Original Research Article

Heat and Associated Health Risks in Delhi

Abstract

Climate change has added significant challenges to nation's worldwide, particularly Southeast Due to their heavy reliance on climate-sensitive industries like forestry, fisheries, and tourism, Asian countries suffer from economic hardship and pass up development opportunities. It has a significant impact on human health, with rising temperatures and air pollution leading to thermal discomfort and health problems for city dwellers. Amplified heat waves, elevated levels of air pollution, and extreme weather occurrences are some of the issues faced by city dwellers. Climate change has aggravated health issues in Delhi, India, that includes respiratory and heat-related illness.

The present study explores a link between temperature variations, land surface temperatures, and health outcomes to assess climate change risks with heat as the prime focus area in Delhi. It investigates the relationship between average maximum temperature and mortality. It explores yearly land surface temperature variations with built-up areas, vegetation and water. This study analyze the impact of temperature variations on specific health conditions. Such assessment due to temperature variation will help inform public health interventions and policies in Delhi. Accordingly the proposals could be framed through understanding of the relationship between heat and health on vulnerable population.

Keyword: Heat Index, Land Surface Temperature, Climate Change, Health Risk,

Introduction

Climate change is a global phenomenon adding substantial challenges to nations all over the world. Climate change particularly impacts developing countries in a multifold way with direct and indirect adverse impacts. These countries, many of which are among the worlds least developed, rely heavily on climate-sensitive sectors get affectively impacted by the increasing climate change (Allison et al., 2009). Existing literature has highlighted the various impacts of climate change. It impacts on various sectors can result in greater economic hardship and missed possibilities for development, particularly in nations lacking the capacity to adapt (Allison et al., 2009). Furthermore, due to climate change-induced migration, Southeast Asian nations face the problem of spatially diversifying household income (Maharjan et al., 2020). Southeast Asian countries' vulnerability to climate change is worsened by insufficient resources, infrastructure, and societal capability to adapt. These countries are frequently impoverished and strongly reliant on natural resources for income and economic growth (Allison et al., 2009).

Climate change-related environmental changes, including rising sea level and extreme weather events like heat waves and cold waves can result in large scale climate induced migration and displacement in vulnerable areas. (Maharjan et al., 2020). This migration can have an impact on household adaption in both positive and negative ways. Migrant remittances can assist diversify household income and provide financial resources for adaptation (Maharjan et al., 2020). However, migration can disrupt social networks and traditional livelihoods, making climate change adaptation difficult (Maharjan et al., 2020).

Climate change is a significant issue that requires immediate response, particularly in Indian cities. Rapid urbanization and population growth in India have increased vulnerability to the effects of climate change (Khosla & Bhardwaj, 2018). Indian cities are already confronted with issues like as amplified heat waves, elevated levels of air pollution, and extreme weather occurrences (Kaur & Pandey, 2021). However, Indian cities' responses to climate change are still in their infancy, with a concentration on isolated project-based initiatives rather than a complete strategic knowledge of the connection between climate and development aspirations (Khosla & Bhardwaj, 2018).

Climate change's impact on human health is an important aspect of climate change in Indian cities. Rising temperatures and levels of air pollution have resulted in thermal discomfort and a variety of health difficulties for city dwellers (Kaur & Pandey, 2021). Furthermore, climate-related extreme weather events, pose serious threats to the population. Due to existing social disparities, vulnerable groups such as the urban poor and women endure a disproportionate weight of climate change impacts (Gogoi & Sarmah, 2023). Heat stress has far-reaching health consequences that go beyond immediate heat-related ailments. metropolitan heat islands, defined as greater temperatures in metropolitan areas than in surrounding rural areas, can increase the impact of rising heat on health (Taha, 2017). Existing research has demonstrated that an increase in the heat index is linked to an increase in the number of deaths and the number of patients suffering from heat induced health conditions. A 1°C increase in mean perceived temperature, for example, was linked to a 2.7% increase in all-cause mortality, a 1.7% increase in respiratory ailments, and a 5.4% increase in the number of people suffering from chronic obstructive pulmonary disease COPD) during a heat wave in Porto, Portugal. (Monteiro et al., 2012).

