Title: Poor environmental conditions, food and water insecurity, neighborhood perceptions, and self-reported physical and mental health in four disadvantaged urban communities in Salvador, Brazil: a cross-sectional study.

Authors and affiliations: Christine E. Stauber1*, Corey Hopwood1, Fabiana Almerinda G. Palma2, Julia Fernandes Calvalcanti Prestes2, Juliet Oliveira Santana2,3, Ana Maria N. Silva2, George Gonçalves Machado2,3, Daiana de Oliveira2,4, Fábio N. Souza2, Nivison Nery Jr.4, Priscilla Elizabeth Ferreira dos Santos2, Adedayo Michael Awoniyi2, Yeimi Alexandra Alzate López2, Diogo César de C. Santiago2, Rachel Helena Coelho5, Juan P. Aguilar Ticona2,4, Scott R. Weaver1, Claire A. Spears1, Amanda K. Gilmore1, Hussein Khalil6, Cleber Cremonese2, Federico Costa2,4,7*.

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1 - School of Public Health, Georgia State University, Atlanta, Georgia, United States.

2 - Collective Health Institute, Federal University of Bahia, Salvador, Bahia, Brazil

3 - Postgraduate Program in Geography, Federal University of Bahia, Salvador, Bahia, Brazil

4 - Gonçalo Moniz Institute, Oswaldo Cruz Foundation (Fiocruz), Ministry of Health of Brazil, Salvador, Bahia, Brazil

5 - Faculty of Economics, Federal University of Bahia, Salvador, Bahia, Brazil

6 - Department of Wildlife, Fish, and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden

7 - Department of Epidemiology of Microbial Diseases, Yale School of Public Health, New Haven, CT06511, USA

*Correspondence to: CES - cstauber@gsu.edu | FC - fcosta2001@gmail.com

Abstract: Emerging evidence suggests an association between environmental conditions and mental well-being. While the physical health impacts of environmental exposures such as contaminated drinking water or open sewers are well-documented with respect to the spread of infectious diseases, the mental health implications of these poor environmental conditions and exposures are less well understood, particularly in the context of urban impoverishment. Addressing the association between urban environmental conditions and mental health remains an important opportunity to reduce barriers to health, improve quality of life, and increase longevity. However, few studies have explored this relationship in the context of Brazil. The purpose of this study was to examine the associations between poor environmental health conditions, food and water insecurity, neighborhood perceptions and self-reported physical and mental health in four disadvantaged urban communities that were receiving a simplified sewage intervention in Salvador, Bahia Brazil. Using baseline surveys, we examined cross-

sectional associations between water, sanitation, and hygiene conditions, food and water insecurity, and neighborhood perceptions with self-reported physical and mental health measured via the Short-Form 12 questionnaire. Poor environmental conditions, such as trash and open sewers near the home, were associated with lower mental health scores (ranging from -1.18 to -2.86 on average). Problems with sewer, sewer overflow, landslides and flooding were associated with worse physical health scores (-2.29 to -3.24 on average). Food insecurity was strongly associated with worse physical and mental health (-1.10 and -1.24 respectively for changes in food insecurity levels). Positive perceptions of neighbors including trust and willingness to help one another were associated with improved mental health scores (0.70-2.34 on average). The results suggest that improving environmental conditions and reducing food insecurity may have a positive impact on both mental health and physical health. Communities should be engaged in developing solutions to address these complex issues.

Keywords: Food insecurity; Mental health; Water insecurity; Sanitation; Slums; Quality of life

Introduction

The global shift from rural and agrarian societies to urbanized environments has accelerated dramatically over the past 150 years, primarily driven by globalization and industrialization.[1] Frequently, migration to cities is incentivized by perceived economic and educational opportunities.[2] Today, more than half of the world's population resides in urban areas, a figure projected to rise to 66% in the coming decades.[3-5] While urbanization can bring economic growth and improved access to services, it also introduces complex challenges, particularly in low- and middle-income countries (LMICs) where infrastructure development often lags behind population growth.[2] In Brazil, for instance, nearly 10% of the urban population lives in favelas, low-income, informal, and largely self-built settlements often with probable high levels of food and water insecurity, and commonly referred to as slums in other LMICs.[6] These areas were recently defined by the Brazilian government as favelas and urban communities which replaces the previous designation as subnormal agglomeration.[6-8] The key characteristics of these areas are lack of tenure to land, inadequate or absent public services and limited or no urban planning which results inadequate basic services such as clean water, sanitation, and healthcare.[9, 10]

The rapid concentration of populations in urban centers has intensified environmental health challenges.[2] Densely populated neighborhoods often experience limited liquid and solid waste management resulting in environmental pollution in addition to limited access to healthcare.[2, 11] In Brazil, both social and environmental determinants of health are closely linked to the spread of infectious diseases and a diminished quality of life highlighted during the COVID-19 pandemic which caused a substantially greater burden of illness in favela communities in Brazil.[9, 12, 13]

Disadvantaged urban communities are places where environmental degradation such as open sewers can transmit diseases along with complex conditions of poverty and systemic inequality.[11] This can be attributed to a history of slavery and racism that continues to drive poverty, educational access and economic power inequalities across race and class.[14-16] Moreover, environmental exposures such as limited access to green space, the presence of trash or lack of sanitation services in urban settings have been increasingly associated with both physical illness such as infectious disease and poor mental health outcomes such as depression and anxiety, underscoring the need for integrated actions to improve urban conditions with potential impact to improve both physical and mental health.[17-19]

Mental health is a growing concern in Brazil.[20] In urban favela environments, residents often face exposure to environmental hazards such as trash, open sewers and rats as well as interpersonal violence, and social instability.[21-23] These communities may be excluded from participating in the development of solutions to improve quality of life and lower the risk of diseases due to the frequent top down nature of government programming intended to address these concerns.[24] During the COVID-19 pandemic, proposed prevention strategies often ignored the multidimensional risk factors disadvantaged communities faced such as multi-generational living conditions and an inability to work from home.[9]

