

FEASIBILITY STUDY

# Heatwave Anticipatory Action

IN RAJSHAHI CITY OF BANGLADESH



BANGLADESH RED CRESCENT SOCIETY  
বাংলাদেশ রেড ক্রিসেন্ট সোসাইটি

# A Feasibility Study on **HEATWAVE ANTICIPATORY ACTION** in Rajshahi City of Bangladesh



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# Executive Summary

Heatwaves are caused by meteorological factors and climate change issues and have a critical effect on human and animal health, agriculture, financial planning, and more. The increase in urban heat islands during heatwaves can damage human health and ecosystem components. In recent years, heatwaves have become more frequent and intense in Bangladesh due to the changing climate, leading to a significant increase in heatwave-related casualties. Rajshahi, the fourth-largest city in Bangladesh, has suffered significantly from the long-lasting heatwaves that devastated the country between April and July. The city's rapid urbanization, deforestation, depletion of water bodies and increase in the number of impervious surfaces have made it increasingly vulnerable to heatwaves. Despite concerns about increasing heatwaves, there has been no evaluation or action to improve heat-health management or comprehensive heat resilience in Rajshahi City.

Nevertheless, the consequences of extreme heat can be prevented. Rajshahi City Corporation (RCC) has a unique opportunity to adapt to increasing heat hazards by implementing efficient risk management at various levels. This can be done by linking policies and incentives and improving community adaptive capacity. Cities must develop a comprehensive strategy that includes early warning systems, adequate preparedness, and adaptive measures to deal with the consequences of extreme heatwaves.

This study looks at the feasibility of developing Anticipatory Actions to heatwaves and protect lives, assets, and livelihoods in Rajshahi City, Bangladesh. The study has four main objectives: to develop a heat index and identify relevant thresholds for early action, detect vulnerable wards for heatwave pilots, assess the impact of the heatwave on vulnerable groups, and propose options to connect social protection systems with the EWEA to minimize the overall impact on the community.

The methodology of this study followed two major steps. First, analysing daily meteorological data on climate variables (maximum temperature trend, heat index analysis, heat threshold and the Urban Heat Island (UHI) effect) of the last 50 years (1972-2022) in Rajshahi City. The second step involved identifying stakeholders and conducting field investigations through participatory exercises, such as Focus Group

Discussions (FGDs) with the targeted groups and Key Informants Interviews (KIIs) with the key stakeholders in Rajshahi City. The outputs of these participatory exercises were analysed using the Analytic Hierarchy Process (AHP) method. The critical aim of the investigation was to collect primary data to substantiate the results from the secondary data analysis and to address data gaps. A detailed analysis was conducted to align proposed early actions with social protection schemes and funding procedures.

The vulnerable groups suggested early action interventions were assessed for costs, benefits, lead times and institutional capacities. The cost-benefit analysis provided a clear idea for scoring interventions in multi-criteria decision-making using the AHP.

The study identified that extreme weather can be categorized as a heatwave when the **maximum temperature exceeds 40°C and the Heat Index (HI) exceeds 55°C for at least 5 consecutive days**. Based on the threshold temperature and the HI, a two-stage Anticipatory Action (AA) trigger is recommended. The pre-activation trigger will be activated 5-7 days before the heatwaves, whereas the activation trigger will be activated 2-3 days prior. These two-stage triggers will assist in taking advanced measures to reduce the potential impacts of the heatwave on the city and its residents.

The analysis of Urban Heat Islands and Heat Index around the city indicates that four wards (4, 16, 19, and 28) are highly vulnerable to heat risks and six more wards (3, 11, 14, 24, 25 and 30) follow in the vulnerability ranking. Preparedness measures for imminent heatwaves are necessary, but long-term and policy-level interventions are critical to reducing urban heat risks, especially in the four most vulnerable wards. The study identifies the five most vulnerable groups

1. Outdoor workers.
2. Elderly, chronically ill and disabled persons.
3. Poor communities residing in slums.
4. Pregnant women, lactating mothers and newborns.
5. School children.

Based on the suggestions by each at-risk or vulnerable group during FGDs, eighteen interventions have been identified that can be classified into 3 groups:

1. Anticipatory Actions (AA)
2. Disaster Risk Management (DRM)
3. A combination of the above two (DRM+AA)

The anticipatory actions are the actions which are feasible and effective actions after the impact forecast and event i.e., within the lead time. The suggested interventions are as follows:

#### Anticipatory Action (AA) Interventions:

- Medical camp & free medicine distribution.
- Financial help during the heatwave.
- Fruit and food baskets.
- Cooling spaces.

#### Disaster Risk Management (DRM) Interventions :

- One-time monetary help to attach board under tin-roof.
- One-time monetary help to improve the ventilation of the kitchen.
- Establishing tube wells.
- Installing solar or charger fan.
- Installing deep motor pumps.
- Providing them with livelihood opportunities.
- Installing shed areas in the school premises.
- Installing cold water filters in schools.
- Providing shade over the driving seat of Rickshaw Pullers

#### Combined (DRM+AA) Interventions :

- Prior warning through the miking system.
- Prior warning through SMS.
- Phone awareness-building training.

It is recommended to implement the AA interventions in several phases, considering the operational costs and volunteer requirements of medical camps and other interventions:

**1st Phase:** a beneficiary medical camp with free medicine, an unconditional cash grant of 2500 BDT per household for slums and prior warning in all four vulnerable communities are proposed as high priorities.

**2nd phase:** interventions such as providing cooling spaces for vulnerable communities, distributing solar fans or charger fans, attaching boards under tin roofs, setting up cooling rooms, and installing cold-water filters in schools are recommended to utilise the resources cost-effectively.

The concerned departments of the Rajshahi City Corporation (RCC) are the primary actors that will lead in the overall coordination, communication and implementation of the AA interventions in Rajshahi. At the same time, the Bangladesh Red Crescent Society (BDRCS), Bangladesh Meteorological Department (BMD), District Relief and Rehabilitation Department (DRRD), Rajshahi Medical College Hospital, Rajshahi Development Authority (RDA) and Water Supply and Sewerage Authority (WASA) are the critical actors for ensuring effective implementation of the proposed early actions.

The detailed analysis to align proposed early actions with social protection schemes and funding procedures revealed that RCC has no heatwave plan and lacks any social protection programs that can address the impacts of heatwaves. This situation provides a unique opportunity to understand, analyse and use existing social protection schemes for heatwaves and take early action. However, the report identified the following recommendations that could address some of the gaps identified in connecting social protection programmes with early warning and early action to minimize the overall impacts on the community:

- Collaborate with the district government to map overlaps between program beneficiaries and vulnerable populations, especially those in informal slums, and provide the necessary support.
- Explore the ways to share beneficiary data from the Department of Social Service (DSS) with BDRCS and other NGOs to facilitate cash support and/or other types of assistance.
- Utilize existing channels such as radio and television, in cooperation with the Ministry of Health and Family Welfare (MoHFW), and BMD, to popularize the modifications to social protection schemes and disseminate tailored messages as awareness support.
- Address challenges in digitizing beneficiary data, improving data accuracy, and enhancing recipients' knowledge and awareness of their entitlements and renewal requirements.
- Conduct a message dissemination workshop among the Working Groups on AA to present study results and explore collaboration opportunities with agencies working with vulnerable communities.
- Advocate for work-from-home solutions during heatwaves and support early warning message dissemination. This recommendation is particularly relevant to sectors such as

communication, finance, business activities, defence, public administration, and education.

- Advocate for research on the link between heatwaves and drought, and the impacts on productivity and livelihoods. Utilize existing research as a foundation and encourage universities and BMD to analyse compounding risks and impacts.
- Implement adaptation measures like insulating household roofs, cooling the community shelters, providing cooling water stands, and greening the urban spaces.

- Engaging with the disaster-affected people to explore the use of funds allocated for rehabilitation in consultations with the disaster and relief department under the district commissioner's office.

Despite some challenges, the study suggests developing an Anticipatory Action for heatwaves in Rajshahi is feasible. The RCC, BDRCS, BMD, and other partners, including DRRD, RDA, and WASA are well-positioned to pilot AA for the heatwave in Rajshahi.