The vulnerability profiles of Indian cities show that they are extremely sensitive to the effects of climate change, such as rising sea levels and violent coastal storms (Jena, 2021). Climate change is having a substantial impact on health in Southeast Asian countries. One of the most significant consequences is increased susceptibility to communicable infections. One reason of health impact of climate change in South Asia is through an increase in extreme weather events. According to Sivakumar and Stefanski (2010), frequent heatwaves and intense precipitation events pose threats to the population, particularly in areas with high rates of poverty and food insecurity. Climate change also has an impact on the stability and resilience of Southeast Asian plant communities. According to Sivakumar and Stefanski (2010), grasses in Southeast Asian drylands are susceptible to climate change and CO^2 levels. Changes in these ecosystems can have a domino effect on the region's food security and livelihoods. This emphasizes the significance of tackling the effects of climate change on agriculture and guaranteeing sustainable food production. Altizer et al. (2013) discuss the relationship between climate change and infectious diseases, highlighting the need to anticipate and monitor pathogen biodiversity and disease trends in natural ecosystems.The American College of Physicians (ACP) emphasizes the necessity of addressing climate change to protect human health (Crowley, 2016). Climate change, can increase the prevalence of respiratory and heat-related ailments, as well as vector-borne and waterborne diseases, food and water insecurity, and malnutrition. These repercussions are particularly troubling for vulnerable populations such as the elderly, the sick, and the homeless. Temperature and precipitation patterns can influence the location and number of disease vectors, potentially raising the risk of diseases like malaria and dengue fever. Climate change-induced migration from rural to urban regions can result in overcrowding and inadequate sanitation, aggravating the spread of infectious diseases. A major health risk in Delhi is air pollution, which is aggravated by climate change. The city already has severe air pollution, and climate change may exacerbate the problem. Climate change, according to the Intergovernmental Panel on Climate Change (IPCC), can lead to greater air pollution due to variables such as higher temperatures and changes in atmospheric circulation patterns. This can have a negative impact on respiratory health, increasing respiratory disorders and exacerbating existing conditions including asthma and chronic obstructive pulmonary disease (COPD). Due to climate change, extreme heat episodes pose a substantial health concern in Delhi. Heatwaves occur in the city, and climate change is anticipated to increase the frequency and intensity of these events. Heat waves can result in heat-related disorders such as heatstroke and dehydration. The elderly, children, and people with pre-existing health issues are especially vulnerable to the health effects of heat.

The present study aims to evaluate the relationship between temperature variations, land surface temperatures, and particular health outcomes in Delhi in order to determine the health risks brought by climate change.With this intent, the mainobjective outlined is to investigate the relationship between average maximum temperature and all-cause mortality data and to explore the yearly variations in land surface temperature and assess the relationship with health.

City Profile

Delhi, India's capital, is situated on the western bank of the River Yamuna. Known for its rich historical and cultural heritage, Delhi serves as the country's political, economic, and educational hub. However, rapid urbanization and population growth have led to environmental challenges that require thorough investigation and analysis. Delhi is infamous for its air pollution and extreme heat conditions as the characteristics of the city (Kushwaha &Nithiyanandam, 2019). Delhi’s urbanization and dense built-up regions have contributed to the establishment of urban heat islands, in which heat is trapped due to impervious surfaces, causing discomfort for humans and greater use of cooling devices with higher power consumption (Kumari et al., 2022). The city’s present district-level vulnerability metrics do not fully account for the effects of heat, posing a challenge to the city’s long term growth (Debnath et al., 2023). Temperature differences within Delhi have been demonstrated to exhibit a north-south and west east gradient, with the center of city experiencing a lower temperature (Singhet al., 2014). However, rising temperatures have been recorded in Delhi’s National Capital Region during the last few decades (Mohan et al., 2012). The present study is aimed at exploring this variability and its effect.

Research Approach

To achieve the research objectives a set of parameters have been identified through the literature. This includes the meteorological parameters to assess the climate change status in Delhi, health data: to evaluate the all-cause mortality trend in Delhi and the land surface temperature variation. Health outcomes (no. of hospital visits) due to certain specific diseases are also taken as a sub parameter of the health.TheMeteorological parameters (monthly data for mean temperature and mean relative humidity) are derived from the NASA's GMAO MERRA-2 assimilation model and GEOS 5.12.4 FP-IT for a period of 1981 to 2021 for Delhi. The heat index is an important metric used in environmental health research to assess the impact of heat on human health (Anderson et al., 2013).The heat index, sometimes referred to as the apparent temperature, expresses how a combination of air temperature and relative humidity feels to the human body. This has profound implications for the comfort of the human body.

