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Environmental racism, infrastructural deprivation and household food insecurity in Brazilian quilombola communities

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Manuscript: Environmental racism, infrastructural deprivation and household food insecurity in Brazilian quilombola communities

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Abstract

Food insecurity disproportionately affects historically marginalised populations and remains a major public health challenge in Brazil. Quilombola communities, Afro-descendant traditional territories shaped by resistance to enslavement, are frequently exposed to infrastructural and environmental deprivation resulting from long-standing institutional neglect. This cross-sectional, community-based study examined the association between environmental and infrastructural deprivation, interpreted through the lens of environmental racism, and household food insecurity in seven quilombola communities in Bahia, north-eastern Brazil, between April 2023 and February 2024. Household data were collected through face-to-face interviews using the Brazilian Food Insecurity Scale (EBIA) and a structured questionnaire on sociodemographic, behavioural and environmental conditions. Food insecurity was dichotomised as food secure versus food insecure. Environmental and infrastructural deprivation was measured using household-level indicators and summarised through a composite Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase, interpreted through the lens of environmental racism and environmental justice. Hierarchical logistic regression models with cluster-robust standard errors were estimated. Among 204 households, 70.6% experienced food insecurity, including 32.4% in severe food insecurity. Food-insecure households were more frequently exposed to lack of street paving, inadequate sanitation, absence of an in-house bathroom, unsafe waste disposal and precarious electricity access. In adjusted analyses, each additional adverse environmental condition was associated with higher odds of food insecurity (OR=1.50; 95% CI 0.94-2.39; p=0.086), suggesting a cumulative pattern of environmental disadvantage. These findings indicate that food insecurity in quilombola communities is shaped by structural environmental deprivation and support integrated policies linking food and nutrition security with environmental justice and basic infrastructure investments.

Keywords: Environmental Racism; Food Insecurity; Quilombola Communities; Environmental Justice; Social Determinants of Health

Research Article

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Running head: Environmental racism and food insecurity

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Abstract

Food insecurity disproportionately affects historically marginalised populations and remains a major public health challenge in Brazil. Quilombola communities, Afro-descendant traditional territories shaped by resistance to enslavement, are frequently exposed to infrastructural and environmental deprivation resulting from long-standing institutional neglect. This cross-sectional, community-based study examined the association between environmental and infrastructural deprivation, interpreted through the lens of environmental racism, and household food insecurity in seven quilombola communities in Bahia, north-eastern Brazil, between April 2023 and February 2024. Household data were collected through face-to-face interviews using the Brazilian Food Insecurity Scale (EBIA) and a structured questionnaire on sociodemographic, behavioural and environmental conditions. Food insecurity was dichotomised as food secure versus food insecure. Environmental and infrastructural deprivation was measured using household-level indicators and summarised through a composite Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase, interpreted through the lens of environmental racism and environmental justice. Hierarchical logistic regression models with cluster-robust standard errors were estimated. Among 204 households, 70.6% experienced food insecurity, including 32.4% in severe food insecurity. Food-insecure households were more frequently exposed to lack of street paving, inadequate sanitation, absence of an in-house bathroom, unsafe waste disposal and precarious electricity access. In adjusted analyses, each additional adverse environmental condition was associated with higher odds of food insecurity (OR=1.50; 95% CI 0.94-2.39; p=0.086), suggesting a cumulative pattern of environmental

disadvantage. These findings indicate that food insecurity in quilombola communities is shaped by structural environmental deprivation and support integrated policies linking food and nutrition security with environmental justice and basic infrastructure investments.

Keywords: Environmental racism; Food insecurity; Quilombola communities; Environmental justice; Social determinants of health

1. Introduction

Food insecurity remains a major global public health challenge and continues to disproportionately affect historically marginalised populations (Militão et al., 2022). Beyond income poverty, food insecurity reflects broader structural processes related to social exclusion, territorial neglect and unequal access to essential resources. In recent years, climate change has intensified extreme weather events, such as floods, droughts and prolonged heatwaves, further exacerbating existing social and health inequities, particularly in low- and middle-income countries (Allen et al., 2025; Bianco et al., 2024; Jiao, 2024).

Environmental racism provides a critical analytical framework for understanding how environmental hazards, infrastructural deprivation, and unequal access to basic services are unevenly distributed along racial and ethnic lines (Casey et al., 2023). Rather than resulting solely from intentional discrimination, environmental racism operates through institutional practices, planning decisions, and public policies that systematically expose racially marginalised groups to unhealthy environments while limiting access to safe water, sanitation, waste management, and adequate housing (Alvarez, 2023).