## 1 Background

### 1.1 Extreme heat risks and impacts in Rajshahi

Bangladesh is a land of hazards that is also a part of the tropical South-Asian monsoon system (Shahid, 2010). Bangladesh has a tropical climate with wide seasonal variation in rainfall patterns and relatively mild temperatures with high humidity (Wahiduzzaman et al., 2022). In the last few decades, the average temperature in Bangladesh has increased by 0.7 to 1 degree Celsius and is likely to rise by 1.4 degree Celsius in the following three decades (Islam, 2009). In recent years in Bangladesh, due to the changing climate, heatwaves have become more frequent and intense (Choi et al., 2021; Hasnat, et al., 2018), and various studies have shown a significant increase in casualties related to heatwave in the region. Heatwaves are caused by meteorological and climate change-related factors, crucial for human and animal health, agriculture, financial planning, and more (Tawsif et al., 2022). A substantial increase in Urban Heat Islands (UHI) due to heatwaves can cause damage to both human health and ecosystem components. It is difficult to avoid the emergence of the Urban Thermal Field Variance Index (UTFVI) without a fundamental decentralization approach (Kafy, 2019).

Rajshahi is the fourth-largest city in Bangladesh, situated on the north bank of the Ganges River and has a total area of 96.72 sq. km. In recent years, the city has suffered significantly as a result of the long-lasting heatwave that devastated Bangladesh, during the months of April-July. Due to its rapid change in land use and land cover, rapid urbanization, deforestation,

depletion of water bodies and increase in the number of impervious surfaces, Rajshahi City is deemed to be increasingly vulnerable to heatwaves (Khan & Blackwell, 2022).

In 2022, the maximum temperature of the season was 40.3°C on April 25, while the mercury stayed between 35° and 39°C in April 2021 in Rajshahi City (BMD data). However, the days with a maximum temperature surpassing 39°C, and occasional periods of up to 65% humidity, happened every year (BMD data, 1990-2020). On some of the warmest summer days in the city, the temperature may even reach 42°C or more (Alamgir et al., 2019). The average land surface temperature in Rajshahi City rose by 4.76°C between 1989 and 2021 (Hasnat, 2022).

As a result of the rapid and pronounced urban expansion of Rajshahi City between 1889 and 2021, the area with urban green spaces decreased by 50% of the quantity needed to meet the requirement for vegetation on plain land (Hasnat, 2022). The land class in Rajshahi City Corporation (RCC) was a predominately agricultural area, which significantly decreased during the last few decades. The decline was deemed to be so substantial that it was considered harmful (Hasan et al., 2021). The agricultural area was reduced from 65.29% (3093.14 ha) in 1989 to 6.61% (313.16 ha) by the end of 2021. The urban area consisted of 3947.56 hectares (83.34%) in 2021, a sharp rise from 540.81 ha (11.42%) in 1989. In the same period, the green-covered area declined from



1008.70 hectares (21.29%) to 405.45 hectares (8.56%). Meanwhile, the agricultural land, the vegetation cover, and the waterbodies declined by 58.68%, 12.73%, and 0.51% respectively (Hasnat, 2022).

As a result, the land use and land cover (LULC) shift in Rajshahi City is so radical, drastic, and substantial that it will amplify the consequences of the heatwave. The land surface temperature (LST) is rapidly increasing in urban areas owing to the decrease in lands covered by water bodies and vegetation. In 2018, 37.63% of the population experienced 37°C to 39°C temperatures. Moreover, rapid urbanization is a key driving factor for LULC and LST changes and the following increase in the urban thermal field variance index (UTFVI). The eventual growth of UTFVI in 54% of the RCC area experienced a high UTFVI effect in 2018, compared to only 30% in 1998 and 45% in 2008 (Kafy, 2019). Moreover, the essential impacts of climate change in the RCC region include extreme heat, droughts, and decreased rainfall.

Heatwaves cause a rise in illness, death rates, and financial losses worldwide. It impacts individual well-being, resulting in pain, discomfort, fatigue, heat stress, heat cramps, heat stroke, and other health symptoms (Rajib et al., 2011). In Rajshahi City, heat-related mortality is not routinely monitored, although the effects are probably substantial given the increases in the temperature and other circumstantial evidence. For instance, Rajshahi City stakeholders who were surveyed stated that elderly people, children, and manual labourers (such as auto-rickshaw drivers, rickshaw pullers, and hawkers) are the most susceptible groups affected by heatwaves (Khan & Blackwell, 2022). Moreover, heatwaves adversely affect the quality of life and earning capacity of daily wage workers. A small-scale assessment of the rickshaw pullers and auto-rickshaw drivers found that working hours were reduced to on average 4 hours a day and over three days during extreme heatwave periods, resulting in more than 20% losses in their incomes (Subedi et al., 2022).

In the Rajshahi City Corporation (RCC) region, 35.18% of households are classified as severely undeveloped, followed by 13.63% as low-developed households and 27.23% as extremely low-developed households. Of about 196,300 poor people living in the RCC region, many are concentrated in slums and densely populated areas that make up about 5.83% (2.767 square kilometres) of the total area (Kafy, 2019). The marginal

population has not been officially recognized, rendering the informal settlements devoid of essential infrastructures such as water supply, sanitation and health services. Due to inadequate housing and limited access to services, people living in these areas spend more of their income on food, water, and maintaining life conditions compared to people who have access to better services. Although RCC and other municipal stakeholders are concerned about the increasing frequency of heatwaves, there has not been any comprehensive evaluation or action plan made to improve heat-health management or comprehensive heat resilience in Rajshahi City (Khan & Blackwell, 2022).

Nonetheless, the consequences of extreme heat are preventable and RCC has a unique opportunity to adapt to increasing heat hazards by implementing efficient risk management at several levels, linking policies and incentives, and improving the adaptive capacity of the communities (Leal Filho et al., 2019). To deal with the consequences of extreme heatwaves, cities must develop a comprehensive strategy that includes early warning systems, adequate preparedness, and adaptive measures. The rapid urban growth and the emergence of UHI can be handled by the urban planners, local government, and environmental engineers, which also provides up-to-date and improved consistency for the urban planners in establishing an encompassing climate resilience policy to make a city more sustainable (Kafy, 2020). In these circumstances, this research proposes to protect communities from the impacts of predictable extreme heat events by supporting, developing and testing Early Warning Systems (EWS) triggers and standard protocols through a bottom-up strategy, linking communities at local and national levels, and integrating risk/impact projections.

## 1.2 Definition of Heatwave

There is no specific recognized definition or threshold for a heatwave that is universally applicable. Generally, a heatwave happens whenever the maximum and minimum temperatures in a place are extremely high during a few-day period depending on the local climate and regional weather patterns.

Countries and organizations define heatwaves differently based on local climatic variability and the environment. However, there is a consensus that an increased temperature above the normal range

characterizes a heatwave. According to the World Meteorological Organization, a heatwave is five or more consecutive days with daily maximum temperature surpassing the average maximum temperature by 5°C (9°F) (Rafferty, 2023). The Australian Bureau of Meteorology defines a heatwave as when the maximum and the minimum temperatures are unusually hot over three days at a location (Bureau of Meteorology, 2023). The IPCC Glossary also defines heatwave as excessively and uncomfortably hot weather.

However, just a high daily maximum temperature does not characterize a heatwave, and the radiation cooling at night and the high percentage of humidity also play an equally important part in the same. The combination of temperature and high humidity is measured by the Heat Index (HI). Heat stress becomes a primary concern for human health and the operability of infrastructure when extremely high night and daytime temperatures persist. Heatwaves amplify the stress on the body by making it harder to recover from the day's heat. The human body cannot shed heat to the environment when ambient air TW is over 35°C (Crownhart, 2021); instead, it begins to absorb heat from the air. As a result, 35°C is considered the temperature at which the human body can no longer cool itself down effectively, which can be lethal for even otherwise healthy people.

The Task Team on Definitions of Extreme Weather and Climate Events (TT-DEWCE) of the World

Meteorological Organization's (WMO) Commission for Climatology Task Team (2018) felt compelled to establish a standardized definition at the global and regional levels by defining a heatwave as three consecutive days of scorching weather (maximum, minimum, and daily average temperature) across an area based on local (station-based) climatological parameters, with thermal conditions recorded above prescribed thresholds. Moreover, according to Nissan et al., (2017), the definition entails "three consecutive days' elevated maximum daily temperatures over 95th percentile, reinstating the importance of night-time conditions for health impacts". Furthermore, in the case of Bangladesh, the Bangladesh Meteorological Department (BMD) recommends three consecutive days rather than the five days suggested by the WMO for defining a heatwave.

