Decoding the Urban Heat Stress among Indian cities

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Even as unprecedented heat waves lashed Indian cities worsening the urban heat island effects this summer, there are far deeper and longer term evidences on the nature of this changing trend impacting the Indian mega cities.

The new analysis by the Centre for Science and Environment (CSE) shows that the heat stress is not just about rising temperature. It is a deadly combination of air temperature, land surface temperature and relative humidity that adversely impact the thermal discomfort and heat stress in cities.

Even if there is variation in air temperature across climatic zones with some parts recording even a decline, the other two factors – relative humidity and land surface temperature combine to enhance discomfort and heat related disease burden. According to the U.S. National Weather Service, the heat index is a measure of how hot it really feels when humidity is factored in with the actual temperature. It is considered that a heat index of 41°C is dangerous to human health.

Assessing the changing trend in heat, relative humidity, and land surface temperature along with day and night time temperatures is necessary to develop a comprehensive heat management plan for the urban centres. This is needed to implement emergency measures during heatwaves to protect public health, and also to develop longer term strategies to mitigate heat by increasing green areas and water bodies, improving thermal comfort in buildings, and reducing waste heat from vehicles, air conditioners and industries..

Addressing the combination of high heat and humidity is particularly important as this can compromise the human body's main cooling mechanism: sweating. The evaporation of sweat from skin cools our bodies, but higher humidity levels limit this natural cooling. As a result, people can suffer heat stress and illness, and the consequences can even be fatal even at much lower ambient temperatures. Interestingly, night time temperature is remaining elevated in cities.

Hence, the Urban Lab at CSE has carried out a comprehensive assessment of all three factors during summer – air temperature, land surface temperature and relative humidity – that contribute to the heat stress, in six megacities of India. This includes Delhi, Mumbai, Kolkata, Hyderabad, Bengaluru and Chennai. The time frame of the study is the summer of January 2001 till April 2024. These six cities are located in different climatic zones and provide insights into regional variations in heat stress.

Methodology and data: The analysis has focused on the trends in day and night time temperature, humidity levels, seasonal variations, trend in land surface temperature and trend in built-up area. This summary report provides highlights and some key findings from all the cities. (For details about each city analyzed please refer to their independent reports.)

The study is based on comparative statistical analysis of temperature and the humidity condition observed in Delhi since 2001. The study's definition of summer is the period from March to August. It is further divided into pre-monsoon (March-May) and monsoon (June-August) as per IMD classification. This is based on publicly available datasets from various national and global agencies. Ambient temperature and humidity data have been sourced from Indian Meteorological Department (IMD) weather stations at Palam and Safdarjung. An average of the findings from these two weather stations is used to represent Delhi in this study. Heat Index computation has been done using the U.S. National Oceanic and Atmospheric Administration's (NOAA) formula. Complex geospatial calculations have been done in python and ArcGIS.

Moreover, freely accessible MODIS Land Science data from NASA Earth Observations has been used for seasonal and long term analysis of land surface temperature. For more granular analysis of heat and land use conditions on extremely hot days, satellite imagery data from the United States Geological Survey (USGS) Earth Explorer website has been used. Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 operational land imager/thermal infrared sensor (OLI/TIRS) satellite imagery were downloaded and used to analyze the land surface temperature, land use, land cover and Normalized Difference Vegetation Index (Green cover).

This city-level assessment focuses on changes in heat patterns over the years for the summer season, urban expansion over the years, and land surface temperature variation during the summer of 2003, 2013, and 2022.

Key highlights

Decoding decadal trends: The heat trends that add to discomfort, heat stress related diseases and worsens thermal comfort are being tracked more granularly by the technical monitoring bodies. The Indian Meteorological Department (IMD) tracks air temperature from its weather stations and according to its Annual Climate Summary – 2023, the year 2023 was the second warmest year on record since nationwide records commenced in 1901.

The annual mean land surface air temperature averaged over India during 2023 was +0.65°C above the long-term average (Period 1981-2010).[i] However, this is lower than the highest warming observed over India during 2016.

On the other hand, the recently released World Meteorological Organisation's (WMO's) State of the Climatein Asia2023 has brought out the variation in the land surface temperature across India. This behaves differently from the ambient air temperature trends. This states that the average land surface temperatures were below normal (1991–2020 reference) in parts of the inland Indian Peninsula In 2023 even though the mean land surface temperature over Asiathe second highest on record.[ii] The WMO's assessment is based on land surface temperature data derived from satellite observations.

The observations of the two agencies show that while air temperatures are higher than average in India, the land temperature is below average. Yet, when relative humidity is combined with high heat worsens the heat stress and adversely impacts human thermal comfort and health.

Overall trends in urban heat stress in mega cities

Variation across climatic zones: Cities in warm-humid climate zone and moderate climate zones show increase while cities in composite climate zone and hot-dry climate zone show decline. Ambient air temperature has changed by less than 0.5°C between 2001-10 and 2014-23.

Relative humidity has increased in all climate zones: This increase made heat stress worse in warm-humid climate zone and moderate climate zones while it has nullified the fall in air temperatures in composite climate zone and hot-dry climate zone especially during monsoon.