The all-cause mortality data has been gathered from the Medical Certification of Causes of Deaths reports from 2001 to 2021. The land surface temperature mapping has been done using the Landsat 8 satellite imagery retrieved from the USGS earth explorer.

Climate Change Profile

In order to understand the climate change in Delhi, temperature and relative humidity have been taken as the two main indicators. From 1979 to 2020 there has been an increase in the mean yearly average temperature trend from 24.6 °C to 24.8 °C showing a linear climate change trend in Delhi. Due to climate change, Delhi's temperature trend is positive and is rising. A monthly data analysis shows that warmer months have been observed in the timeline indicating towards global warming. Highest mean temperature of 25.6 °C was reached in 1987 and in recent past it was recorded as 25.3 °C in 2016 whereas the lowest mean temperature were recorded as 23.3 °C 1983 and 24 °C in 2020 as shown in figure 1.

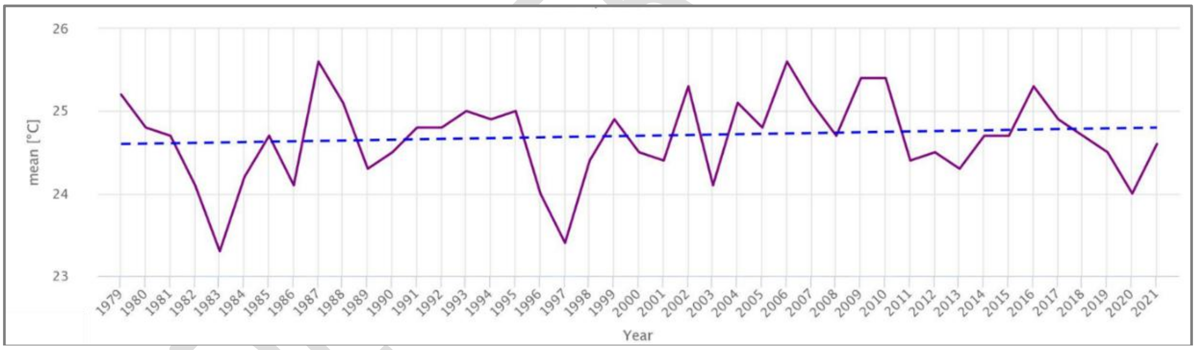

Figure 1 Mean yearly temperature trend 1979-2021 (ERAS, meteoblue)

The precipitation trend has also observed an increasing trend with 630.4 mm in 1980 to 737.8 mm in 2021. There can an observed inverse relationship between temperature and precipitation. Precipitation mean is highest for the year with 1135.5 mm in the year 1983 while in more recent past it has been 2010 with the mean precipitation of 915.5 mm. In 2014 the mean precipitationwas 471.5 mm which was the lowest in the recent past while in a more historical lens 1987 recorded the lowest mean precipitation with 258.5 mm.