The WMO also suggests using the local heatwave definition. In the Focused Group Discussion (FGD) and also during the discussions with the BMD officials, it was found that residents of Rajshahi find it difficult to cope with a heatwave persisting for more than 5 consecutive days. So, considering the WMO definition and recommendation from the BMD officials, a heatwave in Rajshahi can be defined as when the daily temperature exceeds the average maximum temperature by 3°C for 5 consecutive days. However, the Bangladesh Meteorological Department (BMD) has categorized heatwaves into four groups considering maximum temperature and threshold (Chaki et al., 2022), as shown in the table below:

**Table 1 : Heatwave intensity and categories by maximum temperature**

| Heatwave thresholds |                   |           |                                              |
|---------------------|-------------------|-----------|----------------------------------------------|
| Temperature range   | Heatwave type     | Intensity | Brief description                            |
| 36°–38°C            | Mild heatwave     |           | Daily maximum temperature at 2m <38°C        |
| 38°–40°C            | Moderate heatwave |           | 38°C ≤ Daily maximum temperature at 2m <40°C |
| 40°–42°C            | Severe heatwave   |           | 40°C ≤ Daily maximum temperature at 2m <42°C |
| Above 42° C         | Extreme heatwave  |           | Daily maximum temperature at 2m ≤42°C        |

Source: Retrieved from Chaki et al., 2022 and compiled by author, 2023.

The daily average temperature throughout the occurrence is used to determine heatwave intensity. The heatwave intensity was computed by adding the long-term and short-term daily mean temperature anomalies. Following their severity, heatwaves are divided into three types by the Australian Bureau of Meteorology, which are discussed below (Bureau of Meteorology, 2023):

- Low-intensity heatwaves are increasingly common in the supper period. The majority of people can deal with the heatwaves.
- Severe heatwaves are less often and are more likely to be difficult for vulnerable groups like the elderly, especially those with underlying medical conditions.

- Extreme heatwaves can be dangerous if they do not take the necessary steps to keep comfortable, even for healthy people. The likelihood of being impacted is significantly higher for those who work or exercise outdoors.

The threshold for a heatwave in Bangladesh begins around 36°C, as shown in the statistics above. This has a significant linkage with health because of the human body's capacity to adapt to changes in ambient temperature, specifically the TW 35°C threshold that is thought to mark the point at which the body struggles to cool itself. 38°C has been assessed as the heatwave threshold for Rajshahi City. When the temperature in Rajshahi crosses the predefined threshold, BDRCS and GRC would monitor, simulate, and pilot the anticipatory actions for heatwaves in RCC.

## 2 About the Study

This study aims to develop a Forecast-based Action (FbA) and Early Response to heatwaves to protect lives, assets, and livelihoods in Rajshahi. This research endeavours to investigate temporal climatic variables and health data, assess the effects of health and socioeconomic circumstances, identify accessible forecast area sources, evaluate the impact and need assessment of the affected community, and suggest thresholds, triggers, and options for linking the existing social protection systems and early actions to pilot anticipatory action (AA) on the heatwave in the Rajshahi City Corporation (RCC).

### 2.1 Structure of the Report

Section one illustrates the background of heat risks and impacts in the country in general and Rajshahi and surrounding areas specifically. Section two describes the structure of the entire report, and section three shows the objectives, approaches and limitations of this study. Sections four to seven consist of the analysis of secondary data (i.e., climate data, health data, satellite imagery etc.) to assess the impacts of heatwaves and health impacts assessment due to extreme heat, trigger and thresholds models for EA activation based on the available data, models, and forecasts. Section eight examines the Focus Group Discussion (FGD) and

Key Informant Interviews (KIIs) data to evaluate heatwave vulnerability and the need assessment of vulnerable communities employing the Analytic Hierarchy Process (AHP) decision-making method. The purpose of this evaluation is to investigate the critical consequences of heatwaves on slum communities, and outdoor workers, along with identifying essential measures/early interventions. The findings are based on responses from several FGDs with slum dwellers, divided into various groups, such as elderly people, manual labourers, disabled, people with chronic diseases, lactating mothers, school-going children, and so on., along with the findings from the KIIs with government officials, doctors, ward councillors, city corporation officials, etc.

The recommended triggers, thresholds, and early actions will serve as the foundation for piloting/simulating anticipatory actions during heatwaves in Rajshahi City. It is worth mentioning that the study's primary findings have been validated through meetings with relevant stakeholders.

### 3.1 Objective of the Study

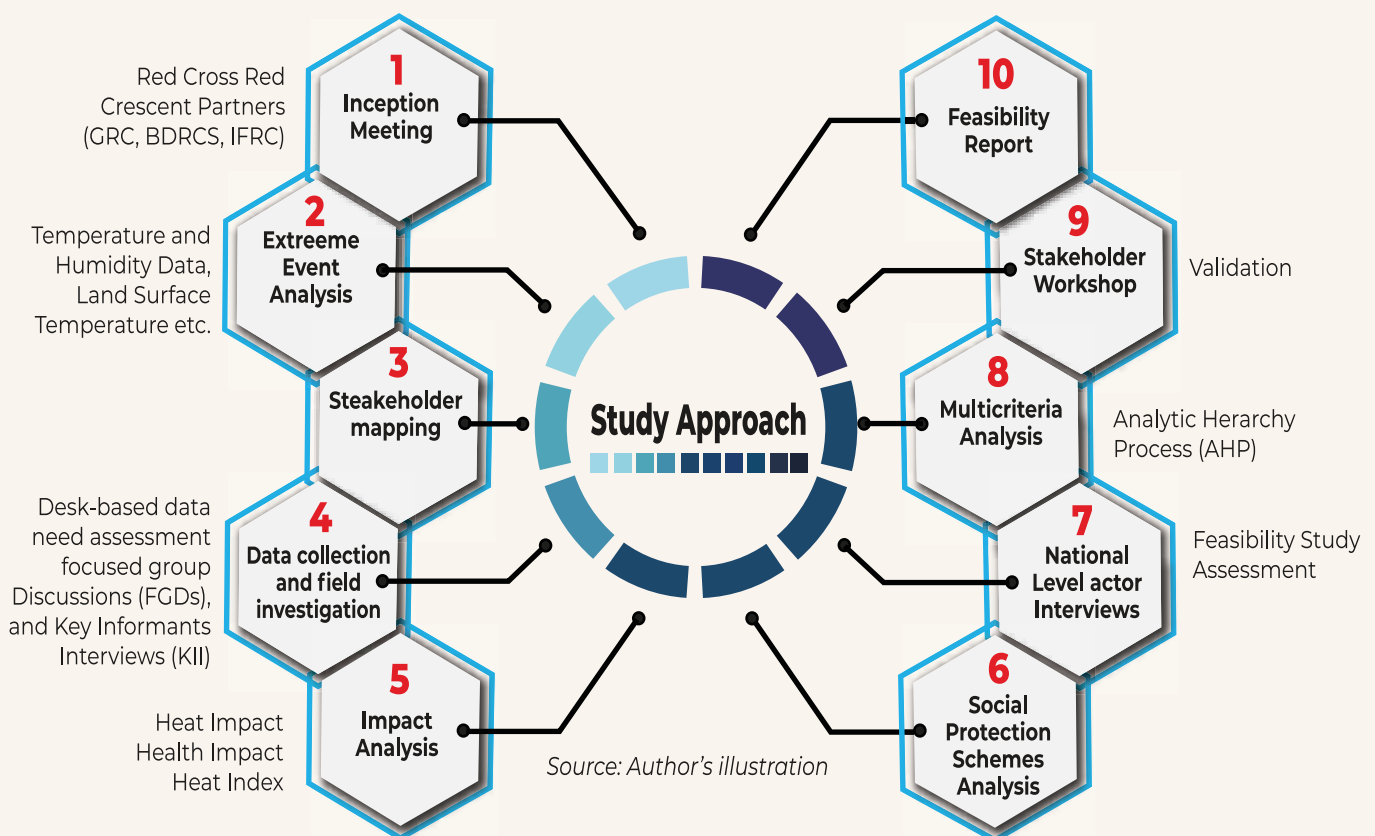
The overall objective is to analyse the feasibility of heatwave anticipatory action (AA) in Rajshahi City. The crucial and specific objectives of the study are to:

- develop heat index and identify relevant thresholds to trigger early actions (the when).
- detect vulnerable wards to pilot heatwave early actions in Rajshahi City (the where).
- assess the impacts of the heatwave on various vulnerable groups (the who).
- propose options to connect social protection systems with EWEA to minimize the overall impacts on community people (the what and for whom).