In Brazil, quilombola communities, Afro-descendant traditional territories formed through historical processes of resistance to enslavement, represent a paradigmatic case of structural environmental injustice (De Jesus et al., 2022). Despite constitutional recognition of their territorial rights, many quilombola communities remain characterised by chronic infrastructural deprivation, environmental vulnerability, and limited access to public services. These conditions are not incidental but reflect long-standing patterns of institutional neglect that shape health outcomes and living conditions across generations (Câmara et al., 2024).

Food insecurity constitutes a key social determinant of health and is closely linked to environmental conditions that affect food availability, access, utilisation, and stability. In quilombola territories, inadequate sanitation, unsafe water sources, precarious waste disposal, and limited urban infrastructure can directly undermine household food security while simultaneously increasing exposure to health risks (Ribeiro et al., 2024). However, empirical research examining the relationship between environmental racism and food insecurity in quilombola communities remains limited, particularly studies that examine environmental racism through measurable environmental and infrastructural indicators (Mengistie et al., 2025).

Most existing studies on food insecurity in Brazil emphasise socioeconomic factors such as income, education, and employment, often underestimating the role of structural environmental conditions and territorial inequality (De Castro Junior et al., 2025). From an environmental health perspective, this represents an important gap, as cumulative environmental deprivation may exert independent and synergistic effects on food insecurity beyond individual-level socioeconomic characteristics (Azimi & Rahman, 2024).

Addressing this gap, the present study examines the association between environmental and infrastructural deprivation, interpreted through the lens of environmental racism, and household food insecurity in quilombola communities in the state of Bahia, north-eastern Brazil. Using a hierarchical analytical framework that integrates sociodemographic, behavioural, and environmental dimensions, this study summarises environmental and infrastructural deprivation through a composite Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase and interprets its cumulative relationship with food insecurity through the lens of environmental racism and environmental justice. By empirically linking structural environmental deprivation to food insecurity in Afro-descendant traditional territories, this study contributes to advancing environmental health research and informing equity-oriented public policies grounded in environmental justice.

2. Materials and Methods

2.1. Study design and setting

A cross-sectional, community-based study was conducted between April 2023 and February 2024 in quilombola communities located in the state of Bahia, north-eastern Brazil.

Quilombola communities are Afro-descendant traditional territories formed through historical processes of resistance to enslavement and are characterised by persistent social, economic and environmental marginalisation (Sato et al., 2026). These communities experience limited access to basic infrastructure and public services, making them particularly relevant for investigating environmental determinants of food insecurity and environmental injustice (Freitas Neto et al., 2024; Ogutu et al., 2026).

The study included seven quilombola communities: Rio dos Macacos, Kaonge, Dendê, Kalembá, Engenho da Ponte, Engenho da Praia and Engenho da Cruz. Differences in territorial size and infrastructural conditions across communities allowed for the assessment of interterritorial inequalities in food security and environmental deprivation.

2.2. Study population and sampling strategy

The study population comprised residents of quilombola households who participated in face-to-face household interviews addressing food security, sociodemographic characteristics, behavioural factors, and environmental living conditions. All households present in the communities during the data collection period and meeting the inclusion criteria were eligible to participate.

In five communities (Kaonge, Dendê, Kalembá, Engenho da Ponte, and Engenho da Praia), a complete household census was conducted due to their small territorial extent. In the Engenho da Cruz community, where both territorial size and the number of households were larger, a systematic spatial sampling procedure was applied. Although census tract boundaries provided by the Brazilian Institute of Geography and Statistics (IBGE, 2022) were available, they extended beyond the locally recognised quilombola territory, making it impossible to prepare a unified and accurate household listing for a simple probabilistic sampling frame. These conditions prevented the construction of a complete sampling frame and therefore precluded the use of a fully probabilistic sampling design.

Given the absence of updated household listings and the territorially bounded nature of quilombola communities, a spatially structured pseudo-probabilistic sampling strategy was adopted, consistent with methodological

recommendations for research conducted in hard-to-reach populations and traditional territories (Bonevski et al., 2014; Leal et al., 2025). Fieldwork was initiated from reference households indicated by local quilombola leaders, followed by systematic household selection at regular spatial intervals, alternating the inclusion of one household and skipping the next (Raifman et al., 2022). This procedure approximates systematic sampling in geographic space, ensuring spatial coverage while acknowledging that equal selection probabilities could not be guaranteed (Vallée et al., 2007; Maduekwe & De Vries, 2019).

To ensure data quality in epidemiological analyses, Silva et al. (2017) applied thresholds considered plausible between 70.0% and 90.0% for data completeness. Accordingly, the data analysed in this study, with 183 households exhibiting 89.7% completeness across the variables of interest, exceeded the minimum completeness threshold reported in the literature and can be described as having a high degree of completeness, supporting the reliability of the analyses (Silva et al., 2017, 2021).