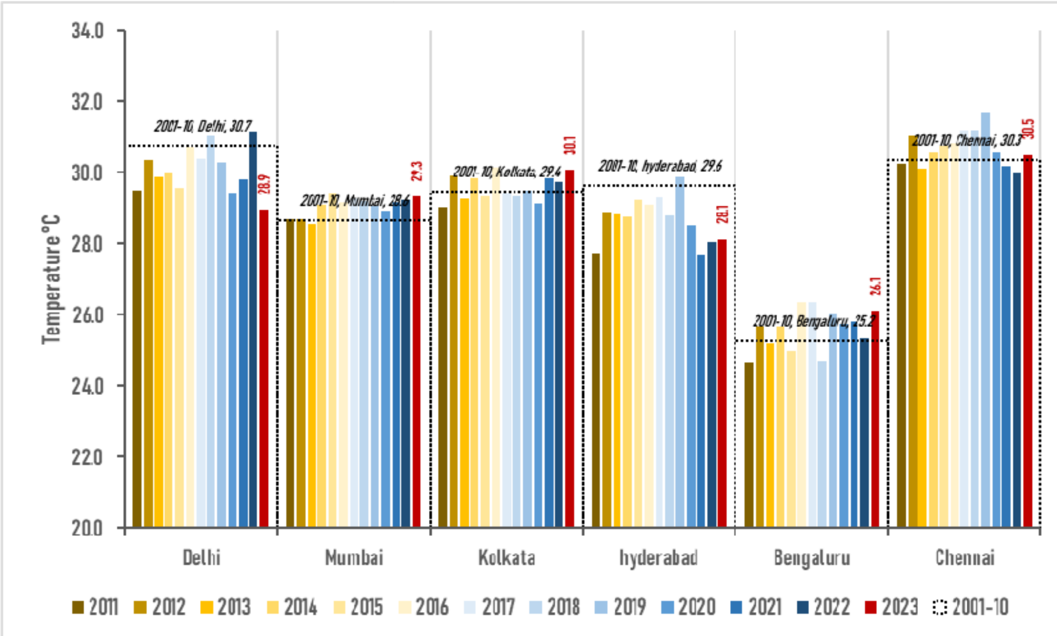
Monsoon are more thermally uncomfortable in Delhi, Mumbai, Kolkata and Chennai with their heat index being higher than pre-monsoon period.

Cities are not cooling down at night at the rate they used to during 2001-10. This phenomena is observed across all climatic zones.

All cities have registered significant increase in their built-up area that contribute to urban heat island effect. There is direct co-relation between increase in built-up area and increase in urban heat stress. Increase in green cover shows impact on daytime temperatures but has no impact on nighttime temperature and increasing heat index in the city.

Ambient air in Mumbai, Kolkata, Bengaluru and Chennai have gotten hotter while Delhi and Hyderabad seems to be bucking the trend: Decadal summertime average ambient temperature has risen by about 0.5°C in Mumbai, Bengaluru and Chennai compared to 2001-10. Kolkata's decadal average is also up by 0.2°C. Delhi and Hyderabad, only two metros which are located in composite climate zones known for the driest and harshest summers, have registered lower decadal average compared to 2001-10. Decadal summertime average for Delhi is down by 0.6°C and for Hyderabad it is down by 0.9°C compared to 2001-10 (see *Graph 1: Trend in summertime seasonal average ambient temperature among megacities 2011-2023*).

Graph 1: Trend in summertime seasonal average ambient temperature among megacities 2011-2023

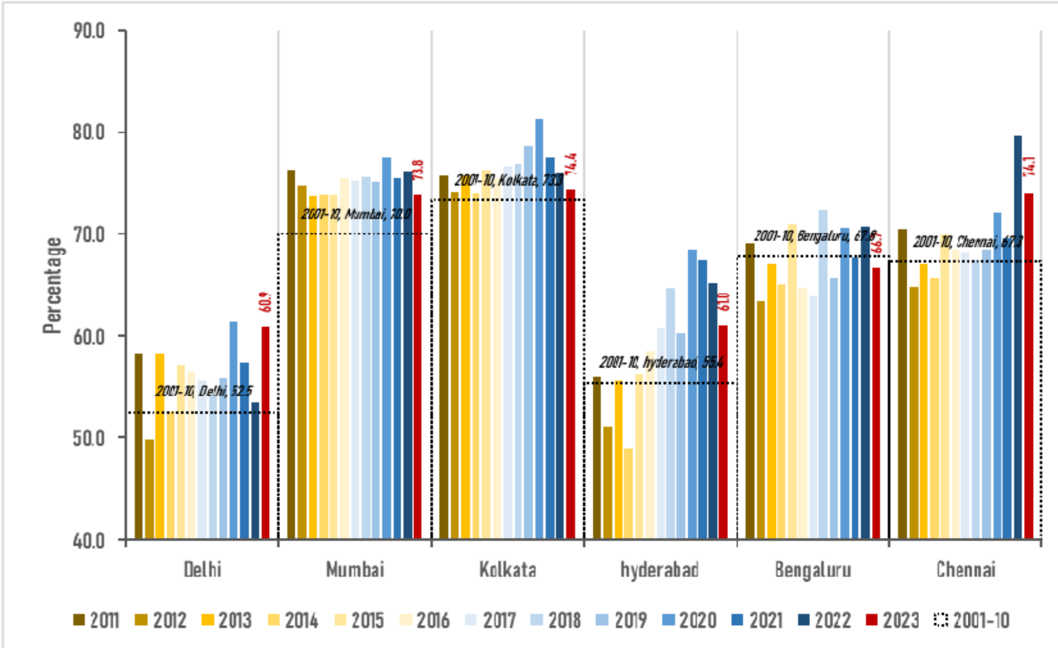


Note: Summer is defined as the period from March to August. A city's weather profile is based on average of all IMD weather stations located in the city. * Data up till 30 August 2023.
Source: CSE analysis of climatological data from IMD