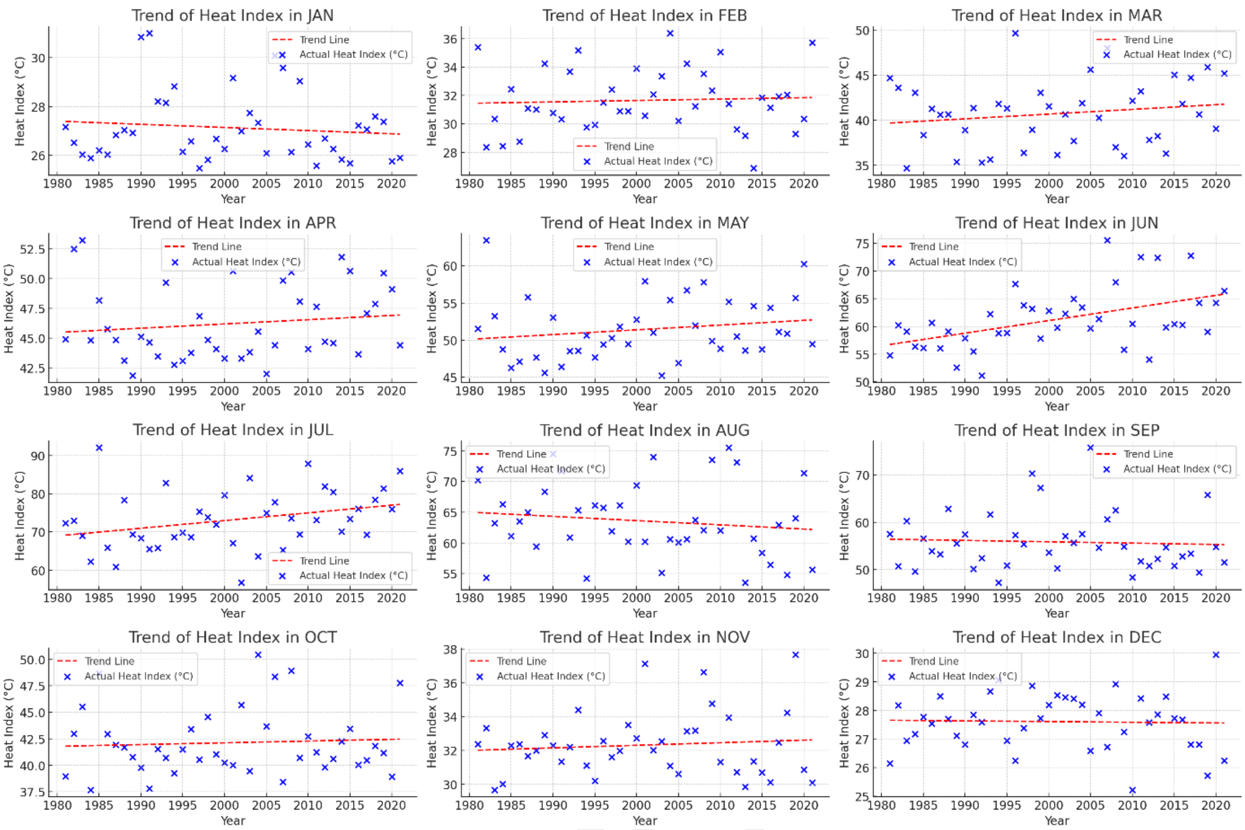

Figure 2 Monthly Trend of Heat Index - Scatter Plots(Author 2023)

The scatter plots above show the trends from 1980 to 2020. The Heat Index varies across different months and years, showing both upward and downward trends at different times. Months of March, April, May, June and July show a significant upward slope indicating an increasing heat index (Figure 2). The rate of increase for the month of June is approximately 0.227 °C per year having the maximum heat index across all months. The statistical significance has been found with p-value is approximately 0.00083, which is statistically significant at conventional alpha levels of 0.05. For the month of July (showing the second highest heat index pattern, the rate of increase is 0.201 °C with a statistically significant p value of 0.04. Heat index matrix for all months shows that heat index was highest in the June, July and August. In the month of June 54.78°C in 1981 increased to 66.44°C in 2021. The same increased from 72.35°C to 85.94°C for the month July 2021. It is also noteworthy that the months of march and October have also witnessed an increasing the temperatures over the years indicating towards more hotter months. The years with the highest heat wave days on record are 2012 and 2019; additionally, there has been a 35% increase in heat wave days, from 49 in 2018 to 90 in 2019.

