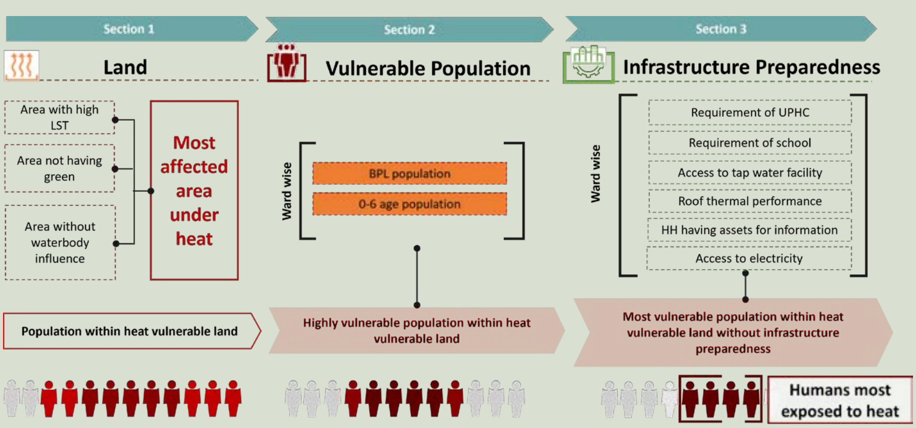
## CASE EXAMPLE: HEAT VULNERABILITY ASSESSMENT—WARD LEVEL

CSE conducted a ward-wise heat vulnerability assessment over Kolkata city. The methodology used for the analysis is illustrated below (see *Figure 31: Methodology for estimation of heat vulnerability*).

### Figure 31: Methodology for estimation of heat vulnerability

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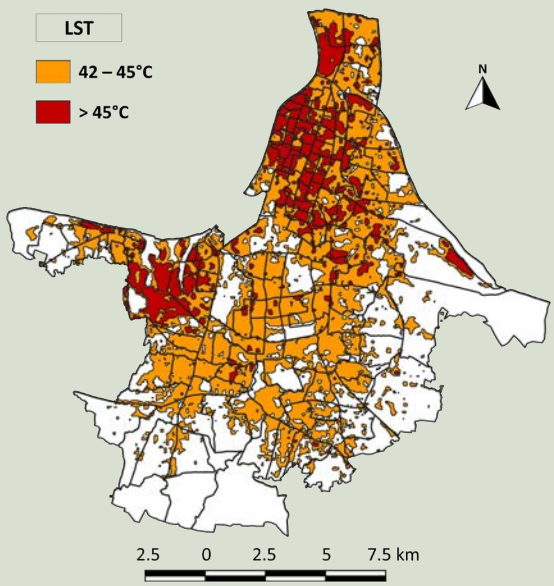
**Step 1: Exposure: Vulnerable land/area**

*a. Identifying the heat-stresses areas*

Based on IMD's criteria for heatwaves and high humidity levels in Kolkata, thresholds of 42°C and 45°C were selected to classify areas into severe (42–45 °C) and very severe (>45 °C) heat categories. A decadal analysis was conducted to assess heat stress across the city.

The analysis identified heat-stressed areas within Kolkata, marked by ward boundaries (see *Map 8: Identified heat-stressed areas in KMC region*). Findings indicated that approximately 58 per cent of the municipal area is susceptible to heat. Of this, 21.44 per cent was classified as very severe heat zones, while the remaining 78.56 per cent fell under severe heat zones. It was observed that almost half (70 out of 144) of the wards had over 90 per cent of their areas categorized as experiencing severe and very severe heat stress. Among these, the entire areas of 26 wards (ward numbers 10, 11, 16, 17, 18, 23, 24, 25, 28, 29, 37, 38, 39, 41, 42, 43, 47, 48, 49, 50, 51, 52, 53, 54, 83 and 84) were found to be affected by heat.

