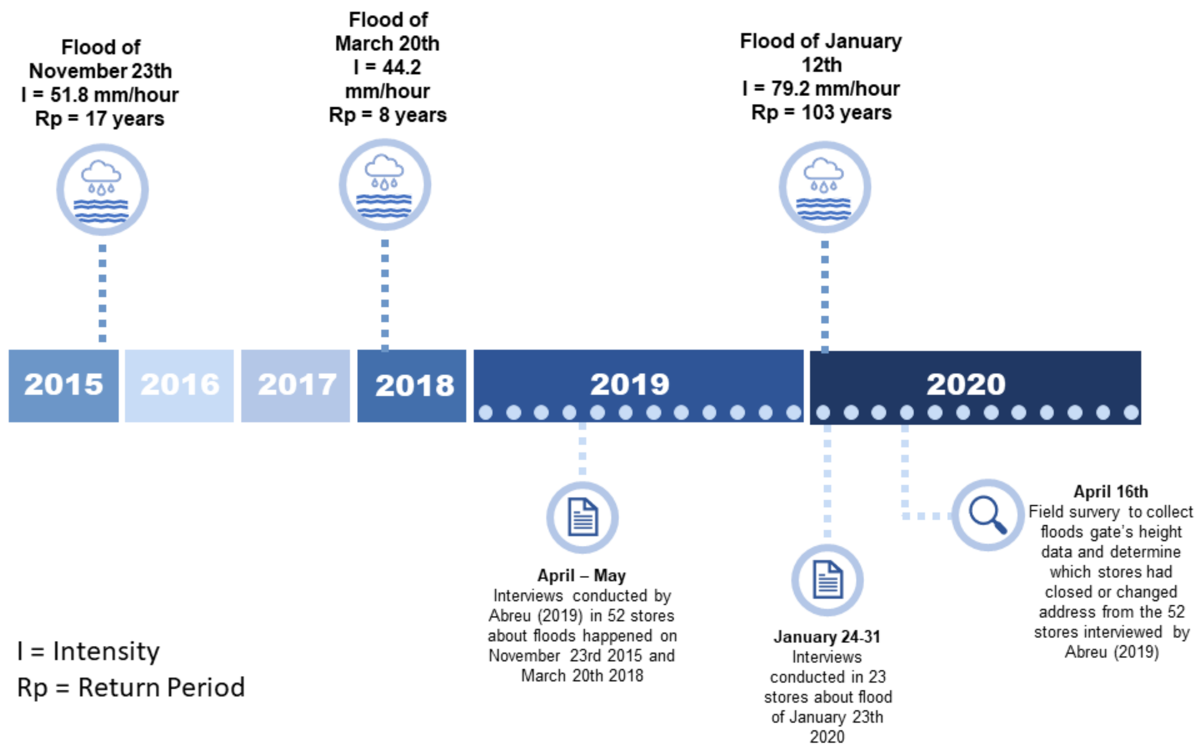
In order to classify the basin as risk neglecting, risk monitoring, risk downplaying or risk controlling we performed a cluster analysis using the K means method that is an algorithm clustering which groups data based on cluster center point closest to data. Its purpose is grouping data with maximum similarity in one cluster and minimize data similarity between clusters (Nainggolan et al., 2019). The questions used to the cluster analysis were "HOW LONG DOES THE ESTABLISHMENT EXIST AT THIS ADDRESS? (YEARS OLD)" and "FLOODGATE HEIGHT (CM)".

Figure 3: The 52 stores interviewed by Abreu (2019).

Source: Prepared by the author (2021)

The choice of the 3 events, 2015, 2018 and 2020 were made due to the magnitude of them that caused a lot of inconvenience and damage to shopkeepers in the region (see Figure 2), which corresponds to a densely urbanized area, with several commercial establishments located on the banks of the Gregório Creek, deserving greater attention. The analysis of historical series was performed using the pluviograph 354890601A (CEMADEN), located in the Gregório Creek basin and the return period was determined based on the most used local IDF equation for the municipality of São Carlos (Barbassa, 1991). In addition, another field survey was carried out in April 2020 to collect floodgate height data and determine which stores had closed or changed addresses, from the 52 stores interviewed by Abreu (2019) in 2019. Figure 4 shows a timeline with the flood events, interviews and field survey conducted. Regarding the geographic organization of the area, Rua Episcopal (Episcopal street) is the 1st floodplain transect to the perpendicular creek. Following is the Rua 9 de Julho (9 de julho street) which is the second floodplain transect perpendicular to the creek. Av. Comendador Alfredo Maffei (Comendador Alfredo Maffei street), on the other hand runs above the river from the intersection with Av. São Carlos (São Carlos avenue). At last, Rua Geminiano Costa (Geminiano Costa street) is the first street parallel to the creek at the left margin.

Figure 4: Timeline of floods considered, and interviews and field surveys conducted.



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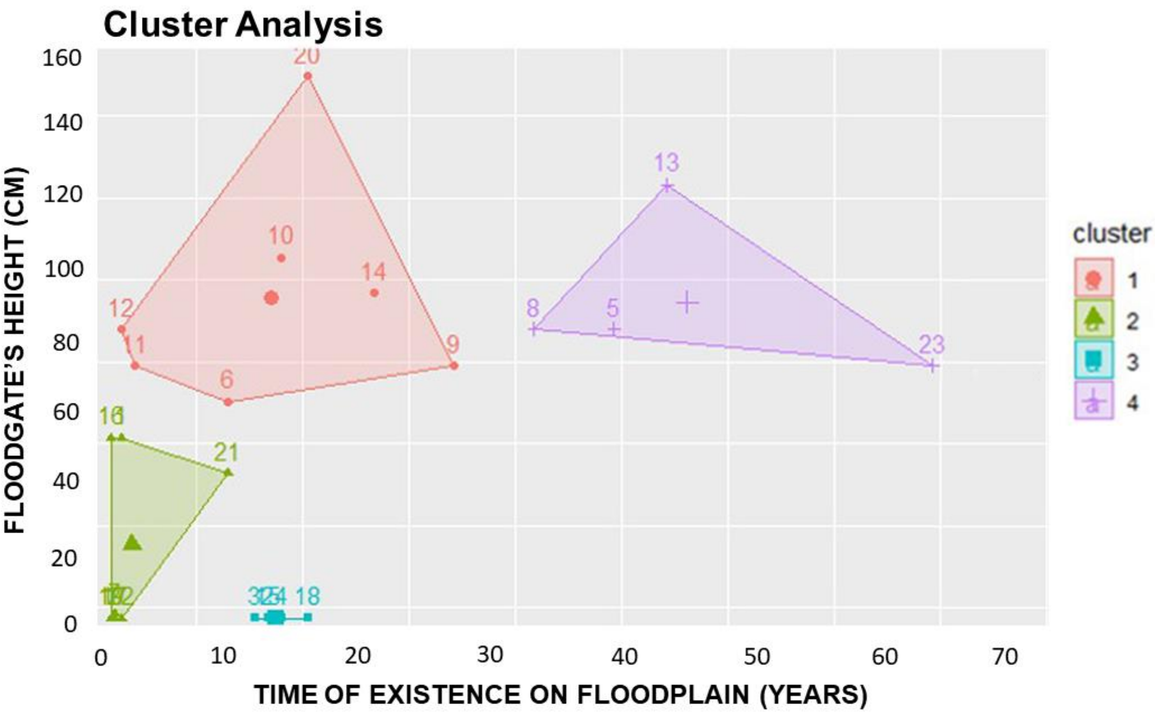
2.3 RESULTS

2.3.1 Ideal types of society

The Gregorio basin has faced several flood events since urbanization started and few measures have been done to increase people's awareness and preparedness against extreme events. In the real world there are a mixture of the 4 ideal types of societies of Ridolfi (2020). Figure 5 shows the distribution of the interviewers into four clusters, 1 and 2 having more representativeness followed by 3 and 4 respectively.

Figure 5: Cluster analysis of ideal types of society.



Source: Prepared by the author (2021)

Cluster 1 has 7 stores (30%) its floodgate height and the existing time varying from 60 to 150cm and 1 to 26 years respectively. It can be classified as risk controlling society, characterized by top-down perspective and use of structure measures as protection that are increased in height over time. Events with water level lower than protection are quickly forgotten and no major losses are recorded while extreme events cause high losses and refresh their memory which decreases as long as no flood is experienced, creating a feeling of safety. Cluster 2 has 7 stores (30%), floodgate height and the existing time varying from 0 to 50cm and 0.2 to 9 years respectively. It can be classified as risk downplaying society that underestimate hydrological extremes, they have no intention of being relocated in case of flood occurrence. Cluster 3 has 5 stores (22%), does not have floodgate and the existing time varying from 11 to 15 years. It can be classified as risk neglecting society characterized by does not adopt any measure for preparedness. The population will not move to another location, regardless of whether the settlement is on a floodplain. Cluster 4 has 4 stores (17%), floodgate height and the existing time varying from 70 to 120cm and 32 to 62 years respectively. Its classification is risk monitoring society this society is aware of being in a precarious balance that can be disturbed if risk is not addressed correctly. It knows that its needs have to change and not nature what caused 2 stores to relocate settlements to a place with less risk.

2.3.2 Characteristics of the flood and its consequences

This paper shows how the population deals with extreme events occurred in 2015, 2018 and 2020 and the measures used after each event. For the 2015 event, the rain intensity at the most intense hour was 51.8mm / hour, which corresponds to a 17 years of return period. In the event of 2018, the most intense hour recorded was 44.2 mm / hour, which corresponds to the 8 years of return period. In 2020, the highest intensity observed was 79.2 mm / hour, which is equivalent to a return period of 103 years. Despite the floods, until 2018, all 52 merchants interviewed declared that they did not intend to leave the site since it is an important commercial spot in the city. However, after the 2020 event, due to its magnitude, 9 establishments (17%) closed and 3 (6%) changed addresses to a less risky area. Through 2020's interviews, it was observed that the main factor that caused the losses was the magnitude of the event, because, according to reports, never before had such a large amount of rainfall precipitated in a short time, more than 92 mm in three hours of precipitation of which 86% occurred in the first hour.

The flood occurred on January 12th 2020 was used to build a social flood map (see Figure 6). To create it, a field visit was made to delimit the floodplain based on the data collected from traders' reports which showed the height that the water reached at each point and how far the flood in the basin went. This map represents the flood spot accurately, as the data collected was fresh in the memory of traders as the area was still under repairs by the government. We talked to shopkeepers to schedule the interview, because several merchants did not want to talk about the flood since they were dealing with the damages trying to reorganize their businesses.

