

Biratnagar Heat Action Plan 2024

Table of Contents

1. Background	5
1.1 City Profile- Biratnagar	5
2. About the Biratnagar Heat Action Plan (HAP) 2024	7
2.1 Purpose and objectives	7
2.2 Approach and tools for developing the HAP	8
3. Heatwave risk in Nepal and Biratnagar	8
3.1 Heatwave Risk in Nepal	8
3.2 Temperature Variation in Biratnagar City	9
3.3 Heatwave Risk in Biratnagar	10
3.4 Heat risks and impacts to the most vulnerable communities	14
3.5 Heat Risks awareness and existing coping mechanism by the vulnerable communities	15
4. Threshold and trigger determination for the heatwave alert	15
5. Heat Hotspots	16
6. City Stakeholder Engagement	18
7. Heat Action Plan	19
7.1 Preparedness (Before a Heat Season)	19
7.2 Response (During a Heat Season)	29
7.3 Long term measures	36
8. Way Forward	41
References	42
ANNEX A: Heat threshold and trigger determination for the heatwave alert	44
A.1 Introduction	44
A.2 Meteorological data (ambient near-surface air and dew point temperature) from ERA5	44
A.3 Threshold for Heat Stress	44
A. 3.1 Composite metric for Heat Stress: The Heat Index (HI; Units: °C).....	44
A. 3.2 Summary statistics of the HI at Biratnagar.....	45
A.4 Trigger for the heatwave alert	46
ANNEX B: Heat Hotspots Analysis	47
B.1 Selections of Indicators	47
B.2. Normalized difference water index	48
B.3 Exposure and Vulnerability Analysis	49
B.3.1 Exposure.....	49
B.3.2 Vulnerability.....	49
ANNEX C: Locations	52

List of Figures

Figure 1: Average temperature Biratnagar, Nepal	5
Figure 2: Ward wise population distribution	6
Figure 3: Population density	6
Figure 4: Approach and Tools for Developing HAP Source: Author's Illustration	9
Figure 5: Maximum temperature of each year from 1990 to 2023, Biratnagar station	11
Figure 6: Number of heatwave events and respective number of days in the heatwave events from 1990 to 2023 (90th percentile)	12
Figure 7: Number of heatwave events and respective number of days in the heatwave events from 1990 to 2023 (95th percentile)	14
Figure 8: Number of heatwave events and respective number of days in the heatwave events from 1990 to 2023 (99th percentile)	15
Figure 9: Schematic of the threshold criteria	17
Figure 10: Heat Hotspot and approximate number on vulnerable population and households	18
Figure 11: Stakeholder Coordination	20
Figure A-1: NDWI	48
Figure A-2: Exposure Analysis	49
Figure A-3: Socio-economic Vulnerability	50
Figure A-4: Physical Vulnerability	50
Figure A- 5: Capacity	51
Figure A-6: Overall Vulnerability	51
Figure A-7: Locations for Water ATM in Biratnagar	53
Figure A-8: Identified Locations for LED Installation in Biratnagar	55
Figure A-9: Identified Locations for Cooling Centres Installation in Biratnagar	57
Figure A-10: Identified locations for distribution of heat relief supplies such as water, electrolyte beverages.	58

List of Tables

Table 1: Number of maximum temperature days at Biratnagar 1990-2023	10
Table 2: Definition of Heatwave, DHM	12
Table 3: Mild, Moderate, and Extreme Heatwave of Biratnagar	12
Table 4: Temperature above 35 degrees for three or more consecutive days in 2021	13
Table 5: Temperature above 35 degrees for three or more consecutive days in 2022	13
Table 6: Exposure and Vulnerability score	18
Table 7: Stakeholder List	20
Table 8: Imminent priority actions for preparedness	22
Table 9: High priority actions for preparedness	25
Table 10: Moderate priority actions for preparedness	27
Table 11: Imminent priority actions for response	31
Table 12: High priority actions for response	34
Table 13: Moderate priority actions for response	35
Table 14: Imminent priority actions for long term measures	38
Table 15: High priority actions for long term measures	40
Table A-1: Himax_90p and Himax_95p at Biratnagar computed using hourly ERA5 Tair and Td	44
Table A-2: Possible heat disorders for people in high-risk groups (e.g., aged, with co-morbidities etc.) when exposed to different thresholds of Heat Index (HI).	45
Table A-3: RL of Himax in °C for Biratnagar corresponding to 2-, 5-, and 10-year RPs. The RLs fall in the mid ‘Danger’ range (41-54 °C) highlighted in amber in Table A-1.	45
Table A-4: List of indicators, their dimensions and category, and rationale behind the selection of indicator	46

1. Background

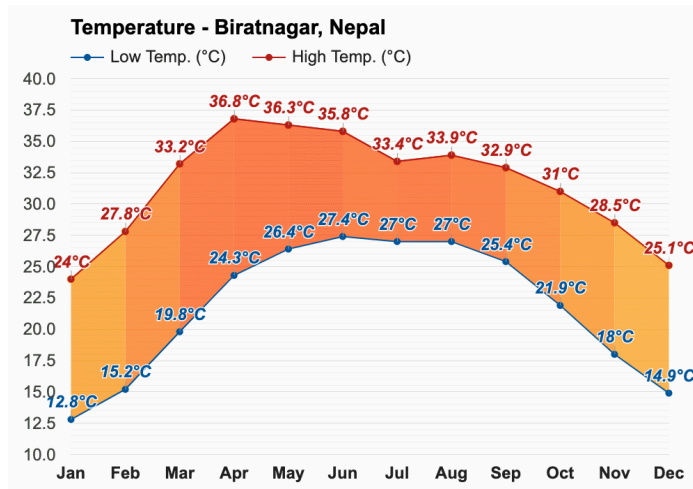
2.1 City Profile- Biratnagar

The Terai region, located in the southern plains of Nepal, is susceptible to high heat problems. Due to its sub-tropical conditions, the Terai region is known for scorching heat and extremely humid weather, contributing to the elevated temperatures. The Terai zone is also situated at a low altitude, resulting in high solar radiation and limited air circulation throughout the lowland region.

Biratnagar City, located in southeastern Nepal, is the capital of Koshi Province and is situated within the Morang district. With a population ranking it among the six largest cities in Nepal, Biratnagar covers an area of 77 km² (The Kathmandu Post, 2023). Biratnagar is also primarily known for its agriculture, productivity, and industries. It also has the nation's first large-scale industry, Birat Jute Mills. Biratnagar has the second-largest industrial corridor in Nepal, which contains some of its largest industries and factories (Brittanica, 2024).

Climatology of Biratnagar: Biratnagar falls in the subtropical climatic zone with high temperatures, humidity, and moderate rainfall. The hottest months are from April to June, with average maximum temperatures exceeding 35°C (Weather Atlas, 2024) (Figure 1). The highest temperature ever recorded in Biratnagar was 42°C on 14th April 1992 (DHM, 2024a). Historical weather data shows humidity during hot days can reach around 72 per cent (DHM, 2024a).

Figure 1: Average temperature Biratnagar, Nepal



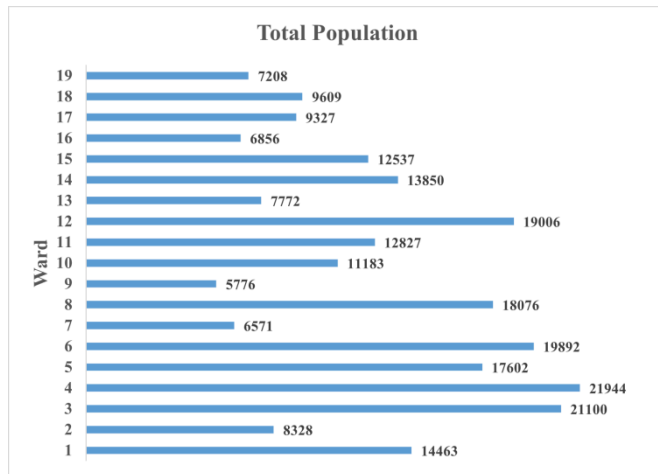
Source: Weather Atlas, 2023

In recent years, Biratnagar has faced significant challenges due to prolonged heatwaves, particularly during summer, i.e., April, May and June (DHM, 2024). For example, on June 6th, 2023, the maximum temperature reached to 40.4°C. Additionally, urban areas have witnessed rising land surface temperatures due to decreased water bodies and vegetation.

Demography of Biratnagar: As of CBS 2021, the total population of Biratnagar City is 243,927. The maximum population in Biratnagar is represented by the age group of 20-39 years (34%), which is followed by the age group of 5-19 years (26.38%). Among the wards of Biratnagar, Ward four has the highest population (8.99% of the total population), followed by Ward Three at 8.65%. The total elderly

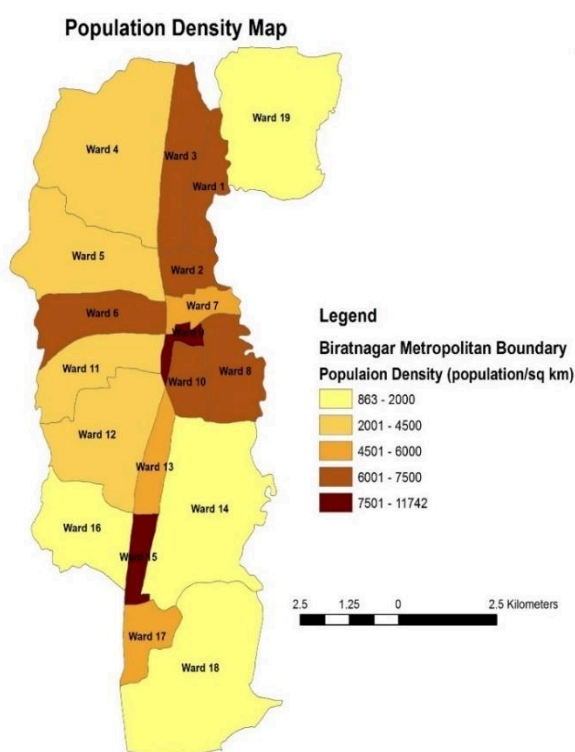
population in Biratnagar is 16,096, with the highest concentration in ward three (11%), followed by ward four (8.5%) and ward five (7.4%). The sex ratio in Biratnagar Metropolitan City is 99.98 males per 100 females. This means there are approximately 99.98 males for every 100 females (CBS, 2021).

Figure 2: Ward wise population distribution



Source: Authors Illustration based on data obtained from CBS 2021

Figure 3: Population density



Source: Authors Illustration based on data obtained from CBS 2021

From the map, it can be seen that the population densities vary widely across different wards of Biratnagar. Wards with smaller areas tend to have higher population densities, while wards with larger areas have lower population densities. For example, according to the Census 2021, Ward 9 has the highest population density, with 10,123 people per square kilometre, covering a relatively small area of 0.57 square kilometres. On the other hand, Ward 18 has the lowest population density, with only 960 people per square kilometre, but it covers a much larger area of 10.01 square kilometres. This demographic profile plays a crucial role in shaping various aspects of the city.

Education in Biratnagar: The literacy rate of the total population aged 5 years and above was 83.61 per cent in the 2021 census, indicating a strong emphasis on education. Both male and female literacy rates are noteworthy, with 89.07 per cent for males and 78.18 per cent for females (CBS 2021).

Health Situation in Biratnagar: Biratnagar Metropolitan City has 33 hospitals, 60 clinics, 16 basic health service centers, and 236 pharmacies.

Housing Structure in Biratnagar: Most households, 40.89%, have reinforced cement concrete with pillars, followed by 38.96% of households with cement-bonded bricks/stone and 7.76% with mud-bonded bricks/stone foundations (CBS 2021).

2. About the Biratnagar Heat Action Plan (HAP) 2024

2.1 Purpose and objectives

The Heat Action Plan (HAP) provides a framework for planning, implementing, coordinating and evaluating extreme heat action across different timescales in Biratnagar to minimize the negative impacts

of extreme heat on the health and livelihood of the city's residents. It also provides an indication to the respective local authorities when and where to act before or during heatwave days and a roadmap to build resilience to the rising temperatures on public health, infrastructure, and the environment in Biratnagar city. Some of the specific objectives of the HAP for Biratnagar are to:

1. Understanding the heat risk in Biratnagar city and how heatwaves have been a threat to the residents of the city
2. Indicating the heat threshold will activate early warning, preparedness, and heatwave response plans, and adaptive measures will be taken to protect the communities.
3. Identifying the heat hotspots that are highly vulnerable to heatwave risk and focusing on heat risk adaptation and mitigation actions is essential.
4. Identify the population group that is more susceptible to heat risks.
5. Provide a roadmap for the local government and other stakeholders associated with providing emergency services, such as the Nepal Red Cross Society (NRCS) and Biratnagar Metropolitan City (BMC), on how to act before, during and after a heating season.
6. Build capacity of key city and non-governmental organization (NGO) stakeholders on heatwave impacts and preventive measures.
7. Define long-term planning measures to make the city more heat-resilient
8. Suggest a mechanism for effective coordination between all the relevant stakeholders to improve the perception of risk at the individual and community levels to strengthen Early Warning, Early Action, and long-term urban planning measures.
9. Highlight heat adaptation and mitigation tools to reduce the risk and make urban systems resilient.
10. Share insights on how Biratnagar city in Nepal could improve or mainstream its preparedness for extreme heat through existing policies and plans.

2.2 Approach and tools for developing the HAP

The HAP was developed using a holistic and inclusive approach. The Figure below shows the detailed processes and methodologies used.



Figure 4: Approach and Tools for Developing HAP

Source: Author's Illustration

3. Heatwave risk in Nepal and Biratnagar

3.1 Heatwave Risk in Nepal

Climate change has been a significant factor in instigating extreme heat occurrences. Approximately 75% of the moderate heat extremes globally over land can be attributed to rising temperatures (Fischer & Knutti, 2015). With the escalating temperatures across South Asia, Nepal stands at the forefront of increased climate and disaster risks (Amadio et al., 2022). Nepal is ranked 135th in terms of vulnerability, 138th in terms of exposure, 129th in terms of sensitivity, and 114th in terms of adaptive capacity out of 192 countries, which shows that Nepal faces a significant challenge in dealing with climate change (ND-Gain, 2021). The future projections indicate that the temperature will increase by 1 degree Celsius from 2016 to 2045, emphasizing the urgent need to act on climate change (Amadio et al., 2022).

Research reveals that between 2002 and 2010, Nepal experienced 25 heatwaves, mainly affecting the Terai region. These events killed twenty-five lives and affected 280 individuals (Dhimal et al., 2018).

Moreover, a 2016 study demonstrated a 2.1% increase in water-borne disease hospitalizations per 1°C temperature rise in the Terai region. Similarly, vector-borne disease hospitalizations surged by 7.3% per 1°C temperature increase in the same area (Shrestha, 2018). The frequency of hot days and nights is also rising across most districts of Nepal (Shrestha et al., 2019).

Additionally, a 2020 research study revealed that households in Nepal spend an average of 3.13 hours indoors daily to shield themselves from extreme heat, reducing working hours by approximately two months annually (Paudel & Pant, 2020). Similarly, a study in eight districts of Nepal on the perception of heat also showed a gap in knowledge regarding awareness of heatwaves and their impacts on outdoor workers. This highlights a need for widespread awareness of heatwaves and targeted community interventions for climate change adaptation, especially regarding heatwaves in Nepal (Joshi et al., 2022).

3.2 Temperature Variation in Biratnagar City

Biratnagar has a sub-tropical climate and experiences both wet and dry seasons. High temperatures, high humidity, and moderate rainfall characterize Biratnagar’s climate. The table below summarises the weather patterns in Biratnagar based on DHM observations spanning from 1990 to 2023. The number of days with maximum temperature in Biratnagar is shown below:

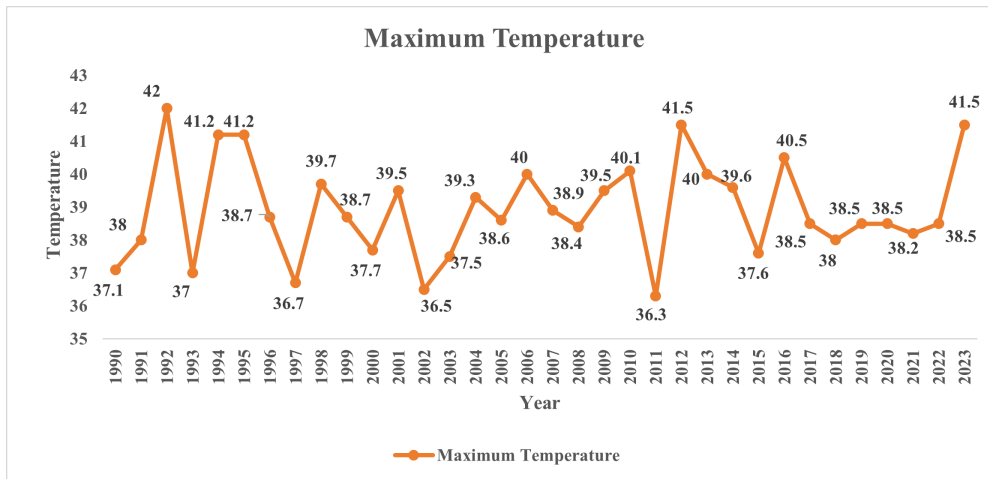
Table 1: Number of maximum temperature days at Biratnagar 1990-2023

Max temperature (°C)	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total	% of total
40 °C and greater	-	-	-	6	7	3	-	-	-	-	-	-	16	0.1%
38°C - 40°C	-	-	-	1	63	8	2	3	1	-	-	-	78	0.6%
35°C - 38°C	-	-	65	283	213	153	94	130	100	18	-	-	1056	8.5%
30°C - 35°C	-	44	614	579	692	762	823	804	800	884	416	6	6424	51.9%
25°C - 30°C	229	641	359	100	105	94	135	117	119	151	590	623	3263	26.4%
20°C - 25°C	609	254	15	-	-	-	-	-	-	-	14	369	1261	10.2%
Less than 20°C	218	6	-	-	-	-	-	-	-	-	-	47	271	2.2%

Source: Author’s Illustration based on data obtained from DHM

During the 34 years (1990-2023), the most common range of maximum temperature was 30-35°C, recorded for 6,424 days (51.9%) out of 12,380 days (excluding the 41 missing records). April, May, and June collectively account for 94 days when maximum temperatures exceed 38°C. Notably, April holds the maximum number of days (283) with temperatures ranging between 35-38°C, while May records 213 days with maximum temperatures between 35-38°C. Based on this analysis, April, May, and June emerge as the hottest months, with a higher possibility of experiencing heatwaves during this period. The maximum temperature data has also been analyzed to determine the overall temperature trends. The figure below shows the variation of extreme temperature.