## Map 8: Identified heat-stressed areas in KMC region



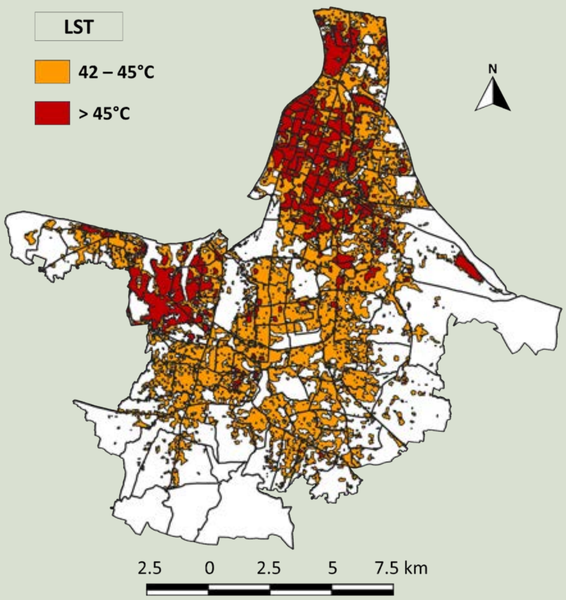

Source: CSE

*b. Extraction and removal of areas with blue and green infrastructures from heat-stressed areas*

Blue and green infrastructures were extracted through NDVI and NDWI (as shown in 'Estimating blue-green infrastructure'). After identifying these infrastructures, they were overlaid with heat-stressed areas. Any overlapping regions were eliminated since they can positively affect micro-climatic improvements.

The integration of blue-green infrastructure within the wards has led to a reduction in heat-stressed areas to about 50 per cent of the total municipal area (see *Map 9: Heat-stressed areas in KMC region with areas under blue-green infrastructures omitted*). Among these, very severe and severe heat zones account for 11.82 per cent and 38.25 per cent of the total municipal area, respectively.

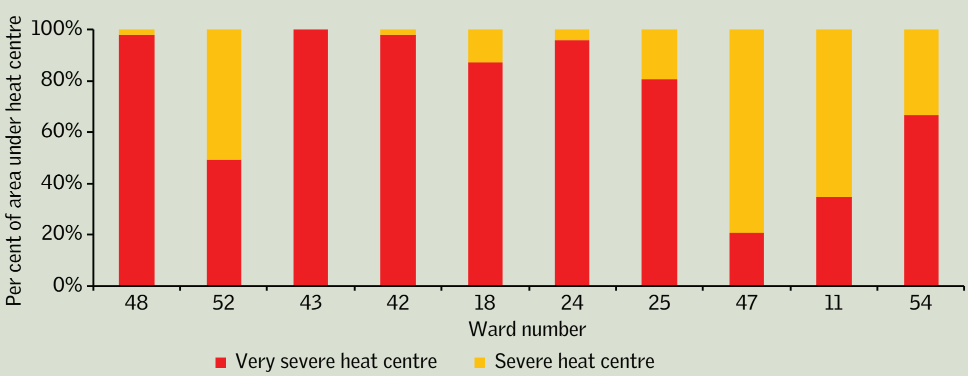
## Map 9: Heat-stressed areas in KMC region with areas under blue-green infrastructures omitted




Source: CSE

Seventy-five per cent of the city's wards (109 out of 144) experience significant heat issues, with over half of their municipal areas affected. Specifically, ward numbers 48, 52, 43, 42, 18, 24, 25, 47, 11 and 54, which house approximately 220,000 residents, face heat stress across nearly their entire areas (see *Graph 8: Wards with >95 per cent of area under heat centres*). Among these, wards 43, 42, 48 and 24, have a combined population of around 80,000 and witnessed over 95 per cent of their areas classified as very severe heat zones. This situation underscores the extensive impact of heat stress in these densely populated regions.