Figure 6: Social Flood Map. The colors represent an external height range reached by water according to voluntary data. The dashed line represents the floodplain of the January 12th 2020 flood.

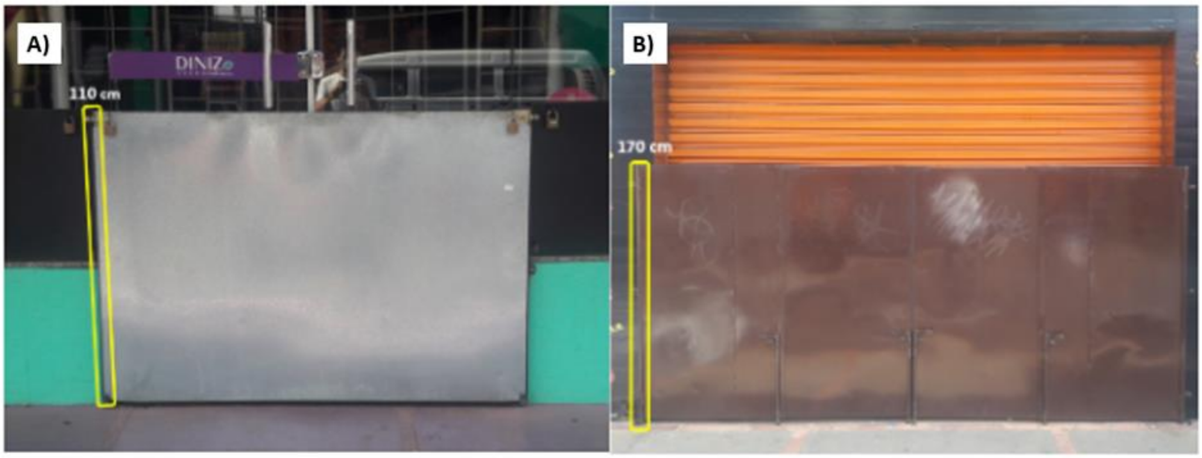
Source: Prepared by the author (2021)

The merchants, in all surveys, stated that the main factor in the level of damage of the event was the height and speed of the water, causing the dragging of objects and vehicles that were on the street. The owner of a home appliance maintenance store said that the door had always prevented the flooding inside the store, but a cart was dragged and hit it, which allowed water to enter reaching a height of 120 cm, causing damage not only in the merchandise, but in the furniture and in a vehicle that was kept inside the store. Water also invaded the establishment through the plumbing system of the building, entering through the drain and toilet. The building is rented and the store owners are thinking of changing location. It is worth noting that the owner of a traditional store registered 125 cm of water height inside the store, even with the 120 cm gates closed, water managed to invade the establishment. It was informed that he has been in this location for 42 years and that it was the biggest flood he suffered. The same owner said he will change his address, because only in January 2020 there were 3 flood events, on January 2nd, 4th and 12th, the latter being the most intense, registering 170 cm of water in front of his store. Another owner of a shoe store also reported that in the 38 years that he owns the establishment, the January 12th, 2020 flood was the most damaging.

2.3.3 Protective measures and water level

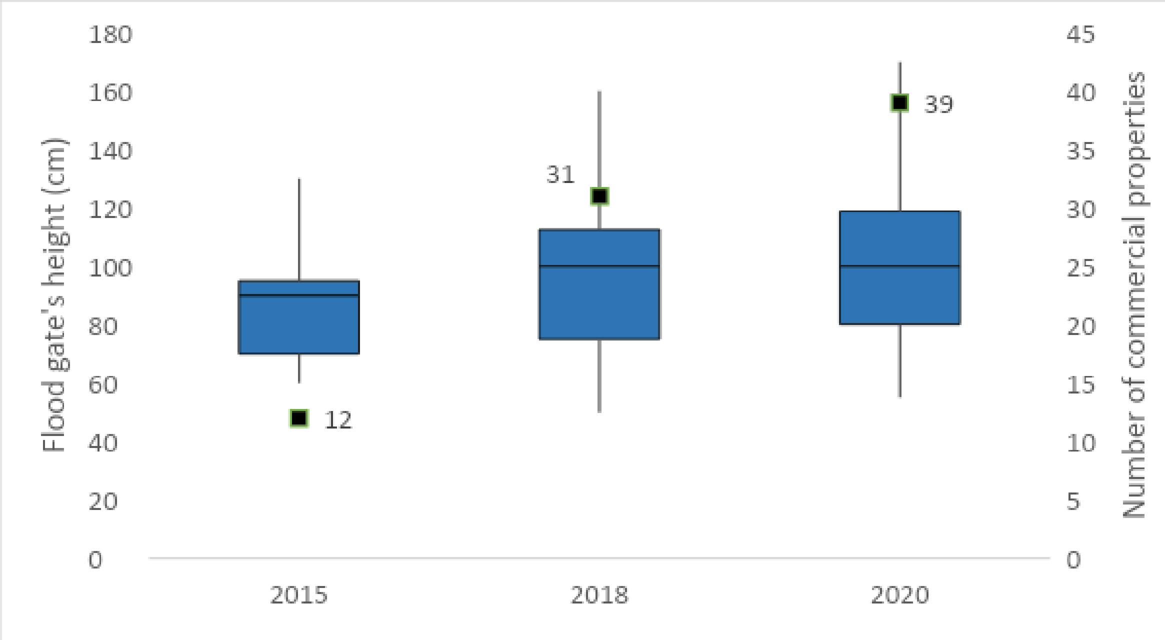
The protective structure most used by shopkeepers are floodgates (Figure 7). According to surveys conducted by Abreu (2019) and the field survey in 2020 in the flood spot, from a sample of 37 stores, in 2015, 12 (32%, average 77.5 cm) had floodgates. In 2018 from a sample of 52 stores, 31 (61%, average 92.7 cm) had gates. In 2020, from the same 52 stores surveyed by Abreu (2019), 39 (75%, average 102 cm) had floodgates. Figure 8 presents a statistical analysis in the form of a box plot of the averages of the installed gates in relation to the respective flood event. The graph shows that, even if the heights measured in 2015 are inside the height intervals found in 2018 and 2020, the median for this year is below the median for the values measured after the other two events. Therefore, we can see an increase in the floodgate's height after 2015.

Figure 7: Example of floodgates installed. A) a store located at Comendador Alfredo Maffei Avenue. B) a store located at Geminiano Costa Street. These pictures were taken on October 10th 2020.



Source: Prepared by the author (2021)

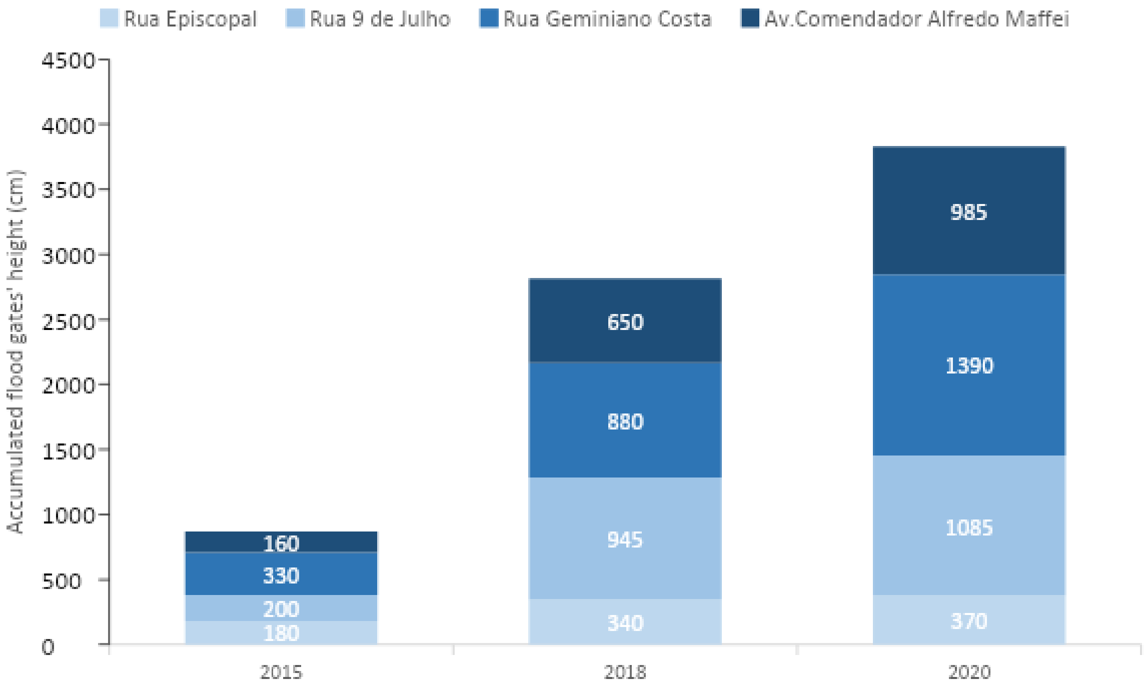
Figure 8: Variation in the height of the gates installed in the stores analyzed between the years 2015, 2018 and 2020. The square shows the number of stores that have gates from the 52 stores studied each year.



Source: Prepared by the author (2021)

Figure 9 presents the sum of floodgates' heights of the properties interviewed after the events of 2015, 2018 and 2020, discretized according to the respective streets in where they are located. This representation assesses the population's preparation for a new threat in view of their experiences accumulated in previous events. We noted that the height of the gates in 2015 were smaller than 2018 and both smaller than 2020, with the total sum of the height of the gates in 2015, 2018 and 2020 being respectively 870 cm, 2.815 cm and 3.830 cm. It was noticed that, as a mitigation measure after 2015, from the 37 stores 16 (43%) installed floodgates and 3 (8%) increased the level of existing floodgates. After 2018 from 52 stores 9 (17%) installed floodgates, 7 (13%) increased the level of existing floodgates. This substantial increase in the cumulative height of gates (Figure 8) and the average height of these gates, represents the population's feedback regarding a new threat level. That means that when they face an extreme event, they respond by raising the gate's height in order to protect themselves against floods. Therefore, it is evident the accumulation of memories resulting from the experiences lived during flood extremes.