Nature of heat is changing as all mega cities show significant increase in relative humidity during summer making it more uncomfortable: Average Relative Humidity (RH) has significantly increased in the last 10 summers compared to 2001-10 average. Barring Bengaluru, decadal summertime average relative humidity has increased by 5-10 per cent in other five mega cities. Last ten summers of Hyderabad have been on average 10 per cent more humid compared to 2001-10 average. Similarly Delhi's last ten summers have been 8 per cent more humid on average compared to 2001-10 average. Mumbai's relative humidity is up by 7 per cent while summers of Kolkata and Chennai are 5 per cent more humid on average compared to 2001-10 (see *Graph 2: Trend in summertime seasonal relative humidity among megacities 2011-2023*). Bengaluru has no change in humidity levels during summers.

Both Delhi and Hyderabad might have registered the most increase in relative humidity level but they are located in one of the driest climatic zones. This significant jump in decadal relative humidity still doesn't bring their overall humidity levels to other mega cities which are located in more humid climates. In fact Mumbai, Kolkata and Chennai are still over 25 per cent more humid than Delhi and Hyderabad. But this increased humidity in part nullifies the marginal drop in ambient air temperatures in Delhi and Hyderabad, while intensifying heat stress in the other four mega cities.

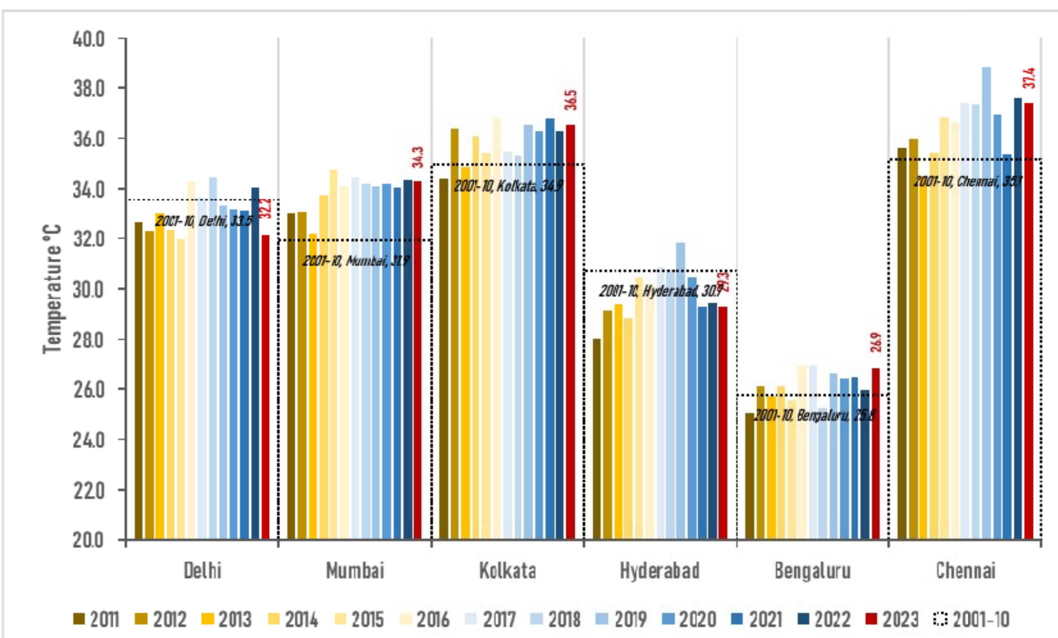
Graph 2: Trend in summertime seasonal relative humidity among megacities 2011-2023



Note: Summer is defined as the period from March to August. A city's weather profile is based on the average of all IMD weather stations located in the city. * Data until 30 August 2023.
Source: CSE analysis of climatological data from IMD

Heat Index rising faster than ambient temperature in all mega cities: Given the rise of relative humidity during summer, the heat index (HI) has risen among mega cities. Chennai´s summer average heat index stood at 37.4°C (impact of humidity: 6.9°C) making it the hottest among the mega cities (see *Graph 3: Trend in summertime seasonal average Heat Index among megacities 2011-2023*). Kolkata with summer HI average of 36.5°C (impact of humidity: 6.4°C) and Mumbai with 34.3°C (impact of humidity: 5°C) were the hottest. Delhi's summer HI average stood at 32.2°C (impact of humidity: 3.3°C) and Hyderabad's at 29.3°C (impact of humidity: 1.2°C). Bengaluru was least hot among the mega cities with a summer HI average of 26.9°C (impact of humidity: 0.8°C).