## Graph 8: Wards with >95 per cent of area under heat centres

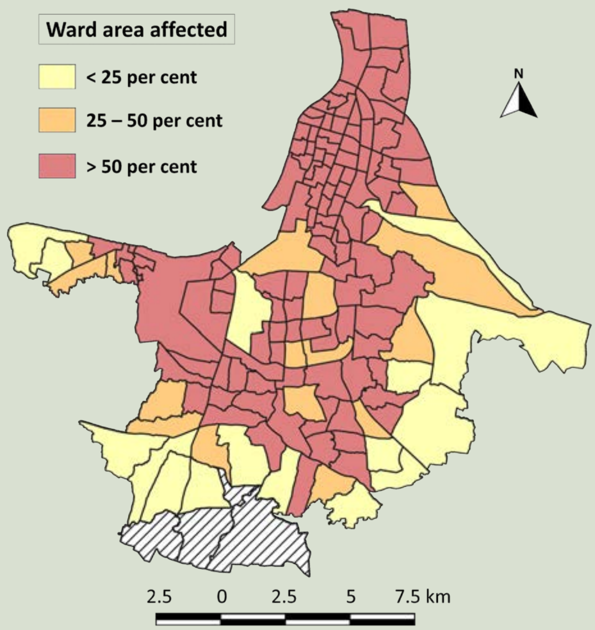



Source: CSE

Regardless of the extent of heat-affected areas, the significance of heat in wards 23, 39, 135, 24, 54, 29 and 41 is pronounced due to their high population density, exceeding 950 people per hectare. In Kolkata, these wards grapple with extensive heat stress, with percentages of affected areas reaching 98.93 per cent, 91.08 per cent, 89.22 per cent, 99.84 per cent, 99.35 per cent, 93.20 per cent and 87.39 per cent, respectively. This underscores the profound impact of heat stress on densely populated areas increasing the residents' susceptibility to heat.

To understand vulnerability, wards with heat-stressed areas contributing to less than 25 per cent were eliminated, as they might exhibit a degree of resilience. The remaining wards with more than 25 per cent of the region under heat stress (125 out of 144) were identified and utilized for further analysis (see *Map 10: Heat-stressed areas in KMC region categorized on the basis of percentage of ward area affected*).

### Map 10: Heat-stressed areas in KMC region categorized on the basis of percentage of ward area affected

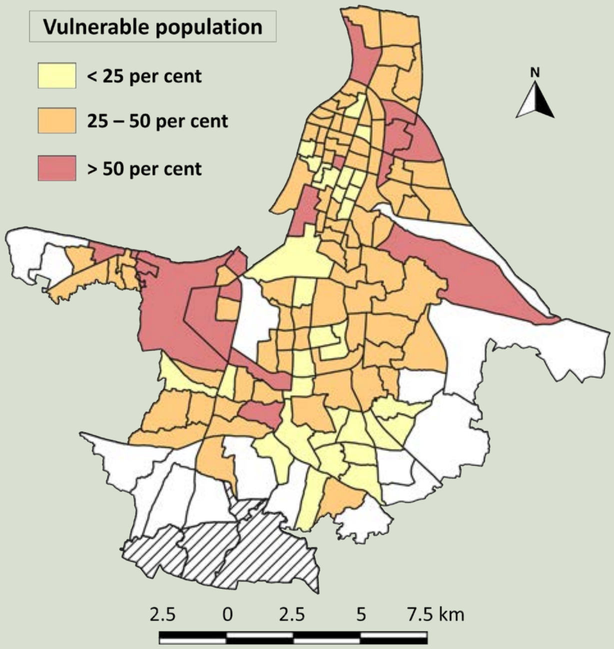



Source: CSE

**Step 2: Sensitivity: Most vulnerable population**

Vulnerability to heat has a large disparity, which revolves around age, gender, socioeconomic status, housing conditions and working environments. People with lower incomes often live and work in settings with high heat exposure, such as construction sites, street vending areas and industrial sheds. These environments use materials that trap heat and lack adequate ventilation. Children are also at risk due to their limited ability to regulate body temperature, slower adaptation rates and reliance on adults for hydration.