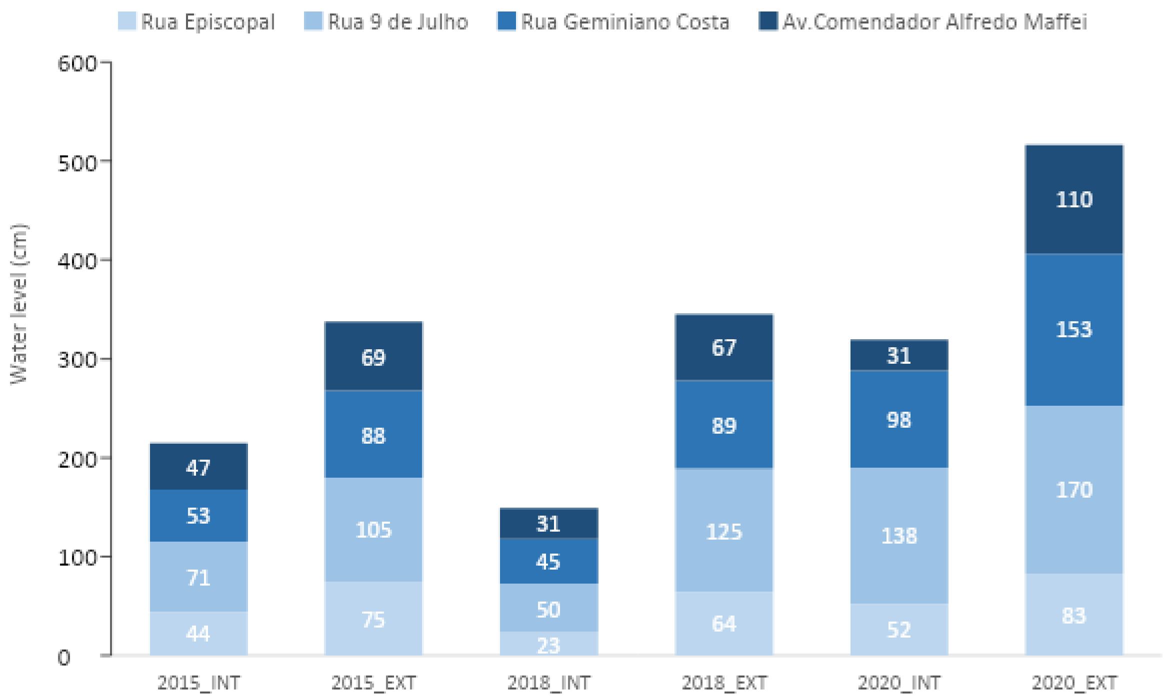
Figure 9: Sum of the flood gates' height separated by the streets considered in this study. The values increased more in the streets 9 de Julho, Geminiano Costa and Comendador Alfredo Maffei after the event of 2015.



Source: Prepared by the author (2021)

In addition to understanding the recurrence of rainfall, another variable for assessing the magnitude of events is the water level. There are two types of water level to be evaluated: the internal water level, which is the height that water reached inside the stores; and external water level, that means the water level outside the store or in the street, verified by the marks of the river sediment left on the walls of establishments. Although the internal and external water level can present the same values, this is not observed in the study area, as most merchants have structures to make it difficult for water to enter their establishment, such as raising the floor in relation to the sidewalk and / or floodgates Based on this premise. Figure 10 presents the averages of the external and internal water level surveyed in 2019 and 2020, from a sample of 37, 52 and 23 stores in 2015, 2018 and 2020 events respectively, located in the area affected by the floods. We analyzed the heights separately to verify the effectiveness of these structures in face of flood events. It is important to say that even with the events of 2015 and 2018 have been addressed in the same survey, the number of samples are not the same because 15 stores have no longer worked in 2015.

Figure 10: Relation between the water levels inside (INT) and outside (EXT) the properties for the 3 observed flood events, 2015, 2018 and 2020.



Source: Prepared by the author (2021)

The stores within the perimeter of the flood spot have a high external water level variation, between 83 cm and 170 cm for 2020 event, 140 cm and 57 cm for 2018 event and 110 cm to 60 cm for 2015 event. Analyzing the internal water level, there is also a difference for the 2020 event they oscillated between 31 cm and 138 cm, for 2018 between 20 and 55 cm and between 75 and 85 cm in 2015. At the beginning of this section, we highlighted that the events had a greater magnitude, in ascending order, in 2018, 2015 and 2020. Thus, we would expect water levels to grow in this order. However, this logic is not met due to the important protective role played by the floodgates installed in the establishments over the years. The analysis of floodgate heights allows to explain the substantial decrease in the internal water level, as well as to analyze the population's feedback regarding the new levels of threat faced, especially with regard to the increase in the floodgate’s height as a way of protection after the events that the owners experienced.

By evaluating the heights by street, we can see the differences considering the spatial characteristics of the floods. At Rua Nove de Julho the difference between the average internal and external water level was the most expressive, around 34 cm for the 2015 event and 75 cm for the event 2018. It can be inferred that this is due to the preparation against flood, since, of the 10 establishments visited, 7 had floodgates (70%) in 2015 and after the 2018 event, all stores installed floodgates or raised them. For 2020 this difference was 32 cm, even with the floodgates, this is due to the magnitude of the event, which reached an external water level of 170 cm. Regarding Rua Comendador Maffei, it is worth noting that, of the 9 establishments interviewed located on the block between Rua Episcopal and Rua 9 de Julho, none had floodgates in 2015. One of the probable reasons is the fact that, according to the merchants, flood events rarely reached this location in events prior to the year 2015, although these properties are located exactly above the Gregório stream, in its buffered portion. After the 2015 event, floodgates were installed in 5 establishments in that block, with the others studying its installation and in 2020 all interviewed stores had floodgates.

Therefore, it appears that, although the external flood height was greater in the event of 2018 compared to 2015, the amount of water that entered the establishments was lower, a fact that can be explained by the greater preparation of the population in relation to the threat flooding in the form of raising the floodgates. However, the preparation based on the events of 2015 and 2018 was not enough to prevent water from entering stores due to the increase in the intensity of the event observed in 2020.

2.4 CONCLUSIONS

The Gregório Creek basin suffers with flood for several years, the shopkeepers deal with this reality like a risk controlling society increasing their individual protection as extreme events happen, which creates a sense of safety. Only a few of them are aware that there is no way to control nature, and therefore it is necessary to change to adapt. According to surveys applied in 2019 (Abreu, 2019) and 2020 addressing 3 flood events in 2015, 2018 and 2020, it was possible to create a social flood map showing accurately the flood spot of 2020’s event using voluntary data of affected people.

The results showed that merchants in the study area have flood protection mechanisms, such as floodgates and store level above the sidewalk level, however due to the magnitude of the event on January 12th 2020, which precipitated an accumulated of more than 92 mm in 3 hours, these measures were not enough at the most critical points, such as at the corner of Rua Geminiano Costa and 9 de Julho, where the height of the water reached 170 cm.

The substantial increase in the accumulated height of floodgates and the average height of these gates, represents the population's feedback in face of a new threat’s level. Therefore, this example is illustrated by the mechanisms of interaction between society and floods presented by Di Baldassare (2015), showing the accumulation of memories resulting from the experiences lived during the extremes of flooding.

Acknowledging the limitation of the sample size this study highlights the recurrent behavior and the use of anticipated memories for adaptation of the commercial property holders in the basin. A new interview should be applied to collect more information about the merchants’ expectations for the basin to better classify the ideal type of society. Future studies should also investigate the efficiency of protection measures and compare them with other practices.

2.5 ACKNOWLEDGEMENTS

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3 TYPE OF SOCIETY AND SOCIAL PERCEPTION ABOUT FLOOD EVENTS IN A BRAZILIAN AMAZON CATCHMENT.

A modified version of this chapter will be submitted to Urban Water Journal as: FIALHO, H. C. P.; SOUSA, B. J. DE O.; MENDIONDO, E. M.; DE OLIVEIRA, P. T. S. Types of society and social perception about flood events in a Brazilian amazon catchment

Abstract: Belém is a municipality located in the northern region of Brazil in the state of Pará, being part of the Amazon region and subject to high rainfall rates. Thus floods in the commercial center of the Campina neighborhood have been one of the main natural disasters that occurs in Belém, mainly in the months of April and May. Here, we studied how the natural and anthropic agents act causing the floods and what are the main implications of these floods, from the point of view of the traders in the area. To map the main causes of flooding, a questionnaire was applied to collect voluntary data from the population working in the region, in addition to data collected in the field, such as photographic records, identification of flooding points, observations of the drainage system, quantification of traders, precipitation action and tide in the area. Our results show that the high tide, the lack of environmental awareness of the population and the garbage on public streets are the most active for the problem of flooding in the area, and that these floods cause huge socioeconomic losses to traders, since 77% of the answers affirmed to suffer negatively from floods and may lose up to 50% of their monthly income during the rainy season. The voluntary data collected allowed us to observe what behavior was adopted in the face of floods, and in this way to classify the region mostly as a fatalistic society, i.e., this society does not adopt hard or soft measures for preparedness and the population will continue to grow in the risky area. Understanding the social perception in a community is the first step to implement more effective measures for risk reduction.

Keywords: stormwater BMPs, floods, BMP cost-benefit analysis, environmental services recovery.

3.1 INTRODUCTION

During the period of 1947 to 1981, the World suffered a total of 762 reported natural disasters, floods were the most frequent followed by tropical cyclones and earthquakes (Shaluf and Ahmadun 2006). In 2014 a total of 324 disasters were reported which affected nearly 141 million people Worldwide (Shah, Mustaffa, and Yusof 2017). In Brazil from 2011 to 2020, 40 flood disasters were registered affecting almost 2,900 people and causing damages estimated in U$2,775,000 (https://public.emdat.be/data).

The main cause of flood is urbanization since it has the potential to increase both the volume and flow of direct runoff. The influence of the occupation of new areas must be analyzed in the context of the hydrographic basin in which they are inserted, to make the necessary adjustments to minimize the creation of future flooding problems (Mori et al. 2021). Soil imperviousness, rivers canalization and occupation of floodplains increase the degradation of watersheds (Campos et al. 2021).

Quantifying the effects of flood can be difficult due to the lack of data related to urban flood extension. The engagement of citizens through the provision of data can be a useful tool to overcome this problem. Interviews, surveys and questionnaires are applied to collect voluntary flood information. Smith and Freedy (2000) applied 690 questionnaires in 1993 to assess psychosocial resource loss as a mediator of the effects of flood exposure on psychological distress and physical symptoms in Mississippi, the United States of America. Terpstra and Gutteling (2008) used an Internet survey in the province of Friesland to check households' perceived responsibilities in flood risk management in The Netherlands. Wang et al. (2018) conducted a questionnaire survey of 719 randomly sampled respondents to investigate the public flood risk perception in four districts of Jingdezhen, China.