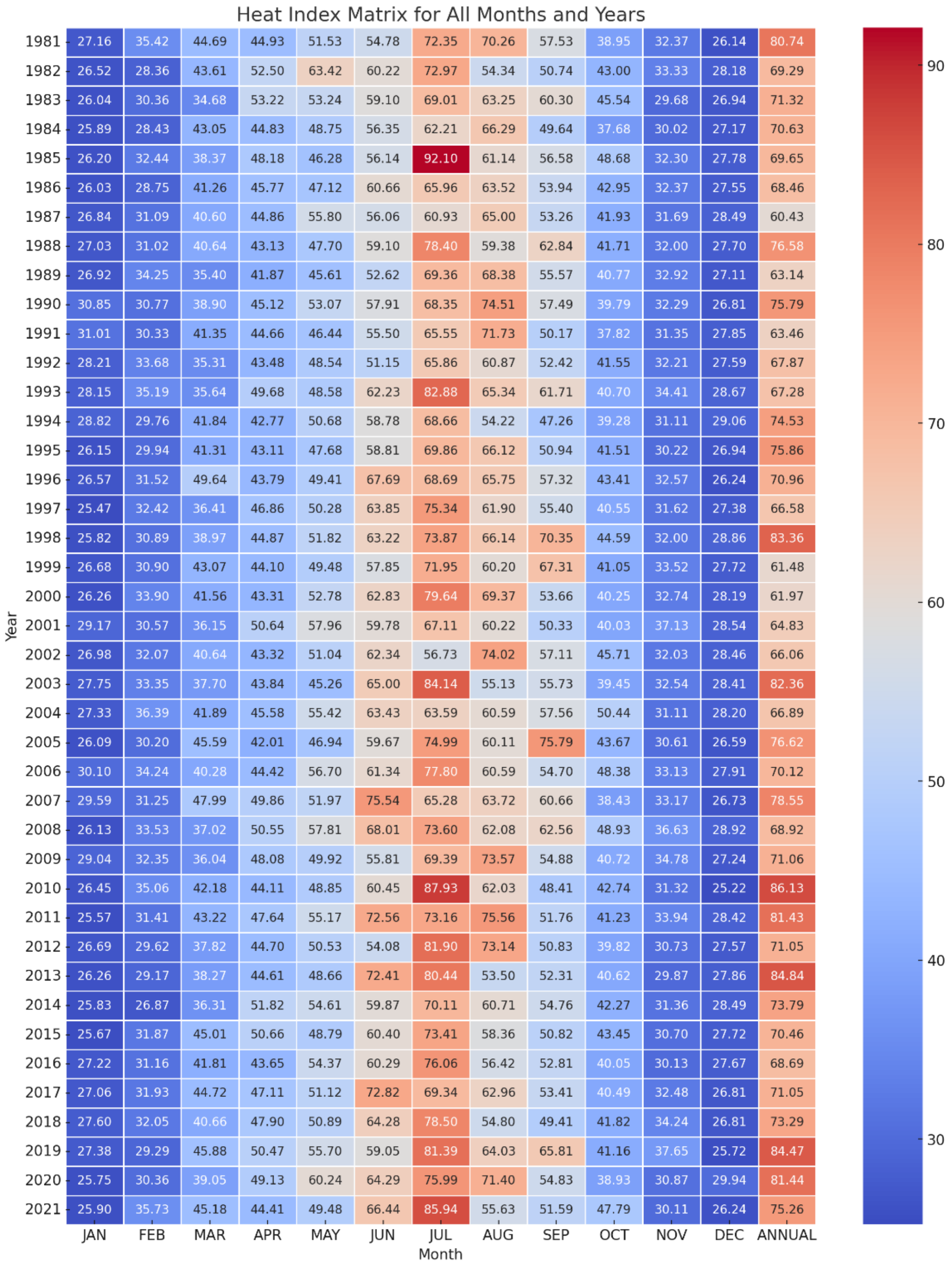

Figure 3 Monthly Heat Index Matrix (Author 2023)

Land Surface Temperature

Land surface temperature mapping was done for the current study between 2017 and 2020, a period of four years. The procedure for creating land surface temperature maps derived from Landsat 8 satellite data (Jovanovska, 2016). The observed variance is in line with the findings of Grover and Singh (2015), who found that—contrary to common belief—the core of Delhi had a lower land surface temperature and the periphery had a higher one.

