Research Proposal: Impact of Waste Accumulation on the Microclimate of Urban Areas

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ABSTRACT

The inadequate disposal of municipal solid waste alters local microclimatic conditions, increasing temperatures and reducing relative humidity. Areas with accumulated waste tend to record higher temperatures and lower humidity levels due to soil impermeabilization caused by materials that absorb and retain heat. Recognizing the importance of understanding these alterations for environmental management and community awareness, this study analyzed the influence of waste accumulation on local microclimatic conditions by comparing areas with and without waste in the city of Felipe Guerra (RN). The research followed the GLOBE Program protocols, with measurements of air temperature, soil temperature, and relative humidity at different observation points. The results demonstrated that waste-accumulated sites exhibited higher temperatures and lower humidity, highlighting the impact of improper waste disposal on the microclimate. Proper waste management therefore contributes to the improvement of local thermal and environmental conditions, and the findings may support environmental education and sustainable waste-management practices in school and community contexts.

Keywords: urban solid waste; microclimate; temperature; humidity. road. We further suggest that the puddle remained liquid because of high salt content.

1. Research Question and Hypothesis

Improper disposal of municipal solid waste is a persistent environmental problem in many Brazilian urban and peri-urban areas. In addition to sanitary and aesthetic impacts, accumulated waste alters the physical characteristics of the surface, replacing vegetation with impermeable, dark, and heat-absorbing materials. This modification disrupts the natural surface–atmosphere energy exchange, increasing air and soil temperatures while reducing relative humidity. Studies indicate that vegetated environments tend to exhibit lower temperatures and higher humidity, whereas degraded or urbanized areas—particularly those containing accumulated waste—can show temperature increases of 2–3 °C (Barros & Lombardo, 2016; Maciel et al., 2018).

These microclimatic alterations occur because vegetation promotes natural cooling through shading and evapotranspiration, while waste prevents heat dissipation and decreases soil permeability. As a result, the presence of waste contributes to the formation of small-scale heat-island effects, intensifying thermal discomfort and altering local environmental conditions. Previous research has demonstrated the influence of land-cover change on microclimate, yet few studies specifically evaluate how improperly disposed waste affects air temperature, soil temperature, and relative humidity in Brazilian contexts.

Given this scenario, understanding the physical impact of waste accumulation on the microclimate is essential for environmental education, sustainable waste-management practices, and community awareness. Using GLOBE Program protocols, this study seeks to compare areas with and without accumulated waste in the municipality of Felipe Guerra (RN), Brazil, to identify measurable differences in microclimatic conditions.

Does the presence of municipal solid waste influence local microclimatic conditions—air temperature, soil temperature, and relative humidity—in urban areas of Felipe Guerra (RN)?

Hypothesis:

We hypothesize that areas containing accumulated municipal solid waste will exhibit higher air and soil temperatures and lower relative humidity compared to nearby vegetated or clean areas, due to heat absorption, reduced soil permeability, and suppression of natural cooling processes.

2. Materials and Methods

The study was conducted in the municipality of Felipe Guerra, located in the state of Rio Grande do Norte, in northeastern Brazil (approximately 5°36′ S and 37°41′ W). The region has a semi-arid climate, characterized by high solar radiation, low annual rainfall, prolonged dry periods, and sparse vegetation typical of the Caatinga biome. The soil in the observation areas presented predominantly sandy texture, low vegetation cover, and high exposure to direct sunlight. These similar environmental characteristics across all sampling points allowed differences between waste-affected areas and control areas to be attributed reliably to the presence or absence of municipal solid waste.

The study was carried out during the region's dry season. All measurements were collected under clear skies, with minimal cloud cover, ensuring that atmospheric variability did not interfere with microclimatic comparisons.

2.1. Observation Points

Eight observation points were selected across the city: four in areas with accumulated municipal solid waste (MSW) and four in clean control areas. Point selection prioritized similar soil characteristics and solar exposure, avoiding locations with grass, nearby buildings, or shade. Each point was georeferenced with latitude, longitude, date, and time of measurement. A map illustrating all observation sites is presented in Figure 1 — Map of Felipe Guerra (RN) highlighting waste-affected and control locations.