The literature has proposed four rationalities to describe the interaction between societies and nature: fatalistic, hierarchical, individualist and egalitarian (Thompson 1990). Ridolfi, Albrecht, and Di Baldassarre (2020) adopted these four rationalities and interpret them from a flood-risk perspective and they proposed four ideal types of society in relation to hydrological extremes: i. risk neglecting, sees nature as an unmanageable system it believes that is impossible to manage risk, so this society does not adopt hard or soft measures for preparedness and the population will continue to grow in the risky area; ii. risk monitoring society is characterized by using inclusive bottom-up strategies to cope their risk, this society assumes that natural resources cannot be controlled while needs can, soft measures are adopted to improve awareness and preparedness, e.g., citizen-based warning system; iii. risk downplaying society perceives nature as a robust system, hydrological extremes are generally underestimated, this society sees no need for collective actions, soft or hard measures are not implemented and the population will not relocate in case of flood and it will continue to grow in the settlement; iv. risk controlling, this society perceives risks and the need to increase preparedness individuals rely on government in a top-down perspective on protective, for protection it is adopted hard measures increasing their height after extreme events.

Belém faces daily environmental problems that result from natural and anthropic processes and cause inconvenience to the population, hindering the dynamics and development of the city. Among such urban problems are those caused by the lack of basic sanitation and environmental education such as dumping and accumulation of solid waste in several unsuitable points in the city, lack or deficiency of drainage and sewage systems, among others (Szlafsztein and de Araújo 2021), thus leading to increase flood frequency.

The flooding problem in Belém has persisted since the foundation of the city (Araujo et. al., 2012) despite its several spatial and structural transformations over the years. According to (Josinete and Mácola 2017), the growth of the city had increased the problem - new areas of floods had been incorporated into existing ones, since risk areas were inhabited.

Within this scenario of sanitation problems, the oldest neighborhoods Cidade Velha and Campina, which form an important tourist, historical and economic center, we could see the influence of several of the agents mentioned for the formation of large floods and socioenvironmental impacts. Campina can be considered the most important economic center of the city and one of the most representative of the region, since in it is located the Ver-o-Peso complex, the largest free market in Latin America (Palácios, Angélica, and Sanjad 2014). This commercial center has a varied assortment of goods in its hundreds of stores that supply both the local population and those from other regions of the Amazon. Consequently, Campina was chosen as the place for this study, whose objective is to check social perception about floods and how the population copes with this hazard.

The causes and implications of floods for local traders were investigated, and the type of society was classified according to Ridolfi, Albrecht, and Di Baldassarre (2020) through on-site observations and data provided by volunteers. The study, which also involved the application of a questionnaire that collected information on flood perception from traders, is of great importance, since the literature lacks research on this issue in the region.

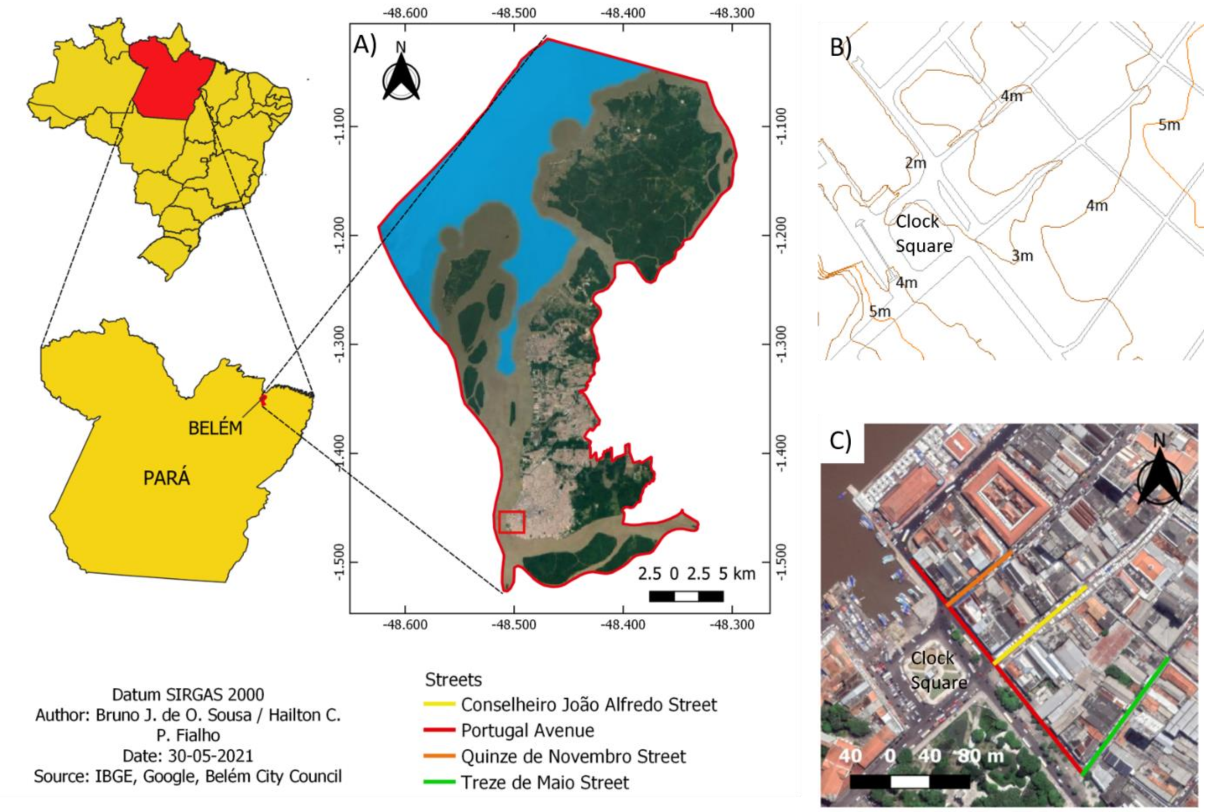
3.2 MATERIALS AND METHODS

3.2.1 Study area

The study was developed in the municipality of Belém, capital of Pará State, located in the Amazon region (Figure 11A), northern Brazil. It is considered the largest city on the Equator line, with a 1,059,466 km² territorial area and 1,393,399 inhabitants, according to a census conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2021). The region is characterized by a 26.4 ° C average temperature, unstable air, and 84% average humidity, favoring the formation of convective clouds (Bastos et al. 2002). The average annual rainfall is 3,000 to 4,000 mm, and the city is located in the Af climatic zone (Köppen classification) (Alvares et al. 2013). Like all the Amazon region, Belém does not have well-defined seasons, but only two climatic periods, namely summer (from June to November) and winter (from December to May), also known as Amazonian winter (Sousa 2016). According to Quaresma, Pedro, and Lira (2014), the topography ranges from 0 to 20 meters in altitude, and most low lands are subjected to the flow of the tides (Figure 11B), which easily reach 3.6 m height and enter the city, contributing to the formation of flooding points (Santos and Rocha 2013).

Campina has an area of 95.8 hectares comprising 87 blocks. The last census (Pará 2011) reported a population of 6,156 inhabitants, and, according to the Municipal Secretary of Economy – SECON (2021), approximately 3,500 merchants are divided into shopkeepers and street traders. Due to the high number of merchants and large size of the neighborhood, a study area was defined for the application of a questionnaire on flood impacts (Table 1), based on the points of highest incidence of flooding (Figure 11C), namely Portugal Avenue, 13 de Maio Street, Conselheiro João Alfredo Street, and 15 de Novembro Street. The number of merchants on these streets is 218, being 103 stores and 115 street vendors.

Figure 11: Map of the study area. A) Location of Belém city; B) and C) region affected by floods. B) topography of the region; C) streets names surrounding the area.



Source: Prepared by the author (2021)

3.2.2 Application of the questionnaire and statistical analyses

The questionnaire was applied after the sample size was calculated for a 5% maximum error for 218 traders by the finite population sample equation. However, at the time of application of the questionnaire, Belém suffered a new outbreak of COVID-19 and went into a 14-day lockdown from March 15th to 29th. As a result, 43 answers were collected, being 23 street vendors and 20 stores.

Table 1: Questionnaire of flood impacts on the commercial center of Belém/PA.

TABLE 1 - QUESTIONNAIRE OF FLOOD IMPACTS IN THE COMMERCIAL CENTER OF BELÉM / PA.	
1. NAME	**2. ADDRESS**
3. TYPE OF BUSINESS:	**4. COMMERCIAL ACTIVITY**
a. STORE b. STREET VENDOR	a. DEPARTMENT STORES, WAREHOUSE ITEMS, CLOTHING AND FABRICS, SHOE AND LEATHER PRODUCTS b. FURNITURE, ELECTRIC HOUSEHOLD APPLIANCES, COMPUTER EQUIPMENT c. PHARMACEUTICAL PRODUCTS, PERFUMERIES AND COSMETICS d. JEWELRY SHOPS, WATCHES AND OPTICS e. RESTAURANTS, SNACKS, BARS AND COFFEE f. NEWSSTAND AND STATIONERY
5. AVERAGE MONTHLY INCOME (US$)	**6. HOW LONG HAVE YOU WORKED IN THIS PLACE?**
7. HOW MANY WEEKLY HOURS DO YOU WORK?	**8. DO YOU USUALLY CHANGE YOUR WORKING HOURS IN THE RAINY PERIOD?**
a. WITHOUT FIXED JOURNEY, UP TO 20 WEEKLY HOURS b. FROM 21 TO 30 WEEKLY HOURS c. FROM 31 TO 40 WEEKLY HOURS d. 41 TO 50 WEEKLY HOURS e. 51 TO 60 WEEKLY HOURS f. MORE THAN 60 WEEK HOURS	a. YES b. NO
9. DO YOU THINK FLOODS AFFECT YOUR ACTIVITIES IN THIS PLACE?	**10. WHAT ARE THE MAIN IMPACTS THAT FLOODS HAVE ON YOUR ACTIVITIES?**
a. YES, POSITIVELY AFFECT b. YES, AFFECT NEGATIVELY c. DO NOT AFFECT d. DON'T KNOW THE ANSWER	a. IMPOSSIBILITY OR REDUCE THE WORKING DAYS b. REDUCE CUSTOMER FLOW c. INCREASE THE NUMBER OF SALES d. REDUCE YOUR BILLING e. INCREASE YOUR BILLING f. CAUSE MATERIAL AND FINANCIAL DAMAGE g. DO NOT SUFFER CHANGES
11. DO YOU THINK OF CHANGING YOUR BUSINESS' ADDRESS?	**12. DO YOU HAVE ANY PROTECTION AGAINST FLOODS?**
a. YES b. NO	a. YES b. NO
12.1. IF YES, WHICH?	**13. HAVE YOU EVER STAYED WITHOUT WORKING OR NEEDED TO CLOSE YOUR ESTABLISHMENT BECAUSE OF THE FLOODS IN THIS AREA?**
□ FLOODGATE □ PERSONAL PROTECTION EQUIPMENT □ HIGHER FLOOR THAN THE SIDEWALK □ WALL □ OTHER	a. YES b. NO
14. IN YOUR OPINION, WHICH MAY BE THE MAIN CAUSERS OF FLOODS IN THIS AREA	**15. THE GOVERNMENT HAS DONE THE NECESSARY TO COMBAT FLOODING IN THE REGION**
a. POLLUTION OF CHANNELS b. PUBLIC TRASH GARBAGE c. THE INTENSE RAIN d. THE HIGH TIDE e. THE LACK OF PUBLIC CLEANING f. THE LACK OF ENVIRONMENTAL AWARENESS OF THE POPULATION g. DRAINAGE PROBLEMS h. LACK OF GOVERNMENT ACTIONS i. OTHER	1-Totally disagree; 2-Disagree; 3-Indecisive; 4-Agree; 5-Totally agree
16. WOULD YOU SAY THAT THE FLOODING MONTHS ARE THAT YOUR COMPANY:	**17. DO YOU HAVE KNOWLEDGE OF FLOOD INSURANCE?**
a. LESS PROFIT b. STAYS STABLE c. MORE PROFIT IF YOU PROFIT MORE OR LESS, ESTIMATE HOW MUCH (%):____________	a. YES b. NO
18. HOW MUCH WOULD YOU BE WILLING TO PAY FOR A FLOOD INSURANCE (US$ ANNUAL)?	**19. GENERAL COMMENTS**