Despite the growing prevalence of mental health issues such as anxiety and depression, access to mental health services remains limited due to a high demand and overburdened public services not to mention the underutilization of services due to stigma.[14, 25, 26] While there are clear links between environmental exposures such as lack of water and sanitation and spread of infectious diarrheal diseases or zoonotic or vectorborne illness,[27] the relationship between environmental exposures and mental health are less well understood, particularly in the context of urban poverty.[28]

Emerging evidence suggests a strong and potentially bi-directional association between environmental conditions and mental well-being.[17, 18, 29] For example, there is growing evidence that being exposed to nature and green spaces is associated with improved mental health. However, it is also as likely that those with mental health issues may be less likely to engage with recreational activities in outdoor environments.[30] Additionally, there is now a substantial amount of literature demonstrating the impact of climate change on mental health showing how environmental conditions can contribute to anxiety and depression.[31] There is also recognition of the impact on neighborhood perceptions and links between environmental conditions and mental health.[23, 32]

Unique to our context, there have been few studies exploring the association between environmental conditions and mental health in Brazil. In the context of water and sanitation, a cross-sectional study found that those living in rural areas with drought were more likely to experience anxiety.[33] In a study examining urban conditions and mental health in São Paulo, researchers found that positive environmental conditions such as increased green space were associated with decreased anxiety.[22] In addition to urban environmental conditions, there is a growing effort to understand how water and food insecurity conditions are linked to mental health concerns as both water and food insecurity have been linked to worse mental health.[34, 35] While food insecurity is important in both rural and urban areas, its components are complex and drivers of the condition vary in these different environments. Brazil saw increases in food insecurity during the COVID-19 pandemic which exacerbated inequalities particularly in poor urban areas.[36] However, there have been no studies specifically examining urban environmental conditions including water and sanitation access or water insecurity or food insecurity in urban favela communities of Salvador, Brazil. This current study aims to address this gap by examining the associations between poor environmental conditions, food and water insecurity, and neighborhood perceptions with physical and mental health in urban favela communities in the city of Salvador, Brazil.

This study was conducted within the design of a larger intervention study evaluating a piped sewerage intervention system in the city of Salvador. The larger study aims to evaluate the effectiveness of this intervention in reducing zoonotic and vector-borne diseases in disadvantaged urban communities.[37] Salvador has the largest population of Afro-Brazilians in the country[38] where the colonial and slavery historical past continues to sustain profound socioeconomic disparities within Salvador's population.[8] According to the Brazilian government's most recent national census, 34.9% of the city's households are in favelas or urban communities, compared to a national average of 8%, representing an important location for research on environmental conditions and mental health.[6] In our study, we hypothesized that there would be associations between poor environmental conditions and worse mental health in addition to worse physical health

among adults in favela communities in Salvador, Bahia, Brazil. In addition, we hypothesized that negative neighborhood perceptions and food and water insecurity would be associated with worse mental health and physical health.

Materials and Methods

Ethics statement

The larger study was originally approved by the Brazilian Ethical Committee (CEP/ISC/UFBA) under number CAEE 32361820.7.0000.5030, and a national research ethics committee (CONEP) linked to the Brazilian Ministry of Health under approval number 6.766.544. All participants were informed about the study and gave their written consent to participate. Data were de-identified and shared with Georgia State researchers on June 8, 2023 after the Georgia State University Institutional Review Board (IRB) reviewed the proposal and determined that it was exempt from IRB review due to the lack of any additional direct contact with human subjects (application H23635).

Study design, setting and participants

The city of Salvador is the fifth largest city in Brazil with an estimated population in 2024 of 2,568,928 inhabitants.[38, 39] Communities that participated in this study were selected based on the criteria for the larger study described in Cremonese et al., 2023.[37] The primary selection criterion was that households were in neighborhoods that were receiving the piped sewer intervention from the Water and Sanitation Company of the State of Bahia (Empresa Baiana de Águas e Saneamento). In addition, the communities were also selected based on the high risk of leptospirosis transmission determined from previous surveillance and risk factor studies.[11, 40] The following communities were included in this study: Nova Sussuarana (NS), Jardim Santo Inácio/Mata Escura (JSI/ME), Arenoso (AR) and Calabetão (CAL). For the intervention study, initial sample size determined the need to recruit approximately 175 per neighborhood cluster which was increased by 30% to allow for attrition. The present study is a cross-sectional analysis of the data collected during the baseline recruitment survey. The participant eligibility for this study included men and women, 18 years of age or older, who slept in the household for at least three nights per week.

Figure 1. Map showing the four study areas (NS, AR, JSI/ME and CAL)

Data collection

Recruitment of households and completion of the baseline survey in these four communities occurred from May 2021 to December 2022. Team members explained the research objectives of the piped sewer intervention study,[37] invited eligible household members to take part in the study and confirmed their agreement by obtaining written informed consent. A household was visited up to three times for recruitment before moving on to the next household selected for participation.