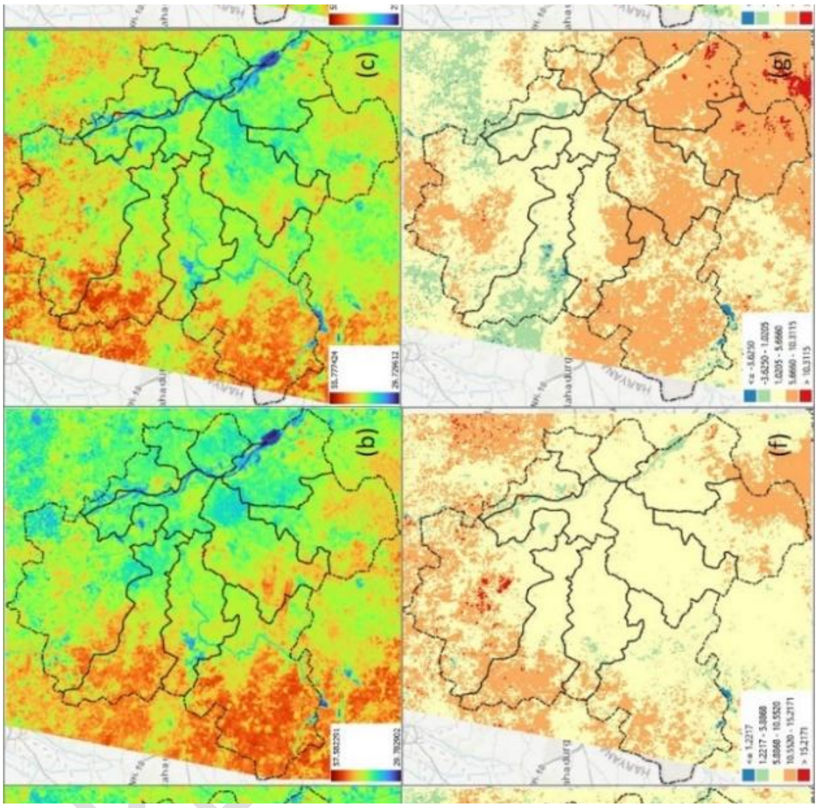

Figure 4 Land surface temperature map of Delhi (a) 2017 (b) 2018 (c) 2019 (d) 2020 (e) Difference of temperature from 2018-2017 (f) Difference 2019-2018 (g) Difference 2020-2019 (h) Difference 2020-2018

In 2017, the land surface temperature varied between 25.07 to 42.98 °C. There were three different ranges: 29.78 to 57.58°C in 2018, 29.73 to 55.77°C in 2019, and 27.90 to 55.28°C in 2020. The shift's position and the size of the temperature change between 2017 and 2020 are shown on the map above. Notable alterations have been observed in the western and southern regions of Delhi. The 2020 map indicates a reduction in Delhi's temperature range, which may be related to the COVID-19-related statewide lockdown.

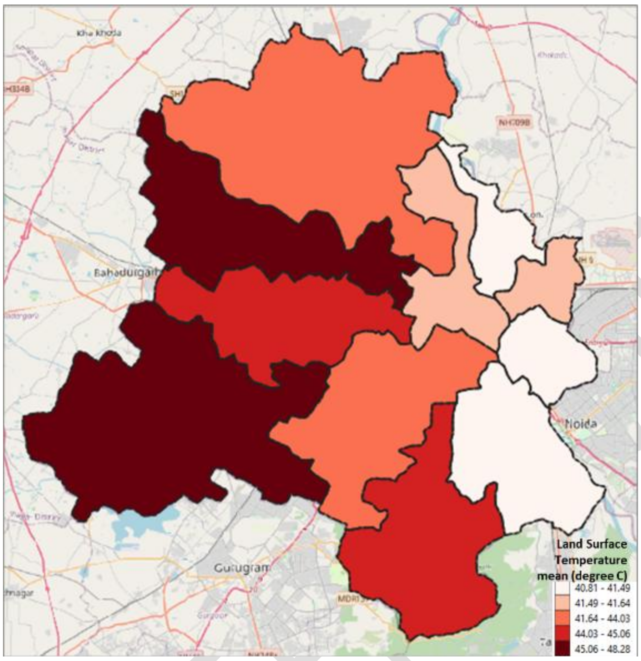

Figure 5 District-wise mean land surface temperature map (Author 2023)

The districts of North West and South West in Delhi have the greatest mean land surface temperature, whereas the districts of North East, East, and South East have the lowest mean land surface temperature, according to district-level zonal statistics. The range of the mean is 40.81 to 48.28°C.

Heat and Health Association

A host of illnesses, such as heat cramps, heat exhaustion, heatstroke, and hyperthermia, can arise in a body exposed to higher-than-normal temperatures and experiencing fast increases in heat gain. Hospital admissions and deaths from heat-related causes can occur suddenly (in a single day) or gradually (over several days), which may accelerate sickness or death in those who are already vulnerable. This is particularly valid during heatwaves' early phases. Higher rates of illness and mortality are associated with seasonal average temperature fluctuations, even in small quantities. Sudden temperature swings can exacerbate long-term health issues, such as diabetes-related disorders and illnesses of the heart, lungs, and brain.