Figure 5: Maximum temperature of each year from 1990 to 2023, Biratnagar station



Source: Author's Illustration based on data obtained from DHM

Maximum temperatures vary from year to year, with some years experiencing higher maximum temperatures than others. The highest maximum temperature recorded over the period was 42°C on April 14, 1992. The data is variable, with some years consistently having temperatures above the average of 38.9°C, while others have temperatures closer to or below the average. The data shows fluctuations in maximum temperatures over the years, indicating variability in weather patterns and increasing trends in temperature changes.

3.3 Heatwave Risk in Biratnagar

Several articles have highlighted the challenges faced by residents of Biratnagar during heatwaves, particularly outdoor laborer's and farmers unable to work in extreme heat (Rising Nepal, 2024). Schools often close during these periods, affecting children's education. Extended load shedding worsens conditions for the most vulnerable (The Kathmandu Post, 2023). Hospitals have noted an increased number of patients with symptoms like fever, skin diseases, and headaches (Regmi, 2009). The adverse impacts of a heatwave are apparent through symptoms like tenderness, pain, muscle cramps, exhaustion, heat strain, heat spasms, heat stroke, etc. Likewise, waterborne diseases are more common during heat season, and the flow of such cases overburdens hospitals.

It is crucial to understand that a heatwave is not a universal phenomenon. It occurs when the maximum temperature rises above for a longer period of time (more than 3 days), a definition that is specific to the local climate and weather patterns in the area. Therefore, there is a pressing need for locally tailored strategies to address heatwaves. The lack of a universally accepted definition or threshold for a heatwave underscores the importance of considering various factors such as the local climate, weather patterns, and the impact it has on health, infrastructure, and services in a particular region. This understanding empowers us to take action and develop strategies that are specific to our local context.

The Department of Hydrology and Meteorology (DHM) has categorized heatwaves into three levels: mild, moderate, and extreme heatwaves and is defined as (DHM, 2024b):

Table 2: Definition of Heatwave, DHM

Mild Heatwave	annual count of days with at least three consecutive days where the maximum temperature exceeds the 90 th percentile for a given period.
Moderate Heatwave	annual count of days with at least three consecutive days where the maximum temperature exceeds the 95 th percentile for a given period.
Extreme Heatwave	annual count of days with at least three consecutive days where the maximum temperature exceeds the 99 th percentile for a given period.

Source: DHM, 2024

Using abovementioned definition, the mild, moderate, and extreme heatwaves are determined by analyzing historical temperature data of the last 33 years (1990-2023) in Biratnagar. So, the mild, moderate, and extreme heatwaves in Biratnagar are shown in the Table below:

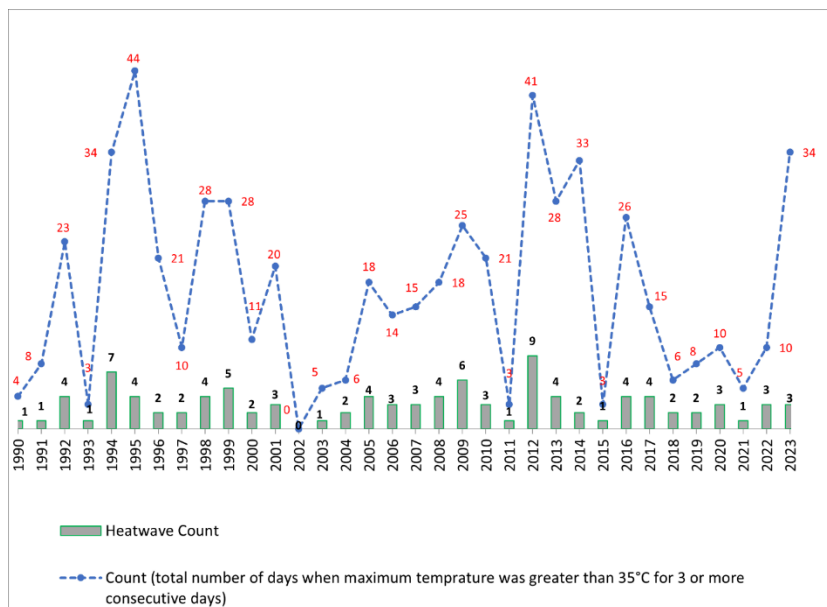
Table 3: Mild, Moderate, and Extreme Heatwave of Biratnagar

Mild Heatwave (90 th percentile)	Occurs when maximum temperature exceeds 35°C for three or more consecutive days
Moderate Heatwave (95 th percentile)	Occurs when maximum temperature exceeds 36 °C for three or more consecutive days
Extreme Heatwave (99 th percentile)	Occurs when maximum temperature exceeds 38.2 °C for three or more consecutive days

Source: Authors Illustration based on DHM data

The Figure 6 shows the number of heatwave events at the 90th percentile that occurred each year from 1990 to 2023, specifically from April to June, as these months are the hottest.

Figure 6: Number of heatwave events and respective number of days in the heatwave events from 1990 to 2023 (90th percentile)



Source: Author’s Illustration based on data obtained from DHM

The numbers highlighted in red represent the total hot days (i.e., above 35°C) during heatwave events in the respective years. For example, based on the definition of a heatwave, a heatwave event can be identified by examining temperatures over several consecutive days. For example, consider the temperatures recorded from April to May in 2021 (Table 4) and 2022 (Table 5).

Table 4: Temperature above 35 degrees for three or more consecutive days in 2021

Date	Maximum Temperature
4/24/2021	35.3
4/25/2021	36.7
4/26/2021	38.2
4/27/2021	37.7
4/28/2021	36.3

Source: Author’s Illustration based on data obtained from DHM

In 2021, from April 24th to April 28th, temperatures were recorded at 35.3°C, 36.7°C, 38.2°C, 37.7°C, and 36.3°C, respectively. These consistently high temperatures, with each day reaching 35°C or higher, indicate a five-day heatwave event. Similarly, in 2022, another heatwave event can be identified (Table 5).

Table 5: Temperature above 35 degrees for three or more consecutive days in 2022

Date	Maximum Temperature
4/14/2022	35.7
4/15/2022	38.5
4/16/2022	37.2
4/17/2022	35.5
4/23/2022	35.2
4/24/2022	35.7
4/25/2022	36.6
5/7/2022	35.3
5/8/2022	35.3
5/9/2022	36.2

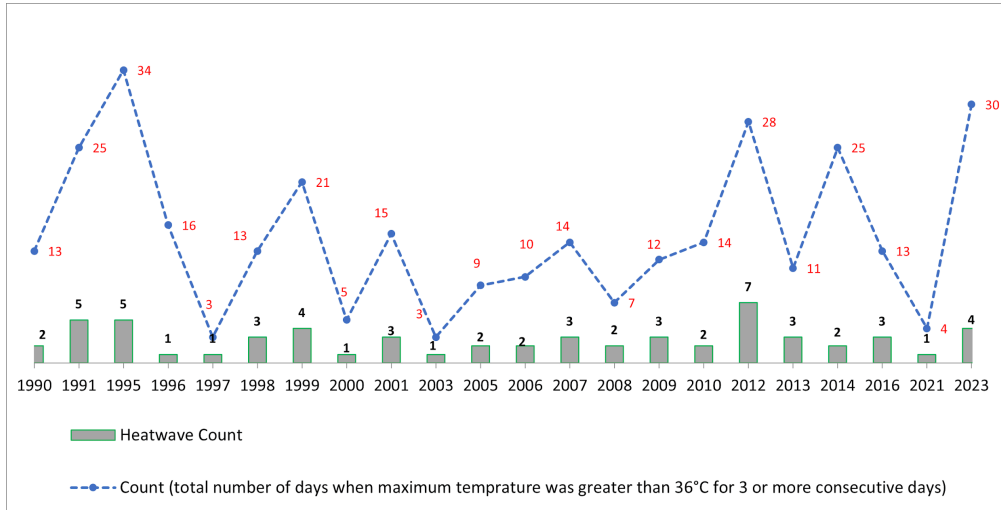
Source: Author’s Illustration based on data obtained from DHM

From April 14th to April 17th, April 23rd to April 25th, and May 7th to May 9th, the temperatures persisted above 35°C for four consecutive days, meeting the criteria for a heatwave. Therefore, three different heatwave events occurred during this period, lasting ten days.

The highest count of days with temperatures exceeding 35°C for three consecutive days was observed in 2012, with 9 heatwave events lasting 41 days. This was followed by 1995, with 34 days and 4 heatwave events, and then 2009, with 25 days and 6 heatwave events. The count of heatwave events in a year varies, with some years experiencing multiple heatwave events while others have only one. This variability in the occurrence of heatwave events, as seen in 2014 and 2012, adds to the complexity of our findings.

The following Figure 9 visualizes the number of heatwave events at the 95th percentile that occurred each year from 1990 to 2023, specifically from April to June.

Figure 7: Number of heatwave events and respective number of days in the heatwave events from 1990 to 2023 (95th percentile)

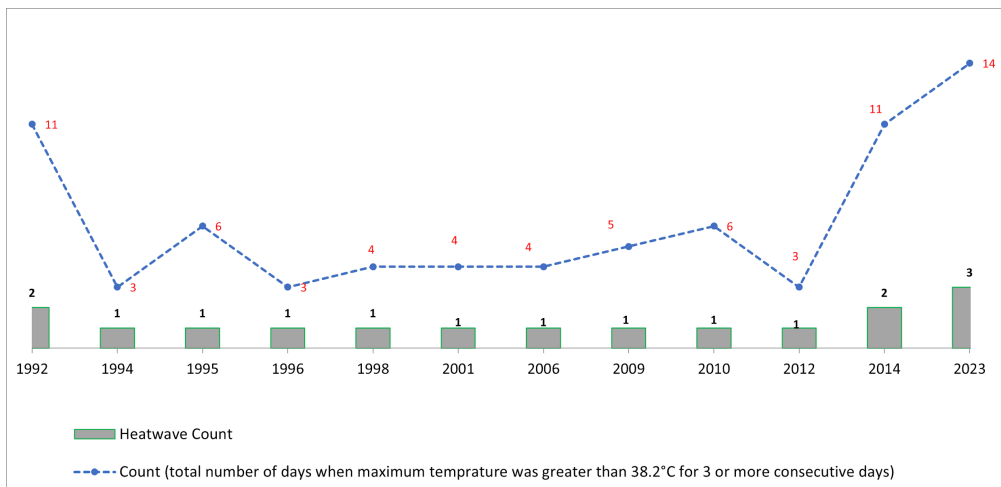


Source: Author’s Illustration based on data obtained from DHM

The highest count of days with temperatures exceeding 36°C for three consecutive days was observed in 2012, with 7 heatwave events lasting 28 days. This was followed by 1995, with 34 days and 5 heatwave events, and 2023, with 30 days and 4 heatwave events.

Figure 8 provides a visual representation of the number of heatwave events at the 99th percentile that occurred each year from 1990 to 2023, specifically focusing on the period from April to June. This time frame is crucial for understanding the seasonal patterns of heatwave events.

Figure 8: Number of heatwave events and respective number of days in the heatwave events from 1990 to 2023 (99th percentile)



Source: Author’s Illustration based on data obtained from DHM

Over 33 years, extreme heatwaves occurred in 12 years, with maximum temperatures exceeding the 99th percentile (38.2°C) for three or more consecutive days. The year 2023 had the highest number of days, with three heatwave events for 14 days, with temperatures above 38.2°C for three straight days. These specific years experienced at least one extreme heatwave event, indicating that such intense heatwaves occurred at irregular intervals but consistently over this period.

As temperatures continue to rise and heatwave events become more frequent, the need to prioritize heat preparedness in Biratnagar becomes increasingly urgent. The significant impact of these heatwaves on the city and its residents, as detailed in chapters 3.2 and 3.3, underscores the importance of developing and implementing a comprehensive heat action plan. This plan is not just a strategic necessity but a direct means of protecting the health of the city's residents, enhancing resilience, and fostering sustainable development.

3.4 Heat risks and impacts to the most vulnerable communities

Heat impacts vary across groups. Majority of The low-income communities of wards 15 and 6 report heat health illnesses such as low blood pressure, headaches, skin rashes, irritation, body aches, laziness, and weakness as the primary health impacts of heat There are about 2,000 economically vulnerable households in ward 15 and 1,775 households in ward 6 (Biratnagar Sub-Metropolitan City, 2024). They face additional challenges such as frequent power cuts, insufficient medicines at health posts, poor kitchen ventilation, and reliance on hand pumps that dry up in summer due to extreme heat. These factors heighten their vulnerability to heat stress and associated health problems. Outdoor workers and auto drivers suffer from heat cramps such as painful muscles, excessive sweating, and clammy hands. They also suffer from dizziness, headaches, and rashes, as they often need to work in extreme heat to complete tasks. In the city, about 443,609 outdoor workers including construction workers, street vendors, daily wagers, and auto drivers, are at risk heat exhaustion and heatstroke as they are exposed to heat for a long time without adequate breaks or hydration.

Special attention needs to be given to lactating mothers and the elderly, as they are particularly vulnerable to heat-related health issues. Lactating mothers often experience a range of health problems like headaches, vomiting, dizziness, skin irritation or rash, eye redness or infection, loose motion, fever, etc. This is because they are already physiologically compromised, and the extra burden of heat makes it necessary for them to have access to cooling and medical treatment. The elderly, on the other hand, suffer from headaches, fatigue, pain, swollen feet, rash, itching, and infection of the eyes. Ageing-related changes in physiology, existing health conditions, and reduced mobility make them particularly vulnerable to heat.

Students, the future of our society, are also significantly impacted by heat. They commonly experience headaches, neck pain, sweating, and body pain, particularly when temperatures exceed 35 degrees Celsius. The main challenges in the school environment include inadequate water availability. Even when water is available, it is often hot due to storage in steel tanks that heat up during extreme summer temperatures. Additionally, many schools in the Biratnagar metropolitan area, such as Bidhya Bikas School (Ward 15), Birat Aaavi (Ward 18), Shankar Pur Aaavi (Ward 2), and Bishu Aaavi School (Ward 14), have tin roofs and lack fans in some classrooms, exacerbating the heat impact. Another significant problem during the summer is the excessive heat inside school buses, which are often overcrowded with around 80 students in buses designed for 58. As the students are more exposed to heat due to

overcrowding and poor ventilation, this overcrowding increases the risk of heat-related illnesses, leading to dehydration and heat exhaustion.

3.5 Heat Risks awareness and existing coping mechanism by the vulnerable communities

The heatwave risk awareness and coping mechanisms differ by group. The awareness and coping mechanisms for heatwave risk differ among groups. School students from grades 8 to 10 demonstrate an understanding of climate change and its impact on disaster management. They are aware of this due to the inclusion of climate change in their science curriculum. Additionally, they possess some knowledge regarding heatwaves and floods, which are more prevalent disasters in Biratnagar city.

Moreover, they can recognize specific heat-related impacts, such as heat cramps, dizziness, skin rashes, and headaches. This group understands the importance of staying hydrated and adjusting their eating habits by incorporating more fruits during the heat season. In contrast, the low-income community perceives heatwaves as a severe threat to their daily lives and health, although many have adapted to the heat without formal coping mechanisms.

Elderly people, a vulnerable group, often rely on traditional practices and personal experience to cope with heat-related issues, highlighting the need for more targeted education. Outdoor workers, despite their awareness of the risks, lack detailed knowledge about effective protective measures, indicating a gap in occupational health and safety. Pregnant women, another vulnerable group, understand the dangers of heat exposure but often lack access to comprehensive information or resources, underscoring the need for improved outreach.

Regarding coping mechanisms, students have reported drinking much water to stay hydrated and avoid outdoor activities during extreme heat. Due to their financial situation, the low-income community stays in shaded areas and uses hand fans but has limited access to fruits or other hydrating foods. Outdoor workers rest under trees, drink water, avoid work during peak heat when possible, and use hand fans. Lactating women and older adults use hand fans, stay in shaded areas, and take frequent showers despite the hot water challenge. Older adults also avoid sitting in rooms with fans due to the hot air they circulate.