### 3.2 Approach

The various steps that have been used to conduct the feasibility study of Rajshahi are illustrated in the following diagram:

**Figure 1: Study Approach**





The study started with an inception meeting with Red Cross Red Crescent Partners (GRC and BDRCS) to present and validate the proposed methodology, data requirements, and logistics planning, in coordination with the Rajshahi City stakeholders.

Daily meteorological data on climate variables (maximum temperature trend, heat index analysis, heat threshold and the Urban Heat Island effect) of the last 50 years (1972-2022) in Rajshahi City has been analysed. A list of stakeholders to be engaged was proposed, and a sample of respondents was chosen with the help of GRC and BDRCS. BDRCS facilitated interviews with the shortlisted stakeholders. A data checklist was also developed, and a desk-based data need assessment exercise was carried out. The data checklist was discussed at the inception meeting and was finalized after that. Later, with support from GRC and BDRCS, different institutions were approached to collect the data that were not readily accessible during desk analysis. In addition to the meteorological data, existing plans and policies, a set of social, economic, and demographic factors that influence people's ability to cope with stress were collected. Data attributed to understanding the physical vulnerability and capacity of the people were also analysed.

The field investigation was conducted through participatory exercises, such as Focus Group Discussions (FGDs) and Key Informants' Interviews (KIIs), in the targeted wards in Rajshahi City and analysed using Analytic Hierarchy Process (AHP). The critical aim of the field investigation was to collect primary data to substantiate the results from the secondary data analysis and to address the data gap. The result will help to understand the different impacts of the heatwave (including exposure, vulnerability and risk) on the community, and outline a proposed list of early actions to reduce the impacts. Through the field research, the socially differentiated consequences of heat were also explored, such as how extreme heat affects people differently based on age, gender, poverty level, disability, health status, residence type and location, and livelihood option.

A total of 12 FGDs involving individuals from five distinct groups, namely elderly, disabled and chronically ill, lactating mothers, individuals residing in slums, students and outdoor workers were conducted. Notably, two FGDs were held for each of the first four groups and four FGDs were conducted with outdoor

workers. During these discussions, participants shared their experiences of the effects of heatwaves and proposed solutions to reduce their suffering. Additionally, Key Informant Interviews (KIIs) were conducted to provide more in-depth insights into the impact of heatwaves.

Furthermore, a detailed analysis was carried out on how proposed different early actions can be aligned with the social protection schemes and with different funding procedures. The impacts and interventions suggested by the vulnerable groups have been analysed, and the cost of implementing each intervention and the expected benefit to them have been evaluated in terms of monetary value. The cost-benefit analysis, identified lead times and the experience of BDRCS for each intervention provided clear indications to apply AHP to determine the multi-criteria decision-making score.

### 3.3 Limitation

Scheduling the participation of the participants from various vulnerable groups and stakeholders to conduct FGDs/KIIs was particularly challenging. The study encountered several limitations due to the lack of availability of required data, particularly regarding the health impact of heatwaves, and the absence of comprehensive information on the effects of extreme heat in Bangladesh. The limitations of the study can be identified through the challenges, such as:

- Health data collection from health officials was quite a challenging task.
- The anomaly and error minimization from health data was significantly challenging.
- Health impact threshold identification due to climatic variability was tricky.
- Some critical respondents were not available due to busy schedules, and this affected the proper collection of primary data.
- Analysing and handling vast amounts of qualitative information required extra efforts, like FGDs and KIIs data and limited resources and timelines posed a significant challenge.

## 4 Temperature Variation in Rajshahi

Rajshahi has a tropical climate and experiences both wet and dry seasons; characterized by high temperatures, high humidity, and moderate rainfall.

The table shown below gives a summary of the weather patterns based on BMD observations spanning from 1981 to 2022:

**Table 2: Number of maximum temperature days in Rajshahi, 1981-2022**

| Max temperature (°C) | Jan | Feb | Mar | Jan | Apr | May | Jun | Jul | Sep | Oct | Nov | Dec | Total | % of total |
|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|------------|
| 40°C and greater     | -   | -   | 6   | 124 | 79  | 13  | -   | -   | -   | -   | -   | -   | 222   | 1.5%       |
| 38°C - 40°C          | -   | -   | 46  | 213 | 119 | 47  | 1   | 1   | -   | -   | -   | -   | 427   | 2.9%       |
| 36°C - 38°C          | -   | 1   | 159 | 259 | 223 | 151 | 21  | 8   | 7   | 2   | -   | -   | 831   | 5.6%       |
| 30°C - 36°C          | 1   | 191 | 661 | 433 | 617 | 803 | 885 | 889 | 843 | 804 | 474 | 2   | 6603  | 44.8%      |
| 25°C - 30°C          | 385 | 624 | 367 | 193 | 239 | 253 | 379 | 378 | 371 | 392 | 709 | 709 | 4999  | 33.9%      |
| 20°C - 25°C          | 628 | 328 | 59  | 19  | 14  | 12  | 17  | 15  | 23  | 36  | 16  | 368 | 1535  | 10.4%      |
| Less than 20°C       | 66  | 6   | -   | -   | -   | -   | -   | -   | -   | -   | 1   | 43  | 116   | 0.8%       |

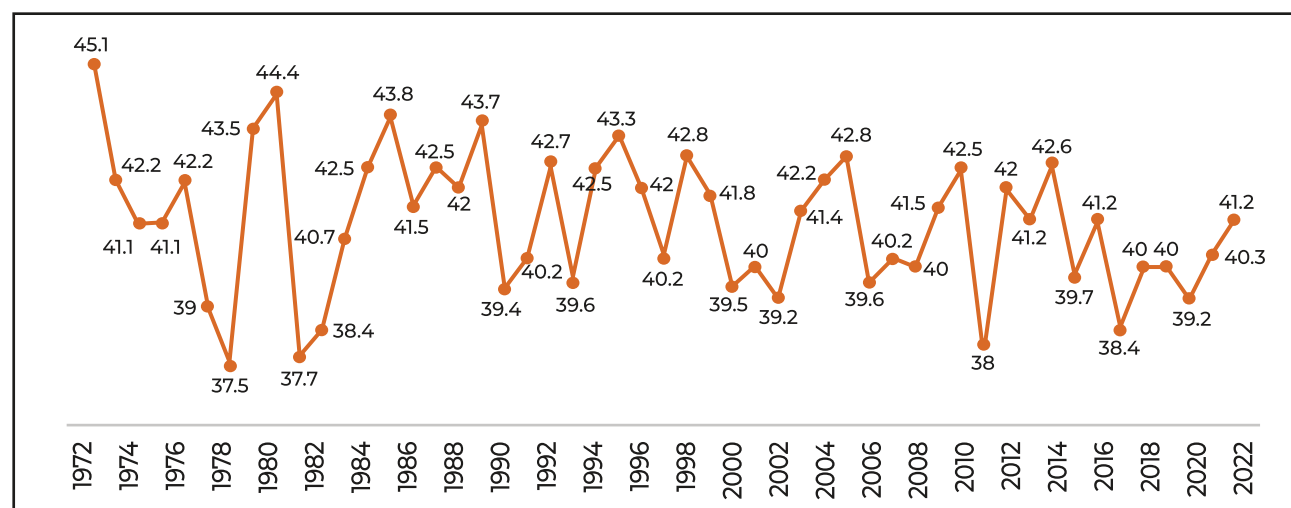
Source: Adapted from Khatun et al., 2016 and BMD data (2011-2022)

In these 41 years, the most common range of maximum temperature remained between 30-36°C, recorded for 6,603 days (nearly 45%) out of 14,733 days (excluding the 597 days of missing records) of the study period. There are 124 days in April and 79 days in May when maximum temperatures exceed 40°C. The maximum number of days (213) with a temperature of 38-40°C is found in April, whereas a total of 259 days with a maximum

temperature record were between 36-38°C. Therefore, the months of March, April, May and June stand out as the hottest in Rajshahi, with a higher possibility of experiencing a heatwave.