Graph 3: Trend in summertime seasonal average Heat Index among megacities 2011-2023

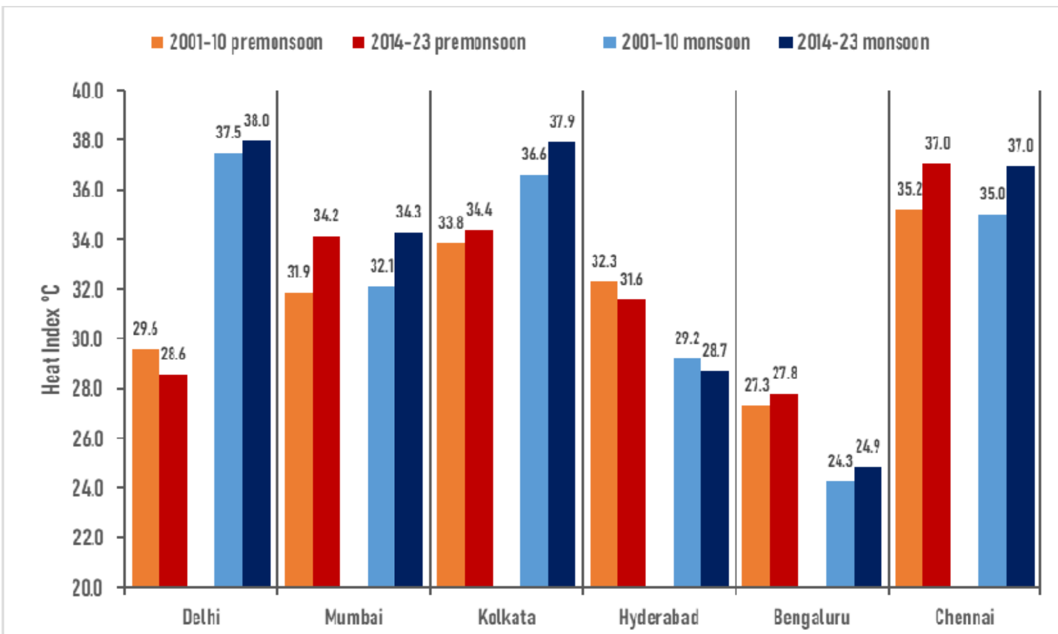


Note:Note: Summer is defined as the period from March to August. A city's weather profile is based on average of all IMD

weather stations located in the city. Heat index has been calculated using the U.S. National Oceanic and Atmospheric Administration formula. * Data up till 30 August 2023.
Source: CSE analysis of climatological data from IMD

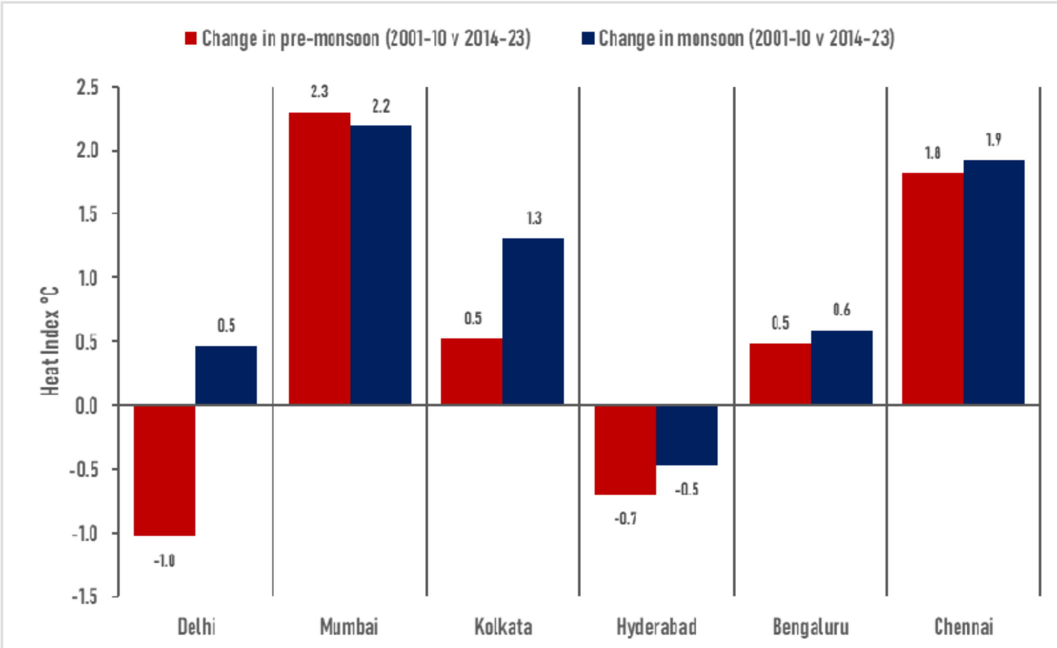
Monsoons are getting more thermally uncomfortable; monsoon in Delhi, Mumbai, Kolkata, and Chennai are already hotter than pre-monsoon: During 2001-10, the Heat Index used to rise between pre-monsoon and monsoon in Delhi, Mumbai and Kolkata while it used to drop for the southern megacities of Hyderabad, Bengaluru and Chennai. This trend has changed and in the last ten summers monsoon has become even hotter in Delhi, Mumbai and Kolkata, while in Chennai the marginal cooling noted with monsoon has disappeared. Monsoon is still a bit cooler than pre-monsoon for Bengaluru and Hyderabad but magnitude of cooling has reduced (see *Graph 4: Comparison of pre-monsoon and monsoon between 2001-2010 and 2014-2023*). Overall, monsoons on average have become 1°C hotter while pre-monsoons are hotter by 0.5°C on heat index compared to 2001-10 level (see *Graph 5: Change pre-monsoon and monsoon between 2001-2010 and 2014-2023*).