Source: Prepared by the author (2021).

Rainfall data of March and April 2021 (months of highest incidence of high tides in the year) were collected from the National Institute of Meteorology (INMET 2021), and those of the tide table from Brazil's navy (Marinha do Brasil 2021) (see Tables 2 and 3) were used for a study of the frequency of floods in the area. The return period of precipitations was also calculated according to the Intensity-duration-frequency curve for Belém (Souza et al. 2012).

Table 2: Days and hours of tide tables and rainfall in Belém for March 2021.

MARCH	1st HIGH TIDE		2nd HIGH TIDE		1st LOW TIDE		2nd LOW TIDE		RAINFALL	
Day	Time	Hight (m)	Time	Hight (m)	Time	Hight (m)	Time	Hight (m)	Time of maximum precipitation	Precipitation (mm)
1st	12:45 AM	3.6	1:05 PM	3.6	7:59 AM	0.3	8:17 PM	0.3	4:00 PM	4
2nd	1:25 AM	3.6	1:43 PM	3.6	8:38 AM	0.5	8:58 PM	0.3	8:00 PM	15.6
3rd	2:07 AM	3.5	2:24 PM	3.5	9:18 AM	0.5	9:41 PM	0.5	7:00 PM	34.7
4th	2:51 AM	3.4	3:07 PM	3.4	10:00 AM	0.8	10:28 PM	0.6	2:00 PM	0.2
5th	3:39 AM	3.1	3:56 PM	3.1	10:47 AM	1.1	11:21 PM	0.9	8:00 PM	7
6th	4:36 AM	2.8	4:55 PM	2.8	11:43 AM	1.4			5:00 PM	9.6
7th	5:48 AM	2.7	6:12 PM	2.7	12:28 AM	1.2	12:57 PM	1.5	1:00 PM	0.2
8th	7:18 AM	2.5	7:43 PM	2.7	1:53 AM	1.4	2:28 PM	1.7	11:00 PM	1.8
9th	8:43 AM	2.5	9:02 PM	2.8	3:22 AM	1.4	3:52 PM	1.5	8:00 PM	9.4
10th	9:46 AM	2.8	10:01 PM	2.9	4:31 AM	1.2	4:54 PM	1.2	1:00 AM	0.4
11th	10:32 AM	2.9	10:46 PM	3.1	5:22 AM	0.9	5:40 PM	1.1	5:00 PM	17.6
12th	11:10 AM	3.1	11:25 PM	3.2	6:03 AM	0.8	6:19 PM	0.8	12:00 AM	14.2
13th	11:43 AM	3.2	11:58 PM	3.4	6:38 AM	0.8	6:52 PM	0.6	2:00 PM	0.2
14th	12:14 PM	3.4			7:10 AM	0.6	7:24 PM	0.6	6:00 PM	0.2
15th	12:30 AM	3.4	12:43 PM	3.4	7:40 AM	0.6	7:55 PM	0.5	6:00 PM	21.8
16th	1:01 AM	3.4	1:13 PM	3.4	8:10 AM	0.6	8:26 PM	0.6	7:00 PM	43.6
17th	1:32 AM	3.4	1:43 PM	3.4	8:40 AM	0.8	8:57 PM	0.6	6:00 PM	6.4
18th	2:04 AM	3.2	2:14 PM	3.2	9:11 AM	0.9	9:31 PM	0.8	5:00 PM	12.6
19th	2:38 AM	3.1	2:49 PM	3.1	9:45 AM	1.1	10:08 PM	0.9	8:00 PM	1
20th	3:18 AM	2.9	3:29 PM	2.9	10:23 AM	1.2	10:53 PM	1.2	7:00 AM	3.8
21st	4:05 AM	2.7	4:21 PM	2.7	11:11 AM	1.5	11:52 PM	1.4	10:00 PM	15.2
22nd	5:11 AM	2.5	5:34 PM	2.5	12:19 PM	1.7			12:00 AM	1.8
23rd	6:40 AM	2.4	7:08 PM	2.5	1:14 AM	1.5	1:52 PM	1.7	N.P.	0
24th	8:09 AM	2.5	8:30 PM	2.7	2:45 AM	1.4	3:20 PM	1.5	10:00 PM	1.8
25th	9:14 AM	2.8	9:31 PM	2.9	3:58 AM	1.2	4:24 PM	1.2	11:00 AM	17.8
26th	10:03 AM	3.1	10:30 PM	3.2	4:52 AM	0.9	5:14 PM	0.9	N.P.	0
27th	10:45 AM	3.4	11:04 PM	3.5	5:37 AM	0.6	5:56 PM	0.6	9:00 PM	9.6
28th	11:24 AM	3.5	11:44 PM	3.6	6:18 AM	0.5	6:37 PM	0.3	6:00 PM	8
29th	12:02 PM	3.6			6:56 AM	0.3	7:16 PM	0.2	5:00 PM	3.8
30th	12:24 AM	3.8	12:40 PM	3.8	7:35 AM	0.3	7:56 PM	0.2	6:00 PM	13.8
31st	1:04 AM	3.6	2:20 PM	3.6	8:13 AM	0.3	8:36 PM	0.2	5:00 PM	34

Source: Prepared by the author (2021).

Table 3: Days and hours of tide tables and rainfall in Belém for April 2021.

APRIL	1st HIGH TIDE		2nd HIGH TIDE		1st LOW TIDE		2nd LOW TIDE		RAINFALL	
Day	Time	Hight (m)	Time	Hight (m)	Time	Hight (m)	Time	Hight (m)	Maximum precipitation time	Precipitation (mm)
1st	1:45 AM	3.5	1:58 PM	3.5	8:52 AM	0.6	9:18 PM	0.5	5:00 PM	3.2
2nd	2:28 AM	3.4	2:40 PM	3.4	9:34 AM	0.8	10:04 PM	0.6	5:00 PM	17.4
3rd	3:15 AM	3.1	3:28 PM	3.1	10:20 AM	1.1	10:57 PM	0.9	5:00 PM	25
4th	4:13 AM	2.7	4:29 PM	2.8	11:17 AM	1.4			9:00 PM	11
5th	5:29 AM	2.5	5:53 PM	2.5	12:06 AM	1.2	12:37 PM	1.7	12:00 PM	0.2
6th	7:07 AM	2.4	7:31 PM	2.5	1:37 AM	1.4	2:18 PM	1.7	2:00 PM	0.2
7th	8:29 AM	2.5	8:48 PM	2.7	3:07 AM	1.4	3:41 PM	1.5	1:00 AM	0.4
8th	9:26 AM	2.8	9:42 PM	2.9	4:12 AM	1.2	4:37 PM	1.2	7:00 PM	9.4
9th	10:08 AM	2.9	10:24 PM	3.1	4:59 AM	1.1	5:19 PM	1.1	8:00 PM	12.2
10th	10:42 AM	3.2	10:59 PM	3.2	5:37 AM	0.9	5:54 PM	0.8	6:00 AM	0.2
11th	11:13 AM	3.4	10:31 PM	3.4	6:09 AM	0.8	6:25 PM	0.6	6:00 PM	55.8
12th	11:42 AM	3.4			6:39 AM	0.6	6:56 PM	0.5	7:00 PM	3.4
13th	12:01 AM	3.4	12:11 PM	3.5	7:08 AM	0.6	7:25 PM	0.5	6:00 PM	9.4
14th	12:31 AM	3.4	12:40 PM	3.5	7:37 AM	0.6	7:55 PM	0.5	6:00 PM	31
15th	1:01 AM	3.4	1:09 PM	3.4	8:06 AM	0.8	8:26 PM	0.6	N.P.	0
16th	1:33 AM	3.2	1:41 PM	3.2	8:37 AM	0.9	9:00 PM	0.8	9:00 PM	8.6
17th	2:07 AM	3.1	2:15 PM	3.1	9:11 AM	1.1	9:37 PM	0.9	5:00 PM	23.4
18th	2:47 AM	2.9	2:57 PM	2.9	9:50 AM	1.2	10:23 PM	1.1	6:00 PM	17
19th	3:36 AM	2.7	3:50 PM	2.8	10:40 AM	1.5	11:23 PM	1.2	5:00 PM	0.4
20th	4:43 AM	2.5	5:05 PM	2.7	11:51 AM	1.7			1:00 PM	0.2
21st	6:11 AM	2.5	6:38 PM	2.7	12:45 AM	1.4	1:24 PM	1.7	N.P.	0
22nd	7:36 AM	2.7	8:00 PM	2.8	2:13 AM	1.4	2:50 PM	1.4	4:00 PM	11.8
23rd	8:40 AM	2.9	9:02 PM	3.1	3:25 AM	1.1	3:54 PM	1.1	9:00 PM	1.6
24th	9:31 AM	3.2	9:52 PM	3.2	4:20 AM	0.9	4:45 PM	0.8	3:00 PM	8.2
25th	10:14 AM	3.4	10:38 PM	3.5	5:06 AM	0.6	5:30 PM	0.5	11:00 PM	21
26th	10:55 AM	3.6	11:20 PM	3.6	5:48 AM	0.5	6:12 PM	0.3	12:00 AM	27.2
27th	11:35 AM	3.8			6:29 AM	0.3	6:53 PM	0.2	N.P.	0
28th	12:01 AM	3.6	12:14 PM	3.8	7:08 AM	0.3	7:34 PM	0.2	8:00 PM	4
29th	12:42 AM	3.6	12:54 PM	3.6	7:48 AM	0.5	8:16 PM	0.3	10:00 PM	10.4
30th	1:25 AM	3.4	1:36 PM	3.5	8:29 AM	0.6	8:59 PM	0.5	12:00 AM	0.8

Source: Prepared by the author (2021).