2.3. Outcome variable: food insecurity

Household food security status was assessed using the Brazilian Food Insecurity Scale (Escala Brasileira de Insegurança Alimentar - EBIA), an experience-based instrument validated for population-based studies in Brazil and aligned with international food insecurity measurement frameworks (Segall-Corrêa & Marin-Leon, 2015; Silva et al., 2022). Based on EBIA responses, households were classified into four categories: food security, mild food insecurity, moderate food insecurity, and severe food insecurity (Lopes et al., 2022). These categories were used for descriptive analyses (Table 1).

For regression analyses, food security status was dichotomised into food secure and food insecure, with the latter category including mild, moderate, and severe food insecurity. This binary variable was used as the dependent outcome in all multivariable models.

2.4. Sociodemographic, socioeconomic, and behavioural variables

Sociodemographic and socioeconomic variables included sex/gender identity, age group, self-reported race/skin colour, educational attainment, marital status, religious affiliation (Barros & Santos, 2023; Tavares & Caroso, 2024), and engagement in paid work. Behavioural variables included the use of medicinal plants (Ramos et al., 2024), engagement in physical activity (Rodrigues et al., 2020), alcohol consumption, and tobacco use (Miranda et al., 2017). These variables are widely recognised as relevant social determinants of food insecurity and health.

All sociodemographic, socioeconomic, and behavioural variables were analysed descriptively according to food security status (Table 2) and included as covariates in the first block of the hierarchical regression models (Model 1).

2.5. Environmental conditions and the Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase

Household-level environmental conditions reflecting structural deprivation and unequal access to essential services were assessed as indicators of environmental and infrastructural deprivation relevant to environmental racism. These variables included presence of street paving in front of the household, access to piped water, presence of a bathroom inside the household, sewage disposal into streets, ditches, or yards, household waste

disposal practices, source of household electricity, and consumption of rainwater stored in cisterns or other containers.

All environmental variables were dichotomised (yes/no) and analysed descriptively and through bivariate association tests according to food security status (Table 3). To capture cumulative environmental and infrastructural deprivation, these variables were combined into a composite Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase (Morello-Frosch et al., 2011; Khadke et al., 2025). Each adverse environmental condition was coded as one point, while favourable conditions were coded as zero. The EIDI score was calculated by summing all adverse conditions, with higher scores indicating greater cumulative environmental and infrastructural deprivation. This additive approach is consistent with environmental justice research emphasising cumulative exposure and overlapping environmental risks (Casey et al., 2017; Romanello et al., 2021).

2.6. Statistical analysis

Descriptive analyses were conducted to characterise the study population and to examine the distribution of food security status across communities (Table 1) and according to sociodemographic, behavioural, and environmental variables (Tables 2 and 3). Categorical variables were summarised using absolute and relative frequencies.

Bivariate associations between environmental conditions and food insecurity were assessed using Pearson's chi-square test or Fisher's exact test, as appropriate. Multivariable analyses were performed using logistic regression following a hierarchical block-wise analytical approach guided by a conceptual framework of social and environmental determinants of health (Abdalla et al., 2024).

Model 1 (M1) included sociodemographic, socioeconomic, and behavioural covariates. Model 2a (M2a) added individual environmental variables to the controls. Model 2b (M2b) replaced individual environmental variables with the Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase, allowing the assessment of cumulative environmental and infrastructural deprivation (Victora et al., 1997; Hotton et al., 2025) (Table 4).

All models were estimated with cluster-robust standard errors to account for potential intra-community correlation, with clustering at the quilombola community level. Results are presented as odds ratios (ORs) with 95% confidence intervals (95% CIs). Model fit was assessed using log-likelihood values (Ahoudou et al., 2025), Information Criterion (AIC), and Bayesian Information Criterion (BIC) (Azanaw & Worede, 2025) (Table 5). Statistical significance was defined as a two-sided p-value < 0.05. Analyses were performed using Stata, version 17.

2.7. Ethical considerations

This study is part of the research entitled "Living conditions and health of quilombola communities in Bahia and Sergipe", conducted by the Institute of Collective Health at the Federal University of Bahia and the Federal University of Sergipe. Data were collected through structured interviews following approval by the Research Ethics Committee of the Institute of Collective Health at the Federal University of Bahia (CEP/ISC/UFBA - Protocol number: 53730021.1.00005030; Opinion: 5,809,996). The study was conducted in accordance with ethical principles for research involving human subjects outlined in the Declaration of Helsinki, which guides the

protection of participant rights, well-being and voluntariness in human research. Participants meeting predefined inclusion criteria voluntarily agreed to participate and provided written informed consent prior to data collection.

3. Results

Table 1 shows a high burden of food insecurity among the quilombola households investigated. Overall, 70.6% of households experienced some degree of food insecurity, with severe food insecurity representing the most frequent category (32.4%), followed by mild and moderate food insecurity, each affecting 19.1% of households.