Graph 4: Comparison of pre-monsoon and monsoon between 2001-2010 and 2014-2023



Note: Pre-monsoon refers to the months of March, April and June. Monsoon falls within June, July and August. Heat index has been calculated using the U.S. National Oceanic and Atmospheric Administration formula.A city's weather profile is based on the average of all IMD weather stations located in the city. * Data until 30 August 2023.
Source: CSE analysis of climatological data from IMD

Graph 5: Change pre-monsoon and monsoon between 2001-2010 and 2014-2023

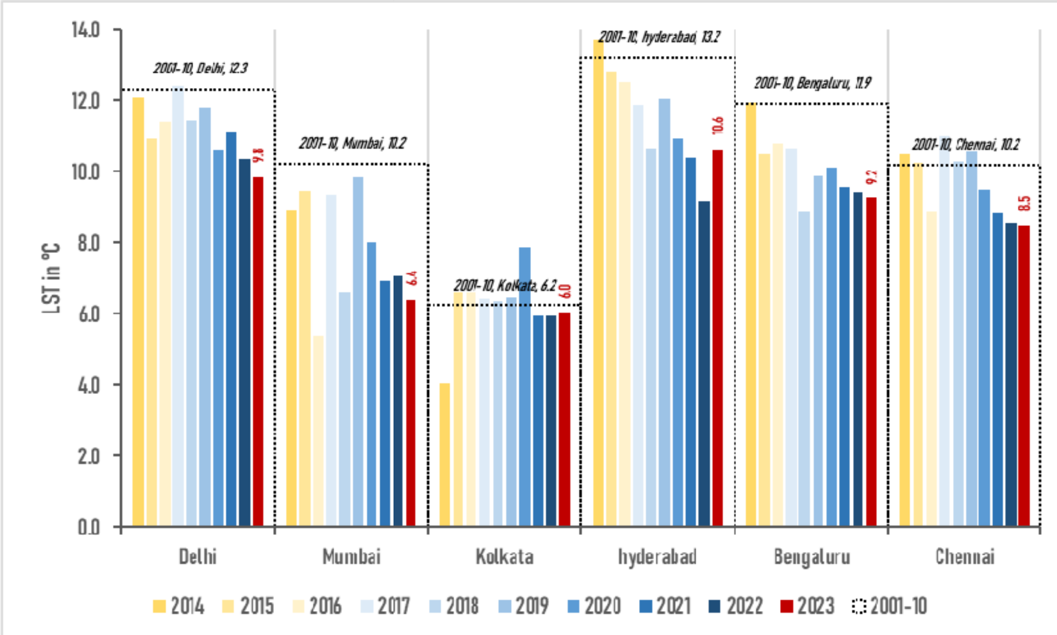


Note: Pre-monsoon refers to the months of March, April and June. Monsoon falls within June, July and August. Heat index has been calculated using the U.S. National Oceanic and Atmospheric Administration formula.A city's weather profile is based on the average of all IMD weather stations located in the city. * Data until 30 August 2023.
Source: CSE analysis of climatological data from IMD

Megacities are not cooling down at night: During summers of 2001-10, the land surface temperature (LST) used to come down by 6.2°C-13.2°C from the daytime peak to nighttime low among the megacities. Hyderabad used to cool down at night the most while Kolkata the least then. Now in the last ten summers (2014-23) the nighttime cooling has reduced to 6.2°C-11.5°C. In the current decade, Hyderabad on an average is relatively cooler by just 11.5°C which is 13 per cent down from 2001-10 level. Delhi nights are a little cooler by just 11.2°C which is 9 per cent down from 2001-10 level. Bengaluru nights are cooling down by just 10.1°C which is 15 per cent down from 2001-10 level. Chennai nights are cooler by just 9.7°C which is 5 per cent down from 2001-10 level. Mumbai nights are cooler by just 7.8°C which is 24 per cent down from 2001-10 level (see *Graph 6: Trend in summertime diurnal cooling of land surface temperature 2014-2023*). Kolkata is the only megacity where night time temperature is cooling down at the same rate as it used to during 2001-10 but it cools down the least among the megacities with LST only dropping 6.2°C at night from the daytime peak. It must be noted that the nighttime cooling is getting even lesser in the last few years for all megacities compared to the mid-2010s.

Hot nights are as dangerous as midday peak temperatures. People get little chance to recover from daytime heat slaughter if temperatures remain high overnight, exerting prolonged stress on the body. A study published in the Lancet Planetary Health by a group of scientists from China, South Korea, Japan, Germany and the U.S. noted that the risk of death from excessively hot nights would increase nearly six-fold.[iii] This prediction is much higher than the mortality risk from daily average warming suggested by climate change models.