The maximum temperature data has also been analysed for the overall temperature trends. The figure below shows the variation in extreme temperature in the past 50 years (1972 -2022).

**Figure 2: Maximum temperature of each year from 1972 to 2022, Rajshahi station**



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

In Rajshahi, the highest recorded temperature occurred in 1972, reaching 45.1°C, while the lowest maximum temperature of 37.5°C was observed in 1978. Over the 50

years analysed, temperatures remained below 40°C in only 12 years, and the recorded maximum temperatures rest of the 39 years were above 40°C.

## 5 Menu of Forecast

A heatwave is a severe weather phenomenon that is primarily determined by the temperature and humidity levels, with additional factors potentially exacerbating the situation. Forecasts for temperature and humidity are obtainable from global and national models, which vary in terms of their lead times and resolutions. The following section examines the forecasts provided by global and national models and their level of accuracy.

### 5.1 Forecast Available at Global Level

At the global level, forecasts for temperature and humidity are available from the European Centre for Medium-Range Weather Forecasts (ECMWF) and Global Forecast System (GFS) models at 9 to 22 km resolution. The following table shows the availability of weather forecasts at the global level, lead time and resolution.

**Table 3: Forecast available globally with different lead times and resolution.**

| Lead time | Forecast Agencies | Model | Access Window          | Content            | Resolution | Format | Accessibility          |
|-----------|-------------------|-------|------------------------|--------------------|------------|--------|------------------------|
| 10 days   | ECMWF             | ECMWF | Windy (Windy, n.d.)    | Hourly temperature | 9 km       | Raster | View-only <sup>1</sup> |
| 10 days   | NOAA              | GFS   | Windy (Ventusky, n.d.) | Hourly temperature | 22 km      | Raster | View-only              |

[Note: The forecast window of ECMWF and GFS is shown in the annexe (Section 11.1.1)]

### 5.2 Forecast Available at Local/National Level

At the local/national level, the Bangladesh Meteorological Department (BMD) provides temperature and humidity forecasts in WRF models at

9 to 18 km resolution. The following table summarizes the BMD forecasts in terms of scale, lead time and resolution.

**Table 4 : Forecast available at national/local level with different lead times and resolutions.**

| Lead time | Forecast Agencies | Model | Access Window | Content             | Resolution | Format      | Accessibility          |
|-----------|-------------------|-------|---------------|---------------------|------------|-------------|------------------------|
| 7 days    | BMD               | WRF   | BMD website   | Maximum temperature | 9 km       | Raster      | View-only <sup>1</sup> |
| 3 days    | BMD               | WRF   | BMD website   | Maximum temperature | 18 km      | Raster      | View-only              |
| 2 days    | BMD               | WRF   | BMD website   | Maximum temperature | Upazila    | Alert (pdf) | Downloadable           |

<sup>1</sup> This implies that users cannot directly download the raw data such as hourly temperature forecast. However, it does not necessarily mean that the forecast is inaccessible to the public or cannot be viewed in any form. Users are still able to access the forecast through respective websites.

### 5.3 Skill of the Available Forecast

This study used BMD observations from 1972 to 2022 to examine the return period of different combinations of temperature and duration of the event. As mentioned in Chapter 1, a heatwave in Rajshahi occurs when the daily maximum temperatures exceed average maximum temperatures by 3°C for 5 consecutive days, as this temperature becomes unbearable for the local population. The average maximum temperature in March, April, and May is 37°C. Considering this, the impact of a heatwave begins when the temperature exceeds 40°C (37°C plus 3°C) for 5 consecutive days.

The return period indicates how frequently extreme temperatures occur, such as temperatures exceeding 40°C in the case of Rajshahi. Analysis of the historical data reveals that the return period for temperatures of 40°C or higher for a period of three or more consecutive days is found once every two years, while for a period of five or more consecutive days, it is found to occur once every four years. Similarly, the return period for temperatures of 42°C or higher for a period of two or more consecutive days is found once every five years, while for a period of three or more consecutive days, it is once every ten years (Section 11.1.3)

According to the dataset, the return period of 40°C for five or more than five consecutive days last occurred in 2016. However, due to the unavailability of forecast data on temperature and humidity from the BMD and the ECMWF archives for Rajshahi, it was not possible to estimate the skill analysis of the forecast.

Hence, we reviewed the available research papers that used the WRF-BMD forecast data to analyse the skill of forecasting. Recent studies have shown that The Weather Research and Forecasting (WRF) model generally performed well in simulating heatwave events over Bangladesh. The model's predictions for temperature, relative humidity, and wind speed closely match the actual data collected by the BMD. Additionally, the WRF model successfully simulated the low-pressure zone over West Bengal and the adjoining area of Bangladesh during the heatwave events. This suggests that the model accurately captured the presence and behaviour of the low-pressure zone, which is a significant meteorological feature, associated with heatwave events in the region (Chaki et.al., 2022).

Research conducted by Perez et al., (2018) evaluates the performance of the WRF model of temperature events (heatwaves and cold waves) worldwide, including Bangladesh. The study finds that the WRF model demonstrates skill in capturing the spatial and temporal characteristics of heatwaves in the region. It indicates that the WRF model can capture the magnitude, duration, and timing of heatwaves and can forecast such events several weeks ahead of time. So, based on the above literature for temperature and humidity it is recommended to use the WRF-BMD forecast data.

## 6 Health Impacts of High Temperature

Rapid increase in heat due to the exposure to hotter-than-average conditions affect the human body's ability to regulate temperature (WHO, 2023). Extreme temperature events can result in a cascade of adverse health issues, such as heat cramps, heatstroke, heat exhaustion, skin disease, hypertension, etc. Therefore, data on adverse health conditions are essential to analyse the impact of extreme temperatures on health. The disease data from 2019 to 2022 has been collected from Rajshahi Divisional Director (Health) Office. The effects of heatwaves have been analysed by incorporating heat index (HI) and maximum temperature data from the BMD observation station at Rajshahi. In this study, the health impacts and heat threshold have been assessed and determined through

heat index for getting a clear indication of the health impact of HI. Besides, several FGDs have been conducted with different vulnerable groups, like outdoor workers, rickshaw pullers, elderly people, lactating mothers, pregnant women, and school-going children to identify their health impacts. Also, KIIs with health officials and other officials have been conducted to identify the impact of heatwaves in different sectors, for instance, health impact, economic impact, etc.

The hospital data of patients affected by dehydration, breathing issues, weakness, exhaustion, blood pressure, asthma, diarrhoea, allergy, skin diseases, headstands, vomiting, pain, organ dysfunction, cardinal infection, and many more during the heatwave periods were also



analysed. Most of the symptoms of those patients are diverse and sometimes difficult to isolate as heatwave patients. According to health officials, the number of patients increased by around 40% during the heatwave period (March to August) in Rajshahi Medical College and Hospital (RMCH). Most patients recovered within three days who had heatwave-related symptoms like shortness of breath, weakness, exhaustion, blood pressure, asthma, etc. However, patients usually do not need more than 7 to 10 days for full recovery.

The RMCH health officials in the KII mentioned that humans can easily cope with 36.8°C temperature, but it depends on individual physical fitness. If the temperature exceeds 37°C, coping mechanisms start to falter, impacting the vulnerable people in the heat-exposed area. When the temperature rises over

38°C, it harms human health. Extreme heat causes extreme sweating, causing the human body to lose its vital nutrients such as sodium and potassium. Severe dehydration and nutrient shortage can impact the GI system, brain disordering, stroke, organ dysfunction, cardiac issues, kidney diseases, waterborne diseases, hygiene-related diseases, poisoning, etc. Around 5% of patients suffer brain, heart, and kidney issues related to extreme dehydration. The elderly group is highly vulnerable to chronic disease and the severity increases significantly during extreme heat. Pregnant women, lactating mothers and children face several health difficulties with discomfort due to extreme heat. Moreover, school-age children are significantly impacted as heatwaves critically affect their education, learning and regular activities. The number of impacted patients and weather variability are shown in Table 5.