Participants were administered a questionnaire to collect information on demographics, socio-economic status, mental and physical health, environmental conditions (sanitation, trash in both at the household level as well as near the household such as in the nearby streets and areas also called peri-domiciliary area), and neighborhood perceptions. The questionnaire included the following validated instruments: the Brazilian Food Insecurity Scale (EBIA) which is a tool specifically validated for assessing food insecurity in Brazil[41], the Household Water Insecurity Experiences Scale (HWISE) a 12-item tool designed to measure household water insecurity, including access, reliability, and adequacy[42]and the Short Form Health Survey SF-12,[43, 44] a validated questionnaire which includes questions to assess self-reported physical and mental health. Measures that were previously developed in English such as the SF-12 or the HWISE tool were translated to Portuguese prior to administering. After translation, the questionnaire was designed and administered electronically using the Research Electronic Data Capture software (REDCap).[45] All data were collected in Portuguese by trained Brazilian research teams, with an average duration of 20 to 30 minutes. Of note, the following questions were only administered to those who indicated they were the head of the household: EBIA scale and the HWISE scale as well as questions on household flooding and landslides related to climate change. These questions were administered to the person who identified themselves as the head of household during the interview because the questions focus on a broad overview of conditions in the household during the last 30 days for the EBIA and HWISE scale or for up to six months for questions about problems related to climate change. The choice of head of household was based on the consideration that this individual exercises responsibilities within the household and is regarded as such by other family members, to ensure that they are the central figure in the household. In our study, the head of household was considered the most appropriate choice for data collection for these specific questionnaires.

Predictor Variables

Demographic Variables

The following demographic characteristics were assessed: age, sex, race, educational attainment, work status and civil status. Age was coded in years, sex was male or female, race categories were those used by the Brazilian Census which include black, brown, white, Asian, and Indigenous. Per the Brazilian Census, those who responded that they self-identified as black or brown were considered Afro-Brazilian. Civil status was classified as single, married, living together or other (being widowed or divorced as they made up ~ 7% of the total sample). For educational attainment, we narrowed the categories to comprise attendance of at least primary, middle or secondary school or higher, and selected the highest level reported. Employment status was classified as having current employment into one of three categories: those who did not work in the last week, worked in last week but in an informal job, or worked in a formal employment in the last week.

Environmental conditions, food and water insecurity, and neighborhood perceptions

Questions about environmental conditions included variables that provided details on potential environmental hazards or concerns such as living near open sewers, bad odor,

or access to piped water, for example. These questions were binary questions (yes, no) and were coded as binary variables. The food insecurity (EBIA) and water insecurity (HWISE) item responses were coded 0 or 1 and summed to create scaled scores. In addition, HWISE scores were categorized into four ordinal categories of water insecurity ranging from light to severe (per numerical values suggested in the user's manual). A total of 10 questions on the perceptions of the neighborhood and neighbors were asked. These consisted of four questions with a five level Likert scale response. There were also six binary questions. From these questions, the following neighborhood perception variables were assessed: willingness of neighbors to help one another, willingness of the participant to help other people, trust in people in the community, support from a neighbor to look after the house when away.

Outcome Variables

The primary outcomes of interest were the physical and mental health scores produced from responses to the SF-12 questionnaire. The physical and mental health scores were calculated using the guidelines from the SF-12 questionnaire. The responses to each domain's questions were summed according to the manual[43] to provide quantitative, continuous scores for physical and mental health. To ensure accuracy of the scores, item scale correlations were checked in accordance with the SF-12 manual. Specifically, we examined correlations between and within mental health domain responses and physical health domain responses. In addition, we examined the range for each and assessed if it fell within the typical range for physical health and mental health scores.

Statistical analysis

Descriptive statistics were calculated to characterize the distribution of the variables. Responses of "Don't know" or "no response" for questions with those options were categorized as missing when the percent of the response was within 3% of the total responses. When the percent "Don't know" or "no response" exceeded 3%, a sensitivity analysis involving categorizing the response alternatively as "yes" and as "no" to assess sensitivity of the findings to handling of these responses was conducted. To assess the association between the primary outcome variables and the predictor variables of environmental hazards, food and water insecurity, and neighborhood perceptions, we performed linear regression examining the bivariate association between each condition and physical health or mental health scores. These are presented as unadjusted associations. In multiple linear regression analyses to examine the associations between environmental predictor variables, food and water insecurity, and neighborhood perceptions and physical and mental outcome variables, we adjusted for demographic variables that had statistically significant bivariate associations with the outcome variables. To address the nesting of participants within neighborhoods, we included neighborhood as a fixed effects factor in the models (using effects coding). A frequentist approach to statistical analysis was taken with two-tailed probability values less than .05 indicating statistical significance. Descriptive statistics were computed, unstandardized regression coefficients and 95% confidence intervals were estimated, and statistical testing was conducted with Stata 18.

Results

A total of 779 participants ≥18 years of age completed the questionnaires during the enrollment phase of the intervention study and were the selected participants for this analysis. Most questions exhibited fewer than <3% missing. There are some important exceptions. Responses on educational attainment and salary resulted in >30% missing. In addition, the measures for food insecurity and water insecurity and climate change questions were only administered to those who identified themselves as the head of household. As a result, some measures resulted in a large proportion missing between 30-60%. Lastly, a smaller number of questions were not administered to respondents due to response skip patterns (i.e. access to piped water and service provider). For example, if someone responded that they did not have access to piped water, they were not asked if they had water from the state water provider. To clarify the response rates, numbers of observations are listed in Table 1 along with the % missing.

Demographic Characteristics

For this study, as described in Table 1, the participants were on average 42 years of age, 63% of the participants were female and 94% were considered Afro-Brazilian. Approximately 1/3 of (37%) of participants reported completing some secondary education or higher, but a large proportion of participants did not respond to questions about education (27% missing). Approximately 46% of the participants reported being single, 47% reported living together or being married and 7% were either divorced or widowed. A majority reported working in the last week (52%) and approximately 40% of those working participants reported being employed in a formal work position. Approximately 20% of the respondents reported receiving the Bolsa Familia program (cash transfer program for eligible female head of household with young children)[13]. Lastly, almost all (93%) respondents reported living in the neighborhood for at least 3 years, and average household size was three members (but ranged from 1 to 11).