Graph 6: Trend in summertime diurnal cooling of land surface temperature 2014-2023

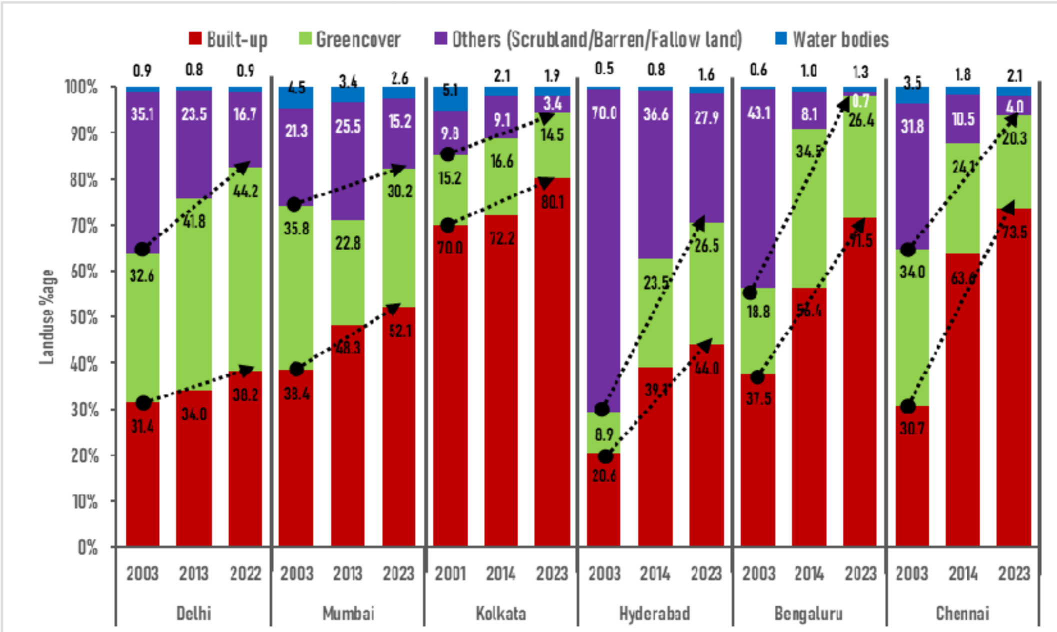


Note: Summer is defined as the period from March to August. * Data up till 30 August 2023.
Source: CSE analysis of monthly MODIS Land Science data from NASA Earth Observations.

All megacities have become more concertize in last two decades which has contributed to rise in heat stress; increase in green cover can moderate daytime heat but is not that ineffective in arresting nighttime heat: Kolkata has highest percentage of its land under concrete and the lowest green cover among the megacities in 2023. Meanwhile Delhi has comparatively the least area under concrete and the most green cover among the megacities (See *Graph 7: Change in landuse pattern among megacities in last two decades*). Over the last two decades, built-up area in Chennai has doubled showing the most rapid concretization. Kolkata has registered only 10 percentage points increase in its built-up area making it the slowest as concretized. Hyderabad has doubled it green cover in last two decade, fastest among megacities. Green cover has declined in Mumbai, Kolkata and Chennai. Most decline was noted in Chennai whose green cover shrank by almost 14 percentage points.

Delhi: Built up area has increased from 31.4 per cent in 2003 to 38.2 per cent in 2022. Green cover has increased from 32.6 per cent in 2003 to 44.2 per cent in 2022.
Mumbai: Built up area has increased from 38.4 per cent in 2003 to 52.1 per cent in 2023. Green cover has decreased from 35.8 per cent in 2003 to 30.2 per cent in 2023.
Kolkata: Built up area has increased from 70.0 per cent in 2001 to 80.1 per cent in 2023. Green cover has decreased from 15.2 per cent in 2001 to 14.5 per cent in 2023.
Hyderabad: Built up area has increased from 20.6 per cent in 2003 to 44.0 per cent in 2023. Green cover has increased from 8.9 per cent in 2003 to 26.5 per cent in 2023.
Bengaluru: Built up area has increased from 37.5 per cent in 2003 to 71.5 per cent in 2023. Green cover has increased from 18.8 per cent in 2003 to 26.4 per cent in 2023.
Chennai: Built up area has increased from 30.7 per cent in 2003 to 73.5 per cent in 2023. Green cover has decreased from 34.0 per cent in 2003 to 20.3 per cent in 2023.

Graph 7: Change in land use pattern among megacities in last two decades



Note: Summer heat wave months (May-June) are chosen to analyze the Normalized Difference Vegetation Index (NDVI) and urban expansion for each year.
Source: CSE analysis of Landsat 7 and Landsat 8 satellite images from United States Geological Survey (USGS) Earth Explorer.

City-wise highlights
Delhi

- **Even though a little cooler than the previous averages, high humidity is worsening the heat stress.**2024 March-April so far has been 3°C cooler than the average of 2014-23.Delhi's summertime has registered 0.6°C lower decadal average ambient air temperature but the relative humidity has increased by 8 per cent between 2001-10 and 2014-23.
- **High humidity is responsible for adding to the heat stress** -- on average 3.3°C of heat stress to the city.
- **City is not cooling down at night.** The diurnal cooling down of land surface temperature between daytime and nighttime is down by 9 per cent.
- **Urban heat island phenomena is stronger at night than daytime in Delhi.** At night the peri-urban area cools down 12.2°C while the city core cools down only 8.5°C. So the city core is cooling down 3.8°C less than its peri-urban.
- **There is direct co-relation between increase in built-up area and increase in urban heat stress**. Increase in green cover shows impact on daytime temperatures but has no impact on nighttime temperature and increasing heat index in the city.
- **Monsoon are getting more thermally unconformable than pre-monsoon.** Average heat index during monsoon is 9.4°C more than pre-monsoon.