Figure 1 — Map of Felipe Guerra (RN). Source: Authors' elaboration (2025).

The waste-affected sites included:

Point 1: near Rua Vereador Aécio Valentim and Rua Vereador José Manassés;
Point 2: near Rua Domilson Crisóstomo and na abandoned soccer field;
Point 3: in the Mirante Boa Vista area, adjacent to na old irregular dumpsite;
Point 4: in Rua Professora Abigail Feitosa, a peripheral urban area.

These sites contained domestic and commercial waste, including plastics, paper, metals, and construction debris.

The control sites included:

Point 5: Rua Tenente Francisco Xavier, near the town center;
Point 6: Rua Tenente Francisco Xavier, lower-altitude area near a slope;
Point 7: near Rua Demilson Crisóstomo, free of waste and distant from polluted sites;
Point 8: former dumpsite at Mirante Boa Vista, currently controlled and clean.
All control points displayed sandy soil and predominantly low vegetation cover, with no solid waste present.

2.2. Data Collection Procedures

Measurements followed the official protocols of the GLOBE Program (NASA) under the Atmosphere category, including air temperature, surface (soil) temperature, and relative humidity.

A calibrated digital thermo-hygrometer was used to measure air temperature and relative humidity simultaneously, while a surface thermometer was used to measure soil temperature under direct sunlight. Measurements were taken once per day at local solar noon (approximately 11:15 a.m.) over two consecutive days, ensuring high solar incidence and minimizing hourly variability.

Air temperature was measured in shaded areas free from nearby structures, trees, or walls, with the instrument positioned approximately 1.5 meters above the ground. Surface temperature was measured by directing the infrared sensor straight at the ground under full sunlight. At each point, five measurements were taken, and the mean was calculated. Relative humidity was recorded at the same times and locations to ensure comparability.

The measurement procedure is shown in Figure 2 — Field measurement of air temperature, soil temperature, and relative humidity.

Figure 2 — Field measurement of air temperature, soil temperature, and relative humidity.
Source: Authors' elaboration (2025).

2.3. Waste Characterization and Data Entry

In areas containing waste, a visual assessment was conducted to identify the predominant types of solid waste (plastic, metal, glass, organic matter, etc.), with photographic documentation of each site. All temperature and humidity data were recorded and submitted through the GLOBE Observer application. The data entry process is illustrated in Figure 3 — Data submission interface in the GLOBE Observer platform.

2.4. Data Analysis

Data were organized into tables, and for each group (waste-affected and control), the mean and standard deviation were calculated for air temperature, surface temperature, and relative humidity.

Mean ($\bar{x}$):

$$Mean = \frac{\Sigma\, x_i}{n}$$

Where:
Σx_i = sum of all measured values
n = number of measurements

Standard deviation (SD):

$$SD = \sqrt{\left[\frac{\Sigma(x_i - x)^2}{n - 1}\right]}$$

Where:
X_i = each measured value
$\bar{X}$ = mean value
n = number of measurements

Differences between the two sampling days were also calculated by subtracting Day 1 averages from Day 2 averages for each point, allowing assessment of short-term variability under similar atmospheric conditions.

The analysis was descriptive and comparative, aiming to identify microclimatic differences between areas with waste accumulation and clean control areas. This approach made it possible to evaluate the physical impact of waste on local temperature and humidity patterns.

3. Data Summary and Analysis

The collected data allowed for the analysis of microclimatic differences between areas with and without urban solid waste accumulation. Eight observation points were selected—four in areas with waste accumulation and four in control areas without waste. All points had similar characteristics, such as soil type, ground cover, and solar exposure. The primary distinction was

the presence or absence of accumulated waste, enabling a clear analysis of the impact of solid waste on the local microclimate.