Heat has important unintended consequences on health as well. Heat can affect how people behave, how diseases spread, how health services are provided, how clean the air is, and how readily available essential social infrastructure such as energy, water, and transportation is (WHO). In just four years, heat waves killed many lives in India (2014–2017). 4,500 persons lost their lives in India alone in just four years (Delhi heat wave action plan, 2023). High heat index readings can pose serious health risks, especially to susceptible populations such as the elderly, young children, and those with underlying medical conditions. Heat-related illnesses like heat exhaustion and heat stroke can result from inadequate control of the body's internal temperature. The relationship between apparent temperature and health concerns in the following ways:

1. Less than 27°C: This is a generally acceptable range of temperatures.
2. 27°C to 32°C: More strenuous exercise than usual; if exposed for an extended length of time, there is a chance of heat fatigue.
3. 33°C to 39°C: During prolonged exposure or physical exertion, there is an increased risk of pain and heat exhaustion or cramps.
4. 40°C to 51°C: There is a high danger of heat exhaustion or cramps, as well as a chance of heatstroke with extended exposure and/or vigorous exercise.
5. Above 51°C: Prolonged exposure and/or physical exertion can result in a very high to extremely high risk of heatstroke or severe heat damage.

For the duration of the study, a heat index health impact matrix for Delhi has been created. It shows that the most comfortable months to visit are December and January, with no occurrences in the middle of the year. The months with the lowest risk are February and November, with no risk during the summer. Moderate Risk is generally absent during the busiest summer months, March through October. April, May, and September are the months with the highest danger, whereas June and August see very few instances. Finally, the hottest months of June, July, and August are when the extreme risk is most prevalent. It is alsosomewhat present in May and September.

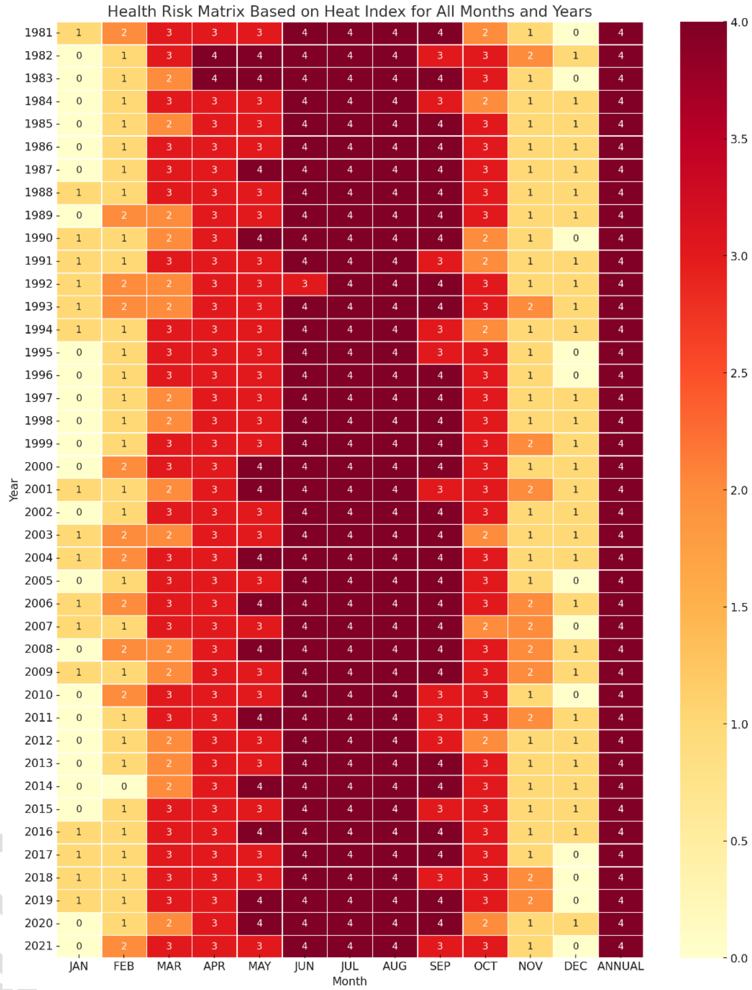

Figure 6 Health Risk Matrix Based on Heat Index for all Months (Author 2023)

The summer months of June, July, and August carry the highest risk of heat-related illnesses, which is consistent with the popular belief that these are the warmest months. There are also a sizable number of years in the "High Risk" and "Extreme Risk" categories for April, May, and September. The "Comfortable" range, which indicates minimal risk from heat, is primarily occupied by the colder months, such as January and December.

From 2001 to 2021, all cause mortality was obtained from the Medical Certification of Causes of Deaths report. Over time, there has been an increasing tendency in the overall cause of death.