Table 1. Participant demographic information in Salvador, Bahia, Brazil (2021-2022) (n=779)

Individual demographic characteristics	Frequency
Age (years), mean (SD)	41.9 (15.3)
Sex, n(%)	
Female	491 (63)
Male	288 (37)
Race, n(%) (self-reported)	
Black	394 (50.6)
Brown	338 (43.4)
White	30 (3.9)
Asian	14 (1.8)
Indigenous	3 (0.4)
Education n(%)	
Primary	69 (8.9)
Middle	207 (26.6)
Secondary	290 (37.2)
Missing	213 (27.3)
Civil Status, n(%)	

Single	355 (45.6)
Married	173 (22.2)
Living together	194 (24.9)
Other (widow, divorced)	57 (7.3)
Household size, average (range)- N=762	3 (1-11)
Worked in the previous week, n(%)	
Yes	402 (51.6)
Formal	161 (20.7)
Informal	240 (30.8)
Didn't respond	1 (0.1)
Did not work in the last week	376 (48.3)
Didn't respond	1 (0.1)
Monthly Salary (R$), average (range)-N=392	1,225 (0-5,000)
Received Cash Transfer (Bolsa Família)	
Yes	161 (20.7)
No	228 (29.3)
Did not respond	1 (0.1)
Not asked (not eligible, no children)	389 (49.9)
Live ≥ three years in the community	723 (92.8)

Environmental, Neighborhood Characteristics and Food and Water Insecurity

Results from the questions regarding access to water, reported environmental problems and concerns, food and water insecurity and neighborhood perceptions are reported in Table 2. Most households reported having access to piped water (97%) which was treated and provided by the state-run water and sanitation provider (EMBASA) (95%). Almost half experienced intermittent service (42%) even though they reported piped water supply. More than half reported some form of water treatment including 44% reported filtering the water for drinking and 12% reported using purchased water for drinking. In terms of other environmental and sanitation conditions, 80% of respondents reported having an open sewer near (within 10 meters) of their house, 64% sighted rats near their house, 61% reported having a bad odor outside of the home, 25% reported trash accumulated near their household and 16% reported living near a hillside. Most respondents (>85%) reported paved roads and street lighting within their neighborhoods.

Table 2. Household characteristics regarding water and sanitation concerns as well as neighborhood perception reported by participants in Salvador, Bahia, Brazil (2021-2022) (n=779)

Variables	Frequency (%)
Piped water	756 (97.1)
No access to piped water	6 (0.8)
Missing	17 (2.1)
Piped water from local service provider	739 (94.9)
Piped water not from local service provider	13 (1.7)
Missing	27 (3.5)
Frequency of water intermittency	
No intermittent service	403 (51.7)

< 3X per week	231 (30.0)
3-6X per week	94 (12.1)
Missing	51 (6.6)
Stores water	461 (59.2)
Does not store water	293 (37.6)
Missing	25 (3.2)
Drinking water treatment	
Filtered	344 (44.2)
Not treated	293 (37.6)
Purchased	98 (12.6)
Other	22 (2.8)
Missing	22 (2.8)
Trash accumulated near house	176 (22.3)
No trash near house	580 (74.4)
Missing	23 (3.0)
Open sewer near house	623 (80.0)
No open sewer near house	138 (17.7)
Missing	18 (2.3)
Reported problems with sewer	302 (38.8)
No problems with sewer	446 (57.2)
Missing	31 (4.0)
Bad smell near house	448 (57.5)
No bad smell near house	313 (40.2)
Missing	18 (2.3)
Rats sighted near house	499 (64.1)
No rats sighted near house	261 (33.5)
Missing	19 (2.4)
Streets lights available	676 (86.8)
No streets lights near house	87 (11.1)
Missing	16 (2.1)
Paved streets	664 (85.2)
No paved streets near house	99 (12.7)
Missing	16 (2.1)
House on a hillside	127 (16.3)
Not on a hillside	636 (81.6)
Missing	16 (2.1)
Neighbors help one another, mean (SD)-N=752	3.41 (1.57)
I help others in my neighborhood, mean (SD)-N=763	4.62 (0.77)
I get along with neighbors, mean (SD)- N=776	4.02 (0.75)
I trust others in my neighborhood, mean (SD)-N=769	2.88 (1.57)
I know my neighbors by name	619 (79.5%)
I do not know neighbors by name	142 (18.2%)
Missing	18 (2.3)
My neighbors could help if I was ill	589 (75.6)
My neighbors could not help if were ill	169 (21.7)
Missing	21 (2.7)
I helped my neighbors when they were ill	555 (71.2)
I have not helped my neighbors when they were ill	202 (25.9)
Missing	22 (2.8)
Would ask neighbors to watch my house while away	547 (70.2)
Would not ask neighbors to watch my house while away	209 (26.8)

Missing	23 (2.9)
Neighborhood association	330 (42.4)
No neighborhood association	336 (43.1)
Missing	113 (13.5)
Sewage overflows into house (last six months)	146 (18.7)
No sewage overflow into house (last six months)	247 (34.8)
Missing	362 (46)
Experience landslides (last six months)	129 (16.6)
Did not experience landslides (last six months)	330 (42.4)
Missing	320 (41.1)
Experience floods (last six months)	162 (20.8)
Did not experience floods (last six months)	302 (38.8)
Missing	315 (40.4)
Food insecurity, average score (SD)(range)-N=467	1.9 (2.0) (0-5)
Water Insecurity, average score (SD)(range)-N=284	12.0 (9.5) (1-44)

Four Likert Scale questions were asked about perceptions of the neighbors with a higher score indicating better or more favorable perception. Of these four questions, the highest average score was for those who said they helped others in their neighborhood (average 4.6/5), followed by how well they get along with others (4.0/5). Lower averages scores were found for how likely neighbors were to help one another and the lowest score was for how much they trust people in their neighborhood (2.9/5). A total of six questions with binary responses were asked about their neighbors. Most respondents felt like they knew their neighbors by name (79%), would help each other if they were ill (71-75%) and would ask their neighbor to watch their house if they were away (70%). About 43% knew about a neighborhood association in their neighborhood and 43% were not aware of one with 14% missing responses because they did not know the answer to this question. The range for the food security scale was 0-5 and the average was 1.9 (SD 2.0). The range for the water insecurity scale was 1-44 and the average was 12 (SD 9.5).