3.2.3 Cluster analises

In order to classify the study area in one of the ideal types of society proposed by Ridolfi, Albrecht, and Di Baldassarre (2020), we performed a cluster analysis using K-means method to create groups and better study the population, it is one of the most popular, simple and fast algorithms for cluster head selection (Purnima and Arvind 2014). The number of groups was defined based on the Elbow method, it is used to determine the best number of clusters by checking the percentage of the comparison of the number of clusters that will form an elbow (Nainggolan et al. 2019).

3.3 RESULTS AND DISCUSSIONS

3.3.1 Precipitation rates and high tide frequency.

Campina neighborhood belongs to the Tamandaré basin - one of the 14 hydrographic basins that form the territory of Belém. Approximately 0.63 km² of the basin are flooded areas, which are equivalent to 36.21% of its territory (Pontes et al. 2017). Precipitations are crucial factors for flooding; however, they must reach certain levels together with the tide for causing floods, i.e., they must be greater than 10 mm (in high tide) or 35 mm (in low tide) (Sousa 2016). Tables 2 and 3 show the high and low tide heights for the months of March and April, respectively, and the maximum rainfall for each day. We calculated the return period of each day but not a day exceeded one year of return period which is 66.59 mm/hour.

Sousa (2016) classified the intensity of rain into four ranges and if it would cause flooding based on the precipitated amount. The author also carried out the same study for the tide level, both studies are shown in Table 4. A comparison of the results in Tables 2 and 3 and those in Table 4 shows the events that can potentially cause floods in the area - 17 precipitation events, of which 14 are moderate and 3 are strong - and 17 high tides for March, and 16 precipitations, of which 13 are moderate, 2 are strong, and 1 is very strong, and 20 high tides for April. Figure 12 displays a flood caused by a high 3.5m tide with no precipitation.

Table 4: Classification of rainfall and tidal intensities.

PRECIPITATION			**TIDE**		
Volume	**Intensity**	**Impact**	**Height**	**Intensity**	**Impact**
> 5mm	Weak	Insufficient to cause flooding in high tide	0 - 1 meter	Insufficient	None
5.1 - 25mm	Moderate	Able to cause flooding in high tide	1.1 - 2 meters	Low	Insufficient to enter the drainage system
25.1 - 50mm	Strong	May cause flooding at low tide	2.1 - 3 meters	Moderate	Enough to cause flooding in lower areas
50.1 <	Very Strong	May cause major flooding	3.1 - 4 meters	High	Sufficient for large floods

Source: Prepared by the author (2021).

Figure 12: Flood occurred on March 30th 2021, at 12:30 PM due to a high tide of 3.5 meters (O Liberal 2021).

Source: O Liberal (2021).

3.3.2 Questionnaire application

The study area comprises two types of business, namely shopkeepers and street vendors. The main difference between them is the former run stores in buildings, with a structure that protects them from rainfall and flood. Street vendors assemble their business every day as carts, tents, or pre-assembled fixed structures (Figure 13), which are more vulnerable to rainfall and flood. From a sample of 43 answers, they are distributed as 47% shops (20 subjects) and 53% street vendors (23 subjects). Towards a better understanding of their points of view and differences between them, their answers were analyzed separately. Table 5 shows a summary of the responses obtained.

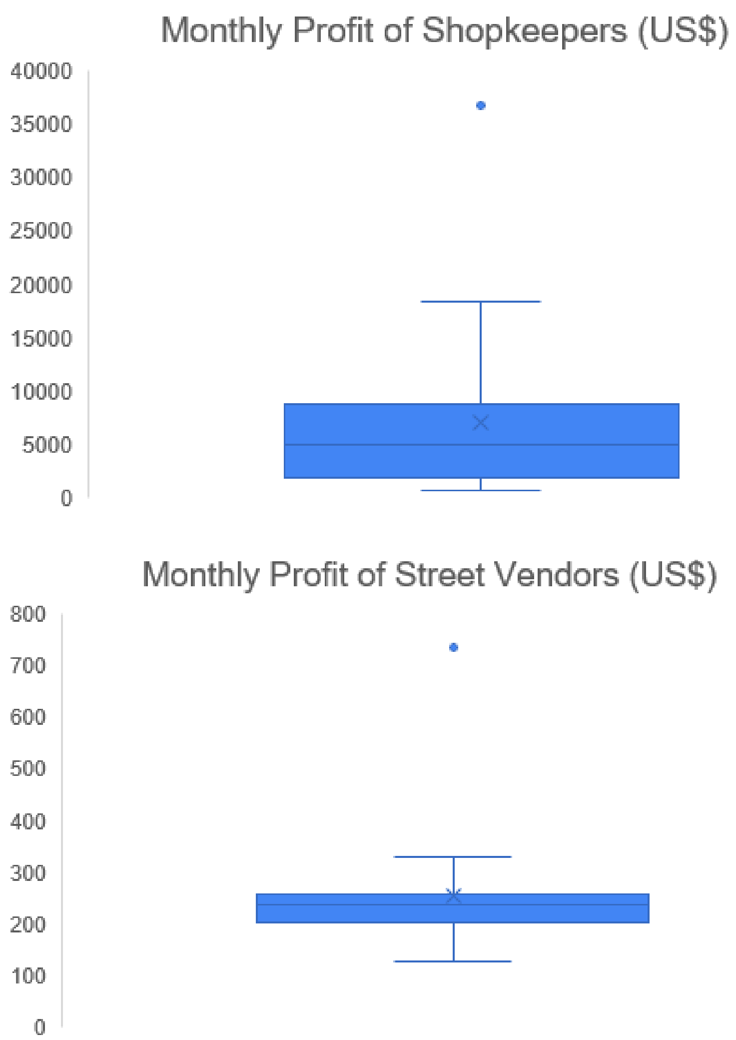
Figure 13: Types of structures of street vendors.

Source: Prepared by the author (2021).

The commercial activity of the shopkeepers is divided into department stores, warehouse items, clothing and fabrics, shoe and leather products (65% - 13 subjects), restaurants, snacks, bars, and coffee (5% -1 subject), jewelry shops, watches and optics (15% - 3 subjects), pharmaceutical products, perfumeries and cosmetics (10% - 2 subjects), and newsstand and stationery (5% - 1 subject). Regarding street vendors, the activity in divided into department stores, warehouse items, clothing and fabrics, shoe and leather products (43% - 10 subjects), restaurants, snacks, bars and coffee (53% - 12 subjects), and newsstand and stationery (4% - 1 subject).

The average profits are US$ 7,023.00 and US$ 254.00 for shopkeepers and street traders, respectively. Such a difference is due to the value of the traded goods - stores have more valuable products in addition to a stock, whereas street vendors work with cheaper products with no stock, thus offering only what is visualized by the customers. Figure 14 displays the monthly profit of shopkeepers and street traders. The dollar exchange rate of April 30th, 2021 was used for changing the values from real to dollar - US$1 was equivalent to R$5.432.

Figure 14: Monthly Profit. A) Shopkeepers and B) Street vendors.



Source: Prepared by the author (2021).

Table 5: Summary of the responses to the questionnaires.

QUESTION	SHOP KEEPERS	STREET TRADERS
3	47%	53%
4	65% - DEPARTMENT STORES, WAREHOUSE ITEMS, CLOTHING AND FABRICS, SHOE AND LEATHER PRODUCTS 15% - JEWELRY SHOPS, WATCHES AND OPTICS 10% - PHARMACEUTICAL PRODUCTS, PERFUMERIES AND COSMETICS 5% - NEWSSTAND AND STATIONERY 5% - RESTAURANTS, SNACKS, BARS AND COFFEE	52% - RESTAURANTS, SNACKS, BARS AND COFFEE 43% - DEPARTMENT STORES, WAREHOUSE ITEMS, CLOTHING AND FABRICS, SHOE AND LEATHER PRODUCTS 5% - NEWSSTAND AND STATIONERY
5	Average Profit of Logists (US$): 7,023	Average Profit of Street Vendors (US$): 254
6	Average time working in the area (years): 10.1	Average time working in the area (years): 12.74
7	From 51 to 60 hours per week	From 51 to 60 hours per week
8	65% - YES 35% - NO	22% - YES 78% - NO
9	85% - YES, AFFECT NEGATIVELY 10% - DO NOT AFFECT 5% - YES, POSITIVELY AFFECT	74% - YES, AFFECT NEGATIVELY 22% - DO NOT AFFECT 4% - YES, POSITIVELY AFFECT
10	75% - REDUCE CUSTOMER FLOW 10% - DO NOT SUFFER CHANGES 10% - IMPOSSIBILITY OR REDUCE THE WORKING DAYS 5% - INCREASE THE NUMBER OF SALES	65% - REDUCE CUSTOMER FLOW 22% - DO NOT SUFFER CHANGES 13% - IMPOSSIBILITY OR REDUCE THE WORKING DAYS
11	5% - YES 95% - NO	100% - NO
12	55% - YES 45% - NO	100% - NO
12.1	91% - HIGHER FLOOR THAN THE SIDEWALK 55% - FLOODGATES 18% - WALL 9% - PERSONAL PROTECTION EQUIPMENT 9% - OTHERS	X
13	25% - YES 75% - NO	35% - YES 65% - NO
14	60% - POLLUTION OF CHANNELS 90% - PUBLIC TRASH GARBAGE 35% - THE INTENSE RAIN 100% - THE HIGH TIDE 65% - THE LACK OF PUBLIC CLEANING 95% - THE LACK OF ENVIRONMENTAL AWARENESS OF THE POPULATION 40% - DRAINAGE PROBLEMS 15% - LACK OF GOVERNMENT ACTIONS 0% - OTHER	35% - POLLUTION OF CHANNELS 96% - PUBLIC TRASH GARBAGE 35% - THE INTENSE RAIN 100% - THE HIGH TIDE 43% - THE LACK OF PUBLIC CLEANING 100% - THE LACK OF ENVIRONMENTAL AWARENESS OF THE POPULATION 48% - DRAINAGE PROBLEMS 35% - LACK OF GOVERNMENT ACTIONS 0% - OTHER
15	20% - Totally disagree 20% - Disagree 40% - Indecisive 20% - Agree 0% - Totally agree	22% - Totally disagree 22% - Disagree 30% - Indecisive 26% - Agree 0% - Totally agree
16	75% - LESS PROFIT 20% - STAYS STABLE 5% - MORE PROFIT	57% - LESS PROFIT 39% - STAYS STABLE 4% - MORE PROFIT
16.1	AVERAGE PROFIT LOSS: 20% AVERAGE PROFIT INCREASE: 15%	AVERAGE PROFIT LOSS: 23% AVERAGE PROFIT INCREASE: 50%
17	60% - YES 40% - NO	100% - NO
18	AVERAGE AVAILABILITY TO PAY: US$ 101.25	AVERAGE AVAILABILITY TO PAY: US$ 0.00