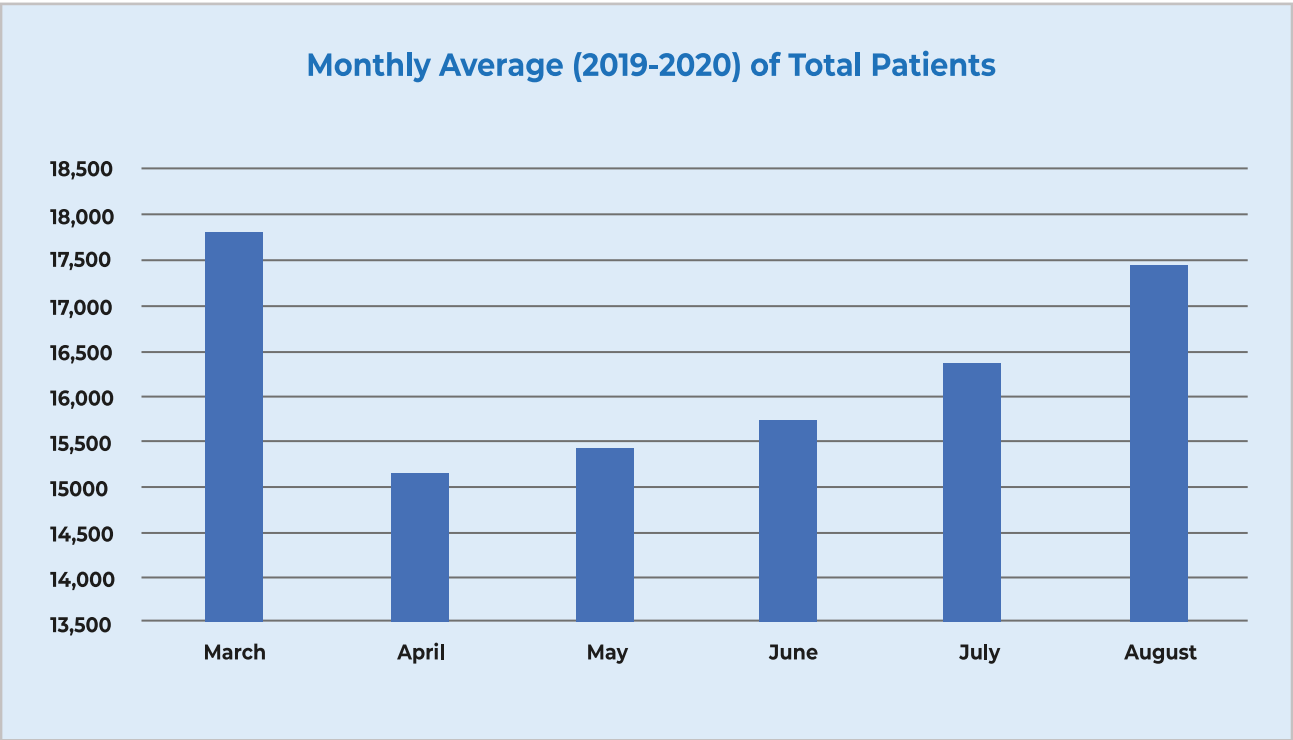
**Table 5: Health impacts by weather factor.**

| Year-Month   | Max. Temp (°C) | Heat Index | Total Patients | Breathing, Asthma & Respiratory | Headache & Migraine | Stroke | Heat Stroke | Skin Disease | Diarrhoea |
|--------------|----------------|------------|----------------|---------------------------------|---------------------|--------|-------------|--------------|-----------|
| March, 2019  | 36.1           | 46         | 17899          | 921                             | 921                 | 2405   | –           | 20           | 5257      |
| April, 2019  | 40             | 61         | 18068          | 898                             | 898                 | 1845   | 4           | 12           | 5633      |
| May, 2019    | 39.5           | 68         | 16108          | 979                             | 979                 | 1827   | 15          | 5            | 3036      |
| June, 2019   | 39.2           | 66         | 16689          | 1200                            | 1200                | 2168   | 24          | 42           | 1612      |
| July, 2019   | 37.4           | 64         | 17633          | 1097                            | 1097                | 2084   | 5           | 49           | 2179      |
| August, 2019 | 36.6           | 64         | 18453          | 690                             | 690                 | 2224   | –           | 39           | 4321      |
| March, 2020  | 35.8           | 46         | 14669          | 990                             | 990                 | 1221   | 8           | 19           | 3000      |
| April, 2020  | 39.2           | 54         | 6358           | 277                             | 277                 | 39     | –           | 35           | 1221      |
| May, 2020    | 38             | 63         | 7044           | 460                             | 460                 | 2828   | –           | 12           | 1084      |
| June, 2020   | 37             | 63         | 9086           | 413                             | 413                 | 1801   | –           | 26           | 1478      |
| July, 2020   | 36.4           | 64         | 8637           | 70                              | 70                  | 862    | –           | 0            | 1216      |
| August, 2020 | 36.4           | 63         | 11708          | 106                             | 106                 | 1601   | 12          | 6            | 347       |
| March, 2021  | 37.7           | 51         | 18531          | 572                             | 572                 | 3538   | –           | 38           | 1692      |
| April, 2021  | 40.3           | 62         | 18060          | 972                             | 972                 | 2305   | –           | 108          | 2300      |
| May, 2021    | 38.6           | 64         | 18611          | 522                             | 522                 | 1414   | –           | 117          | 3226      |
| June, 2021   | 37.5           | 65         | 17385          | 620                             | 620                 | 5607   | 5           | 41           | 1451      |
| July, 2021   | 36.8           | 60         | 18111          | 706                             | 706                 | 1855   | –           | 84           | 1951      |
| August, 2021 | 36.2           | 61         | 18494          | 598                             | 598                 | 2741   | 16          | 69           | 1024      |
| March, 2022  | 38.5           | 56         | 20138          | 626                             | 626                 | 3065   | –           | 17           | 4238      |
| April, 2022  | 41.2           | 66         | 18144          | 432                             | 432                 | 714    | –           | 76           | 1580      |
| May, 2022    | 36.7           | 60         | 19965          | 380                             | 380                 | 683    | –           | 60           | 1594      |
| June, 2022   | 37.5           | 62         | 19838          | 201                             | 201                 | 489    | –           | 17           | 1314      |
| July, 2022   | 39.6           | 65         | 21113          | 645                             | 645                 | 4359   | –           | 35           | 3592      |
| August, 2022 | 36.9           | 69         | 21159          | 1073                            | 1073                | 935    | –           | 30           | 5158      |

Table 5 shows a summary of hospital data on patients with six particular health issues and diseases in Rajshahi City from March to August 2019 to 2022<sup>2</sup> in a total of 24 sets. Moreover, it related the data of the patients with the monthly average maximum temperature and heat index derived from the BMD, observed at Rajshahi station during the same period. The average number of patients was in the range of 17,000 per month, and the maximum number of patients was in March and August. March is highly exposed to the heatwave, and the number of patients are usually also high. The number of patients dealing with heatwave-related issues varies from 10-2500 (Figure

3), which is about 30-40% of the total number. An increase in the number of patients, about 500-700 additional (13% of usually expected), have been observed to be dealing with six common health issues (Figure 4) when the temperature exceeds 38°C (moderate heatwave class as per BMD). It is assumed this additional number of patients suffered from the heatwave. Generally, the average temperature in April is 1-2 degrees Celsius higher than in March. Nevertheless, the precipitation in April is much higher than in March. The monthly average precipitation in March is 24.8mm, whereas the monthly average in April is 63.7mm<sup>3</sup>. So, the health impact rate in April is relatively lower than in March.