Mumbai

- **Both air temperature and humidity have increased worsening the heat stress**. Mumbai's summertime has registered 0.6°C increase in decadal average ambient air temperature while the relative humidity has increased by 7 per cent between 2001-10 and 2014-23.
- **High humidity is responsible for adding more to heat stress:** This is adding on average 5°C of heat stress to the city. Heat Index of the city has increased by 7 per cent. 2024 March-April so far has been similar thermally to the average of 2014-23.
- **Both pre-monsoons and monsoons are more thermally uncomfortable** (by over 2°C) in Mumbai. Thermal distinction between monsoon and pre-monsoon has disappeared.
- **Mumbai's is not cooling down at night at same rate as it used to do during 2001-10**. But the diurnal cooling down of land surface temperature between daytime and nighttime is down by 24 per cent.

- **Urban heat island phenomena is stronger at night than daytime in Mumbai.** During the daytime core of Mumbai is 3.5°C cooler than its peripheries and peri-urban areas during the summer. But at night the core of Mumbai is 0.4°C warmer than its peripheries and peri-urban areas
- **There is direct co-relation between increase in built-up area and increase in urban heat stress.** Mumbai's built up area has increased from 38.4 per cent in 2003 to 52.1 per cent in 2023. Green cover has decreased from 35.8 per cent in 2003 to 30.2 per cent in 2023.

Kolkata

- **While decadal air temperature change is nominal, humidity has increased worsening the heat stress:** Kolkata's summertime has registered insignificant change in decadal average ambient air temperature but the relative humidity has increased by 5 per cent between 2001-10 and 2014-23.
- **High humidity is responsible for adding on average 6.6°C of heat stress to the city**. Decadal Heat Index of the city has risen by 3.5 per cent on average.
- **Days with daily Heat Index exceeding 41°C or the danger mark has tripled compared to 2001-10.**
- **Monsoon are getting more thermally unconformable than pre-monsoon.** Average heat index during monsoon is 3.5°C more than pre-monsoon.
- **Unlike other metros, Kolkata's is still cooling down at night at same rate as it used to do during 2001-10.**
- **But the diurnal cooling down of land surface temperature between daytime and nighttime is just a difference of 6°C on average.**
- **During the daytime core of Kolkata is 1.8°C warmer than its peripheries and peri-urban areas while at night the difference is of 1.2°C.** This is the evidence of urban heat island effect.
- **There is direct co-relation between increase in built-up area and increase in urban heat stress.** Built up area has increased from 70.0 per cent in 2001 to 80.1 per cent in 2023. Green cover has decreased from 15.2 per cent in 2001 to 14.5 per cent in 2023.

Hyderabad

- **Even though air temperature has not seen appreciable increase, humidity level has increased worsening the heat stress.** Air Hyderabad's summertime has registered 0.9°C drop in decadal average ambient air temperature but the relative humidity has increased by 10 per cent between 2001-10 and 2014-23.
- **High humidity is responsible for adding on average 1.5°C of heat stress to the city.**
- **High number of summer days experience high temperature:** Hyderabad has 30-90 days in summer when the daily ambient temperature exceeding 37°C mark.
- **Pre-monsoon are thermally more unconformable than monsoon** in Hyderabad. Average heat index during monsoon is about 3°C less than pre-monsoon.
- **Hyderabad's is not cooling down at night at same rate as it used to do during 2001-10.** But the diurnal cooling down of land surface temperature between daytime and nighttime is down by 13 per cent.
- **Urban heat island phenomena is stronger at night than daytime** in Hyderabad. During the daytime core of Hyderabad is 0.7°C cooler than its peripheries and peri-urban areas during the summer. But at night the core of Hyderabad is 1.9°C warmer than its peripheries and peri-urban areas
- **There is direct co-relation between increase in built-up area and increase in urban heat stress.** Built up area has increased from 20.6 per cent in 2003 to 44.0 per cent in 2023. Green cover has increased from 8.9 per cent in 2003 to 26.5 per cent in 2023. Increase in green cover shows impact on daytime temperatures but has no impact on nighttime temperature and increasing heat index in the city.

Bengaluru

- **While summertime temperature has increased relative humidity is quite stable:** Bengaluru's summertime has registered 0.5°C increase in decadal average ambient air temperature while the relative humidity has remained stable over last two decades. 2024 March-April so far has been significantly hotter (about 3°C) compared to average of 2014-23.
- **Humidity is responsible for adding on average 0.6°C of heat stress to the city.**Heat Index of the city has increased by 2 per cent.
- **Pre-monsoon are more thermally unconformable than monsoon.** Average heat index during pre-monsoon is 3°C more than monsoon.
- **City is not cooling down at night.** The diurnal cooling down of land surface temperature between daytime and nighttime is down by 15 per cent.
- **Urban heat island phenomena is stronger at night than daytime** in Bengaluru. During the daytime core of Bengaluru is 0.6°C cooler than its peripheries and peri-urban areas during the summer. But at night the core of Bengaluru is 2.5°C warmer than its peripheries and peri-urban areas
- **There is direct co-relation between increase in built-up area and increase in urban heat stress.**Built up area has increased from 37.5 per cent in 2003 to 71.5 per cent in 2023. Green cover has increased from 18.8 per cent in 2003 to 26.4 per cent in 2023. Increase in green cover shows impact on daytime temperatures but has no impact on nighttime temperature and increasing heat index in the city.