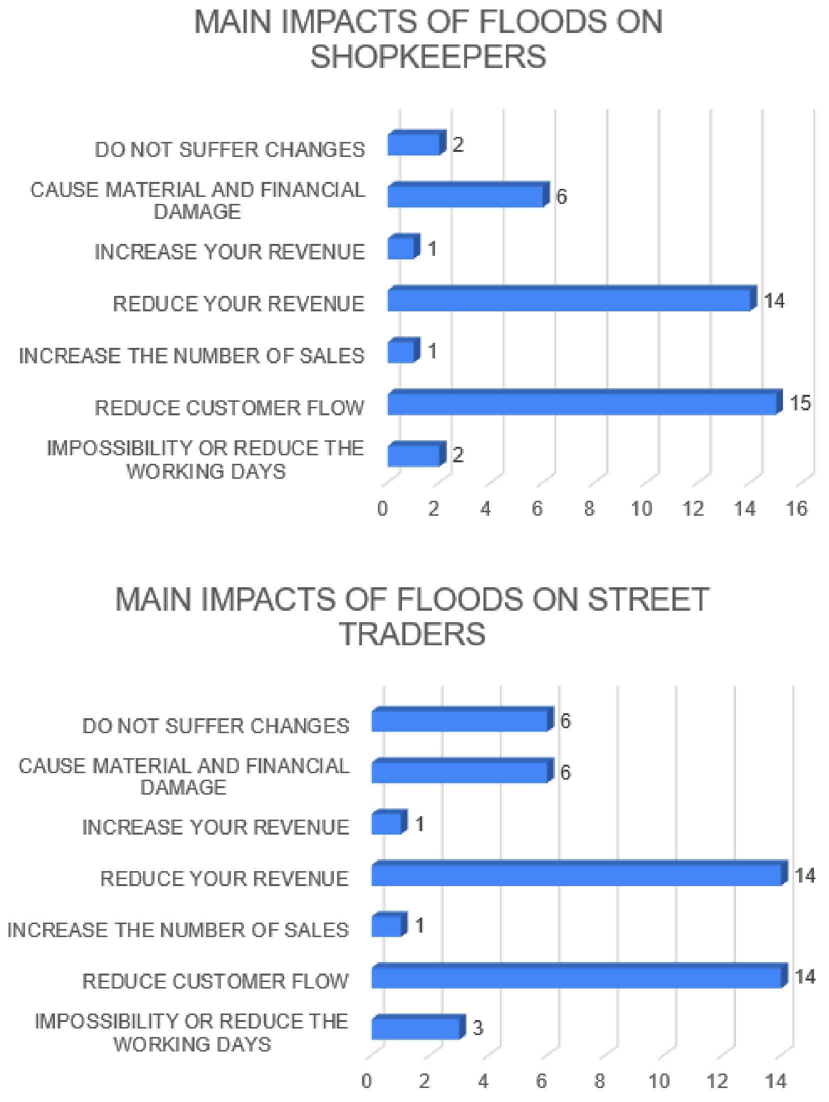
Source: Prepared by the author (2021).

The time in years the vendors work in the area is extremely important to check the adaptations and protections measures against flood through memory of past events. According to Folke (2006), the concept of memory is the accumulated experience based on the history of a system, which provides the basis for identifying sources of renewal, innovation, recombination and self-organization after stressful conditions. Di Baldassarre et al. (2013) reported an adaptive effect related to the observation of the high frequency of floods associated with a reduction in vulnerability. For shopkeepers and street vendors the average time of working in the area is 10.1 and 12.8 years respectively.

All street vendors surveyed have no protection measures, while 55% (11 subjects) of shopkeepers do. The most common measure is floor higher than the sidewalk (91%), which does not reflect memory adaptation of past events, since such structures had been built before shopkeepers started their activities on site. The second most used protection is floodgates (55%); however, its use cannot be related to memory, since the stores that applied them had the highest monthly profit and not necessarily the longest stay in the area. Wall was also used as a protection (18%), followed by personal protection equipment (9%) and others (9%).

The weekly workdays of 100% of the responses are 51 to 60 hours, from Monday through Saturday. 65% of shopkeepers (13 subjects) and 22% of street traders (5 subjects) change their working hours during the rainy period due to flooding, stores keep their doors closed and most street vendors remain in their businesses. Regarding the economic loss caused by floods, 85% of the shopkeepers (17 subjects) claimed they were negatively affected, with an average profit loss of 20% per month, 10% (2 subjects) reported no loss, and 5% (1 subject) increased their profit by 15%. Street traders showed a similar behavior, i.e., 74% (17 subjects) were negatively affected, with an average profit loss of 31% per month, 22% (5 subjects) reported no loss, and 4% (1 subject) increased their profit by 50%. Such a profit increase is due to the type of merchandise sold, the stores are specialized in umbrellas and raincoats, having their product valued in rainy season.

Figure 15: Negative effects of floods.

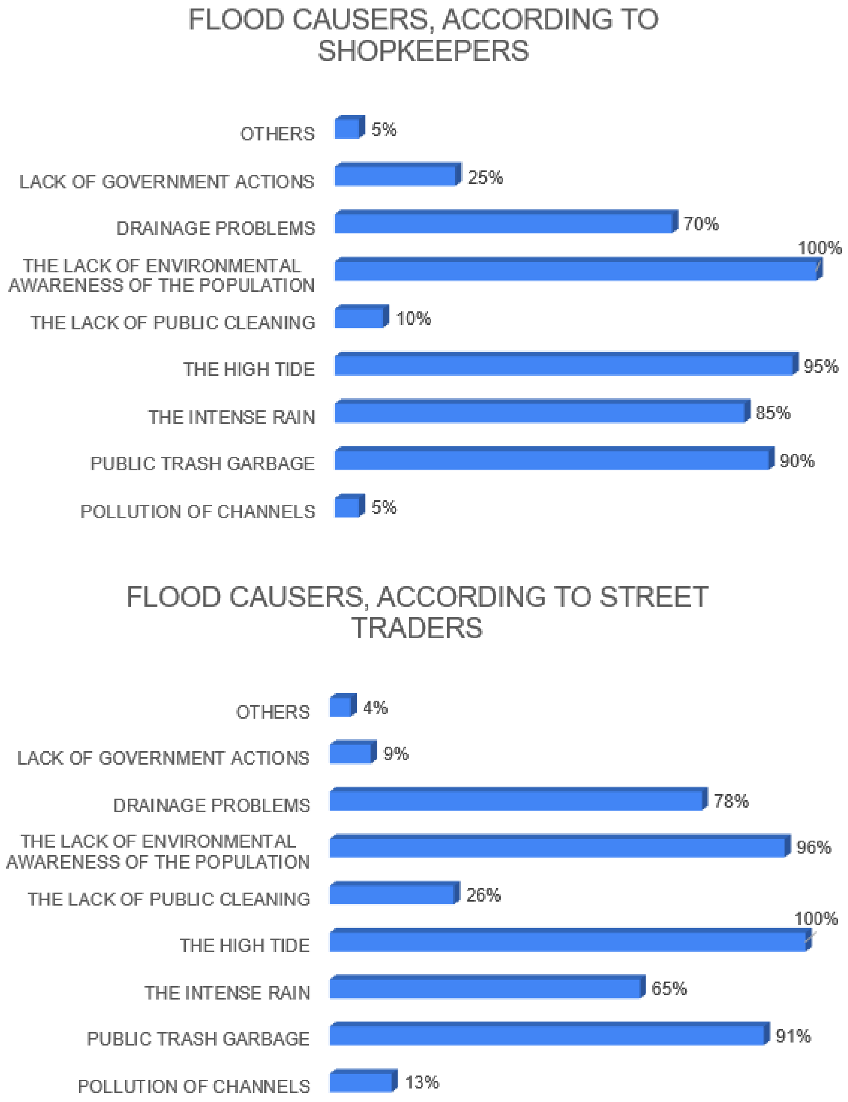


Source: Prepared by the author (2021).

The merchants were asked on the main negative impacts of floods on their business, and more than one answer could be given. According to Figure 15, reductions in the flow of customers and revenue are the main problems, followed by material and financial damage. The use of flood insurance can be a solution to economic losses, since it compensates for all or part of the damages. The merchants were asked if they were aware of this type of risk transfer - 60% of the shopkeepers (12 subjects) replied they were, and 100% of the street vendors (23 subjects) answered they were not. When asked about the willingness to pay for this protection, only 2 shopkeepers showed interest in hiring flood insurance, paying US $ 184.00 and US $ 1,841.00 annually.

Social perception of floods is essential for the understanding of peoples´ awareness level; therefore, the participants were asked on the causes of floods in the area – they could choose more than one alternative. Figure 16 shows no big difference between the groups, since for both, the causes were lack of population´s environmental awareness, high tide, and public garbage. Image data collected from the area revealed irregular waste disposal points near the drainage system (Figure 17a), which, together with high tide events, frequent in March and April, confirmed the social perception about lack of environmental awareness, garbage on public roads, and high tide as the main causes of flooding.

Figure 16: Causes of floods in the area.



Source: Prepared by the author (2021).

Figure 17: Photographic records of the study area. A) debris left by merchants; B) example of a damaged curb drain.

Source: Prepared by the author (2021).