Table 1 (about here)

The community-level analysis showed marked interterritorial inequalities. Engenho da Cruz concentrated the highest absolute number of households in all categories of food insecurity, especially moderate (59.0%) and severe (33.3%) food insecurity. In Rio dos Macacos, a high proportion of severe food insecurity was observed (28.8%), despite a low relative frequency of food security (10.0%). A similar pattern was identified in Engenho da Ponte, where severe food insecurity reached 16.7%.

By contrast, Kaonge had a higher proportion of households with food security (18.3%) and a low frequency of severe food insecurity (3.0%). Dendê, Kalembá and Engenho da Praia showed intermediate distributions, with a predominance of mild and moderate food insecurity.

Table 2 presents the sociodemographic, socioeconomic, and behavioural characteristics of participants according to food security status. Food insecurity was more frequent among cis women (64.4%) than among cis men (34.2%), while gender-diverse participants represented a small proportion of the sample, limiting interpretation for this subgroup.

Table 2 (about here)

By age group, food insecurity was mainly concentrated among adults aged 30-59 years, with higher proportions in the 30-39-, 40-49-and 50–59-year groups. Participants aged 60 years and over also had a high frequency of food insecurity, indicating that the problem affects different life stages.

Regarding schooling, food insecurity was substantially more frequent among those without formal schooling (24.6%), while individuals with complete primary education had a lower relative proportion of food insecurity (11.8%). It was also observed that most of the participants were without a formal marital bond, with food insecurity being higher among single, separated/divorced or widowed (78.5%) compared to those married or in a stable union (65.4%).

Productive insertion also varied by food security status. Food insecurity was more frequent among households without paid activity, suggesting that labour-market exclusion and limited access to stable income may reinforce household vulnerability. These descriptive findings were considered alongside the multivariable models, which adjusted for selected sociodemographic and behavioural covariates.

Health-related behaviours varied across food security status, including the reported use of medicinal plants, physical activity, alcohol consumption and tobacco use. These variables were retained as behavioural covariates because they may reflect broader differences in living conditions, access to care, household routines and social vulnerability rather than isolated individual choices.

Table 3 presents the distribution of environmental and infrastructural conditions according to household food security status in the quilombola communities studied. A marked lack of basic urban infrastructure was observed, disproportionately affecting households experiencing food insecurity and revealing persistent socioenvironmental inequalities.

Table 3 (about here)

The absence of street paving in front of the household was highly prevalent (89.2%) and was more frequent among food-insecure households (93.0%) compared to those with food security (80.0%). Similarly, the lack of piped water affected 16.7% of households, with a higher proportion among food-insecure households (19.4%) than among food-secure households (10.0%).

The absence of a bathroom inside the household was reported in 12.2% of the sample and was substantially more common among food-insecure households (16.0%) compared to food-secure households (3.3%). In addition, inadequate sewage disposal directly into streets, open ditches, or yards was reported by 94.1% of households, with slightly higher prevalence among food-insecure households (93.0%).

The consumption of rainwater stored in cisterns or other containers was reported by 3.4% of households and occurred more frequently among those experiencing food insecurity (4.7%). Regarding solid waste management, only 39.7% of households reported direct or indirect waste collection services, while the majority disposed of waste through burning or burial within the household premises or in vacant land (60.3%). This practice was more prevalent among food-insecure households (63.2%).

Concerning household lighting sources, 59.8% of households had electricity with an individual or community meter. However, a substantial proportion relied on precarious lighting sources, such as electricity without a meter, oil, kerosene, or gas (40.2%). These conditions were more frequent among food-insecure households (43.8%) compared to food-secure households (31.7%).

Overall, these findings demonstrate that households experiencing food insecurity are systematically exposed to poorer environmental and infrastructural conditions, characterising a pattern of environmental racism that reinforces social vulnerability and undermines the human right to adequate food in quilombola communities.

Table 4 presents adjusted odds ratios and 95% confidence intervals for the three logistic regression specifications: the model with sociodemographic controls (M1), the model including individual environmental variables (M2a), and the model using the Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase (M2b).

Table 4 (about here)

In Model 2b, each additional unit of environmental and infrastructural deprivation, as measured by the EIDI, was associated with a 50% increase in the odds of food insecurity (OR=1.50; 95% CI 0.94-2.39; p=0.086), indicating a trend towards a cumulative effect of adverse environmental conditions on food insecurity after adjustment for sociodemographic and behavioural factors.

Other environmental indicators, such as rainwater consumption, showed high odds (OR=9.01; 95% CI 0.78-104.78; p=0.079) but with a wide confidence interval and marginal statistical evidence. These estimates should therefore be interpreted cautiously, particularly because of the low prevalence of this exposure.