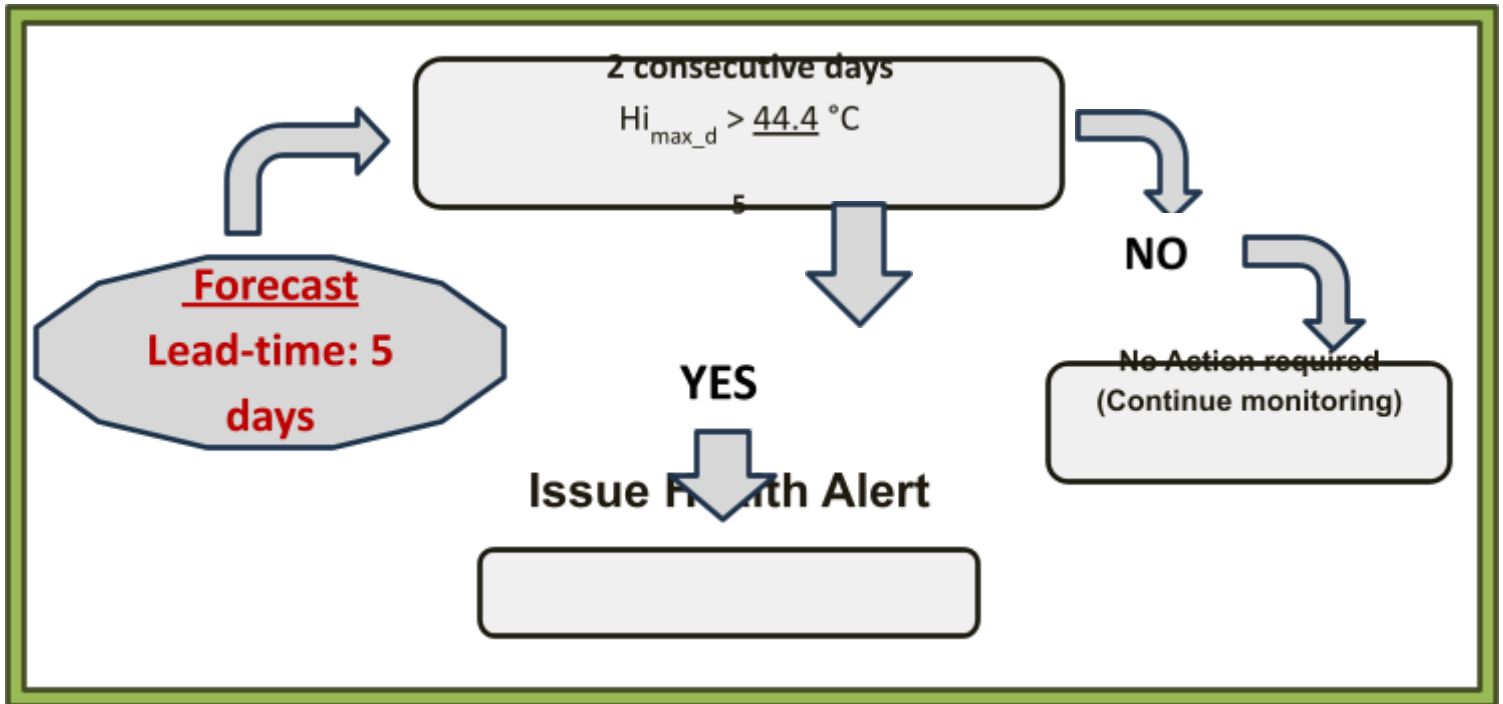
4. Threshold and trigger determination for the heatwave alert

The threshold for heat warning is based on an assessment of dangerous ambient heat stress conditions using historical hourly records of ambient near-surface temperature (Units: °C) and relative humidity (Units: %) spanning 01/01/1979 – 31/12/2023 at Biratnagar. The two variables are combined as hourly near-surface Heat Index (HI; Units: °C), an index of ambient heat stress conditions commonly used in operational heat alerts.

The detailed data source used in this report's development of the HI is in Annex 1. The rationale, choice, and development of the daily maximum HI (HI_{max_d}) threshold are elaborated on.

The proposed heat threshold criteria for Biratnagar are the result of a meticulous analysis. The analysis suggests a heatwave alert when the Heat Index (HI_{max}) reaches or exceeds 44.4°C for at least two consecutive days. The trigger for this alert would be the daily maximum heat index (HI_{max}) on a 5 or 7-day forecast lead time, ensuring a proactive approach to heatwave management.

Figure 9: Schematic of the threshold criteria



Source: Author's Illustration

5. Heat Hotspots

Heat hotspots map has been constructed incorporating three components – exposure, vulnerability, and adaptive capacity. Each component is associated with a set of indicators and is determined based on an analysis of those indicators. The details of the indicators for the respective components have been discussed in the annex (Annex, Table A-4).

The three parameters of population density, built-up area, and heat hotspot area have been used for exposure analysis. Based on this, the highly exposed wards of Biratnagar are 2, 3, 6, 7, 9, 10, and 15 (Annex, Figure A- 2). These wards are highly exposed to heat for specific reasons. For instance, Wards 9 and 7 experience heat exposure due to their high population density, leading to increased heat generation from human activities and buildings. Additionally, Wards 15 and 9, characterized by more built-up areas, experience elevated temperatures as these surfaces absorb and retain heat. Meanwhile, Wards 7 and 3 face heat exposure due to the high heat hotspot areas, likely resulting from a dense concentration of buildings and roads, which contributes to heat retention. Understanding these specific reasons is crucial for formulating targeted solutions.

For vulnerability analysis, thirteen different socio-economic, physical, and adaptive parameters have been used (Annex, Table A-4). When assessing vulnerability, it is crucial to identify areas subjected to extreme heat. This knowledge is essential for developing effective strategies to help communities cope with high temperatures. However, the most at-risk individuals may only sometimes be in the areas experiencing the

most intense heat. By identifying these hotspots, preventive measures can be implemented to safeguard vulnerable groups during heat waves. Local authorities, emergency responders, and meteorological departments can collaborate to determine appropriate actions in these areas.

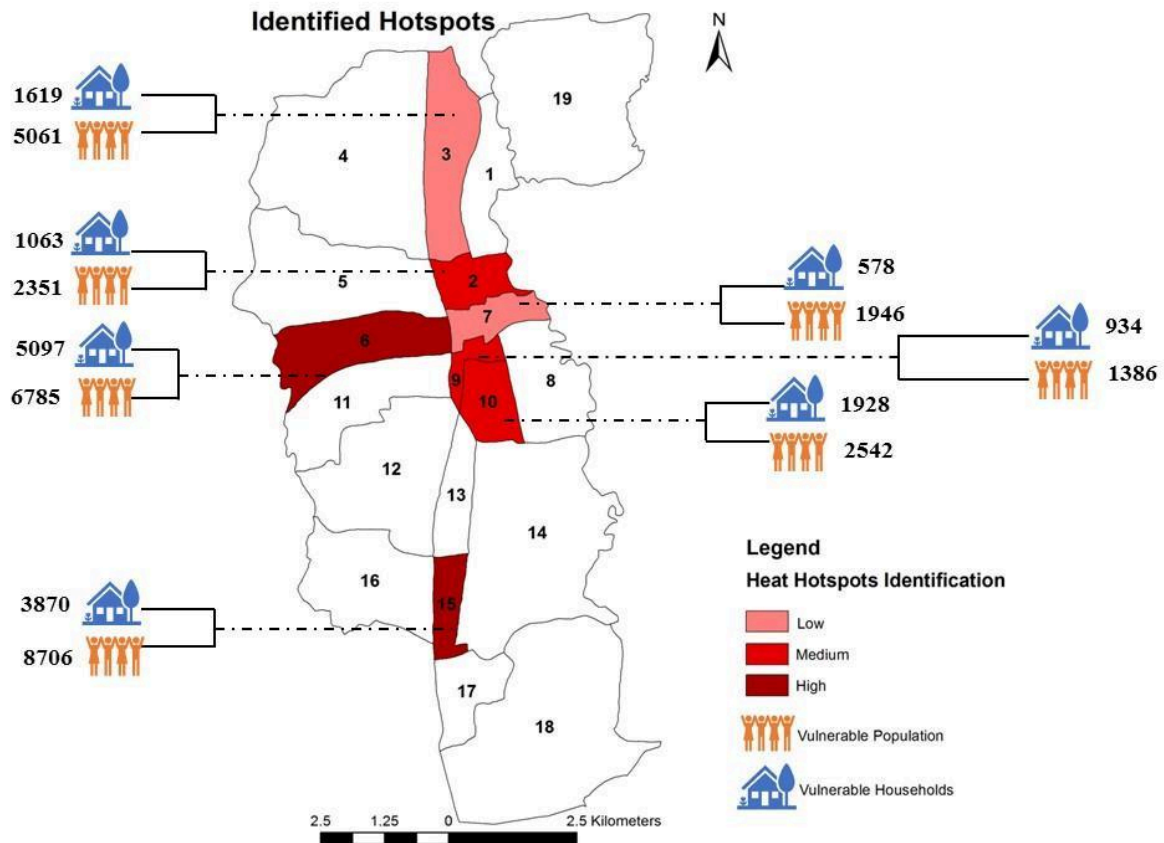
The vulnerability index score calculated based on thirteen different parameters, (shown in Table 6) has been used to rank these seven highly exposed wards, reflecting their level of vulnerability. Ward 15 and Ward 6 are the most vulnerable wards, followed by 2, 9, 10, 7, and 3 (Figure 10).

Table 6: Exposure and Vulnerability score

Ward	Exposure	Overall Vulnerability	Ranking
15	0.67	0.61	1
6	0.56	0.40	2
2	0.49	0.28	3
9	0.62	0.25	4
10	0.64	0.24	5
7	0.79	0.21	6
3	0.71	0.15	7

Source: Authors Illustration

Figure 10: Heat Hotspot and approximate number on vulnerable population and households



Source: Author’s Illustration based on data obtained from Biratnagar Sub-Metropolitan City¹

The Figure 10 above also shows the approximate number of the most vulnerable people and the number of vulnerable households in the identified heat hotspots wards.

The main reasons for the heat hotspots in these specific wards (especially wards 15 and 6) are:

- High population density.
- Extensive built-up areas.
- Busy highways with blacktopped road surfaces and heavy traffic.
- Socioeconomically vulnerable populations.
- Low ability to cope with heat.

Incorporating these findings into a heat action plan will enable BMC to prioritize resources and implement effective heat mitigation strategies in the most vulnerable and highly exposed wards, ensuring targeted and timely interventions to protect public health and safety during extreme heat events.

¹It is important to note that the vulnerable population and household figures indicate a broad overview of the degree of vulnerability. These figures might not be entirely accurate as some populations/ households may be counted more than once. For instance, a household with a hand pump for drinking water and a tin roof could be the same, leading to potential repetition in the data.

6. City Stakeholder Engagement

City stakeholder engagement is a crucial step in developing and implementing heat action plans. The local stakeholders provide diverse insights and expertise, contributing to a comprehensive understanding of the challenges posed by heat waves. Pre-identification of these stakeholders will also be useful in defining their roles and responsibilities clearly, which is important in the needed coordinated and efficient response to heat emergencies. The pre-identified stakeholders for Biratnagar are:

Table 7: Stakeholder List

S.N.	Name of Organization
1.	Department of Urban Development and Building Construction
2.	District Administration Office (DAO)
3.	Health Division, BMC
4.	Department of Health Service, Biratnagar
5.	Office of Hydrology and Meteorology (OHM), Dharan
6.	Department of Hydrology and Meteorology, Biratnagar
7.	Environment Department, BMC
8.	Disaster Department, BMC
9.	Ward Disaster Management Committee (WDMC)
10.	Water Supply Cooperation, Biratnagar
11.	Nepal Electricity Authority (NEA), Biratnagar
12.	Information and Communication Department, BMC
13.	Education Division, BMC
14.	Media
15.	Nepal Red Cross Society (NRCS), Morang District Chapter (DC)

Source: Author's Illustration

By recognizing and leveraging the importance of stakeholder engagement, cities can ensure the formulation of inclusive and highly effective heat action plans. These plans guarantee the protection of public health, build resilience, and promote sustainable urban development in the face of growing risks from heat. Similarly, during each phase of heat action activities, engaging various stakeholders is crucial.

Biratnagar Metropolitan City and NRCS Morang DC will collaborate in various heat-related activities with all concerned stakeholders, as outlined in Figure 11.

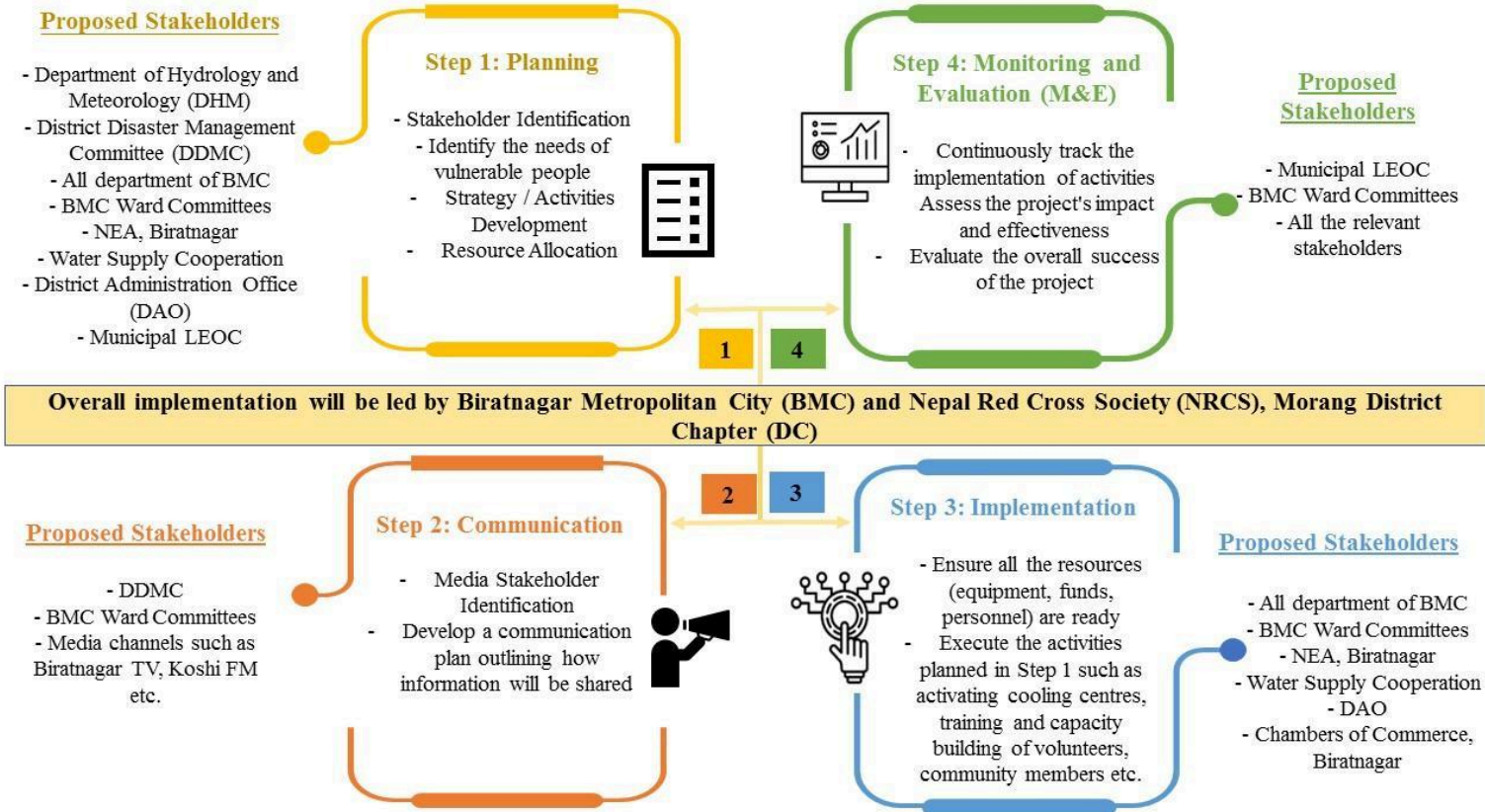


Figure 11: Stakeholder Coordination

Source: Authors Illustration based on Stakeholder Consultation

Stakeholders can use this coordinated strategy to develop and implement a strong heat action plan, to reduce the effects of extreme heat events on public health and strengthen the city's resilience. Continued coordination and proactive steps are required to achieve the common aim of implementing the Heat Action Plan in Biratnagar.

7. Heat Action Plan

7.1 Preparedness (Before a Heat Season)

One of the critical steps in HAP is the preparedness phase of the heat wave action plan. The preparedness phase involves several processes: planning, organizing, implementation, equipping, training, assessment, and enhancement. The goal is to prevent, respond to, and recover from extreme heat waves. The order of priorities for readiness measures in the upcoming heat season is determined through Key Informant Interviews (KII), Focus Group Discussions (FGD), and workshops with stakeholders (Table 8, 9, 10).