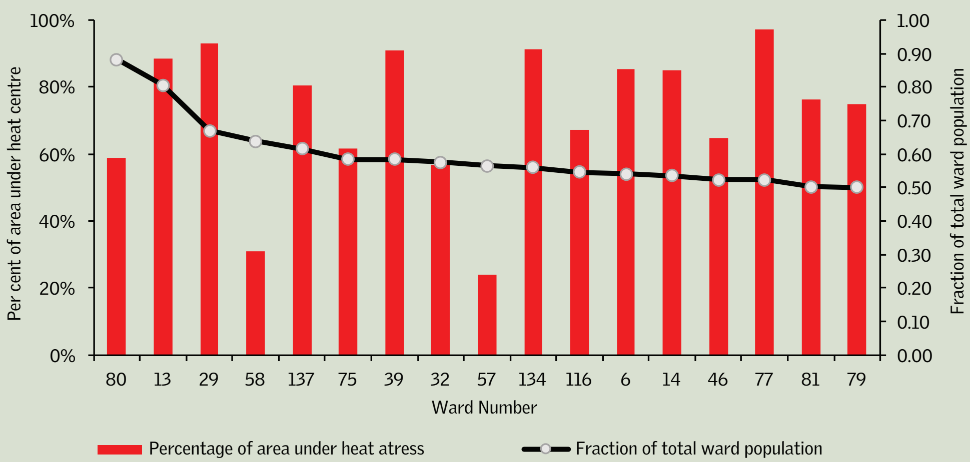
### Map 11: Categories of wards based on most vulnerable population (BPL and children—0–6 years)




Note: Population datasets can be sourced from the Census of India.

Source: CSE

### Graph 9: Wards with a high fraction of vulnerable population and percentage of area under stress




Source: CSE

Vulnerable wards were further categorized on the basis of presence of population—below poverty line and young children aged 0–6 years. The proportion of these groups in each vulnerable ward was calculated in relation to the total ward population and classified into three categories (see *Map 11: Categories of wards based on most vulnerable population [BPL and children—0–6 years]*). Seventeen wards—80, 13, 29, 58, 137, 75, 39, 32, 57, 134, 116, 6, 14, 46, 77, 81 and 79—had over 50 per cent of their population in high-risk areas (see *Graph 9: Wards with a high fraction of vulnerable populations and percentage of area under stress*). This shows where communities with limited resources are hit hardest by heat stress.

**Step 3: Adaptive capacity**

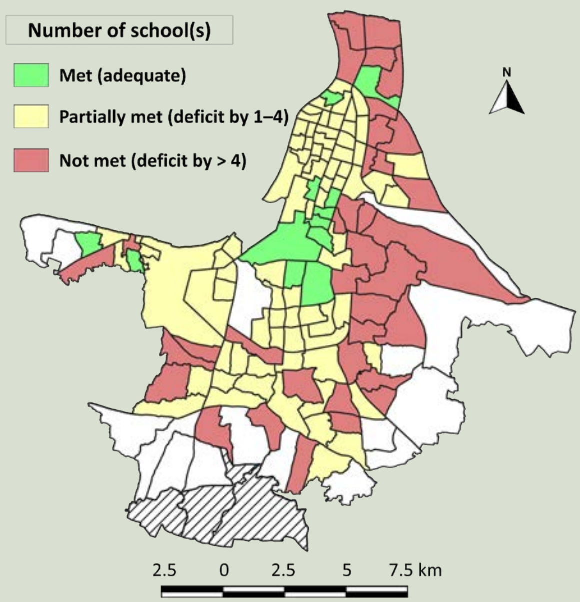
Availability of infrastructure plays a key role in reducing vulnerability and strengthening coping mechanisms. Assessing preparedness involves looking at how ready different wards are to handle heat-related issues. Six heat-related infrastructural parameters, including number of healthcare centres and schools; access to tap water, electricity and information; and the thermal characteristics of roofing materials were examined. These factors were analysed for the 125 wards where more than 25 per cent of the area is affected by heat stress.

Note: These datasets can be sourced from various entities, including the Census of India, municipal corporations, Public Health Engineering Departments (PHEDs) and urban local bodies.

*a. Number of primary schools*

On the basis of Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines, which recommend at least one primary school for every 5,000 people, the existing number of schools in each ward was compared to the ideal count. The gaps were then divided into three categories: met, partially met and not met (see *Map 12: Infrastructure preparedness: availability of schools*).