**Figure 3: Monthly average of total patients during March to August (2019-2022)**



*Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.*

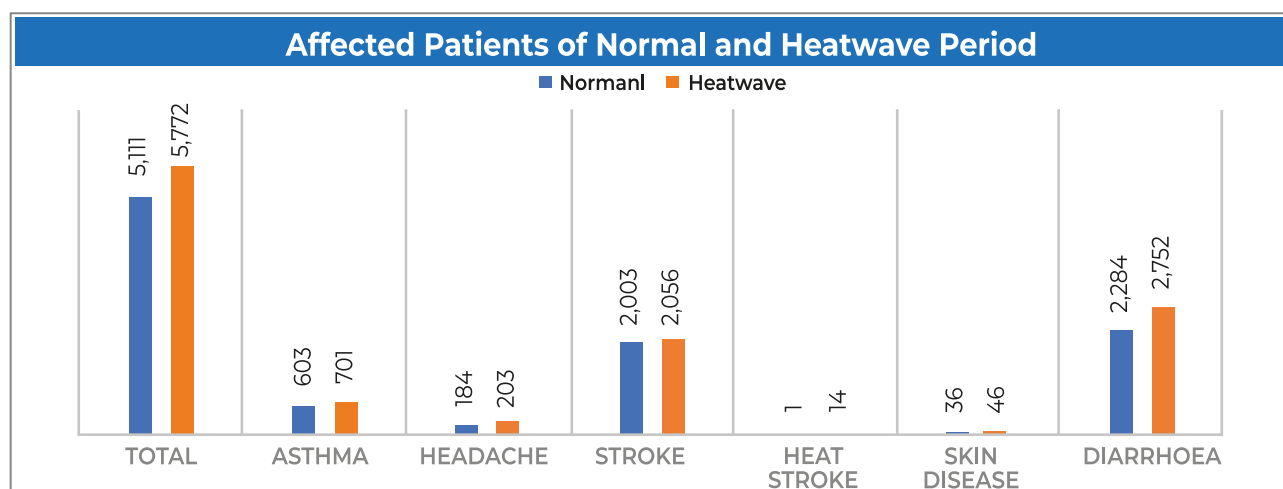
It must be noted that the average temperature in April is 1-2°C higher than in March. Nevertheless, the precipitation in April is much higher than in March. The monthly average precipitation in March is 24.8mm, whereas the monthly average in April is 63.7mm. Furthermore, April is the month of

festivals in Bangladesh, so people generally go out less and celebrate the time mostly indoors with family and friends. So, they get less exposure to extreme heat. Despite April being the hottest month, it can be the main reason behind the fewest patients.

<sup>2</sup> The hospital data obtained only for 6 months due to time limitations, as the data anomaly and error minimization is a cumbersome and time taking process. The hospital data obtained only for 6 months due to time limitations, as the data anomaly and error minimization is a cumbersome and time taking process.

<sup>3</sup> <https://live3.bmd.gov.bd/p/Normal-Monthly-Rainfall>.

**Figure 4: Number of affected patients with six health issues in normal and heatwave periods (2019-2022)**

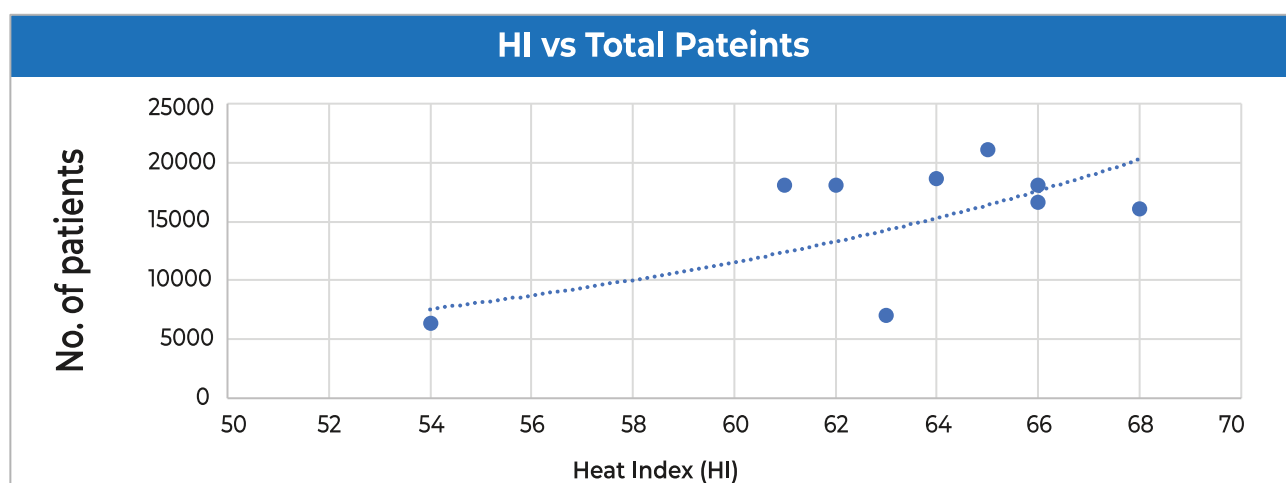


Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

Figure 4 shows that the number of patients increases<sup>4</sup> when the heat index crosses the thresholds i.e., 37°C. The records show the average temperature difference between with and without heatwave is 2-3°C. Further investigation was carried out to find the threshold of heat index (HI) as a proxy for the impact on health due to heatwaves. The total patients were plotted against

the computed heat index, and the result shows (Figure 5) that the impact starts when HI is over 50. The number of patients (six health issues) increases exponentially after HI 60. Around 85% of patients are impacted when the heat index exceeds 55. Also, the upper-rising trendline indicates that the increase in the number of patients is proportional to the increase in HI (Figure 5).

**Figure 5: Increase the number of patients due to increased heat index (HI)**



Sources : Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

Figure 5 shows the increasing trends of total patients with the heat index. The impact on health has been analysed to assess the whole health impact scenario during the entire extreme heat period. Individual diseases and the overall health impact have been evaluated concerning HI. The trajectory of health

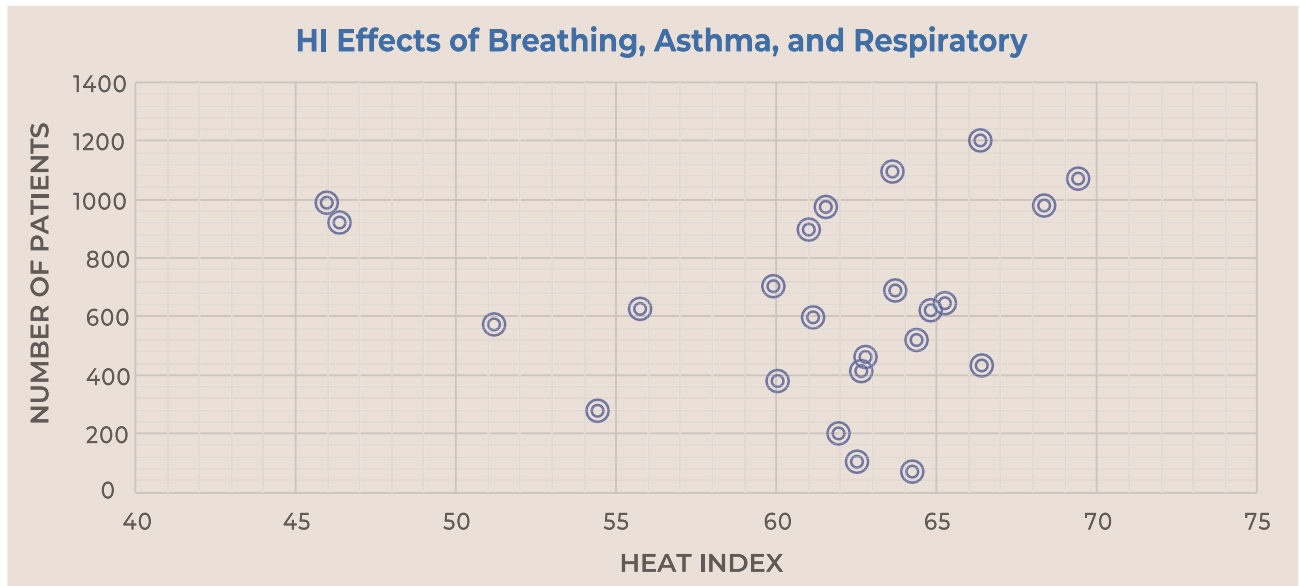
impact or the number of patients admitted to the hospital can be seen upward when the Heat Index (HI) is over 55. The health impacts due to heatwaves get severe when HI touches 60 and above. Weather variability affects humans by impacting their health in various ways due to the rise in heat index. Figure 6

<sup>4</sup> The rate of patients increases in the heatwave period by 6-7% more than the normal period. Especially the rate of Diarrhoea impact is high during the whole year. But 9-10% of patients increase during the heatwave period.

presents the impact of the increase in HI on breathing, asthma, and other respiratory issues. The HI effects on breathing, asthma, and respiratory issues start when the

HI is above 45 and significantly increase when the HI is 60 or more.