Table 8: Imminent priority actions for preparedness

Key activities	Target Areas/ Communities	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities
Identification of key stakeholders	City wide and all the residents of Biratnagar	Biratnagar Metropolitan City (BMC)	District Administration Office (DAO) Nepal Red Cross Society (NRCS), Morang District Chapter (DC) Meteorological Department (Office of Hydrology and Meteorology (OHM), Dharan) Ward Disaster Management Committee (WDMC) Disaster Department Water Supply Cooperation Nepal Electricity Authority (NEA), Biratnagar Department of Health Services Department of Forest Tole Lane Organizations (TLO) Social organization	BMC will lead the identification of key stakeholders by organizing meetings with the DAO, the NRCS, Morang DC and other secondary stakeholders. BMC will conduct meetings to gather detailed information about the roles and interests of potential stakeholders. NRCS, Morang, DC, will help identify and reach out to community-based organizations and volunteers. Coordination meetings will be organized regularly to involve and inform all relevant actors throughout the process.
Developing a heat early warning system	City wide and all the residents of Biratnagar	OHM, Dharan	BMC NRCS, Morang DC Media Health Department Other agencies	The OHM, Dharan will collect and analyze real-time weather data to predict heatwaves and then disseminate this information to BMC through a dedicated communication protocol. Using emails, SMS alerts, and official websites, BMC will pass on the warnings to NRCS, Morang DC, Media, and the Health Department. The Media will broadcast the heat

				warnings and safety tips through TV, radio, newspapers, and online portals, while NRCS, Morang DC and BMC will utilize social media. Here is a case study of the Early Action Protocol and the development of a heat early warning system in Bangladesh: https://bit.ly/3X915Kc
Identifying vulnerable populations and heat hotspots	City wide and all the residents of Biratnagar	BMC	Disaster Department of BMC NRCS, Morang DC WDMC	The Disaster Department of BMC will collaborate with WDMC and NRCS Morang DC to conduct community surveys and consultations and gather information on local vulnerabilities.
Raising awareness through distributing pamphlets; TV and radio broadcasts; and social media postings (Facebook, Twitter)	City wide and all the residents of Biratnagar	NRCS, Morang DC	Disaster Department of BMC NRCS, Morang DC WDMC OHM, Dharan Media Junior Youth Red Cross (JYRC) volunteers	NRCS, Morang, DC, will take the lead in raising awareness about heat-related issues. They will design/ print pamphlets that contain information and safety tips, which will be distributed to vulnerable communities. To ensure widespread coverage, NRCS, Morang DC and the Disaster Department, BMC will collaborate with local TV and radio stations to broadcast heat warnings and preventive measures. In addition, NRCS and Morang DC will regularly post updates and advisories on their social media platforms, such as Facebook and Twitter. The Disaster Department will support these efforts by coordinating the dissemination of information and ensuring that all materials reach the target populations effectively.
Training to Red Cross volunteers and individuals working with disaster response to effectively identify signs of heat-related illnesses	Red Cross Volunteers District Chapter Volunteers Subchapter volunteers Junior Youth Red Cross (JYRC) volunteers Individuals working with disaster response Rapid Response Team (RRT) youth volunteer TLO's volunteer Female Community Health Volunteer (FCHV)	NRCS, Morang District Chapter (DC)	Health Division, BMC Department of Health Services	The NRCS, Morang DC, will lead the training of Red Cross volunteers and individuals working with disaster response to identify signs of heat-related illnesses effectively. NRCS will organize training workshops and develop educational materials in collaboration with the Health Division and BMC. Experienced healthcare professionals will conduct the sessions, providing practical guidance on identifying and responding to heat-related health issues. The Health Division will contribute by sharing medical expertise and protocols and ensuring the training content is accurate and up-to-date. Case study of the Volunteers training in Phoenix, USA: https://bit.ly/4bIt08b

Installing water ATMs or community water points.	All the residents of Biratnagar (especially to pedestrians, outdoor workers, street vendors etc)	Water Supply Corporation	BMC WDMC Community organization Private Sectors	Before the upcoming heat season, BMC plans to install water ATMs. The BMC plans to install water ATMs or community water points before the upcoming heat season. The identified four locations for water ATMs are in Rani Bhansar, Jogbani- Ward 15, Bus Park- Ward 11, Hospital Chowk- Ward 7, and Haat Khola- Ward 7 (Annex, Figure A-7). Representatives from each Ward will work together with BMC and Drinking Water Cooperation to implement the water ATMs. The ward members will be responsible for monitoring and managing these water ATMs/ water points.
Implementing water mist systems as a permanent feature in public spaces, such as parks, bus stops or market area	All the residents of Biratnagar (especially to pedestrians, outdoor workers, street vendors etc.)	BMC	NRCS, Morang DC LEOC WDMC Private Sectors	Implementing water mist systems as a permanent feature provides relief during periods of extreme heat and also help support long-term climate adaptation efforts. Misting systems work by producing a tiny mist of water droplets that evaporate fast, providing a cooling effect. They are extremely effective in lowering ambient temperatures and providing comfort in hot areas. This can be done in collaboration with BMC and other private organizations. The strategic locations for water mist include are Bus stand – Ward 8, Roadcess Chowk- Ward 12, Rani Bhansar, Jogbani Ward 15 etc.
Planning for changing school schedules in the morning during / Scheduling examinations before the start of the heat period	School/ college students	Education Development and Coordination Unit, BMC	School Management Committee Individuals' schools/ colleges Private & Boarding Schools' Organization Nepal (PABSON) and Non- Private & Boarding Schools' Organization Nepal (NPABSON)	The Education Development and Coordination Unit of BMC will lead the planning to change school schedules to morning hours and schedule examinations before the start of the heat period. They will coordinate with the School Management Committees and individual schools/colleges to adjust academic calendars and daily timetables. Meetings will be held with school administrators to discuss and implement these changes effectively. The Education Development and Coordination Unit will also inform parents and students about the new schedules through official notifications.
Adding extra beds, arranging fans and coolers in hospitals	All hospitals and clinics of Biratnagar	Department of Health Services	Health Division, BMC Koshi Hospitals NRCS, Morang DC Private Sectors	The Health Service Department of Biratnagar will collaborate with the Health Division, BMC, and NRCS to evaluate the availability of hospital beds for the expected influx of patients during the heatwave. Before the heat season, all hospitals and clinics in Biratnagar must check whether their equipment, such as refrigerators, freezers, fans, and air conditioning units, are functioning correctly. If they are not, the respective hospitals can repair or replace the equipment. In hospitals with high patient volumes, such as Koshi Hospital, temporarily increasing bed capacity may

				be possible. Additionally, fans and coolers will be installed in the waiting areas of hospitals and clinics to improve comfort.
Capacity building programs for healthcare professionals	Medical staff at Koshi Hospital Biratnagar Nursing Hospital and other private clinics Nursing staff, paramedics, field staff, family physicians, paramedics, volunteers of NRCS, Morang DC and future healthcare and public health professionals. Female Community Health Volunteer (FCHV)	Department of Health Services	Health Division, BMC NRCS, Morang DC	<p>The training objectives may include:</p> <ul style="list-style-type: none"> • Increasing awareness of heat-related illnesses. • Identifying at-risk individuals. • Understanding treatment options for heatstroke and other heat-related diseases. • Implementing appropriate first aid procedures. <p>In addition, the training may also highlight the potential side effects of certain medications and specific considerations for patients more vulnerable to heat. Individuals with diabetes, for example, are advised to drink a lot of water to prevent dehydration and to regularly monitor their glucose levels during the peak heat season when there is high temperature and humidity. Similarly, older adults and their caregivers are encouraged to stay cool using lukewarm water and fans instead of cold water.</p> <p>Case study of the capacity building programs to health care professionals, Ahmedabad, India: https://bit.ly/3x70GNE</p>

Table 9: High priority actions for preparedness

Key activities	Target Areas	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities
Dedicated heat task teams within the municipality	Ward	BMC	Health organization NRCS, Morang DC Ward Committee Department of Hydrology and Meteorology (DHM) Disaster department Water Supply Cooperation NEA, Biratnagar	BMC has already established dedicated heat task teams within the municipality to enhance heatwave preparedness and response. These teams comprise representatives from health organizations, the NRCS, DC, Ward Committees, DHM, NEA, Biratnagar, Water Supply Corporation, Education Department, Disaster Department, etc. BMC will lead the formation and coordination of these teams, ensuring clear roles and responsibilities.

<p>Developing a ward/ municipal level plan for heat response/action activities</p>	<p>Nepal Red Cross Society (NRCS), Morang District Chapter (DC) Ward Committees Government organizations Department of Health Services Drinking Water Supply Cooperation Nepal Electricity Authority (NEA) Biratnagar</p>	<p>BMC</p>	<p>NRCS, Morang DC Local Disaster Management Committee (LDMC) WDMC</p>	<p>BMC will collaborate with NRCS, Morang DC and LDMC to create a heat action plan for the upcoming heatwave. The plan should be completed by Nepali month Chaitra (mid-March) This plan will outline the actions to be taken after a heat alert, such as raising public awareness, providing drinking water/ electrolytes etc. NRCS, Morang DC, and ward committees will work with specific groups to prepare for and implement the planned activities during the upcoming heat season. Case study of Heat Action Plan, Nepalgunj: https://bit.ly/4ejXj6W</p>
<p>Workshops for teachers regarding heat protection tips and materials that they can disseminate in classrooms</p>	<p>All schoolteachers</p>	<p>Education Department, BMC</p>	<p>School Management Committee NRCS, Morang DC</p>	<p>The Education Department of BMC will organize workshops for school and college teachers. These workshops will focus on heat protection tips and educational materials that can be used in classrooms. Collaborating with the School Management Committees and the NRCS, Morang DC, the Education Department will develop training content and educational materials centred around heat safety. NRCS, Morang DC will/can share their expertise in disaster preparedness and distribute additional resources. The workshops will cover important information on staying hydrated and cool during a heatwave and how to seek help if experiencing any adverse effects on health. Teachers will also learn about the warning signs of heat stress and basic first aid techniques.</p>
<p>Installing LED screens with rolling temperature and humidity</p>	<p>All the residents of Biratnagar (especially to pedestrians, outdoor workers, street vendors etc)</p>	<p>BMC</p>	<p>NRCS, Morang DC DHM NEA DAO Private offices Banks District and local level humanitarian agencies Federation of Nepalese</p>	<p>BMC, in coordination with NRCS, Morang DC, will lead the initiative to install LED screens displaying rolling temperature and humidity updates for all residents, especially pedestrians, outdoor workers, and street vendors. BMC will collaborate with the DHM to provide accurate and timely weather data. Partnerships with private offices and banks can be established to identify and utilize strategic locations for the screens, ensuring maximum visibility and impact. The identified strategic locations for LED installation are Jogbani Ward 15, Roadcess Chowk- Ward 12, Traffic Chowk- Ward 11 and Haat khola-Ward 7 (see Annex, Figure A-8).</p>

			Chambers of Commerce and Industry (FNCCI)	Beside this, the strategic locations for LED are BMC office, Kanchanbari, etc.
Updating existing databases regularly, including hospital admissions and emergency case records, to track heat-related cases	Koshi Hospital Biratnagar Nursing Hospital and other private clinics	Department of Health Services, Morang	BMC Koshi Hospitals	All hospitals and clinics in Biratnagar city must maintain records of admissions and emergency cases for heat-related illnesses. The Department of Health Services in Morang has the authority to mandate that all healthcare facilities implement a proper database system for documenting all instances related to heat-related illnesses. The Health Division department of BMC, in collaboration with NRCS and Morang DC, will regularly monitor hospitals and clinics to ensure that all heat-related illness data is accurately recorded.
Providing financial assistance and incentives for low-income households to access cooling solutions such as hand or electric fans/ solar energy	All the residents of Biratnagar (especially vulnerable communities and groups of Wards 15, 6, 2, 9,10,7, 3 and 19)	WDMC	NRCS, Morang DC Local organizations District and local level humanitarian agencies	BMC can lead the initiative to provide financial assistance and incentives for low-income households to access cooling solutions such as hand or electric fans and solar energy, targeting especially vulnerable communities and groups in Ward 2, 3, 6, 7, 9, 10, 15, and 19 other high-risk areas. Ward Committees will help identify eligible households and facilitate the distribution of funds and resources. The NRCS, Morang DC, and local organizations will support these efforts by assisting with outreach and ensuring the effective delivery of cooling solutions.
Changing workers schedules and shifts	Vulnerable groups who work outside during extreme heat	Chambers of Commerce, Biratnagar	BMC Factory owners	The Biratnagar Chamber of Commerce will work with managers from industrial and construction companies, as well as BMC, to plan for changes in the work schedules of external workers.

Table 10: Moderate priority actions for preparedness

Key activities	Target Areas	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities
Review water and electricity plans and policies	-	BMC	Water Cooperation Supply NEA, Biratnagar	Water Supply Corporation and NEA, Biratnagar, will lead a review of water and electricity plans and policies, respectively, to ensure they are robust and effective in extreme heat events. This initiative will involve close collaboration with the BMC. The BMC will assist in identifying existing practices and informing current and future policy initiatives. The Water Supply Corporation will focus on maintaining a constant potable water supply. NEA will design strategies for uninterrupted power supply

				by regulating load shedding based on backup power availability in critical infrastructure such as hospitals and cooling centres and will manage this in collaboration with the BMC.
Updating climate, disaster and heat action plans and policies	-	BMC	Environment and Disaster Department NRCS, Morang DC	The BMC's Disaster Department will lead the updating of climate, disaster, and heat action plans, along with other associated policies, to strengthen preparedness for extreme heat events. This initiative will involve collaboration with the Environment Department and the NRCS, Morang DC, and other governmental stakeholders. The Environment and Disaster Department will provide expertise on environmental impacts and disaster response strategies, while NRCS, Morang DC, will contribute insights on community-based approaches and emergency preparedness.
Establishing cooling centers	Pedestrians, outdoor workers, street vendors, etc	BMC	NRCS, Morang DC Water Cooperation Supply Nepal Electricity Authority (NEA) Health Department	During the heating season, BMC, NRCS, Morang District DC, Water Supply Corporation, NEA, and Health Department will coordinate and collaborate to establish cooling centres to provide relief for pedestrians, outdoor workers, street vendors, and other vulnerable groups. In the peak months of the summer season (April-June), the timings will be 11 in the morning to 4 in the afternoon. BMC will initiate the process by identifying the appropriate locations and facilitating the establishment of these centres. The Water Supply Corporation and NEA will ensure the availability of water and electricity at these centres. The Health Department will provide medical support and guidance on heat-related health issues. The identified strategic locations for cooling centres are Bus stop – Ward 8, Roadcess Chowk- Ward 12, Rani Bhansar, Jogbani Ward 15 (Annex, Figure A-9). Case study from Hanoi, Vietnam: https://bit.ly/4c5HSNB
Identification of community cooling centers in public buildings and offices for establishing the short-term cooling center targeted for heat seasons	Pedestrians, outdoor workers, street vendors, etc	BMC	NRCS, Morang DC Health Department Ward Disaster Management Committee Private sectors Chambers of Commerce, Biratnagar	BMC can take the lead in requesting public buildings like governmental and private offices and city malls, such as Bhatbhateni, to share some cooling spaces with outdoor workers and pedestrians during extreme heat.

Increasing roof reflectivity	Household with tin roofs (especially in wards 6, 14, 15, 18, and 19)	BMC	Department of Urban Development and Building Construction NRCS, Morang DC District and local level humanitarian agencies Private sectors	BMC, in coordination with the Department of Urban Development and Building Construction, will raise awareness among residents about cool roof reflectivity. The BMC can also aim to paint 50 households with heat-reflective and UV-resistant coating, specifically those with tin roof houses. When selecting households, vulnerable communities with tin roofs in Wards 6, 14, 15, 18, and 19 can be considered. BMC, in collaboration with the Department of Urban Development and Building Construction, NRCS, and Morang DC, can work on the cool roof initiative programs. Case Study of white roof initiative from Ahmedabad: https://bit.ly/4c5DPAP
CGI roof replacement of schools/colleges	All students and teachers	Education Division, BMC	Education Development and Coordination Unit, Morang District and local level humanitarian agencies Private sectors	The Education Division of Biratnagar can take the initiative to replace Corrugated Galvanised Iron (CGI) roofs in schools and colleges. The Education Division, in collaboration with District, local, and private sector humanitarian agencies, can also increase the roof reflectivity with heat-reflective and UV-resistant coatings. These options will help the learning environment of classrooms and protect students from extreme heat.
Capacity building for occupationally exposed groups and their supervisors	Traffic police Outdoor workers Street vendors Auto drivers/ rishshwa pullers etc	NRCS, Morang DC	BMC Chambers of Commerce, Biratnagar	The NRCS, Morang DC, in collaboration with BMC and the Chamber of Commerce, will organize capacity-building initiatives for various occupational groups and their supervisors. These include traffic police and workers working in the open, street vendors, auto drivers and rickshaw pullers. Workshops and training will focus on recognising heat impacts and the strategies they can deploy for heat-related prevention and emergency response. The workshop will aim to share the best plan for keeping cool in the heat and getting the proper interventions to avoid health concerns. The workshop will also help them identify signs and symptoms of heat stress, heat stroke, and basic first aid. Participants will also receive training on recognizing the warning signs of heat stress and heatstroke, along with basic first aid techniques. Case study from Abu Dhabi: https://bit.ly/3x70GNF
Stockpile emergency supplies such as bottled water,	Koshi Hospital Biratnagar Nursing Hospital and other private	Department of Health Services, Morang	Health Department, BMC	The Department of Health Services, Morang, in collaboration with Health Department of BMC, Koshi Hospital, Biratnagar Nursing Hospital, and other private clinics, and the NRCS, Morang DC, can stockpile

electrolyte drinks, first aid kits, and cooling supplies (e.g., fans, misters)	clinics NRCS, Morang DC			emergency supplies to prepare for heatwave events. These supplies will include bottled water, electrolyte drinks, first aid kits, and cooling supplies such as fans.
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7.2 Response (During a Heat Season)

The heat season is a period when heatwaves are common throughout the region. Both individuals and city authorities should take measures to control heat. For instance, efforts at the city level require multiple stakeholders to carry out various tasks to reduce the impacts of heat. Therefore, it is essential to disseminate the results to health and social care professionals and the vulnerable community. This information should include how people can protect themselves from heat-related illnesses, detect symptoms, and where individuals can find services such as cooling centres and water distribution points. The following response activities have been identified from the stakeholder workshops, KII and FGD, highlighting the priority areas for response activities during the upcoming heat season (Tables 11, 12, and 13).