## Map 12: Infrastructure preparedness: availability of schools



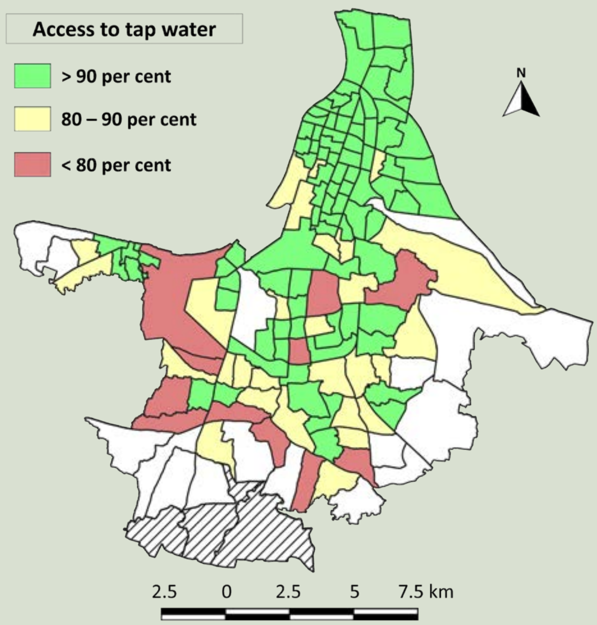

Source: CSE

Only twelve wards (63, 61, 47, 8, 138, 5, 69, 50, 53, 62, 70 and 133) had a sufficient number of schools, meeting the criteria. In 77 wards, the number of schools fell short by one to four, so they were classified as partially met. The remaining wards had a deficit of more than four schools and were categorized as not meeting the requirements. The situation was concerning in certain wards: wards 3, 14 and 58 had a deficit of 10 schools each, while ward 66 lacked 14 schools.

*b. Access to tap water*

An analysis was conducted to evaluate access to treated tap water across the wards. The findings were categorized into three groups: wards with less than 80 per cent access, those with 80 per cent to 90 per cent access, and wards where 90 per cent or more households had treated tap water connections (see *Map 13: Infrastructure preparedness: access to tap water*).

### Map 13: Infrastructure preparedness: access to tap water



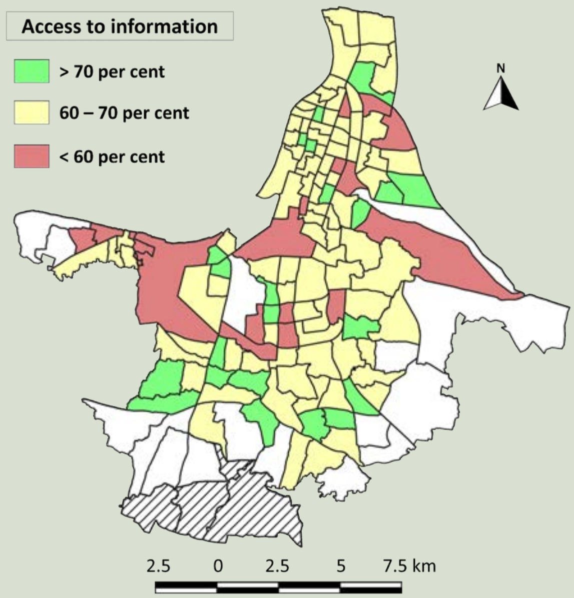

Source: CSE

The analysis revealed that 68.80 per cent of the wards had more than 90 per cent of households with treated tap-water connections, indicating string access. Additionally, 22.40 per cent of wards fell into the 80 per cent to 90 per cent range, showcasing moderate access. Meanwhile, 8.8 per cent of the wards had less than 80 per cent of households connected to treated tap water, indicating a gap in accessibility.

Certain wards—5, 18, 20, 19, 17, 8, 40, 4, 104, 2, 83, 35, 28, 68, 36, 42, 38, 7, 88 and 103—performed exceptionally well, with over 98 per cent of households connected to treated tap water. However, wards 129, 115, 100 and 132 faced serious challenges, with fewer than two-thirds of households having access, highlighting the need for improvement in these areas (see *Map 13: Infrastructure preparedness: access to tap water*).