Table 5 presents the main fit statistics for the estimated logistic models. The inclusion of environmental variables in Model 2a reduced both the AIC and BIC compared with Model 1 (controls only), indicating improved fit. The use of the Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase (Model 2b) also improved fit in relation to Model 1, although not as much as the set of individual environmental variables.

Table 5 (about here)

4. Discussion

This study examined the association between environmental and infrastructural deprivation, interpreted through the lens of environmental racism, and household food insecurity in quilombola communities in Bahia, Brazil. The findings showed a high prevalence of food insecurity, affecting 70.6% of households, with severe food insecurity reaching 32.4%. Food-insecure households were more frequently exposed to infrastructural deprivation, including lack of street paving, inadequate sanitation, absence of an in-house bathroom, unsafe waste disposal, and precarious electricity access. In the adjusted models, cumulative environmental and infrastructural deprivation, measured by the Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase, was associated with higher odds of food insecurity, suggesting a trend towards cumulative environmental effects in quilombola territories.

This pattern is consistent with evidence from other quilombola communities in Brazil. In Alagoas, Duarte et al. (2024) found that food insecurity affected more than two-thirds of quilombola families and was associated with living conditions and sociodemographic factors. In Tocantins, Maciel et al. (2021) reported a 71.2% prevalence of food insecurity among quilombola communities, with greater vulnerability among female-headed households and families facing socioeconomic disadvantages.

Reviews of the literature underscore that lack of basic infrastructure, low income, and limited access to services exacerbate nutritional vulnerability in these populations (Lima et al., 2022). Historical inequalities rooted in the legacy of slavery have been shown to underpin these disparities across Brazilian regions (Gubert et al., 2017).

Marked disparities across communities highlight that food insecurity is not uniformly distributed but shaped by unequal territorial investment and infrastructure provision. Communities with higher concentrations of environmental and social deprivation, such as Engenho da Cruz and Rio dos Macacos, exhibited the highest prevalence of moderate and severe food insecurity. These findings are consistent with research conducted in other quilombola populations in Brazil, which has documented high prevalences of food insecurity and associations with social and material inequalities, including low household income, limited access to basic services and precarious living conditions (Carter et al., 2012; Cherol et al., 2021).

This interterritorial heterogeneity underscores that food insecurity extends beyond household-level socioeconomic characteristics and reflects broader patterns of spatial inequality, consistent with environmental justice frameworks. Spatial analyses have shown that food insecurity prevalence and its adverse health impacts are concentrated in socially deprived areas, reflecting deep structural and environmental inequities (Joseph, 2025).

Moreover, global reports emphasise that systemic inequalities in access to food systems and resources produce uneven food security outcomes across regions and groups (Murray et al., 2023). Recent work integrating socioeconomic, health and infrastructure indicators further confirms that spatial disparities in vulnerability are

linked to uneven provision of critical services (Gomes et al., 2025). These findings align with conceptualisations of food justice that frame uneven access to nutritious food as a social and environmental injustice (López Cifuentes et al., 2026).

The descriptive and bivariate analyses revealed that households experiencing food insecurity were systematically exposed to poorer environmental conditions, including lack of street paving, inadequate sanitation, unsafe waste disposal, and precarious electricity access (Table 3).

These environmental deficits are not random but represent long-standing patterns of institutional neglect in quilombola territories. Similar associations between infrastructural deprivation and adverse health outcomes have been documented in environmental health research, particularly among racially marginalised and socioeconomically disadvantaged populations (Alvarez & Evans, 2021; Hendricks, 2022). Quantitative and conceptual work in environmental justice demonstrates that environmental health inequalities arise where historically marginalised communities face disproportionate exposure to multiple environmental burdens, leading to unequal health risks and outcomes (Van Horne et al., 2023).

Moreover, scholars of environmental inequality highlight that benefits and burdens related to infrastructure and environmental services are unevenly distributed across socio-spatial groups, reinforcing cumulative disadvantage (Ramachandran et al., 2025). In the Brazilian context, systematic reviews and conflict mapping show that lack of basic infrastructure and environmental services in racialised and excluded territories contributes directly to poor health outcomes and reflects deeper structural exclusion (Chakraborty et al., 2016; Alvarez & Evans, 2021).

The multivariable models provide robust evidence that environmental conditions play an independent role in shaping food insecurity. In Model 2a, the presence of basic infrastructure, such as paved streets and in-house bathrooms, was associated with substantially lower odds of food insecurity (Table 4). These findings suggest that investments in sanitation, mobility, and housing quality may directly improve food security by facilitating access to food markets, reducing health-related expenditures, and enhancing household living conditions (Vuong et al., 2022). Previous studies in environmental health have similarly shown that improvements in basic infrastructure are associated with better nutritional and health outcomes in vulnerable populations (Khan et al., 2025).