Table 11: Imminent priority actions for response

Key activities	Target Areas/ Communities	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities?
Providing alert messages to the residents	All the residents of Biratnagar	BMC	DAO NRCS, Morang DC Media DHM Private Organizations District and local level humanitarian agencies TLOs	BMC, in collaboration with the DAO, the NRCS, Morang DC, local media outlets, the DHM, and private organizations, will provide alert messages to all residents of Biratnagar. These messages will warn residents about impending heatwaves and guide them on necessary precautions and actions. Media partners will play a crucial role in broadcasting alerts through television (name), radio, newspapers, and online platforms to reach out to vulnerable groups and ensure effective communication channels are utilized to prompt necessary action.
Activating heatwave response plans to citywide	All the residents of Biratnagar	BMC	DAO NRCS, Morang DC Media DHM NEA TLOs	The BMC, in coordination with the NRCS and Morang DC, will implement all heat response plans, including opening cooling centres and increasing access to drinking water.
Raising awareness through mobile public address systems; distributing pamphlets; TV and radio broadcasts; and social media postings	All the residents of Biratnagar	BMC	Ward Committee Disaster department, NRCS, Morang DC Private Organizations TLOs Social Organizations	NRCS, Morang, DC, will take the lead in raising awareness about heat-related issues. The necessary materials for awareness campaigns, including banners and posters, have already been prepared and can be found at this link: https://preparecenter.org/toolkit/heat/heat-action-posters/ . These materials will be distributed in strategic locations, such as in front of schools, the municipal office, Koshi Hospital, the bus park, and the airport. To ensure widespread coverage, NRCS, Morang DC, and the Disaster Department, BMC will collaborate with local TV and radio stations to broadcast heat warnings and preventive measures. The media can also share the prepared heat awareness videos, which can be accessed at this link: https://vimeo.com/showcase/9459591 . Additionally, NRCS Morang DC will regularly post updates and advisories on their social media platforms, such as Facebook and Twitter. The Disaster Department will support these efforts by coordinating the dissemination of information and ensuring that all materials reach the target populations effectively.

Distributing heat relief supplies such as water, electrolyte beverages, and cooling towels to affected communities	Vulnerable communities and groups of Wards 15, 6, 2, 9,10,7, 19 and 3.	Health Division, BMC	Drinking water cooperation NRCS, Morang DC WDMC District and local level humanitarian agencies Private Sectors	The Health Division of BMC, in collaboration with the Drinking Water Cooperation, NRCS, Morang DC, and Ward Committees, can distribute heat relief supplies such as water, electrolyte beverages, and cooling towels to vulnerable communities in wards such as 15, 6, 2, and 7 (Annex, Figure A-10). BMC can coordinate efforts, ensuring supplies are procured and distributed efficiently to affected areas. The Drinking Water Cooperation can contribute by providing clean drinking water for distribution. NRCS, Morang DC will assist in mobilizing volunteers and facilitate the distribution process within their respective areas, ensuring that supplies are allocated equitably in coordination with ward committee members.
Ringing the bell for drinking water breaks for students	Schools and colleges	Education Division, BMC	School Management Committee NRCS, Morang DC BMC Drinking Water Supply Corporation	<p>The Education Department, working alongside School Management Committees, the NRCS, and Morang DC, can implement a bell-ringing system for drinking water breaks in schools and colleges. This initiative will aim to keep students hydrated and mitigate heat-related health issues. The schools/ colleges can give two short breaks by clicking the school bell two times a day, one at 11:30 a.m. and another at 2:30 p.m. That will be a good reminder for students to drink some water.</p> <p>The Education Department can establish and enforce guidelines for these breaks, while individual schools/colleges will ensure the bell system's proper operation in collaboration with their staff. Additionally, the NRCS Morang DC can contribute by raising awareness among students about the importance of hydration during school hours.</p> <p>Case study from Kerala, India regarding water breaks for students: https://bit.ly/4583KFZ</p>
Deploying medical units such as Rapid Response Team (RRT) to provide on-site medical care and assistance to those affected by heat-related illnesses	Vulnerable communities and groups	Department of Health Services	Health Division, BMC Hospitals Youth club NRCS, Morang DC District and local level humanitarian agencies DAO District Police, BMC	The Department of Health Services, in coordination with the Health Division of BMC and the NRCS, Morang DC, will deploy Rapid Response Teams (RRT) medical units to offer on-site medical care and aid to vulnerable communities and groups affected in Wards 15, 6, 2, 9,10,7, and 3 by heat-related illnesses. The Department of Health Services will lead the deployment of RRTs and ensure they are equipped with essential medical supplies and well-trained personnel. The Health Division of BMC will collaborate with local hospitals and youth clubs to identify and prioritize areas requiring medical assistance.

To activate cooling centers	Pedestrians, outdoor workers, street vendors, etc	BMC	NRCS, Morang DC Water Cooperation Supply Nepal Electricity Authority (NEA) Health Department	BMC will activate the cooling centres after initiating the heat response plan in collaboration with the NRCS, Morang DC. NRCS volunteers, with support from BMC, will monitor and manage the cooling centres. The Nepal Electricity Authority, Biratnagar, will regulate and assure the availability of electricity. Likewise, the Water Supply Corporation, Biratnagar, will ensure the availability of drinking water in the cooling centres. Case study from Hanoi, Vietnam: https://bit.ly/4c5HSNB
Increasing staffing at hospitals to attend to the influx of patients during a heat season	Koshi Hospital Biratnagar Nursing Hospital and other private clinics	Department of Health Services	BMC	To address the increase in patients during a heat season, Koshi Hospital, Biratnagar Nursing Hospital, and other private clinics can increase their staffing levels. The Department of Health Services, in collaboration with BMC, can oversee this initiative. Koshi Hospital, BMC can provide support and coordination to implement increased staffing measures effectively across healthcare facilities.
Offer free medical services, including antipyretics (such as paracetamol), coolants (such as cooling pads, ice packs) and electrolytes	Vulnerable communities and groups	BMC	Health Division NRCS, Morang DC WDMC	BMC, in collaboration with the Health Division, NRCS, Morang DC, and other relevant stakeholders, can offer free medical services. This initiative can include the provision of essential medications such as paracetamol and electrolytes. NRCS, Morang DC, and other partners such as WDMC can assist in mobilizing resources and community outreach efforts.
Establishing protocols for emergency communication and coordination between government agencies, healthcare facilities, and community partners	-	BMC	DAO Health Department DHM Media NRCS, Morang DC	BMC will establish protocols for emergency communication and coordination among government agencies, healthcare facilities, and community partners. This initiative will require collaboration with the DAO, Health Department, DHM, media outlets, and the NRCS, Morang, DC. BMC will facilitate the development of communication channels and protocols to ensure that information is disseminated promptly and effectively during emergencies.
Installing water pots for animals	Street animals	Agriculture and Livestock department	BMC Residents of Biratnagar WDMC Social Organizations	The Agriculture and Livestock Department of BMC, in coordination with private organizations such as Sahara Animal Care and residents of Biratnagar, will install water pots for street animals to ensure their hydration and well-being. This initiative aims to provide water to street animals, especially dogs, during periods of

				<p>extreme heat. The Agriculture and Livestock Department will oversee the placement and maintenance of the water pots, ensuring they are easily accessible and filled with clean water. BMC will support and coordinate with local communities to find suitable locations for installation. The Agriculture and Livestock Department can also raise awareness among city residents and request them to keep water pots on their roofs or terraces for birds during the peak heat season. Residents of Biratnagar will play a vital role in monitoring the water pots and refilling them as needed, fostering a sense of community responsibility towards animal welfare.</p>
<p>Providing awareness about how to store food properly during heat waves</p>	<p>All the residents of Biratnagar (especially the vulnerable communities)</p>	<p>Health Division, BMC</p>	<p>NRCS, Morang DC Local media outlets WDMC and TLO</p>	<p>The Health Division of BMC, in collaboration with NRCS, Morang DC, local media outlets, WDMC and TLO can conduct awareness campaigns to disseminate information on proper food storage techniques during heat waves. Special focus will be given to reaching out to vulnerable communities through targeted outreach programs and local TLOs. It is also important to educate about the signs of food spoilage, such as unusual odors and textures. For the vulnerable population, many may not have access to refrigerators. In this context, they can store their food in a container and wrap the container with a wet cotton cloth. This method helps keep the food cool.</p>
<p>Conducting post-event assessments to evaluate the effectiveness of heatwave response efforts and identify areas for improvement.</p>		<p>BMC</p>	<p>NRCS, Morang DC</p>	<p>Within one month after the end of the heating season, BMC and the NRCS, Morang DC, will collaborate to conduct post-event assessments. These assessments aim to assess the effectiveness of heat action activities, especially the response efforts, and identify areas that need improvement. This initiative will thoroughly evaluate various aspects of the response, including communication, coordination, resource allocation, and community outreach. BMC will start the evaluation process by discussing four primary questions for the after-action review:</p> <ul style="list-style-type: none"> i) What was in the plan? ii) What happened? iii) What worked well, what did not work well, and why? iv) What could be improved and how? <p>Based on the assessment findings, recommendations will be provided to strengthen future heatwave preparedness and response strategies.</p>

Table 12: High priority actions for response

Key activities	Target Areas	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities
Operating a telephone helpline for elderly people	Elderly people	BMC	Nepal Telecom Ncell and other media Volunteers, NRCS, Morang DC	Volunteers from NRCS Morang DC can operate a telephone helpline for older adults. The BMC will provide a list of elderly individuals and their contact numbers. NRCS Morang DC can oversee the overall monitoring of the situation. This initiative aims to assess the health of elderly individuals and provide advice to help them cope with high temperatures. This program can be conducted every year from April to June. Case study from Spanish Red Cross Society: https://bit.ly/3Rc7wIB
Awareness through LED boards by sharing temperature and awareness messages	All the residents of Biratnagar (especially to pedestrians, outdoor workers, street vendors etc)	BMC	DHM NEA NRCS, Morang DC Private Sectors	BMC, in coordination with NRCS, Morang DC, will lead the initiative to activate LED screens and display rolling temperature and humidity updates for all residents. BMC will collaborate with the DHM to provide accurate and timely weather data.
Door-to-door outreach in high-risk neighborhoods to distribute heat relief supplies	Vulnerable communities such as Wards 15, 6, 2, 9,10,7, 19, and 3.	Volunteers, NRCS, Morang DC	BMC Health Department	Volunteers from the NRCS, Morang DC, will conduct door-to-door outreach in high-risk neighbourhoods, such as specific wards 15, 6, 2, 9,10,7, 19 and 3 to distribute heat relief supplies. These supplies will include water, electrolyte beverages, and cooling towels, among other essentials. Case study from Netherlands Red Cross Society: https://bit.ly/3Rc7wIB
Collaborations with community organizations or shopping malls like Bhatbhateni to offer temporary cooling shelter to outdoor workers	Pedestrians, outdoor workers, street vendors, etc	Chamber of Commerce, Biratnagar and Industry	Shopping Malls NRCS, Morang DC Community organizations	The Chamber of Commerce, Biratnagar and Industry, in collaboration with shopping malls such as Bhatbhateni and various community organizations, can offer temporary cooling shelters for pedestrians, outdoor workers, street vendors, and other vulnerable groups. Shopping malls can provide designated areas within their premises as cooling shelters, offering relief from the heat during peak hours. If needed, NRCS, Morang DC, can mobilize volunteers to assist in managing the shelters and providing support to those in need.
Continuously monitoring the activities listed under the plan	-	BMC	NRCS, Morang DC	BMC will continuously monitor the activities listed under the heat response plan in collaboration with the NRCS and Morang DC. BMC will establish a dedicated task force to oversee the implementation and progress of each activity, ensuring that all measures are executed effectively and on schedule. NRCS, Morang DC, will

support this effort by providing regular updates and gathering feedback from the community.

Table 13: Moderate priority actions for response

Key activities	Target Areas	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities?
Making sure water and electricity supplies are available to hospitals and other critical facilities during heat events	-	Department of Health Services	Drinking water cooperation NEA NRCS, Morang DC	The Department of Health Services, in collaboration with the Drinking Water Corporation, NEA, and the NRCS, Morang DC, will work together to ensure uninterrupted water and electricity supplies to hospitals and other critical facilities during heat events. The Department of Health Services will oversee this initiative and ensure that contingency plans are in place to sustain essential services. The Drinking Water Corporation will manage the supply and distribution of water to these facilities, while the NEA will ensure a stable and uninterrupted electricity supply.
Enforcing regulations to protect outdoor workers from excessive heat exposure	Outdoor workers	DAO	BMC Trade union Private Sectors	In collaboration with BMC and the Chamber of Commerce, the DAO will enforce regulations to protect outdoor workers from excessive heat exposure. The Chamber of Commerce will develop and implement guidelines that set maximum allowable working hours during peak heat periods, mandate regular breaks, and provide outdoor workers access to shade and hydration. BMC will support enforcing these regulations by conducting regular inspections and ensuring compliance among employers.
To distribute drinking water from tankers to the common people	Vulnerable wards such 14, 15, 16, 17 and 18.	WDMC BMC	Drinking water supply cooperation	Drinking water supply cooperation can distribute clean drinking water through tankers to communities that depend on hand pumps, such as Wards 14, 15, 16, 17, and 18, as hand pumps tend to dry up in the summer season. This can be done in collaboration with Ward Committees and BMC. Case Study Red Crescent Society of Tajikistan, activating drinking water based on a forecast: https://bit.ly/3Rc7wIB
To organize kiosks in high traffic areas for awareness	High-traffic areas such as Pushpalal Chow, Roadaccess, Jaljala Road, and Jogbani Border, Kanchanbari chowk, Bargachi chowk, etc	NRCS, Morang DC	BMC Drinking water cooperation JYRC volunteers	NRCS and Morang DC, together with BMC, will organize kiosks in high-traffic areas such as Pushpalal Chow, Roadaccess, Jaljala Road, and Jogbani Border, where there is a high inflow of people, especially outdoor workers, street vendors, and auto drivers. NRCS Morang DC with the help from JYRC volunteers will distribute drinking water, electrolytes, and critical heat awareness messages through the kiosk.

<p>Keeping the data of each patient coming to healthcare facility, suffering from heat illness and producing weekly reports of the public health impact</p>	<p>Koshi Hospital Biratnagar Nursing Hospital and other private clinics</p>	<p>Department of Health Services</p>	<p>BMC</p>	<p>The Department of Health Services and BMC can request all the hospitals in Biratnagar to keep data on each patient coming for healthcare with heat-related symptoms. This will help to understand the actual cases of heat-related symptoms people are experiencing and plan adaptive measures accordingly.</p>
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7.3 Long term measures

Biratnagar is currently seeing rapid urbanization, which has increased the frequency and severity of heatwaves. To address these challenges effectively, it is crucial to implement comprehensive HAPs that focus on long-term measures. These measures are not limited to immediate responses or preparedness for heatwave events alone; they aim to build resilience and mitigate the long-term impacts of rising temperatures on public health, infrastructure, and the environment. These long-term measures are also based on the stakeholder workshop, KII, and FGD (Tables 14 and 15).