*c. Access to information*
An analysis was conducted to evaluate information accessibility in different wards. The findings were categorized into three distinct categories, i.e. wards with less than 60 per cent access, those with 60 to 70 per cent access, and wards where more than 70 per cent of households had access (see *Map 14: Infrastructure preparedness: access to information*).

## Map 14: Infrastructure preparedness: access to information




Source: CSE

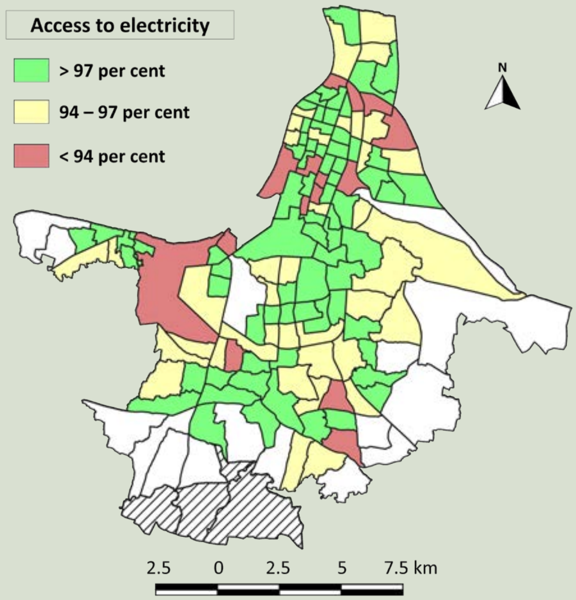
The analysis showed that 21 out of 125 wards had over 70 per cent of households with access to information, reflecting strong accessibility. Another 87 wards fell within the 60–70 per cent range, showing moderate accessibility. However, 17 wards had less than 60 per cent of households connected to information sources, indicating a gap.

Three wards—18, 23 and 34—excelled, with more than 75 per cent of households having access to information, indicating positive progress. In contrast, ward 80 had the lowest access, with only 44.80 per cent of households connected to information sources, pointing to the need for improvements in this ward.

*d. Access to electricity*
An analysis was conducted to evaluate electricity accessibility in different wards, and the results were divided into three categories: wards with less than 94 per cent access, those with 94–97 per cent access, and wards with 97 per cent or more households having access to electricity (see *Map 15: Infrastructure preparedness: access to electricity*).

The study revealed that 56 per cent of the wards had more than 97 per cent of households with electricity, indicating good accessibility. Another 32 per cent of the wards fell within the 94–97 per cent range, showcasing moderate accessibility. However, 12 per cent of the wards had less than 94 per cent of households with electricity, highlighting a gap in accessibility.

## Map 15: Infrastructure preparedness: access to electricity




Source: CSE

Wards 18, 40, 50, 19, 23, 5, 55, 135, 68, 77 and 30 stood out, with 99 per cent or more households connected to electricity, showcasing successful electricity distribution. In contrast, wards 96, 52, 80 and 45 had less than 89 per cent access to electricity, emphasizing a need for improvement in these areas.

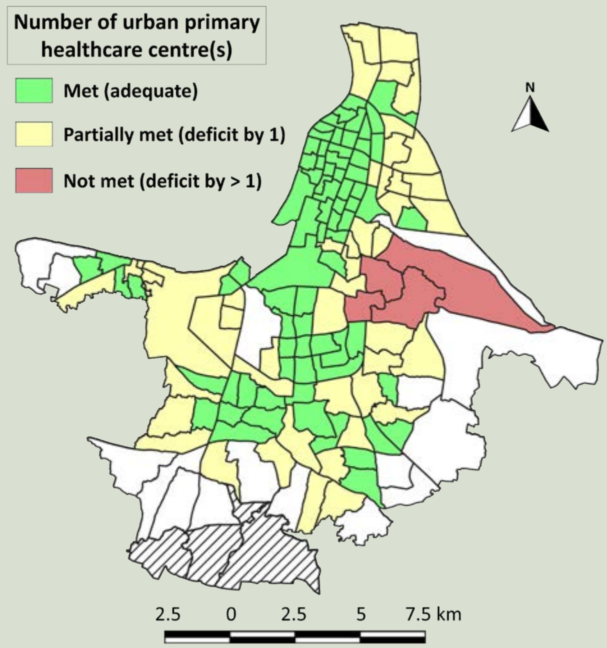
*e. Number of primary healthcare centres*

According to the NHM framework, a standard primary healthcare centre (PHC) should serve 30,000 people. Based on this standard, the number of ideal PHCs was compared with the existing ones in each ward. The disparities were categorized into three groups: met, partially met, and not met (see *Map 16: Infrastructure preparedness: access to urban primary healthcare centres*).