Data collection occurred over two consecutive days around local solar noon (~11:15 a.m.), under stable weather conditions, with no rain, strong winds, or abrupt weather changes. This ensured reliable comparisons between locations. The results are presented in Tables 1 and 2, showing individual measurements for each collection day, and in Table 3, which summarizes the overall averages for each point based on the two-day observation period.

Table 1 – Air temperature, relative humidity, and surface temperature, Day 1

Point	Condition	Air Temp (°C)	Humidity (%)	Surface Temp (°C)
1	With waste	41.9	20	50.8
2	With waste	42.1	21	50.7
3	With waste	38.7	32	55.8
4	With waste	42.4	27	52.9
5	Without waste	38.9	31	51.0
6	Without waste	37.6	38	49.5
7	Without waste	37.8	33	48.4
8	Without waste	39.4	28	48.7

Source: Authors' elaboration (2025).

Table 2 – Air temperature, relative humidity, and surface temperature, Day 2

Point	Condition	Air Temp (°C)	Humidity (%)	Surface Temp (°C)
1	With waste	43.2	23	52.7
2	With waste	43.5	27	52.6
3	With waste	40.0	36	56.6
4	With waste	43.1	29	54.0
5	Without waste	40.1	33	52.2
6	Without waste	38.3	40	50.4

7	Without waste	38.7	34	49.7
8	Without waste	40.6	30	50.3

Table 3 – Overall averages of measured variables

Point	Condition	Air Temp (°C)	Humidity (%)	Surface Temp (°C)
1	With waste	42.3	20	51.0
2	With waste	43.0	26	50.6
3	With waste	38.9	34	56.2
4	With waste	42.5	28	53.0
5	Without waste	39.0	32	52.1
6	Without waste	37.6	40	49.8
7	Without waste	37.7	32	48.6
8	Without waste	39.6	28	48.8

Table 4 – Mean differences in temperature and humidity between areas with and without waste

Point	Condition	Δ Humidity (%)	Δ Air Temp (°C)	Δ Surface Temp (°C)
1	With waste	3	1.3	1.9
2	With waste	6	1.4	1.9
3	With waste	4	1.3	1.2
4	With waste	2	0.7	1.1
5	Without waste	2	1.2	1.2
6	Without waste	2	0.7	0.9
7	Without waste	2	0.9	1.3

8	Without waste	3	1.2	1.6

Table 5 – Means and standard deviations of measured variables

| Condition	Mean Air Temp (°C)	SD Air Temp	Mean Humidity (%)	SD Humidity	Mean Surface Temp (°C)	SD Surface Temp
With waste	41.7	1.87	27	5.77	52.7	2.56
Without waste	38.5	0.98	33	5.03	49.8	1.60

Graph 1 – Comparison of air temperature, relative humidity, and surface temperature between areas with and without waste

Graph 1 – Comparison of air temperature, relative humidity, and surface temperature in areas with and without waste
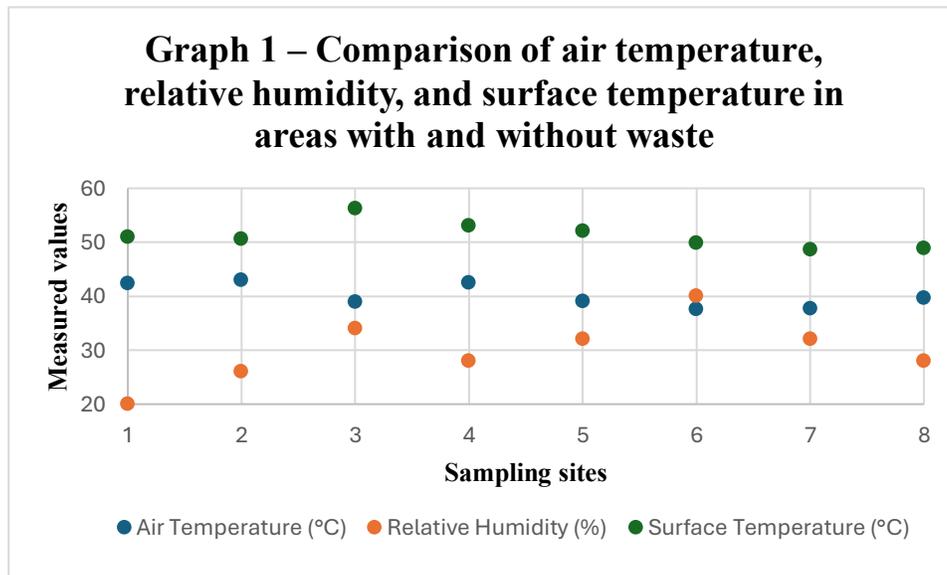
Illustrates clearly that areas with waste show higher temperatures and lower relative humidity than control areas.