Table 14: Imminent priority actions for long term measures

Key activities	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities?
Roadside plantation, plantation in park, maintenance of green areas	Environment Department, BMC	Department of Forest Department of Urban Development and Building Construction Department of Road Other non-governmental organizations Ward Committees and TLO	The Environment Department of BMC will lead the maintenance of roadside plantations and park plantations and the maintenance of green areas. The identified strategic locations for tree plantation are in Ward 7 of Jaljala Chowk and Airport Chowk, Milan Chowk area of Ward 19, Dharam Chowk- Ward 3, and the main highways of Biratnagar. This initiative will be implemented with the Department of Forest, the Department of Urban Development and Building Construction, the Department of Roads, and several non-governmental organizations (NGOs). The Environment Department of BMC will coordinate the planning and execution of these activities. They will ensure the selection of suitable plant species and the maintenance of tree species.
School Plantation	Environment Department, BMC	Education Department, BMC Academic Institutions	The Environment Department of BMC, in collaboration with the Education Department of BMC and various academic institutes, will initiate a school plantation program. The Education Department will coordinate with schools to integrate these activities into the academic calendar and ensure active participation from students and staff. This initiative aims to enhance green spaces within school premises.
Promoting sustainable transportation options, such as cycling lanes, pedestrian-friendly streets, car free zones	Environment Department, BMC	Department of Urban Development and Building Construction NEA Physical Infrastructure and Transport Department DAO Private Sector BMC	The Environment Department of BMC will promote sustainable transportation options, including developing cycling lanes, pedestrian-friendly streets, and car-free zones in collaboration with the Department of Urban Development and Building Construction, NEA, DAO, the private sector, and various BMC departments. The Environment Department will plan and implement these sustainable transportation projects, ensuring they are integrated into the city's urban development plans. NEA can also ensure that lighting and electric vehicle charging stations are included in the plans. The private sector will be encouraged to participate by promoting and investing in sustainable transportation initiatives.
Establishing partnerships with educational institutions to incorporate heatwave preparedness into school curricula.	Education Department, BMC	Educational Institutes (all school/ colleges)	The Education Department of BMC will establish partnerships with educational institutions to incorporate heatwave preparedness into school curricula. The Education Department will develop comprehensive heatwave preparedness programs and integrate them into the existing curriculum of all schools and colleges. This initiative aims to educate students on the risks of heatwaves, preventive measures, and emergency response protocols.
Promote green roofing	Department of Urban Development and Building Construction	BMC NRCS, Morang DC Other Agencies	The Department of Urban Development and Building Construction, in collaboration with BMC and the NRCS, Morang DC, can promote the adoption of green roofing. The Department can take the lead in promoting green roofing projects by establishing clear guidelines. BMC can

			contribute to this initiative by providing financial incentives and raising awareness through campaigns that emphasize the advantages of green roofing, such as energy efficiency and better urban air quality.
Establishment of heat ward in government hospitals	Health Division, BMC	Koshi Hospitals Private Hospitals	The Health Division of BMC, in collaboration with Koshi Hospitals, will establish dedicated heat wards in government hospitals. These wards will be dedicated to treating heat-related symptoms. The Health Division of BMC will strategically plan and carry out the provision of essential supplies, including medical equipment, cooling systems, and skilled personnel, to effectively address heat-related illnesses. This initiative aims to enhance government hospitals' ability to accommodate the increasing influx of patients during heatwaves, guaranteeing timely and efficient medical attention. Case study of dedicated heat ward for heat stroke in Ahmedabad, India: https://bit.ly/3Vwo0xW
Cool Permeable/Pavements	Department of Road	Department of Urban Development and Building Construction	The Department of Road, in collaboration with the Department of Urban Development and Building Construction, can promote and implement the installation of cool permeable pavements in Biratnagar. The Department of Urban Development and Building Construction can incorporate permeable pavement projects into more comprehensive urban planning efforts, strategically placing them in areas with high traffic and heat vulnerability. This initiative is designed to improve urban infrastructure by creating cooler and more environmentally friendly streetscapes. This can be done in hospitals, schools, governmental offices, and footpaths.
Enforce the use of long-sleeve construction clothing and helmets	BMC	Chambers of Commerce, Biratnagar	BMC, in collaboration with the Commerce of Chambers, can enforce regulations requiring long-sleeve construction clothing and helmets for all construction workers. Chambers of Commerce will develop and implement guidelines mandating these safety measures to protect workers from excessive heat exposure and potential injuries.
Mainstreaming heat risk into disaster planning	Disaster Department, BMC	Department of Urban Development and Building Construction Environment Department, BMC NRCS, Morang DC	The Disaster Department, BMC will lead the effort to mainstream heat risk into disaster planning. This can be done in collaboration with the Department of Urban Development and Building Construction, the Environment Department of BMC, and the NRCS, Morang DC. The Disaster Department will integrate heat risk assessments and mitigation strategies into existing disaster management plans, ensuring that heatwaves are considered alongside other potential hazards. The Department of Urban Development and Building Construction can also incorporate heat risk reduction measures into urban planning and infrastructure projects.
Promoting Fish Farming	Agriculture and Livestock department	BMC Ward Committees	The Agriculture and Livestock Department, in collaboration with Ward Committees, will promote fish farming initiatives, particularly in Wards 4, 6, 16, etc. They will provide technical support and guidance to individuals and communities interested in starting fish farming projects. Ward Committees will assist in identifying suitable locations for fish farms and mobilizing local resources.

Incorporating heat into building codes to standardize good practices	Department of Urban Development and Building Construction	BMC	The Department of Urban Development and Building Construction, in coordination with BMC, will include heat resilience measures in building codes to establish consistent best practices. The primary goal of this initiative is to guarantee that new construction projects for houses, malls, and other structures adhere to guidelines that improve heat resilience. To accomplish this, the department can create and enforce building codes that integrate heat resilience practices like cool and green roofs, heat resilient materials, blinds, canopies, energy-efficient design, and more.
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Table 15: High priority actions for long term measures

Key activities	Primary Stakeholder	Secondary Stakeholder	How to carry out the activities
Increasing roof reflectivity	BMC	Department of Urban Development and Building Construction Private sector NRCS, Morang DC	BMC, in coordination with the Department of Urban Development and Building Construction, will raise awareness among residents about cool roof reflectivity. The BMC can also aim to paint 50 households white, specifically those with tin roof houses. When selecting households, vulnerable communities with tin roofs in Wards 6, 14, 15, 18, and 19 can be considered. BMC, in collaboration with the Department of Urban Development and Building Construction, NRCS, and Morang DC, can work on the cool roof initiative programs. Case Study of white roof initiative from Ahmedabad: https://bit.ly/4c5DPAP
Building new ponds or enlarging existing ponds or water bodies and protecting water bodies	Department of Urban Development and Building Construction	Department of Water Services BMC Ward Committees	The Department of Urban Development and Building Construction, in collaboration with the Department of Water Services, BMC, and Ward Committees, can undertake initiatives to enlarge existing ponds, protect water bodies, and build new ponds. The ponds, such as Rani Mai Pokhari and Manta Pokhari of Ward 14, will be maintained and regularly cleaned. New ponds can be developed in wards 4,5,6,8, 11,12 etc., which have a very low Normalized Difference Water Index (NDWI) (Annex, Figure A-1). Furthermore, Ward Committees can also assist by identifying suitable locations, engaging local communities, and mobilizing resources at the grassroots level.
Offering incentives or rewards for residents who implement heatwave mitigation measures, such as installing reflective roofing or upgrading insulation.	BMC	NRCS, Morang DC Other Agencies	BMC can collaborate with the NRCS and Morang DC to offer incentives or rewards to residents who implement heatwave mitigation measures, such as installing reflective roofing or upgrading insulation. For example, for people willing to paint their tin roofs white, BMC can provide around 30-50% of the cost of paint to encourage other residents For low-income population or financially challenged households, BMC can do it in free. NRCS and Morang DC

			can support this initiative by conducting awareness campaigns to educate the community about the ongoing financial incentives and how to access the incentives.
Incorporating heat stress projections into land-use planning processes to guide development in heat-resilient ways	Department of Urban Development and Building Construction	BMC	The Department of Urban Development and Building Construction, in collaboration with BMC, can incorporate heat stress projections into land-use planning processes to guide cities' development in heat-resilient ways. This will ensure that future developments are designed to withstand and mitigate heat-related challenges.
Change in hospital layout, orientation	Department of Health Services	Health Division, BMC	The Department of Health Services, in collaboration with the Health Division of BMC, can implement changes in hospital layout and orientation to improve heat resilience. For example, hospital maternity wards can be shifted to the ground floor if they are on the top floor. This would allow easy access for pregnant and lactating women to reach the wards, and ground floor wards are generally cooler than those on the top floor. The Health Division at BMC can also promote the installation of windows in east-west directions to ensure proper wind flow.
Raising awareness of energy-efficient appliances such as use of LED (light-emitting diode) bulbs or CFL (compact fluorescent light) bulbs	NEA	NRCS, Morang DC BMC	In coordination with the NRCS and Morang DC, the NEA can raise awareness and provide information about energy-efficient appliances. The information can include how LED (light-emitting diode) bulbs use up to 80 per cent less energy than incandescent bulbs and how they result in cost savings and reduced energy consumption. The NRCS and Morang DC can also support these efforts through community outreach programs and by promoting the campaign in schools.
Promoting/ Constructing traditional bamboo shaded sitting areas and waiting areas, allocating areas for parks and green spaces	Department of Urban Development and Building Construction	Department of Roads BMC WDMC	The Department of Urban Development and Building Construction can promote and construct traditional bamboo-shaded sitting areas and waiting areas, mainly in heat-prone areas (15, 6, 2, 9,10,7, and 3) and high-traffic areas of Biratnagar, such as Puspala Chowk and Jaljala Chowk. BMC and WDMC members can engage the community in the planning and maintaining these spaces.
Distributing heat-resistant seeds and drought-tolerant crops to farmers	Agriculture and Livestock department	BMC WDMC	The Department of Agriculture and Livestock of BMC can provide heat-resistant crops or drought-tolerant crops to the local farmers. The WDMC can help identify the farmers whose primary profession is farming and whose lives depend on agriculture. The department can distribute millet, buckwheat, lentils, sesame, chickpeas, etc.
Promoting drip irrigation	Agriculture and Livestock department	BMC WDMC	The Department of Agriculture and Livestock of BMC and WDMC can promote drip irrigation in areas where people mainly depend on agriculture, such as wards, and in water-stressed areas,

			such as wards 14, 15, 17, 18, etc. This initiative will help farmers reduce water usage during the heat season and support sustainable agricultural practices.
Distribution of ceiling fan to schools with tin roofs and no fans	BMC	Academic institutions Private sectors District and local level humanitarian agencies	BMC, in collaboration with academic institutions, will distribute ceiling fans to schools with tin roofs and no existing fans. This initiative has already started, as BMC is identifying schools in need, procuring the ceiling fans, and distributing 500 ceiling fans. This initiative can be extended in the long run, as so many schools in Biratnagar don't have fans. This initiative aims to improve the students' learning environment by reducing heat stress and enhancing comfort for students.

8. Way Forward

A comprehensive HAP has been meticulously crafted for Biratnagar, following a holistic and inclusive approach. The development of this plan was guided by a rigorous three-tier process, which included a thorough literature review and scientific analysis, extensive consultation with key stakeholders, and active community engagement. This robust process ensures the credibility and effectiveness of the Biratnagar HAP 2024.

The Biratnagar Metropolitan City (BMC) authority, in collaboration with other stakeholders, has to take the stewardship to take the HAP forward into implementation to reduce heatwave impacts and related losses in the city. The BMC has to be a convener for all the coordination and stakeholder engagement processes for the heat action in the city. The BMC, in collaboration with the NRCS DC office, can ensure the setting up of a regular coordination mechanism to bring together the relevant stakeholders to implement the different measures as recommended in the HAP.

In the HAP, preparedness, response, and long-term adaptation measures have been prioritized into 3 categories. This will facilitate the BMC and NRCS in planning and allocating the budget effectively. The BMC can take the lead in scoping the funding opportunities from the existing or upcoming government plans or schemes at the local, provincial, or national level and integrate the actions with those schemes or plans. Furthermore, some initiatives need minimal to no financial resources. So, the authorities can emphasize implementing those actions immediately.

The BMC and the respective branch of NRCS should actively seek support from various non-governmental and bilateral organizations. Private entities and the local business chamber of commerce can play a crucial role in supporting the implementation of some of the measures. The authorities should initiate dialogues to access the corporate social responsibility fund. Moreover, they should establish a framework for regular updates of the HAP. This ensures that the plan remains dynamic, incorporating lessons learned from implementation, community feedback, and success stories from other cities.

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ANNEX A: Heat threshold and trigger determination for the heatwave alert

A.1 Introduction

This document discusses the threshold for heat warning over Biratnagar (Lat 26.48 N, Lon 87.27 E) in Nepal. The threshold for heat warning is based on an assessment of dangerous ambient heat stress conditions using historical hourly records of ambient near-surface temperature (Units: °C) and relative humidity (Units: %) spanning 01/01/1979 – 31/12/2023 at the two locations. The two variables are combined as hourly near-surface Heat Index (HI; Units: °C), an index of ambient heat stress conditions commonly used in operational heat alerts.

Rest of the report is structured as follows. Section 2 begins by outlining the data source used in the development of the HI in this report. The rationale, choice, and development of the daily maximum HI (HI_{\max_d}) threshold are elaborated in Sections A.2 and A.3.

A.2 Meteorological data (ambient near-surface air and dew point temperature) from ERA5

Hourly 2-meter air temperature (T_{air}) and dewpoint temperature (T_d) from ERA5 (both in °C) were extracted for all grid-cells within the national boundary of the Kingdom of Nepal spanning 1979-2023. ERA5 is a global climate reanalysis data product and resolves meteorological fields at 0.25° (~30 km) gridded resolution. It is the most recent and advanced global atmospheric reanalysis from the European Centre for Medium-Range Weather Forecasts (ECMWF) family of reanalysis datasets (Muñoz-Sabater, J. et al., 2021; Hersbach et al., 2018, 2020)². It resolves many atmospheric and land-surface parameters in near real-time, thus offering numerous meteorological parameters from 1950 to near-present day. The relative humidity (RH) required for the computing of the Heat Index (HI; Section 3) was computed utilising the T_{air} and T_d .

The choice of a reanalysis data product for constructing a meteorological index was motivated by two reasons: (i) Lack of historical surface observations spanning a consistent long time-period (without any data gaps) at hourly time resolution for both two variables (T_{air} , and T_d or RH)³ required to assemble the HI; (ii) Reanalysis products and ERA5 in particular have been previously used in environmental-health impacts assessments and are found to be a suitable alternative as meteorological exposure variables (Mistry et al., 2022).

A.3 Threshold for Heat Stress

A. 3.1 Composite metric for Heat Stress: The Heat Index (HI; Units: °C)

A commonly used meteorological exposure variable that accounts for both heat and humidity is the Heat Index (HI) first defined by Steadman (1979) and implemented by Rothfusz (1990). The

² ERA5 is made available by the ECMWF through the Copernicus Climate Change Service (C3S) Climate Data Store (<https://climate.copernicus.eu/climate-reanalysis>).

³ While daily station observation records of T_{air} and RH were made available for the two locations, the data lacked the required details for a thorough assessment to identify historical levels of HI_{\max_d} . For instance, the station observations were recorded at a particular time in the day and not made available as hourly records, thus making it impossible to assemble a historical long time series of HI_{\max_d} to further understand the dangerous exposures to humid heat likely encountered by the local population.

HI has more recently been revised and extended by Lu and Romps (2022)⁴. The HI is routinely applied as an operational heat stress metric in the US and a growing number of countries⁵. A recent published study (Lo et al., 2023) and another in review (Guo et al., 2023 *in rev.*) examine the relationship between a number of Heat Stress Indices (HSIs) and human mortality at a global scale, concluding that no single HSI including T_{air} can be uniformly applied as location-specific meteorological exposure variable in health-impact assessments. However, the complex exposure-mortality relationship examined using HSIs at a number of locations over mountainous regions in the tropics show that the HI performs better to other metrics including T_{air} (Guo et al., 2023 *in rev.*). It must be noted though that various combinations of T_{air} and RH can result in the same value of HI.

A. 3.2 Summary statistics of the HI at Biratnagar

The historical hourly values of the HI spanning 1979-2023 at Biratnagar was first calculated using the extracted ERA5 T_{air} and RH (gridcell) as input variables⁶, following which the hourly fields are aggregated to daily maximum HI (Hi_{max_d}). Table A-1 provides a of the 90th (Hi_{max_90p}) and 95th (Hi_{max_95p}) percentiles of the Hi_{max_d} at Biratnagar.

Table A-1: Himax_90p and Himax_95p at Biratnagar computed using hourly ERA5 Tair and Td

Hi_{max_90p} (°C)	Annual average no. of days between 1979-2023 with $Hi_{max} > Hi_{max_90p}$	Hi_{max_95p} (°C)	Annual average no. of days between 1979-2023 with $Hi_{max} > Hi_{max_95p}$
42.9	36	44.4	18

To facilitate interpretation of the percentile values, a Hi_{max_90p} of 42.9°C at Biratnagar would imply that the local population would have been exposed to daily maximum values of HI above 42.9°C for about 10% of days between 1979-2023 (approx. 36 days on average annually) (Table 1). Such days would fall in the categories ‘Danger’ as defined by the US National Weather Service (NWS) (Table A-2).

⁴ The HI as defined by the U.S. National Oceanic and Atmospheric Administration (NOAA)-National Weather Service (NWS), is a widely used measure of apparent temperature that accounts for the effects of T_{air} and RH using Steadman’s model of human thermoregulation. As noted by Lu and Romps (2022) in their recent study: “Steadman’s model, however, gives unphysical results when the air is too hot and humid or too cold and dry, leading to an undefined Heat Index. Steadman’s thermoregulation model is extended to define the Heat Index for all combinations of T_{air} and RH, allowing for an assessment”.

⁵ The Indian Meteorological Department (IMD) has recently implemented the HI in their operational weather forecasts on an experimental basis. Similarly, the Thai Meteorological Department (TMD) has been issuing heat alerts using the HI <https://www.nationthailand.com/thailand/general/40026353>

⁶ As noted earlier, RH is not directly available in ERA5 but derived using T_{air} and T_d .

Table A-2: Possible heat disorders for people in high-risk groups (e.g., aged, with co-morbidities etc.) when exposed to different thresholds of Heat Index (HI).

Category	Heat Index	Possible heat disorders for people in high risk groups
Extreme Danger	130°F or higher (54°C or higher)	Heat stroke or sunstroke likely.
Danger	105 - 129°F (41 - 54°C)	Sunstroke, muscle cramps, and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity.
Extreme Caution	90 - 105°F (32 - 41°C)	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity.
Caution	80 - 90°F (27 - 32°C)	Fatigue possible with prolonged exposure and/or physical activity.

Source NOAA-NWS

While both these HI_{max_90p} and HI_{max_95p} falls in the ‘Danger’ category as defined by the US-NWS, the marginal increase in the HI_{max_95p} values (by approx. 1.5°C relative to the HI_{max_90p}) can increase additional discomfort and result in additional health complications in the vulnerable population; such as the elderly, infants and pregnant women, outdoor workers and those with existing co-morbidities such as cardiovascular, diabetes and chronic kidney disease.

The next steps involving estimation of the return -periods (RP) and -levels (RLs) of HI_{max_d} to understand the heat stress levels and the corresponding (average) recurrence periods.

A.3.3 Estimation of the Return Period (RP) and Return Level (RL) of HI_{max} and heat stress trigger

Using Generalised Extreme Value (GEV) (Coles 2001) implemented in the R package *extRemes v.2.0* (Gilleland and Katz, 2016), the next step involves deriving the annual maximum over Biratnagar (HI_{max_ann}), which then form the maxima blocks for fitting the probability density functions. This in turn would imply 45 HI_{max_ann} values since the ERA5-derived HI data spans 45 years over 1979-2023. The resulting RLs corresponding to 1-in- 2-, 5- and 10-year RPs estimated using GEV are summarised below in Table 3 for Biratnagar.