Conversely, the increased odds of food insecurity associated with cumulative environmental and infrastructural deprivation highlight the importance of addressing overlapping environmental risks. In Model 2b, each additional adverse environmental condition captured by the Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase was associated with higher odds of food insecurity, indicating a consistent trend towards cumulative effects, even though the association did not reach conventional levels of statistical significance. This interpretation is consistent with cumulative environmental vulnerability frameworks, which emphasise how multiple environmental burdens can overlap and deepen disadvantage in marginalised territories (Huang & London, 2012; Van Daalen et al., 2023).

From a policy perspective, these findings suggest that socioeconomic interventions alone are insufficient to address food insecurity in quilombola communities. While income, education, and employment remain important determinants, as reflected in the protective effects observed in the sociodemographic models (Model 1), the persistence of environmental effects after adjustment indicates that structural investments in basic infrastructure

are essential. Similar conclusions have been drawn in international studies linking environmental deprivation to food insecurity and health inequities (Tofail et al., 2025).

The Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase proposed in this study offers a practical and policy-relevant tool for identifying priority territories and monitoring environmental injustice. By summarising environmental and infrastructural deprivation through measurable household-level indicators, the EIDI enables the integration of environmental equity considerations into food and nutrition security policies, urban planning and environmental health surveillance. Composite indices have been increasingly recommended in environmental health research as instruments for guiding resource allocation and evaluating policy impacts, although their construction and interpretation require transparency and contextual validation (Stevens et al., 2023; Hassett et al., 2025).

4.1. Limitations of the study

Some limitations should be considered when interpreting these findings. First, the cross-sectional design precludes causal inference between environmental conditions and food insecurity, as observed associations reflect conditions at a single point in time. Second, the sample size for certain environmental exposures was relatively small, resulting in wide confidence intervals for some estimates, particularly for low-prevalence conditions such as rainwater consumption. This may have limited statistical power to detect significant associations for specific variables. Third, environmental conditions and household characteristics were self-reported, which may be subject to reporting bias. Nevertheless, the use of standardised questionnaires and a validated food insecurity scale help mitigate this limitation.

Importantly, the composite Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase mitigates potential measurement error associated with single environmental indicators by integrating multiple dimensions of infrastructural deprivation, thereby strengthening construct validity and better reflecting cumulative environmental and infrastructural deprivation.

Future longitudinal studies could further strengthen causal inference by examining whether changes in environmental infrastructure precede changes in household food insecurity over time. For example, Carter et al. (2012), in a longitudinal study of children in Québec, showed that local social environmental factors, including material deprivation, social deprivation, social cohesion, disorder, and living location, were associated with changes in household food insecurity over time.

Similarly, the WASH Benefits studies in Bangladesh and Kenya used cluster-randomised designs to evaluate the effects of water quality, sanitation, handwashing and nutrition interventions in rural households, offering a useful methodological reference for assessing how environmental and nutritional interventions may influence health and social outcomes over time. More recent follow-up evidence from rural Bangladesh also showed that early water, sanitation, handwashing and nutrition interventions had sustained impacts at school age. Such longitudinal and intervention-based approaches would be particularly valuable in quilombola territories, where historical infrastructural deprivation may produce cumulative and intergenerational effects on food insecurity.

4.2. Practical and policy implications

Food insecurity was highly prevalent in the quilombola communities studied and was associated with cumulative environmental and infrastructural deprivation, even after adjustment for sociodemographic and behavioural factors.

Households exposed to poorer environmental conditions, such as lack of sanitation, inadequate water supply, unsafe waste disposal, and limited urban infrastructure, presented higher odds of food insecurity. The results suggest that environmental and infrastructural deprivation may operate cumulatively, reinforcing food insecurity as environmental disadvantages accumulate. These findings support the study objective by showing that environmental and infrastructural deprivation, interpreted through the lens of environmental racism, is a key structural determinant of food insecurity in quilombola territories.

Overall, these findings indicate that food insecurity in quilombola communities is not only an individual or socioeconomic problem, but also a structural and territorial issue shaped by environmental injustice. Addressing food insecurity in these communities requires integrated responses that combine food and nutrition security policies with investments in sanitation, water access, waste management, electricity, mobility and territorial protection.

Declarations

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Tables

Table 1. Distribution of food security status across quilombola communities, Brazil (n=204).