Chennai

- **Both air temperature and relative humidity have increased worsening the heat stress:** Chennai's summertime has registered 0.4°C increase in decadal average ambient air temperature while the relative humidity has increased by 5 per cent between 2001-10 and 2014-23. 2024 March-April so far has been hotter (about 1°C) compared to average of 2014-23.
- **High humidity is responsible for adding on average 6.3°C of heat stress to the city.** Heat Index of the city has increased by over 5 per cent.
- **More days with high heat index:** Days with daily Heat Index exceeding 41°C or the danger mark has tripled compared to 2001-10.
- **Both pre-monsoons and monsoons have become thermally more uncomfortable** with about 2°C rise in heat index. Thermal distinction between pre-monsoon and monsoon has almost disappeared with both periods being equally hot and muggy.
- **City is not cooling down at night.** The diurnal cooling down of land surface temperature between daytime and nighttime is down by 5 per cent.
- **Urban heat island phenomena is strong in Chennai.** During the daytime core of Chennai is 0.8°C warmer than its peripheries and peri-urban areas during the summer. At night the core of Chennai is 0.9°C warmer than its peripheries and peri-urban areas
- **There is direct co-relation between increase in built-up area and increase in urban heat stress.** Built up area has increased from 30.7 per cent in 2003 to 73.5 per cent in 2023. Green cover has decreased from 34.0 per cent in 2003 to 20.3 per cent in 2023.

The trend in heat stress is expected to only worsen with climate change: The technical summary of the Intergovernmental Panel on Climate Change (IPCC), Working Group-I, Sixth Assessment Report (AR6 WG-I) notes that it is almost certain that the frequency and intensity of heat extremes and duration of heat waves have increased since 1950 and this will keep increasing even if global warming is stabilized at 1.5°C.[iv] Combining climate change projections with urban growth scenarios, it can be said with very high confidence that future urbanization will amplify the projected increase in local air temperature.

With reference to urban centres, the IPCC Working Group-II, in its assessment (AR6 WG-II), also notes with confidence that hot extremes, including heat waves, have intensified in cities. It further notes that urban areas experience air temperatures that are several degrees warmer than surrounding areas, especially during the night. The urban heat island effect can add 2°C to local warming, reducing the adaptive capacity of cities and increasing the aforementioned risks.[v] This is due to reduced ventilation, heat trapping by closely-spaced tall buildings, heat generated directly from human activities, heat-absorbing properties of concrete and urban building materials, and limited vegetation. Infrastructure related to transportation, water, sanitation, energy and others has been compromised by extreme and slow-onset events, resulting in economic losses and disruption of services, impacting the well-being of people.

Next steps: Need heat management plans in cities

Implement city-specific heat management plans: Such planning approaches also need to go much deeper than the immediate emergency response to help cope with specific heat events during summer and prevent heat lock-in. This is not only about summer action for public health protection but more sustained action throughout the year to heat proof the city and undertake heat mitigation, along with monitoring, to improve the overall adaptive thermal comfort of built structures and reduce energy and carbon intensity of built environment.

Action plan needs to target all heat generators: The key heat generators include concrete built surfaces, barren land, and waste heat generators including vehicles, industries, and cooling devices. This requires adoption of guidelines and action plans to reduce thermal load on buildings and enhance thermal comfort and management of waste heat.

City-wise intervention to modify land-use to mitigate heat: Ensure reversal land-use changes to expand the green areas and water bodies for stronger cooling effect. Increase shaded areas in the city.

Develop a tracking mechanism for annual and diurnal trends in temperature, humidity and the overall heat index to inform planning and implementation.

Consider both day time and night time temperature for management plans: It is often noted that health emergency action considers the high daytime temperatures and not the nighttime temperatures and relative humidity. This overall trend poses risks to both public health and the energy security of the city, underlying the need tointegrate this consideration into informing the heat action plan. The heat problem is not just about focusing on daily maximum temperatures crossing the 45°C benchmark—the standard focus during summer—but involves a much more complex set of indices.

Strengthen scientific tracking of key factors impacting heat: Develop and combine a robust database on ambient heat and temperature, surface heat absorption and land surface temperatures, changing land-use, including vegetative cover and water bodies that are determinants to the heat island effect and relative humidity. This requires effective leveraging of the available satellite technology. Given advancements in technology, such data is available but needs policy integration.

Need emergency action plans for heat wave episodes to protect public health: Emergency action needs to develop emergency health care system for heat related disease burden, expansion of shaded areas in cities and ensure availability of drinking water in public spaces, reducing heat exposures for the vulnerable and occupationally exposed groups in cities, among others.

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[i] India Meteorological Department 2024. *Annual Climate Summary – 2023,* Government of India, Pune.

[ii] World Meteorological Organization 2024. *State of the Climate in Asia 2023*, World Meteorological Organization, Switzerland.

[iii] Cheng He et al 2022. "The effects of night-time warming on mortality burden under future climate change scenarios: a modelling study", The Lancet Planetary Health, Volume 6, Issue 8.

[iv] Arias, P.A. et al. 2021. *Technical Summary. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK.

[v] IPCC 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. In Press.