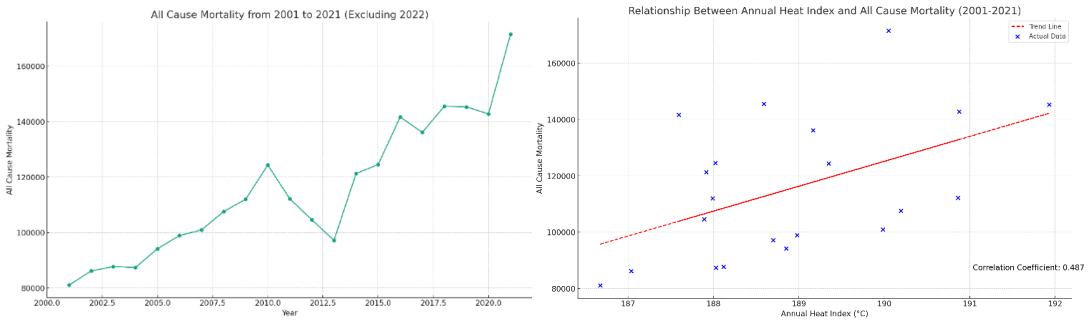

Figure 7 (a) Trend of all-cause mortality from 2001 to 2021 (b) Scatter plot between annual heat index and all cause mortality 2001 to 2021

With a correlation coefficient of roughly 0.487, the analysis shows a statistically significant moderate positive association between the yearly Heat Index and All-Cause Mortality for the years 2001 to 2021. This correlation is visually supported by the scatter plot's trend line, which shows that there is a tendency for All-Cause Mortality to grow in tandem with an increase in the yearly Heat Index. This highlights the possible negative effects of rising temperatures on public health by indicating that years with higher Heat Index values are linked to higher death rates.

The correlation's p-value of less than 0.05 confirms the observed relationship's statistical significance. This supports the theory that the observed correlation may indicate a causal relationship that calls for additional research rather than being the result of random chance. The results highlight the need for more thorough research to fully comprehend the complex interaction that exists between climate variables—like the Heat Index—and public health effects.

The following outcomes were obtained from hospital visits conducted in 2018 to investigate the relationship with heat:

Table 1 Health Outcome and Land surface Temperature Correlation (Author 2023)

Health Outcome	P-value	Correlation Coefficient
Number of newborns having weight less than 2.5 kg	0.001	0.25
Outpatient - Hypertension	0.010	0.30
Outpatient - Stroke	0.000	0.71
Outpatient - Acute Heart Diseases	0.008	0.21
Outpatient - Diabetes	0.0001	0.56
Mental Illness	0.010	0.15

With a correlation coefficient of 0.71, stroke (paralysis) and land surface temperature have the strongest direct association. This implies that the number of stroke patients who are discharged from hospitals tends to rise in tandem with an increase in land surface temperature. A correlation coefficient of 0.56 indicates that diabetes and land surface temperature have a very significant direct association. With correlation values of 0.30 and 0.25, respectively, hypertension and the number of babies born weighing less than 2.5 kg (low birth weight) have moderate direct connections with land surface temperature.With correlation values of 0.21 and 0.15, respectively, Acute Heart Diseases and Mental Illness have comparatively weaker direct associations with land surface temperature. Given that each of the dataset's health outcomes has a p-value of less than 0.05, they are all statistically significantly correlated with land surface temperature.

Conclusion

As seen through the analysis, temperature (both apparent and land surface) has significant impacts on the morbidity and mortality. The findings reveal that Delhi faces significant health risk throughout the city due to the increasing heat. Assessing health risks (mortality and morbidity) when temperatures rise is critical for understanding the potential effects on human populations. This assessment aids in the identification of risk and the development of appropriate solutions for mitigating the health concerns linked with rising temperatures. Furthermore, it enables policymakers to make educated decisions and put required policies in place to preserve public health. This data can also be used to prioritize resources and allocate money for public health projects. Vegetation and water bodies play an important role in maintaining microclimatic conditions such as lower land surface temperature and higher humidity. These natural components aid in cooling the surroundings and providing relief from the heat. Communities can establish microclimates that decrease the health effects of rising temperatures by protecting and improving green spaces and bodies of water. Furthermore, implementing measures such as urban greening and water management methods can help to maintain comfortable and safe living conditions in cities. Heat and climate change-related health impacts can be mitigated through efficient planning and climate-sensitive urban planning, data-driven decision making, and targeted interventions.

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