Section	Category/community	Food security n (%)	Mild food insecurity n (%)	Moderate food insecurity n (%)	Severe food insecurity n (%)	Total N	Total %
Overall	Food security	60 (29.4)				60	29.4
Overall	Mild food insecurity		39 (19.1)			39	19.1
Overall	Moderate food insecurity			39 (19.1)		39	19.1
Overall	Severe food insecurity				66 (32.4)	66	32.4
By community	Rio dos Macacos	6 (10.0)	1 (2.6)	3 (7.7)	19 (28.8)		
By community	Kaonge	11 (18.3)	4 (10.3)	1 (2.6)	2 (3.0)		
By community	Dendê	2 (3.3)	2 (5.1)	3 (7.7)	4 (6.1)		
By community	Kalembá	4 (6.7)	3 (7.7)	5 (12.8)	5 (7.6)		
By community	Engenho da Ponte	4 (6.7)	6 (15.4)	4 (10.3)	11 (16.7)		
By community	Engenho da Praia	2 (3.3)	3 (7.7)	0 (0.0)	3 (4.6)		
By community	Engenho da Cruz	31 (51.7)	20 (51.3)	23 (59.0)	22 (33.3)		

Source: Food security status assessed using the Brazilian Food Insecurity Scale (EBIA). Percentages in community rows are column percentages within each EBIA category.

Table 2. Sociodemographic and socioeconomic characteristics according to food security status among quilombola communities, Brazil, 2023–2024.

Attribute	n	%	Food security n (%)	Food insecurity n (%)
Gender identity				
Cis man	73	40.0	24 (40.0)	49 (34.2)
Cis woman	128	63.0	36 (60.0)	92 (64.4)
Gender-diverse / prefer not to answer / other	2	1.0	0 (0.0)	2 (1.4)
Age group				
18-29 years	34	16.7	6 (10.0)	28 (19.4)
30-39 years	36	17.7	11 (18.3)	25 (17.4)
40-49 years	48	23.5	14 (23.3)	34 (23.6)
50-59 years	30	14.7	9 (15.0)	21 (14.6)
60 years and over	56	27.5	20 (33.4)	36 (25.0)
Race/skin colour				
White	5	2.5	0 (0.0)	5 (3.5)
Black	156	76.9	44 (73.3)	112 (78.3)
Brown	39	19.2	15 (25.0)	24 (16.8)
Yellow	1	0.5	0 (0.0)	1 (0.7)
Indigenous	2	1.0	1 (1.7)	1 (0.7)
Attended school				
No	28	13.9	4 (6.7)	24 (16.9)
Yes	175	86.1	56 (93.3)	118 (83.1)

Attribute	n	%	Food security n (%)	Food insecurity n (%)
Marital status				
Married/living together/stable union	101	49.8	36 (60.0)	65 (45.4)
Single/separated/divorced/widowed	102	50.3	24 (40.0)	78 (54.6)
Has religion				
No	36	17.9	7 (11.7)	29 (20.6)
Yes	165	82.1	53 (88.3)	112 (79.4)
Performs paid activity				
No	120	60.0	29 (49.1)	91 (64.6)
Yes	80	40.0	30 (50.9)	50 (35.4)
Physical exercise				
No	72	35.8	24 (40.0)	48 (34.0)
Yes	129	64.2	36 (60.0)	93 (66.0)
Alcohol consumption				
No	105	52.5	31 (52.6)	74 (52.4)
Yes	95	47.5	28 (47.4)	67 (47.6)
Tobacco use				
No	187	92.6	58 (96.7)	129 (90.8)
Yes	15	7.4	2 (3.3)	13 (9.2)

Source: Authors' elaboration. Percentages may not total 100 due to missing data. Selected behavioural variables are shown.

Table 3. Distribution of environmental conditions according to food security status among quilombola communities, Bahia, Brazil, 2023-2024.

Environmental condition	n	%	Food security n (%)	Food insecurity n (%)
Paved street in front of the household				
No	182	89.2	48 (80.0)	134 (93.0)
Yes	22	10.9	12 (20.0)	10 (7.0)
Running water in the household				
No	34	16.7	6 (10.0)	28 (19.4)
Yes	170	83.3	54 (90.0)	116 (80.6)
Bathroom inside the household				
No	25	12.2	2 (3.3)	23 (16.0)
Yes	179	87.8	58 (96.7)	121 (84.0)
Sewage disposal in street, ditch or yard				
No	192	94.1	58 (96.7)	134 (93.0)
Yes	12	5.9	2 (3.3)	10 (7.0)
Consumes rainwater stored in cisterns or other containers				
No	197	96.6	58 (96.7)	139 (96.5)
Yes	7	3.4	2 (3.3)	5 (3.5)

Environmental condition	n	%	Food security n (%)	Food insecurity n (%)
Main destination of household waste				
Collected directly or indirectly	81	39.7	28 (46.7)	53 (36.8)
Burned/buried on property, thrown in vacant lot or other	123	60.3	32 (53.3)	91 (63.2)
Household lighting source				
Electricity with own or community meter	122	59.8	41 (68.3)	81 (56.2)
Electricity without meter, non-electric source, or unknown	82	40.2	19 (31.7)	63 (43.8)

Source: Authors' elaboration. The number of observations varies according to the availability of response for each variable.