Table A-3: RL of HI_{max} in °C for Biratnagar corresponding to 2-, 5-, and 10-year RPs. The RLs fall in the mid ‘Danger’ range (41-54 °C) highlighted in amber in Table A-1.

Return Period (RP) 1-in- (n) Years	Return Level (RL) for HI_{max} (°C) Biratnagar
2	47.9
5	49.6
10	51.0

A.4 Trigger for the heatwave alert

Comparing the RL of HI_{max} for Biratnagar in Table 3 with the corresponding HI_{max_95p} in Table 1, a RL corresponding to any RP exceeds the HI_{max_95p} value. For instance, while on average 18 days with daily

HI_{max} values of 44.4 °C (Table A-1) have occurred at Biratnagar, the higher values of HI_{max} corresponding to the 1-in-5 RP that is typically chosen for the purpose of an Early Action Protocol (EAP), would be even more rare in occurrence.

Put differently, the RL in Table A-3, especially the one corresponding to the 1-in-5 Year RP at Biratnagar, can be better suited for setting as a trigger in an EAP framework. Instead, here, the HI_{max_95p} values that are occurring on an average 18 days annually, are already in the lower-bound of the dangerous category in Table A- 2, and therefore cannot be neglected for issuing heat-health alerts. For this reason, the threshold levels for issuing a heat warning at Biratnagar are recommended to be set as its respective daily HI_{max} values of 44.4 °C. In an operational setting, such as when using a weather forecast on 5- to 7-day lead time to issue an early heat warning, a criterion to allow at least two consecutive days of daily HI_{max} > 44.4 °C can also be used when issuing such an alert.

ANNEX B: Heat Hotspots Analysis

B.1 Selections of Indicators

Table A-4: List of indicators, their dimensions and category, and rationale behind the selection of indicator

Indicators	Dimension	Positive or negative indicators	Category	Rationale for selection
Population density	Sensitivity	Positive	Exposure	Increased population density, population growth, and dispersal increase heat susceptibility.
Built up area	Sensitivity	Positive	Exposure	Areas with dense infrastructure and buildings tend to retain heat, increasing exposure to extreme temperatures.
Heat hotspot areas	Sensitivity	Positive	Exposure	These areas experience higher temperatures, indicating increased exposure to heatwaves.
Population with low income	Sensitivity	Positive	Socio-economic vulnerability	Low-income populations may lack resources to cope with extreme heat, increasing vulnerability.
Age group population (below 5 years and above 65 years)	Sensitivity	Positive	Socio-economic vulnerability	These age group populations are sensitive to the effects of extreme heat, less aware of the impacts of extreme heat, and must rely on others to keep them cool and hydrated during a heatwave.
Outdoor workers	Sensitivity	Positive	Socio-economic vulnerability	Outdoor workers are at increased risk of heat-related illnesses due to prolonged exposure to heat.
Informal Settlements	Sensitivity	Positive	Socio-economic vulnerability	Areas with non-regulated housing often lack adequate infrastructure and access to services, exacerbating sensitivity and socio-economic vulnerability to heatwaves.
Education	Adaptive Capacity	Negative	Socio-economic vulnerability	Higher education levels indicate better awareness and ability to adopt adaptive measures. A high literacy rate is significantly associated with lower infant mortality rates and improved sanitation facilities (Subedi et al., 2022).
Housing Structure	Sensitivity	Positive	Physical vulnerability	Population living in tin houses/ metal roofs absorbs heat when directly exposed to the sun and this can

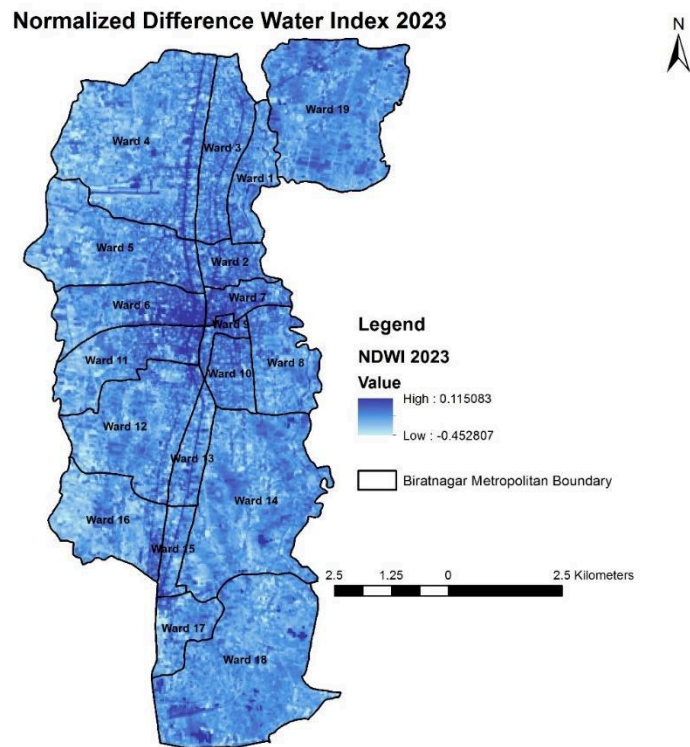
				have an impact on the population living below the tin roofs.
Hospital	Adaptive Capacity	Negative	Adaptive Capacity	Access to a functional healthcare infrastructure is important for a community's overall health and well-being.
Household Access to Fan	Adaptive Capacity	Negative	Adaptive Capacity	Access to cooling devices like fans improves adaptive capacity by helping individuals cope with heat stress.
Household Access to piped drinking water	Adaptive Capacity	Negative	Adaptive Capacity	Having direct access to public and private taps improves a household's ability to cope with extreme heat and other adverse conditions
NDVI (Normalized Difference Vegetation Index)	Adaptive Capacity	Negative	Adaptive Capacity	Higher vegetation density indicates better natural cooling and shade, enhancing adaptive capacity.

Source: Adapted from Subedi et., al 2023 and author’s Illustration

B.2. Normalized difference water index

Normalized Difference Water Index (NDWI) helps to identify and map water bodies or wetlands. The NDWI of Biratnagar of 2023 is shown in the figure:

Figure A-1: NDWI



Source: Author’s Illustration based on satellite image

B.3 Exposure and Vulnerability Analysis

B.3.1 Exposure

Exposure analysis helps to identify the risks and impacts associated with extreme heat events. For example, this helps to identify populations, regions, or sectors that are most vulnerable to extreme heat events.

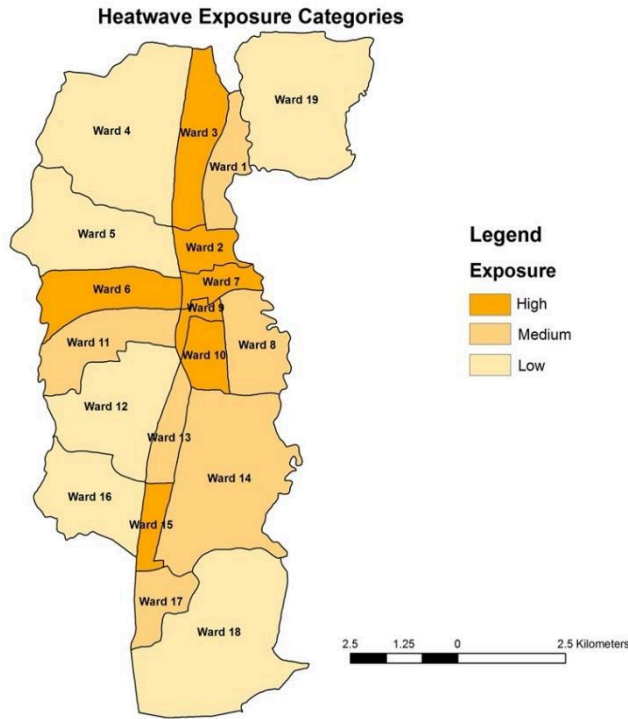


Figure A-2: Exposure Analysis

Source: Author's Illustration

B.3.2 Vulnerability

Vulnerability can be defined as the incapacity of individuals or groups to predict, cope with, resist, and recover from the impacts of heatwaves. Three primary forms of vulnerability—socioeconomic vulnerability, physical vulnerability, and capacity vulnerability—have been identified to analyze and understand the groups most at risk.

Figure A-3: Socio-economic Vulnerability

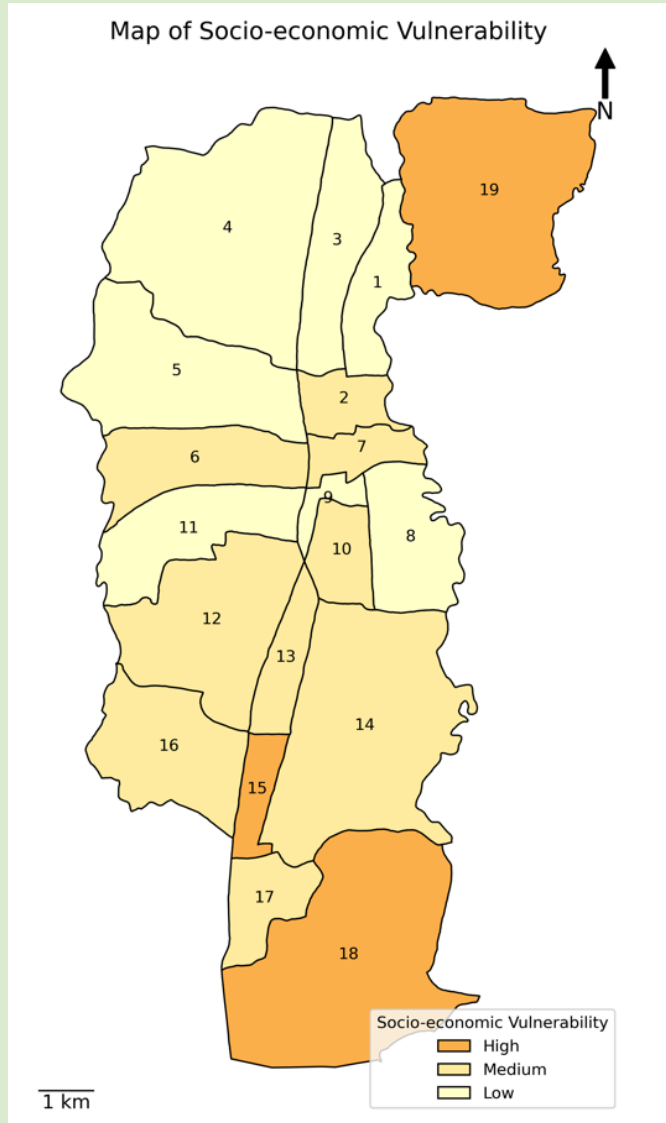
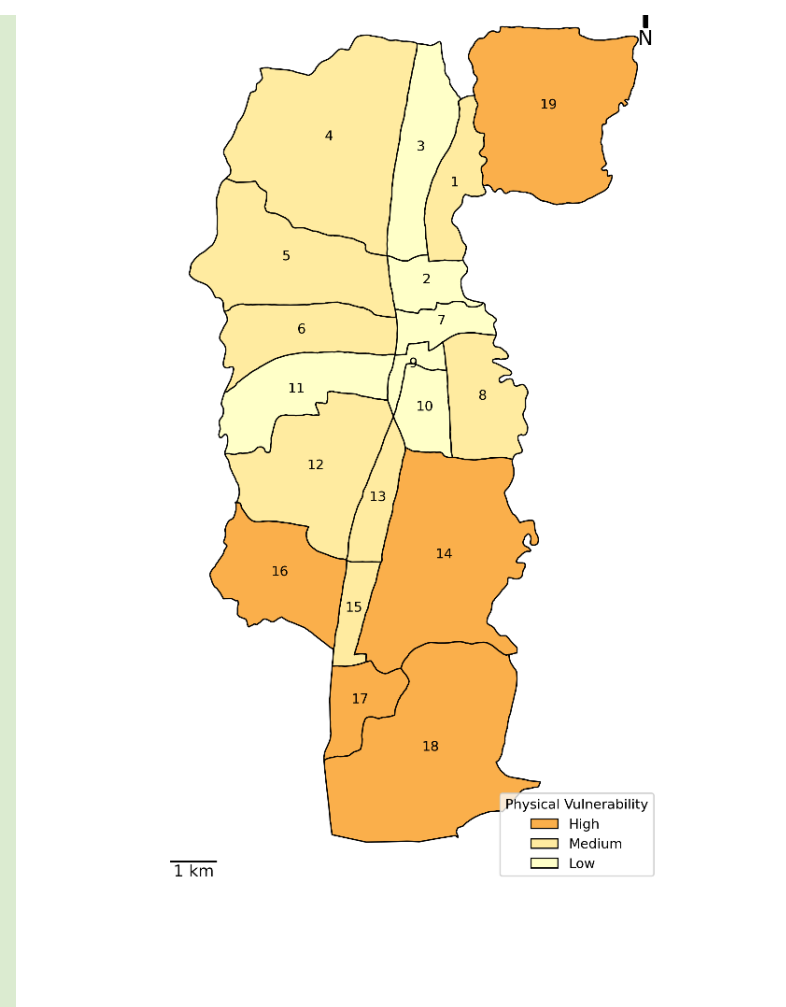
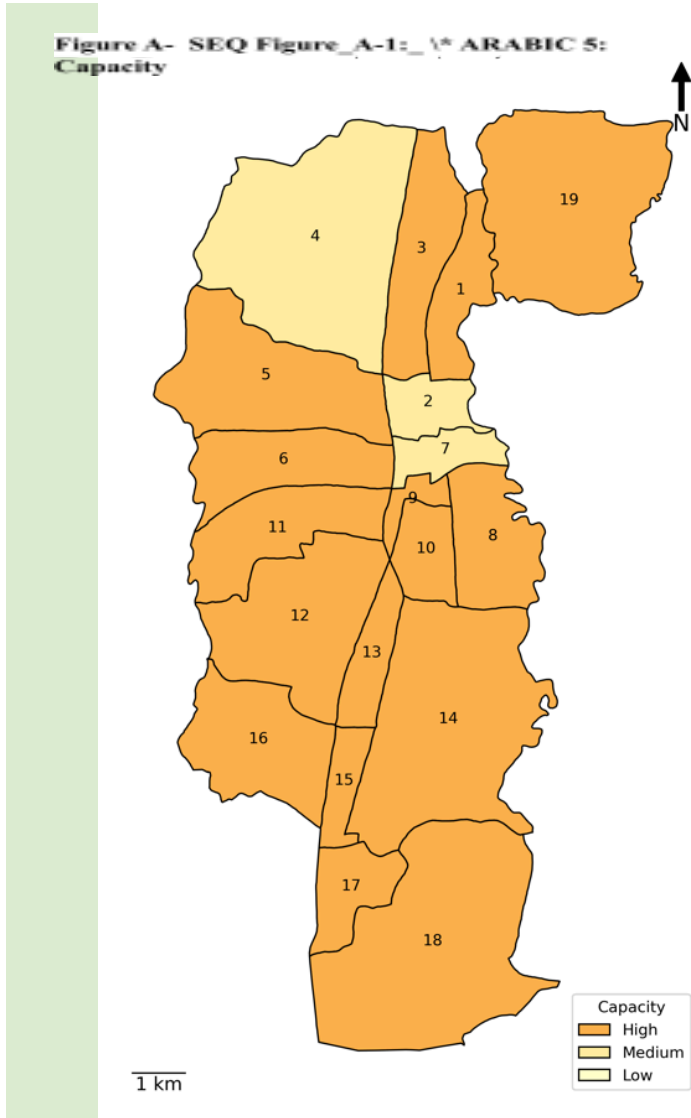


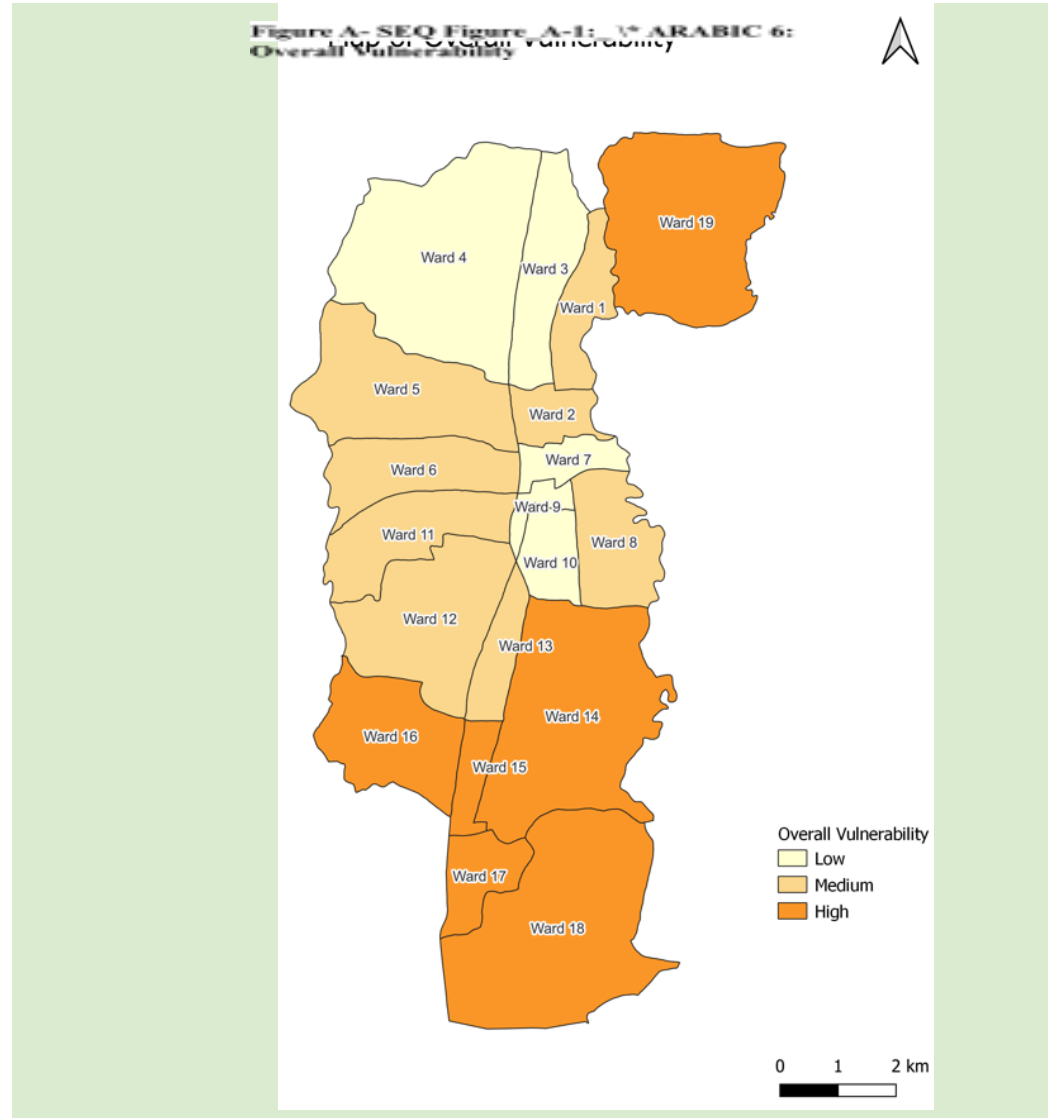
Figure A- SEQ Figure_A-1: _^v ARABIC 4: Physical Vulnerability