Primary outcome variables

The composite score for the physical health questions, hereafter referred to as PCS12, had a mean of 47.6 (SD 10.6) with a range from 12-65 and a median of 51 (results not shown). The mental health composite score, hereafter referred to as MCS12, had a mean of 51.4 (SD 10.9) with a range of 16-72 and a median of 54. The scores for physical and mental health were somewhat normally distributed but slightly left skewed. Based on an analysis of the results according to the SF-12 manual, the scores produced were generally aligned with expected scores including a mean near 50 and a standard deviation near 10. In addition, domain responses related to physical health including general health, physical functioning and bodily pain were highly correlated with PCS-12 scores. The domains related to mental health including vitality, and social functioning were highly correlated with MCS-12 scores. Accordingly, the MCS-12 and PCS-12 scores were not correlated which was expected.

Association between demographic variables and primary outcomes of interest

Using bivariate linear regression, we examined associations between demographic variables and PCS-12 or MCS-12. We based our assessment of statistically significant association by examining the p-value <0.05. Based on these conditions, the following variables were statistically significantly associated with either PCS-12, MCS-12 or both: age, sex, current work status, current school attendance, and civil status. Being female was statistically significantly associated with worse physical and mental health scores (a negative coefficient). Increasing age (in years) was associated with better mental health and worse physical health scores. Race was not associated with differences in PCS-12 or MCS-12. As a result of the statistically significant associations and based on existing literature suggesting plausible potential for inclusion,[14, 23, 46] we included age, sex, current work status, civil status current school attendance and neighborhood in the adjusted models. While other variables such as monthly salary and level of educational attainment would have been helpful to include, they had a large portion of responses missing and therefore were not included in the adjusted models.

Associations between poor environmental conditions, food and water insecurity, neighborhood perceptions and physical and mental health

We examined environmental conditions, measures of food and water insecurity, and neighborhood perceptions to see how they were associated with measures of physical and mental health. Poor environmental conditions included exposure to trash, sewage and rats as well as access to water. Broadly, we found that those respondents who reported poor environmental conditions had lower physical or mental health scores on average indicating a negative association between environmental hazards and physical and mental health. The results of the analysis for associations between physical and mental health scores for bivariate models (unadjusted) and adjusted models as shown in Table 3. Specifically, the following water and sanitation conditions were statistically significantly associated with lower mental health scores in unadjusted and adjusted models: water service disruption, trash near the house, bad odor near the house, and problems with sewers. These conditions were associated with MCS12 scores ranging from -1.30 to -2.86 lower on average. The largest negative effect was found for those who reported trash near the house. They had -2.86 (95% CI: -4.64, -1.07) MCS12 lower score in the adjusted model. We found that having access to paved roads in the neighborhood had the greatest positive impact on MCS12 score with those who had paved roads in their neighborhood having on average 2.87 greater score (95% CI: 0.56, 5.18).

Table 3: Unadjusted and Adjusted Associations between Environmental Characteristics and Physical and Mental health Scores in Salvador, Brazil (2021-2022)

Environmental Condition	PCS12 (Physical Health) B(95% CI) N	PCS12 (Physical Health) Adjusted B(95% CI) N	MCS12 (Mental Health) B(95% CI) N	MCS12 (Mental Health) Adjusted B(95% CI) N
Access to piped	-4.19 (-13.5, 5.15)	-5.97 (-14.8, 2.85)	7.16 (-2.3, 16.7)	4.49 (--4.65, 13.7)

water	N= 738	N=736	N=738	N=736
Provided by regional service provider	1.20 (-4.65, 7.04) N=729	1.89 (-3.66, 7.45) N=727	3.03 (-2.89, 8.04) N=729	1.70 (--4.05, 7.45) N=727
Experiences water service disruptions	-0.49 (-1.60, 0.61) N=706	-0.49 (-1.67, 0.69) N=704	**-1.35 (-2.47, -0.23)*** N=706	**-1.30 (-2.53, -0.081)*** N = 704
Store water at house	-1.45 (-3.03, 0.13) N=730	-0.64 (-2.14, 0.87) N=728	0.75 (-0.84, 2.33) N=730	0.0093 (-1.47, 1.65) N=728
Trash near the house	-0.95 (-2.77, 0.88) N=732	-1.18 (-2.90, 0.54) N=730	**-2.43, (-4.28, -0.59)*** N=732	**-2.86 (-4.64,-1.07)***** N=730
Open sewer near the house (<10 m)	-1.15 (-3.10, 0.79) N=736	**-2.22 (-4.13, -0.32)*** N=736	-0.86, (-2.87, 1.15) N=738	-0.015 (-2.00, 1.97) N=736
Bad smell near the house	-1.29 (-2.86, 0.26) N=737	-1.25 (-2.74, 0.23) N=735	**-1.81 (-3.38,-0.23)*** N=737	**-1.59 (-3.14, -0.056)*** N=735
Problem with sewer	**-2.34 (-3.88,-0.79) *** ** N=739	**-2.73 (-4.19,-1.26)***** N=738	**-1.67 (-3.27, -0.067)*** N=739	**-1.77 (-3.33, -0.20)*** N=738
Rats near the house	-0.27 (-1.89, 1.35) N=736	-1.13 (-2.68, 0.42) N=734	-1.29 (-2.93, 0.35) N=736	-1.03 (-2.63 0.58) N=734
Street lights	-1.48 (-3.91, 0.95) N= 739	-1.04(-3.37, 1.29) N=737	0.84 (-1.63, 3.32) N=739	0.72 (-1.70, 3.13) N=737
Paved roads	-1.50 (-3.81, 0.82) N=739	--1.06(-3.30, 1.17) N=737	**3.00 (0.66, 5.35)*** N=739	**2.87 (0.56, 5. 18) ** ** N=737
Sewer overflow	-2.08 (-4.29, 0.13) N=416	**-2.68 (-4.81, -0.55)*** N= 415	-2.25 (-4.54, 0.027) N=416	**-2.34 (-4.56,-0.12) * N=415**
Flooding	**-2.61 (-4.69, -0.53)*** N=462	**-3.24 (-5.27, -0.22)***** N=461	-1.04 (-3.16, 1.09) N=461	--1.04 (-3.15, 1.07) N=461
Landslides	**-2.22 (-4.43, -0.15)*** N= 456	**-3.17 (-5.38,-0.96)***** N=456	-1.69 (-3.95, 0.58) N=456	-1.51 (-3.81, 0.78) N=456
Food Insecurity Scale (1-5)	**-1.14 (-1.61, -0.67)***** N=464	**-1.10 (-1.547,-0.63)***** N=464	**-1.52 (-2.00,-0.04)***** N=464	**-1.24 (-1.72,-0.76)***** N=464
Water Insecurity Scale (0-44)	-0.040 (-0.18, 0.10) N=273	-0.057 (-0.20, 0.086) N = 273	-0.073 (-0.22, 0.075) N=273	-0.023 (-0.18, 0.13) N=273