Table 4. Adjusted odds ratios (OR) and 95% confidence intervals (95% CI) for food insecurity according to multivariable logistic regression models.

Variable	Model 1 OR (95% CI)	Model 2a OR (95% CI)	Model 2b OR (95% CI)
Control variables			
Gender identity: cis woman (ref.: cis man)	-	1.43 (0.58-3.55)	1.23 (0.55-2.70)
Age group: 50-59 years (ref.: 18-29 years)	-	0.32* (0.10-0.98)	0.24** (0.09-0.64)
Attended school: yes (ref.: no)	-	0.30* (0.10-0.87)	0.25* (0.09-0.76)
Self-declared Black: yes (ref.: non-Black)	-	2.88*** (1.70-4.86)	2.52*** (1.55-4.08)
Environmental variables (Model 2a)			
Paved street: yes (ref.: no)	-	0.28*** (0.21-0.37)	-
Running water: yes (ref.: no)	-	0.47 (0.10-2.28)	-
Bathroom inside household: yes (ref.: no)	-	0.31** (0.12-0.77)	-
Sewage disposal: yes (ref.: no)	-	2.51 (0.33-18.91)	-
Consumes rainwater: yes (ref.: no)	-	9.01* (0.78-104.78)	-
Garbage collection: yes (ref.: no)	-	0.71 (0.29-1.72)	-
Electricity access: yes (ref.: no)	-	1.05 (0.38-2.92)	-
Environmental and Infrastructure Deprivation Index (EIDI), per one-point increase	-	-	1.50† (0.94-2.39)

*Notes: OR = odds ratio; CI = confidence interval; ref. = reference category. For binary variables, "no" was used as the reference category unless otherwise specified. For gender identity, cis man was the reference category. For age group, 18-29 years was the reference category. The EIDI was modelled as a continuous variable, with ORs representing the change in odds of food insecurity for each one-point increase in the index. *p<0.10; **p<0.05; ***p<0.01; †p<0.15. Model 1 includes sociodemographic control variables only. Model 2a includes individual environmental variables. Model 2b replaces environmental variables with the Environmental and Infrastructure Deprivation Index (EIDI).*

Source: Authors' elaboration.

Table 5. Comparison of numbers of observations (N), log-likelihood, AIC and BIC between logistic models.

Statistic	M1	M2a	M2b
N	183	183	183
Log-likelihood	-96.39	-90.12	-92.45
AIC	220.78	210.24	214.90
BIC	250.10	240.32	244.87

Notes: After excluding households with missing data on covariates, the final analytical sample comprised 183 households.

Source: *Authors' elaboration.*

Biography and Photo File

Manuscript: Environmental racism, infrastructural deprivation and household food insecurity in Brazilian quilombola communities

Note to Editorial Office: Short narrative biographies are provided below for all authors. Individual author photographs should be uploaded in the submission system or inserted in the spaces indicated below. If any author declines to provide a photograph, this should be explicitly indicated in the corresponding space.



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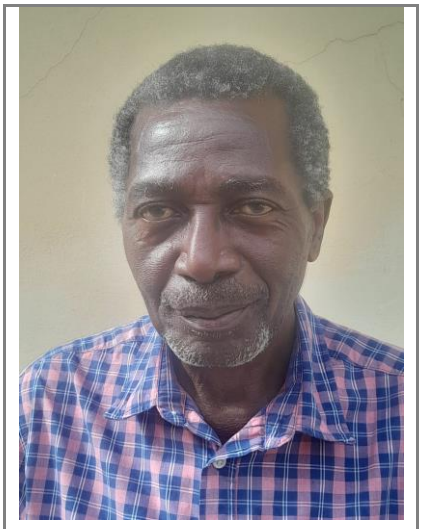
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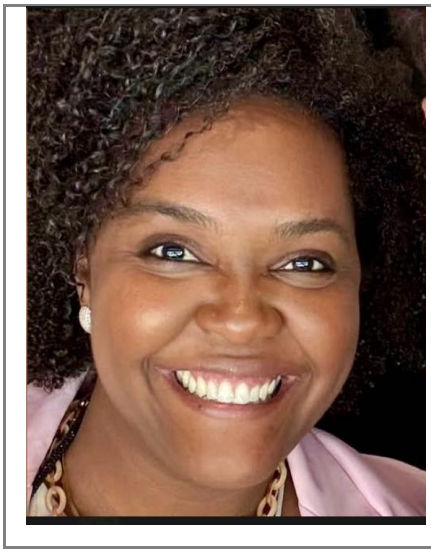
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