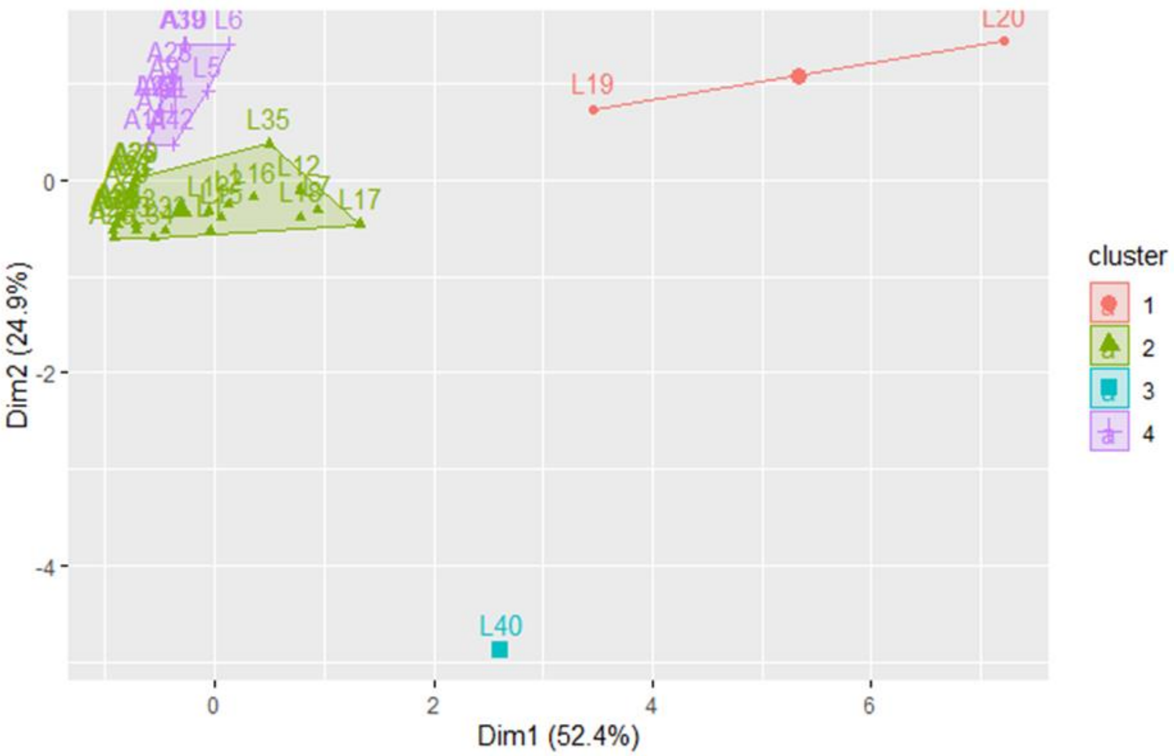
The heavy rains and drainage problems were also pointed out as important factors - several damaged curb drains (Figure 17b) found hindered the flow of rainwater, thus contributing to the emergence of floods. Lack of both governmental actions and public cleaning, polluted channels and other factors were also reported. Interestingly, public garbage was considered one of the main reasons for the floods, whereas lack of public cleaning and governmental actions exerted little influence on them. An explanation is that there are garbage and debris collection, but the population dumps their residues uncontrollably, added to the high precipitation rate in the region, this ends up contributing to the formation of floods.

Governmental actions are fundamental for the prevention of floods. The participants were asked to classify the statement “THE GOVERNMENT HAS DONE THE NECESSARY TO COMBAT FLOODING IN THE REGION”, made by our group, from 1 (totally disagree) to 5 (totally agree). 10% (2 subjects) of shopkeepers “totally agreed”, 20% (4 subjects) “agreed”, 25% (5 subjects) were “indecisive”, 25% (5 subjects) disagreed, and 20% (4 subjects) totally disagreed, whereas 4% (1 subject) of street traders “totally agreed”, 30% (7 subjects) “agreed”, 17% (4 subjects) were “indecisive”, 26% (6 subjects) disagreed, and 22% (5 subjects) totally disagreed. Despite the problems found in the study area, only one subject, out of 43, would move to another location, because the area have been the commercial center of the city since its foundation, thus keeping a strong cultural identity.

3.3.3 Ideal type of Society classification

Figure 18 shows the four groups created by the K-means method. Cluster 1 has two stores characterized by having high monthly income of U$18.900 and U$37.800, 20 and 30 years in the place, and both do not want to hire flood insurance. Cluster 2 has 27 subjects (14 stores and 13 street vendors) its monthly income varies from U$132.30 to U$11,340.00, average of years in place of 5.15 years, and it does not have interest in hiring flood insurance. Cluster 3 has one store, monthly income of U$ 11,340.00, ten years in the place, and it has interest in hiring flood insurance paying U$1,890.00 annually. Cluster 4 has thirteen subjects (3 stores and 10 street vendors) its monthly income varies from U$ 207.9 to U$ 2,268.00, average of years in place of 22.79 years, and only one store wants to hire flood insurance paying U$ 189,00 annually.

Figure 18: Cluster analyses.



Source: Prepared by the author (2021).

We studied the clusters to classify them in one of the four ideal types of society, in the real-world societies they are a mixture of the 4 stylized cultures (Thompson et al. 1990; Ridolfi et al., 2020). Cluster 1 is characterized as downplaying society due to the long time at the site, little preparation against floods and not intending to change location the stores are aware of flood insurance but have no willingness to pay for it. Cluster 2 and 4 are characterized as risk neglecting societies due to little or no flood preparedness, lack of knowledge about protective measures and no intention to move even though suffering financial losses of up to 50% in the rainy season. Cluster 3 can be characterized as a risk controlling society since the store is located in the area most affected by the floods, and even so it prefers to invest in individual protection measures, such as gates and low walls and in flood insurance, rather than moving the establishment to a region with less risk.

The results from the questionnaire show that the studied area can be classified, mostly, as risk neglecting society because they see nature as a force impossible to manage. In hydrological extremes, this society does not adopt hard or soft measures for preparedness and the population will continue to grow, regardless of the risk of new floods (Ridolfi, Albrecht, and Di Baldassarre 2020).

3.4 CONCLUSIONS

The city of Belém suffers from constant flooding, making the local society see it as something natural that is already part of everyday life. In this paper through information collected in the questionnaires we classified the Campina neighborhood as risk neglecting society due to the unpreparedness for floods, taking no action or inadequate measures for protection, the perception that it is impossible to manage risks and no intention to move to a different place. (Ridolfi, Albrecht, and Di Baldassarre 2020). The topographic map and tide tables show that the study area is very susceptible to high tides, allowing it to enter the drainage system, which is very frequent in March and April, coupled with high precipitation rates makes the area classified as a high risk for flooding.

Merchants do not want to move to a different place despite the frequent floods and the economic losses suffered, with an average of 20% and 31% of gains for shopkeepers and street vendors respectively. The main causes for floods lack of population´s environmental awareness, high tide, and public garbage, and the factors of least influence are lack of both governmental actions and public cleaning, pollution of channels, and others. Regarding the actions of public authorities, out of 43 answers, 47% of the respondents believe the necessary measures are not taken, 21% are undecided and 38% approved them.

Despite suffering significant losses, 100% of street vendors have no flood protection measures, and 55% of shopkeepers do. Such protections are hard measures, such as floor higher than the sidewalk, floodgates, and walls. When asked about flood insurance, 100% of street vendors (23 subjects) were not aware of it, whereas 60% of shopkeepers (12 subjects) knew this type of risk transfer; however, only 10% (2 subjects) were interested in hiring flood insurance, paying US$ 184.00 and US$ 1,841.00 annually.

The consequences of flooding in urban areas are relevant, and range from impacts on health, property values, transport infrastructure, and other harmful effects such as loss of time that might be spent on work and study, damage to properties, and psychological stress. Societies that rely on top-down hierarchies and structural measures as protection against flood may still suffer high losses in extreme events, whereas those that invest in awareness through inclusive and participatory approaches have reduced flood losses (Ridolfi, Albrecht, and Di Baldassarre 2020).

Future researches should identify the best way for the implementation of a Bottom-up governance model and effective protection measures towards reductions in the impacts of floods in the region.

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4 GENERAL CONCLUSIONS

Due to the great impact that floods cause on the population of a city, basin or region, it is important to understand the social perception of this phenomenon and how those affected deal with it. In this study we investigated, from the point of view of those affected, the impacts caused by floods in two basins characterized as commercial centers in the municipalities of São Carlos and Belém, southeast and north of Brazil respectively. However, the lack of data on those affected by the floods constitutes a major obstacle to understanding the social dynamics existing between the population and the floods. Therefore, voluntary data were collected through interviews and questionnaires to verify the main impacts felt by traders in the affected regions.

In the municipality of São Carlos in the Gregório basin, the floods that affect the commercial center occur due to intense rainfall, added to high rates of soil impermeability and high inclination of the land. Many participants responded that what makes floods more serious is the flash flood that accompanies them, which may be able to drag objects and even vehicles, which in turn can collide with stores and cause more damage. Therefore, as a protective measure, shopkeepers use floodgates to prevent water from entering their establishments, which proves to be effective to some extent, since from 2015 to 2020 the sum of the height of the floodgates, in the stores studied, quadrupled, showing that this protection is actually paleative, serving to give a sense of false security, causing memories of these extreme events to be forgotten. Taking these characteristics into account, we can classify the Gregório basin, mostly, as a risk cotrolling society, as the reaction to a new level of threat is to increase its individual protection and having no intention to move to a less risky area.

In the municipality of Belém, the commercial center is located in the Campina neighborhood in the Tamandaré basin. The region has been facing flooding problems since the foundation of the city. These floods occur more frequently in the months of April and May, which comprises the Amazon winter. The high rates of precipitation, high tide phenomena and low topographic level are the main natural causes of floods in the region. The results showed that merchants in the region lose up to 50% of their monthly profit in the winter months, and according to them, there are anthropic factors that influence the appearance of floods, such as garbage on public roads and the population's lack of environmental awareness. A striking feature of the region is the fact that the population is used to this scenario, as it is part of everyday life, so few stores have protection measures against floods and even suffering loss of profitability, the vast majority do not intend to change their business to another place. Due to these characteristics we can classify the area mostly as Risk negleting society, because they understand floods as a natural event and do not take measures to deal with it.

The study of these basins shows different types of floods and different ways of dealing with them. Brazil, being a country that comprises different climatic regions, has very different realities, therefore, very different societies. Future studies should be done to find effective ways to deal with floods taking into account social perception, thus initiating bottom-up strategies to deal with them.