Out of 125 wards, 75 were found to meet the PHC requirements. However, 46 wards had a shortage of one PHC each, falling into the partially met category. Four wards showed the most significant gaps: wards 65, 59 and 58 lacked two PHCs each, while ward 66 had a shortfall of three, placing them in the not-met category.

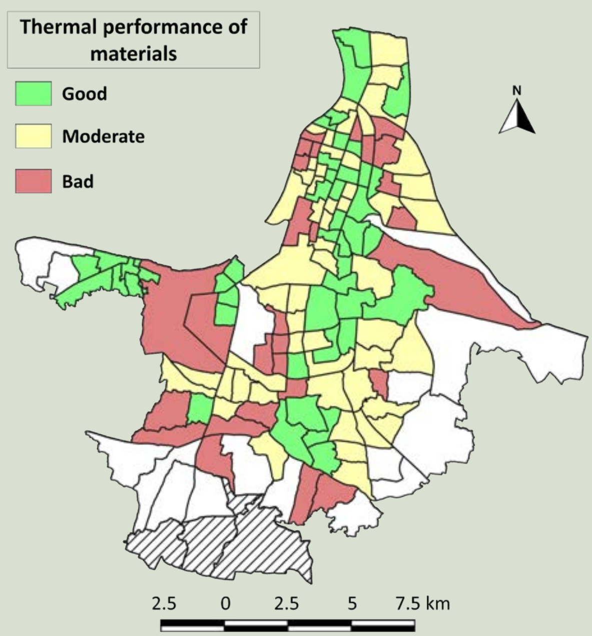
**Healthcare infrastructure in slums of Kolkata:** The number of urban primary healthcare centres (UPHCs) needed depends on the layout of slum areas. In cities where slums are spread out, each UPHC serves about 50,000 people, while it can serve 75,000 in densely packed slum areas. Typically, UPHCs are designed to support around 25,000–30,000 people in slums, ensuring that healthcare is tailored to the specific needs of urban areas, considering the density of slum settlements. According to Kolkata Municipal Corporation, approximately 1.5 million people in Kolkata live in slums. Based on the NUHM guidelines, the city would ideally need 30 UPHCs, each serving 50,000 residents. However, Kolkata currently has approximately 144 PHCs, far exceeding the recommended number. This shows the city's strong commitment to healthcare infrastructure, going well beyond the standard NUHM recommendations.

## Map 16: Infrastructure preparedness: access to primary healthcare centres




Source: CSE

## Map 17: Infrastructure preparedness: thermal performance of materials




Source: CSE

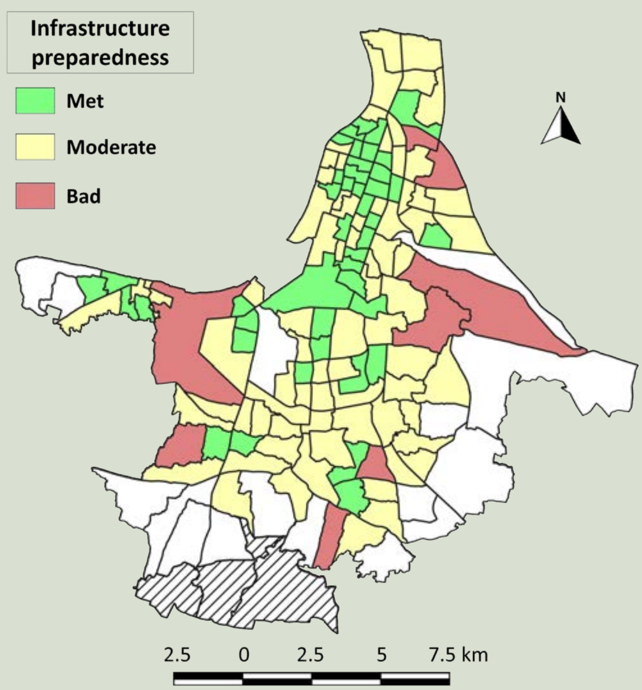
*f. Thermal performance of roof materials*
A ward-level assessment of the thermal performance of roofing materials was conducted, based on the percentage of roof material types and their U-values to create a thermal performance index. Lower index values represent better thermal efficiency, meaning the material transfers less heat. The index was divided into three categories: good, moderate and poor (see *Map 17: Infrastructure preparedness: Thermal performance of materials*).