Adjusted models included age, sex, civil status, work in the last week, current school attendance, and neighborhood

*, *** indicate p-value <0.05, <0.005

With respect to PCS12, the following water and sanitation conditions were statistically significantly associated with lower PCS12 scores: open sewer near the house, problems with sewer, sewer overflow, flooding and landslides. These conditions were associated with PCS12 scores ranging from -2.22 to -3.24 lower on average. The largest effect was found for those who reported flooding in the last six months, which had on average -3.24 (95% CI: -5.27, -1.22) lower PCS12 compared to those who did not experience flooding.

We also examined food insecurity and water insecurity. Higher food insecurity scores were statistically significantly associated with worse physical and mental health scores in both unadjusted and adjusted models. More specifically, an increase in food

insecurity (higher level of food insecurity across any dimension) was associated with a -1.07 average lower (95%CI: -1.54,-0.60) PCS12 score and a -1.21 lower MCS12 score (95%CI: -1.70, -0.73). When assessing the relationship between water insecurity, we found no statistically significant associations with PCS12 or MCS12 scores.

When examining perceptions of neighbors, each of the four Likert-scaled response questions were statistically significantly associated with increased MCS12 scores as shown in Table 4. An increase in Likert scores to more favorable perceptions or stronger agreement score was associated with higher MCS12 from 0.72 to 2.36 on average. For example, higher agreement for participants who said they get along with others in their neighborhood (units ranged from strongly disagree to strongly agree scaled from 1-5) was associated with an increase in 2.36 for the MCS12 score on average (95% CI:1.36, 3.37). None of the Likert Scale measures were associated with any statistically significant differences in PCS12. Of the binary response measures, two were statistically significantly associated with PCS12. Those who reported that they get help from their neighbors when ill had a lower physical health score of -2.13, (95%CI: -3.88, -0.37). Separately, those who reported that they could help if their neighbor was ill had statistically significantly higher PCS12 scores on average 2.23 (95% CI: 0.59, 3.89). None of these five questions were found to be statistically significantly associated with changes in MCS12.

Table 4: Unadjusted and Adjusted Associations between Neighborhood Perceptions and Physical and Mental health Scores in Salvador, Brazil (2021-2022)

Neighborhood perception	PCS12 B(95% CI) N	PCS12 Adjusted B(95% CI) N	MCS12 B(95% CI) N	MCS12 adjusted B(95% CI) N
Neighbors help one another	0.16 (-0.34, 0.65) N=742	-0.041 (-0.51, 0.443) N=740	**0.76 (0.25, 1.27)*** ** N=742	**0.72 (0.23, 1.21)*** ** N=740
I help others in my neighborhood	0.34 (-0.65, 1.31) N=753	-0.20 (-1.14, 0.75) N=751	**1.06 (0.049, 2.06)*** N=753	0.73 (-0.26,1.72) N=751
I get along with others in my neighborhood	0.57 (-0.45, 1.56) N=752	0.48 (-0.49, 1.44) N=750	**2.81 (1.78, 3.83)*** ** N=752	**2.36 (1.36, 3.37)*** ** N=750
I trust my neighbors	-0.11 (-0.59, 0.38) N=747	0.10 (-0.36, 0.56) N=745	**1.03, 0.53, 1.52)*** ** N=747	**0.74 (0.26, 1.23)*** ** N=745
I know most of my neighbors by name	-0.80 (-2.76, 1.15) N=750	-1.29 (-3.14, 0.56) N=748	-1.13 (-3.14, 0.88) N=750	-1.06 (-3.01, 0.89) N=748
I have a neighbor who can help if I am ill	**-2.29 (-4.12, -0.47)*** ** N=747	**-2.13 (-3.88, -0.37)**** N=745	0.065 (-1.81, 1.94) N=747	-0.033(-1.81, 1.86) N=745
I helped a neighbor when they were sick	**2.51 (0.78, 4.23)*** ** N=745	**2.23(0.59, 3.89)**** N=744	-0.082 (-1.86,1.69) N=745	0.76 (-0.99, 2.50) N=745
A neighbor can	-0.35 (-2.04, 1.35)	-0.34 (-1.95, 1.28)	1.43 (-0.31, 3.17)	0.79 (-0.91, 2.49)

watch my house while I am away	(N=746)	N=744	N=746	N=744

Adjusted models included age, sex, civil status, work in the last week, current school attendance, and neighborhood

*, *** indicate p-value <0.05, <0.005

Discussion

Environmental Hazards, Food and Water Insecurity.