Graph 2 – Mean values and standard deviations of measured variables in areas with and without

Graph 2 – Influence of waste accumulation on temperature and humidity conditions
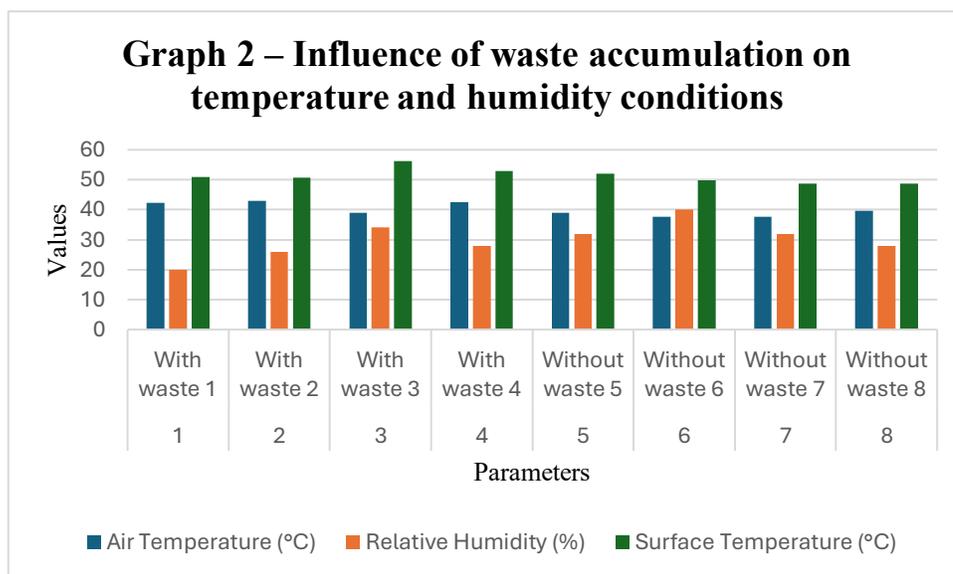
waste

Source: Authors' elaboration (2025).

Highlights greater thermal and humidity variation in areas with waste, showing consistent microclimatic impact.

4. Results, Discussion, and Conclusion

The collected data demonstrate that MSW accumulation significantly alters local microclimate. Areas with waste exhibited:

Higher air temperatures (average increase of ~3°C compared to control areas);
Higher surface temperatures (average 52.7°C vs. 49.8°C in control areas);
Lower relative humidity (average 27% vs. 33% in control areas);

These differences are attributed to the presence of dark, impermeable materials such as plastics and metals, which absorb and retain solar heat while reducing soil evaporation. Lower vegetation cover in these areas further amplifies heating by reducing shading and natural cooling.

The consistent differences between the two measurement days indicate stable microclimatic effects directly linked to waste presence rather than temporary weather fluctuations. Areas without waste showed more homogeneous temperatures and humidity, reinforcing the influence of waste accumulation on local conditions.

These findings highlight that improper waste disposal not only creates sanitary and visual problems but also impacts thermal comfort and environmental quality. Managing solid waste properly can mitigate local heating and dryness, improving public health and urban environmental conditions.

Future studies should extend the measurement period, include multiple times of day, and consider cloud cover to provide a more complete temporal and spatial understanding of microclimatic variations.

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