Out of the 125 wards analysed, 44 showed excellent thermal efficiency, with index values below 6. Another 53 wards were classified as moderate, having index values between 6 and 12. The remaining wards performed poorly in thermal efficiency. Wards 137, 135, 138, 139, 87, 38, 60, 29 and 75 had strong thermal resilience, with index values under 3. In contrast, wards 89, 15, 79, 112 and 113 had the worst thermal performance, with index values exceeding 20.

*Cumulative infrastructure preparedness*
The infrastructure preparedness of wards with high heat and vulnerable populations was evaluated using six parameters. Based on the cumulative scores, the wards were classified into three categories: met, partially met and not met.

A total of 43 wards achieved the 'met' status, indicating strong preparedness. Another 74 wards were in partially met category, highlighting moderate preparedness. Wards 32, 129, 66, 96, 13, 113, 80 and 58, however, were identified as needing substantial adaptation (see *Map 18: Ward-wise infrastructure preparedness in heat centres*).

## Map 18: Ward-wise infrastructure preparedness in heat centres

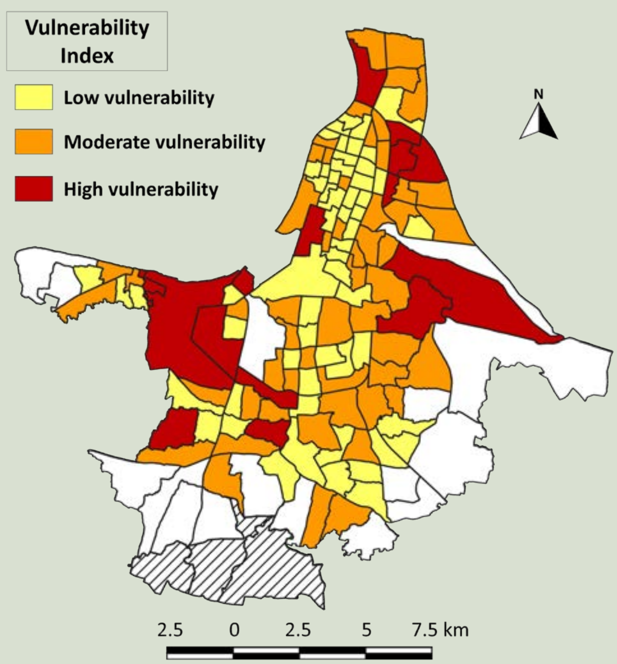



Source: CSE

**Step 4: Vulnerability Index**

A cumulative assessment of heat vulnerability (estimated using Equation 9) considering both the size of vulnerable population and infrastructure preparedness showed that 57 wards have low vulnerability as they house fewer vulnerable residents and have strong infrastructure preparedness. Fifty-three wards fall into the moderate vulnerability category, with a moderately vulnerable population and infrastructure readiness. In contrast, 15 wards face high heat vulnerability, due to a significant vulnerable population and limited infrastructure preparedness. The highly vulnerable wards—75, 134, 116, 6, 46, 29, 14, 81, 79, 129, 66, 32, 13, 80 and 58—collectively accommodate 675,080 people and need priority action to mitigate the risk (see *Map 19: Ward-wise vulnerability map of area under Kolkata Municipal Corporation*).

## Map 19: Ward-wise vulnerability map of area under Kolkata Municipal Corporation




Source: CSE