Source: Author's Illustration

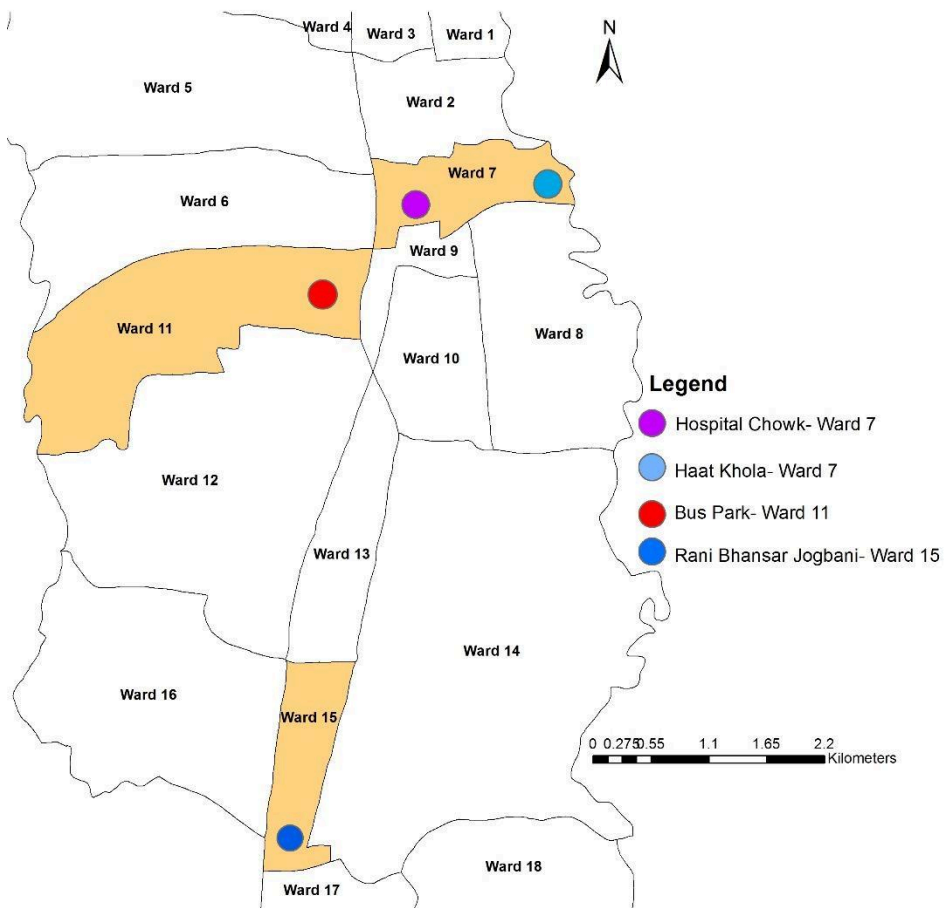


Source: Author's Illustration



ANNEX C: Locations

Figure A-7: Locations for Water ATM in Biratnagar





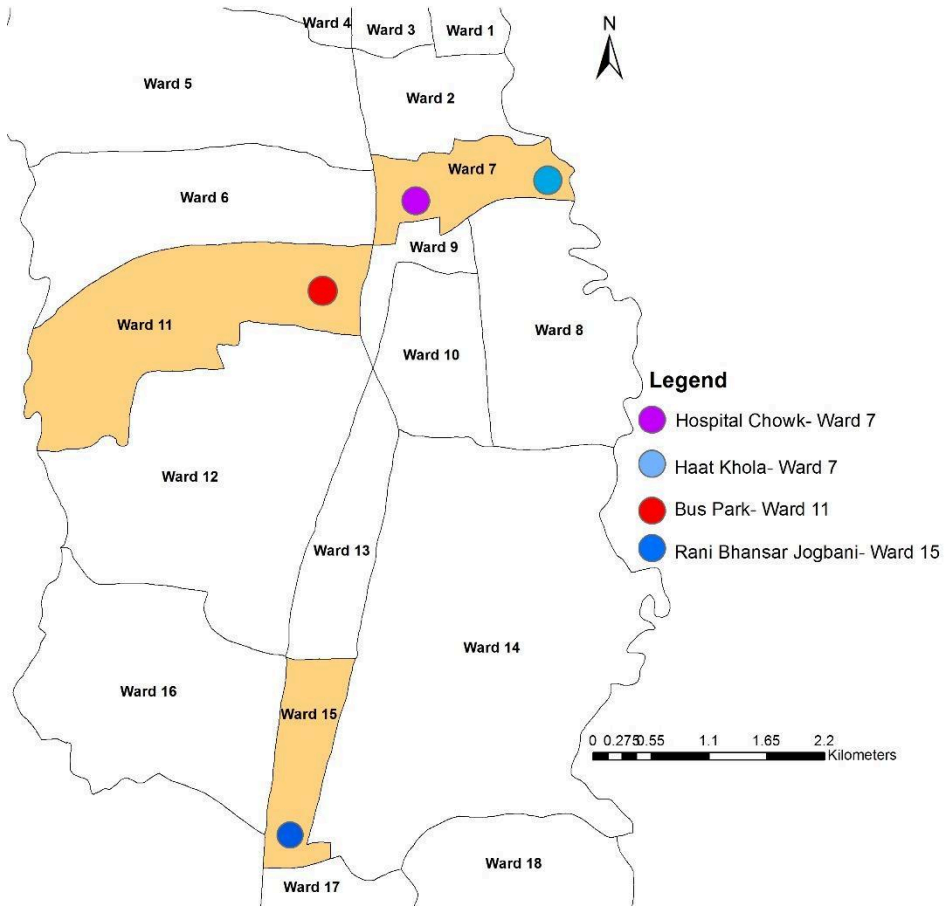
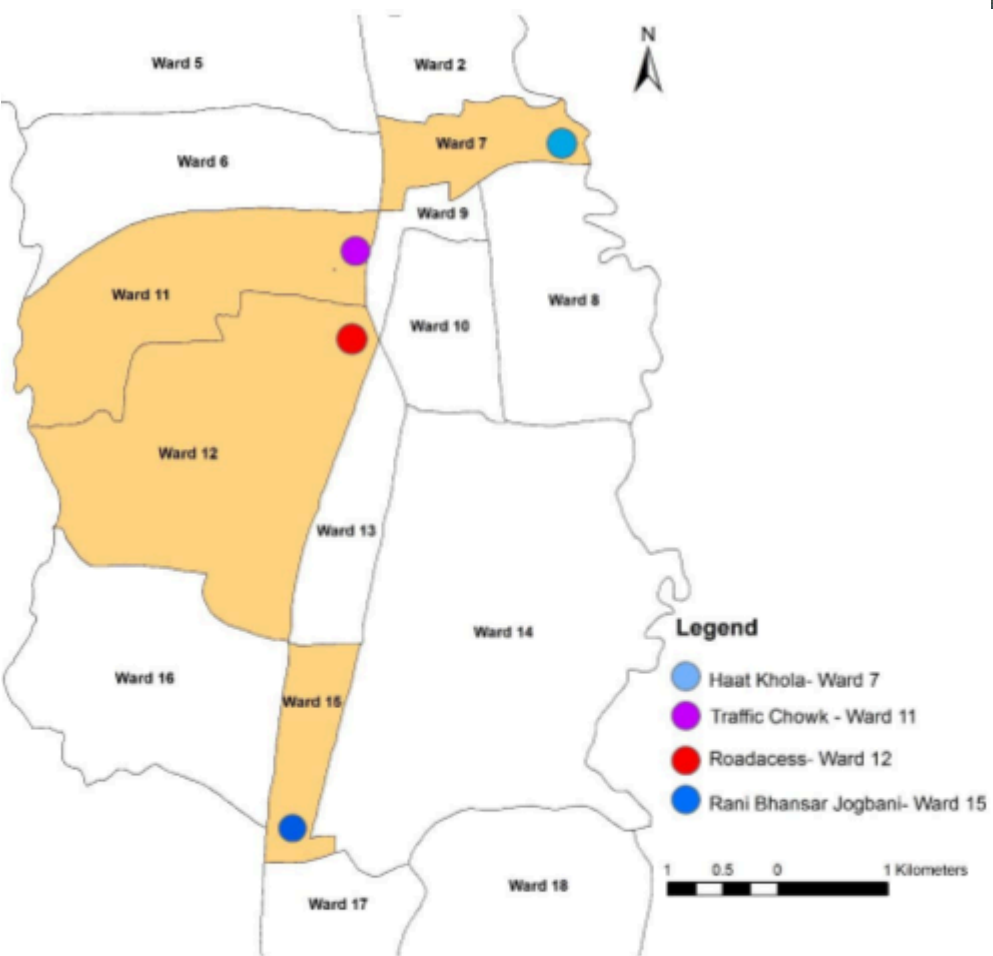


Figure A-8: Identified Locations for LED Installation in Biratnagar



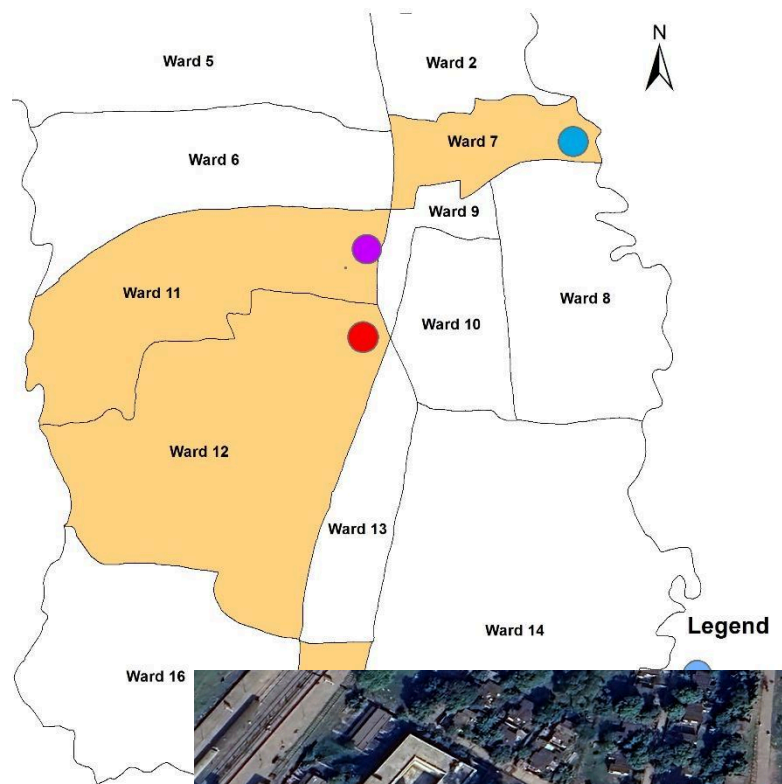
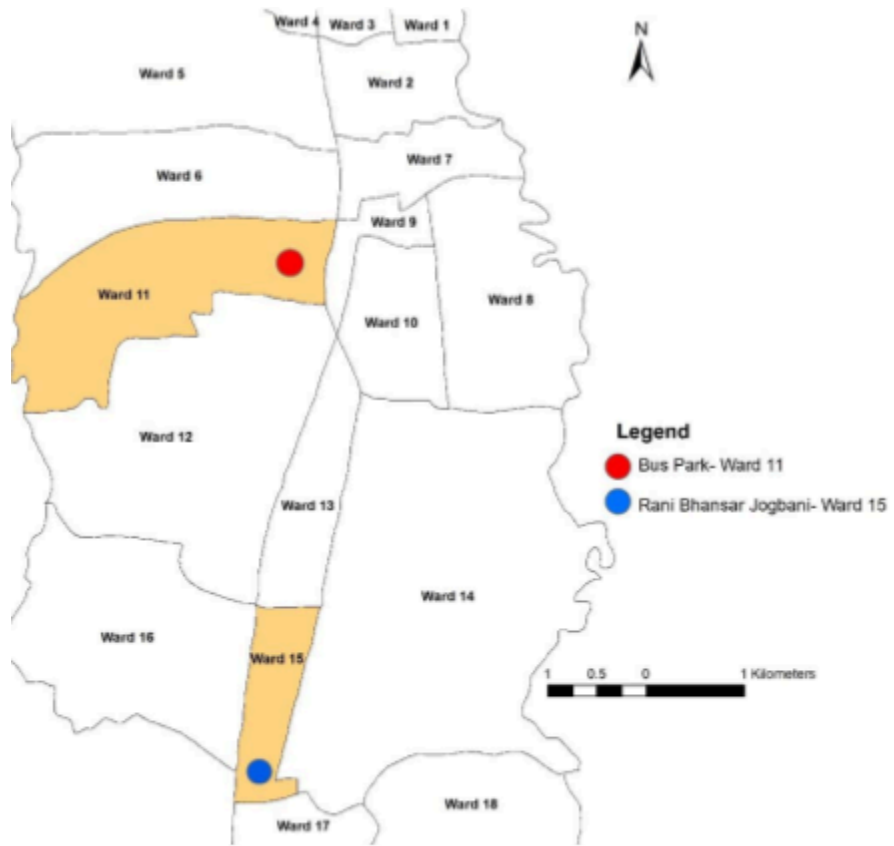


Figure A-9: Identified Locations for Cooling Centres Installation in Biratnagar



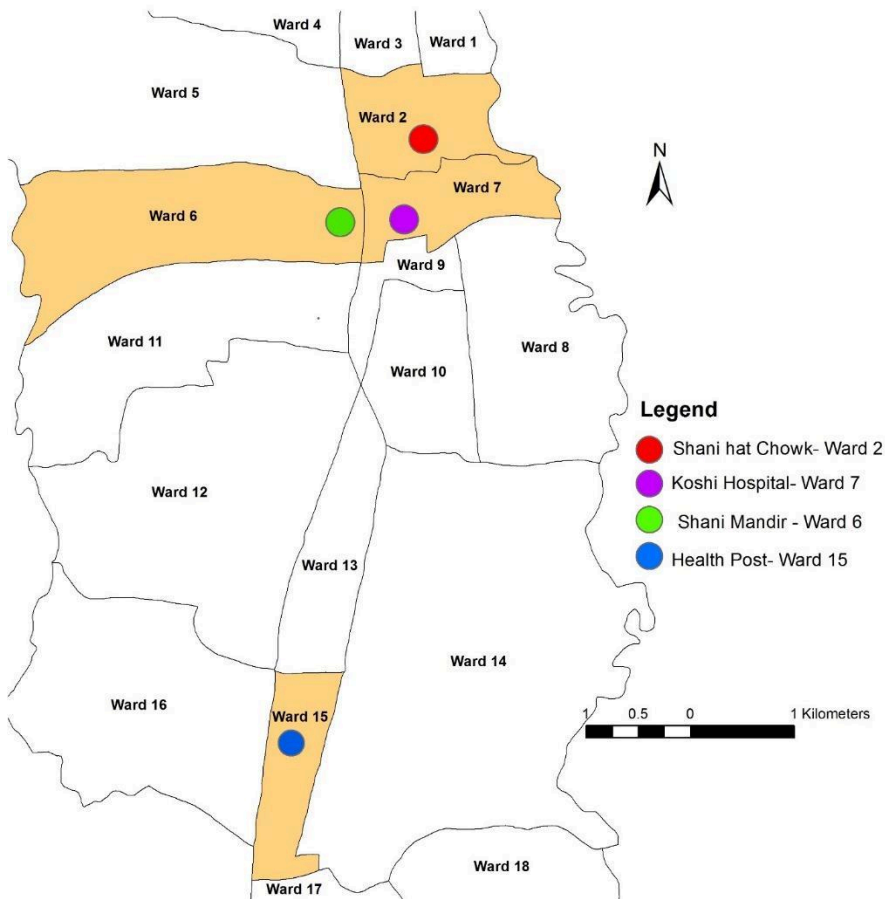


Figure A-10: Identified locations for distribution of heat relief supplies such as water, electrolyte beverages.