In our cross-sectional analysis of approximately 800 adults from four urban favela communities in Salvador, Brazil we found statistically significant associations suggesting a negative impact of poor environmental conditions on physical and mental health. Poor environmental conditions measured by the presence of visible trash, open sewers, sewer problems and bad odor were associated with a decrease in mental health. In addition, climate related weather hazards including flooding, landslides, sewer overflow, sewer problems and open sewers were associated with a decrease in physical health. Our findings support previously identified associations from a meta-analysis which found inadequate sanitation was associated with common mental disorders.[18] It is important to note that most of these studies in recent meta-analyses or review papers focused on rural areas or broad measures of sanitation such as access to toilet facilities.[18, 47] None of the studies examined urban environmental conditions related to sanitation in Brazil.[17, 18] A study in Mumbai, India, corroborated our findings showing that slum dwellers living in structurally substandard housing and exposed to flooding, rats, inadequate water and sanitation had three times higher odds of experiencing common mental disorders.[48] Our results suggest that even when access to water and sanitation infrastructure is present, poorly functioning infrastructure negatively impacts physical and mental health for urban favela communities. Our work contributes to the growing understanding of the links between sanitation conditions and mental health in urban environments, especially in places where sewered sanitation is available and can be implemented or improved.

We found negative associations between specific conditions linked to climate concerns such as flooding, landslides and sewer overflow and physical health. In these communities in Salvador, flooding, landslides and exposure to sewer have frequently been documented to increase infectious disease risk such as leptospirosis and Zika virus.[11] While we did not document the specific physical health conditions with our study, physical health risks include infectious disease risks as well as risk from injuries, stress-related physical characteristics or even exacerbation of chronic conditions.[17]

Although coverage of piped water supply was high, intermittent supply and reports of water treatment were common suggesting poor safety and quality perceptions.[49] We found that water service disruption was associated with worse mental health, this association was lower in magnitude and strength when compared to trash or sewer problems suggesting a more limited impact of water access on mental health in our study. While there is increasing evidence that water insecurity can be linked to mental health disorders,[18, 50] we were not able to corroborate that in our study. This may be

due to high level of access to piped water which limited the overall severity of water insecurity. We also had a smaller number of observations which may limit our ability to detect these associations.

We found a strong association (in both magnitude and effect size) between food insecurity and physical and mental health. There is growing recognition of the links between food insecurity and mental health which was also recently documented in adults in Mexico.[50] During the COVID-19 pandemic, Brazil experienced increased hunger and food insecurity across the country. [51] While food insecurity is not directly caused by the poor environmental conditions reported in our study, environmental conditions have been demonstrated to impact food insecurity in both urban and rural communities in Brazil.[52] Furthermore, food deserts which lack healthy unprocessed options are common concerns in urban environments and have been shown to be associated with food insecurity in Brazil.[53] Our findings highlight the need to consider both environmental conditions, food insecurity and physical and mental health as we begin to understand the interplay of environmental exposures and mental health for urban favela communities.

Neighborhood perceptions

We found that positive neighborhood perceptions were associated with better mental health scores across many of the conditions measured. The greatest effect was found for the question about getting along with neighbors and measures of mental health suggesting that the greater the agreement, the stronger the impact. This is an important consideration for communities facing many social and environmental challenges. Perceived trust in others may support mental health through exchange of mutual support and trust.[54] Neighborhood strengths such as ability to help one another or lean on other community members may serve as a protective factor for mental health .[21, 32, 55] As found in a slum community in Bangladesh, social networks, support, and friendship were associated with reductions in stress and anxiety, thereby improving the community's mental health.[56] The same was observed in women in urban communities in Ibadan, Nigeria.[57] Although we found that those who reported receiving help when ill had worse physical health, it is likely that these results reflected the fact that the respondent who answered had been ill previously. The opposite may occur when a neighbor responds they have helped another neighbor. It may be that this duty falls to healthier (and younger) neighbors. Overall, these neighborhood perceptions deserve additional attention to determine how they can help mitigate or modify the mental health challenges related to environmental conditions and food insecurity in communities.

Our study has several limitations that should be considered but do not diminish our findings. Our primary recruitment criterion for participant selection was they reside in a household where a piped sewer intervention would be implemented. We used self-reported surveys as the primary source of information on services and conditions. Also, for some conditions, we focused on the head of household. These can limit the generalizability of these findings. In addition, this analysis is cross-sectional and therefore we can only discuss associations and not causality. These limitations require more cautious interpretation of our findings.

Nevertheless, our findings have important implications for urban environmental conditions, especially in settings where piped sewer interventions are possible such as these urban favela communities in Brazil. Our study provides important insight into underserved and understudied area of investigation about environmental degradation, food insecurity in a region with high proportion of Afro-Brazilians. Our findings highlight the need to better understand and address the potential detrimental impact of poor environmental conditions on physical and mental health and the ability for positive neighborhood perceptions to influence mental health. Further work is needed to identify sustainable and acceptable solutions for improving these environmental conditions and reducing food insecurity. Communities should be fully engaged in deriving solutions to improve them. Lastly, our study supports the need to include mental health measures in studies of environmental conditions that have more traditionally focused primarily biomedical outcomes.

Conclusion

Overall, the current study contributes to the literature by documenting associations of poor environmental conditions, neighborhood perceptions, and food and water insecurity with physical and mental health in communities that are predominantly Afro-Brazilian in Salvador, Brazil. Safe and accessible water, sanitation and solid wastes services have the potential to provide broad health benefits beyond reductions of infectious diseases and their potential impact on mental health should not be overlooked. Community engaged and derived solutions to address these complex issues are important components to improving health as our understanding of the interplay of environment, mental health and physical health evolves.

Authors' contribution

Conceptualization –AKG, CAS, CES, FC, HK

Data curation – FNS, NNJ

Formal analysis -CES, CH, JPAT,

Funding acquisition – AKG, CAS, CC, CES, FC, HK, YAAL

Investigation – DO, DCCS, FAGP, PEFS, AMNS, JFCP

Methodology – JPAT, RHC, SRW

Project administration – CC, CES, FC

Resources – CES, FC, YAAL

Software – CES, CH, NNJ

Supervision – CC, CES, FC, SRW

Validation –CES, CH, FC, FAGP, FNS, AMA, JPAT, JFCP, RHC, AMNS

Visualization – CES, GGM, JOS

Writing – original draft – AKG, CAS, CES, CH

Writing – revision, review and editing: All

Declaration of interests

The authors have declared that no competing interests exist.

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Availability of data and materials

The datasets used and/or analyzed during the current study cannot be shared publicly because of personal information of participants in the survey, at the individual and household level. Researchers who wish to access the data can contact Dr. Mitermayer Galvão Reis, Principal Investigator, Oswaldo Cruz Foundation (mitergreis@gmail.com), data manager at the Oswaldo Cruz Foundation, Dr. Nivison Nery Junior (nivison.nery@fiocruz.br, nivisonjr@gmail.com) or Dr. Max Eyre, Department of Disease Control, London School of Hygiene & Tropical Medicine, London, United Kingdom, (max.eyre@lshtm.ac.uk).

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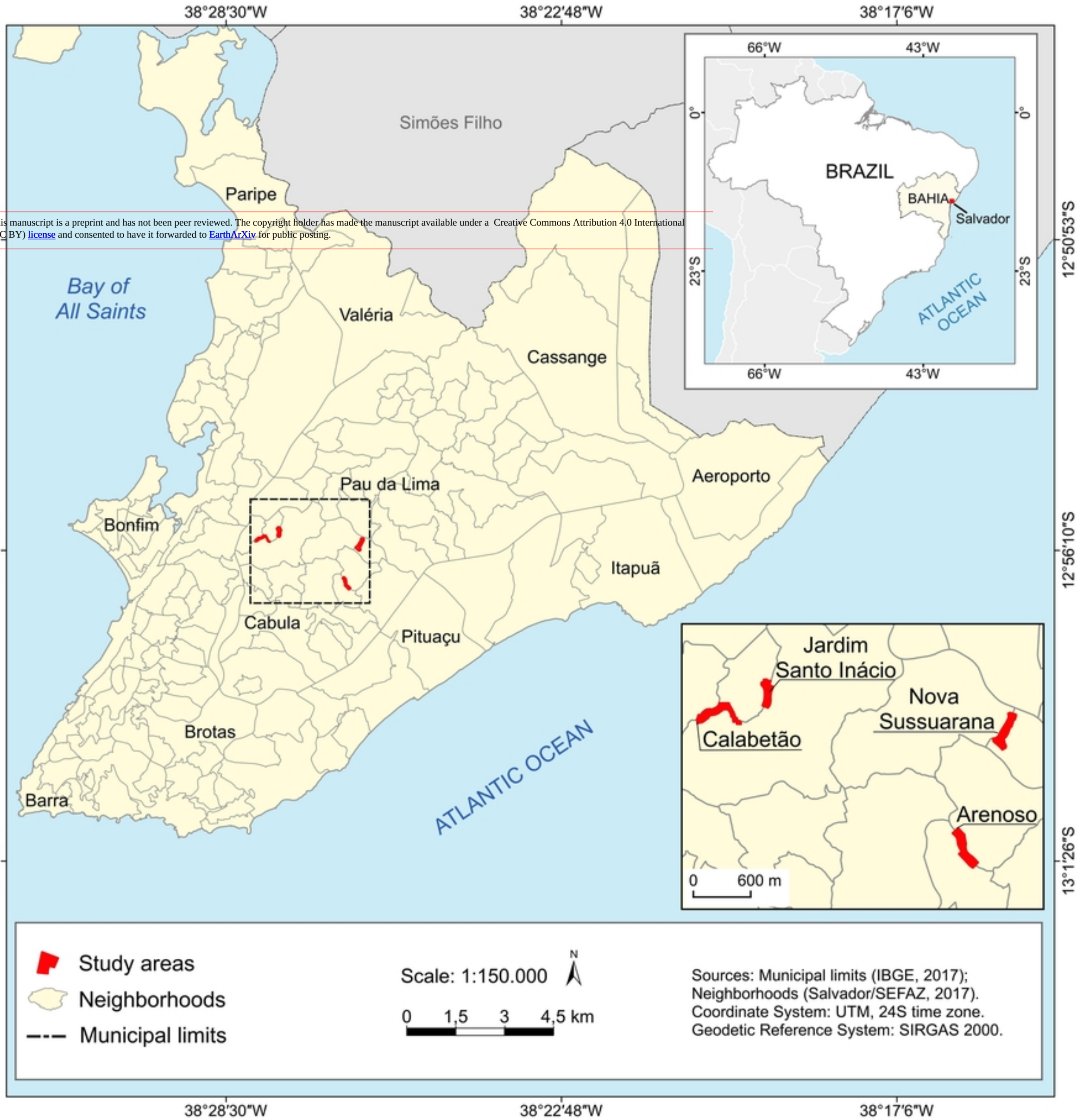
Location of the study areas of the Sanitary Intervention Project to prevent leptospirosis in the city of Salvador, Bahia



Figure