**Figure 6: Impacts on breathing, asthma and respiratory issues due to increased HI**

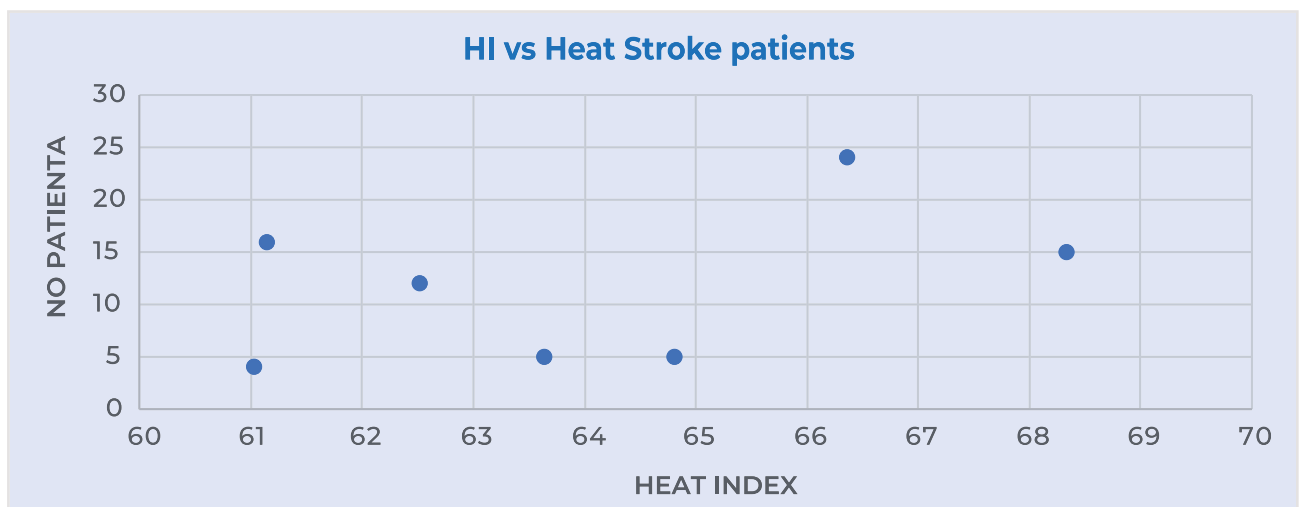


Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

Heat stroke is the most common issue caused by heatwaves. However, the indirect effect of heatwaves increases the severity of other health issues adversely. The entire heatwave period generally affects the increased number of heat stroke patients. Figure 7 shows that the number of patients with heat strokes increases exponentially after crossing HI 60. The number of total patients also increases depending on

the HI rise, with a sharp rise when it exceeds 60. Although, patients with heat strokes grow rapidly when the HI exceeds 60 (Figure 7). Moreover, most heat stroke patients were affected in May, June and August (Figure 8). Around 70% of heat stroke patients were impacted from June to August, whereas 30% were impacted from March to May.

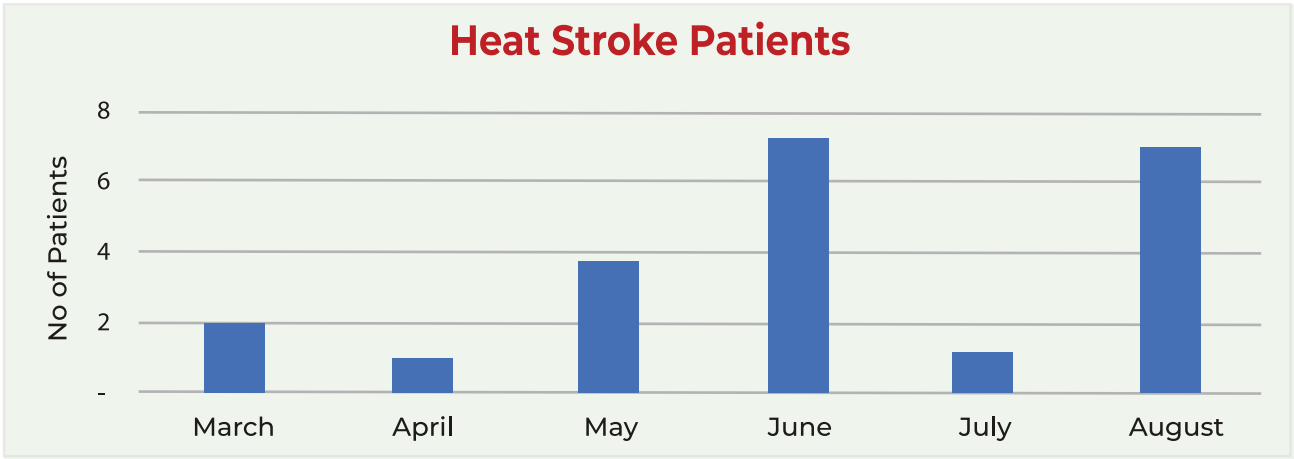
**Figure 7: Impacts of HI to increase the number of heat stroke patients**



Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.



Figure 8: Monthly distribution of the affected number of heat stroke patients

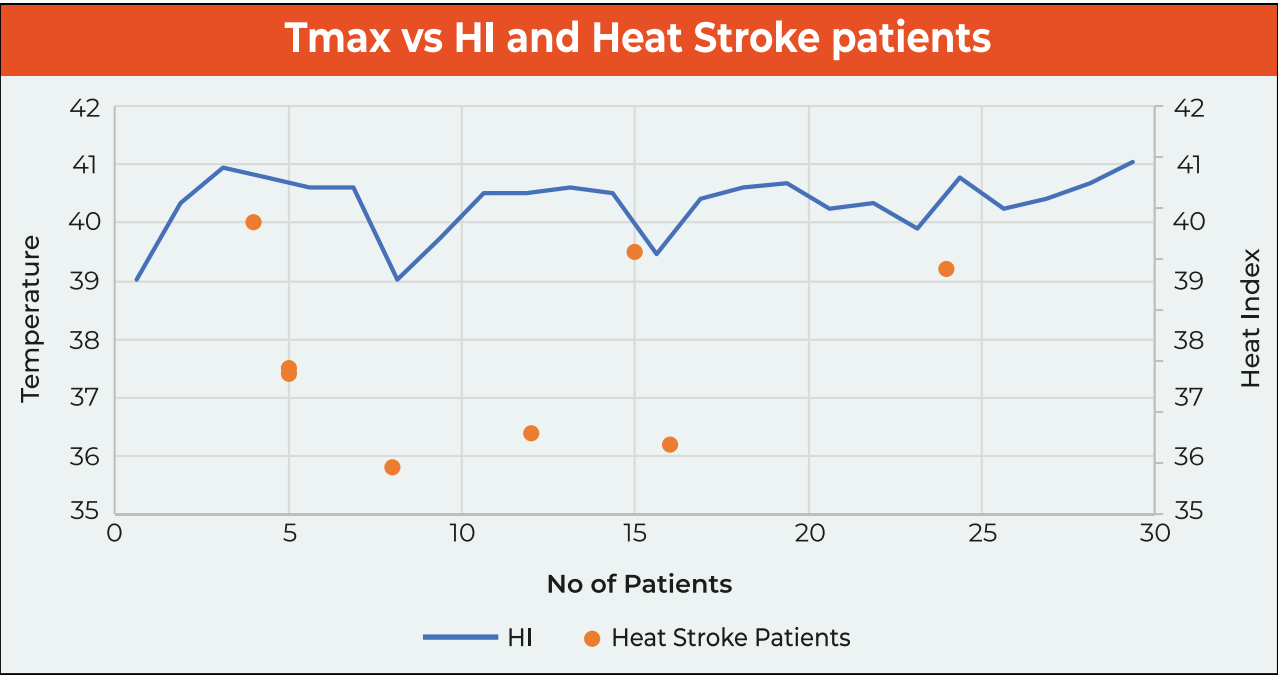


Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

Several reasons are responsible for strokes, high blood pressure, and extremely hot weather being some of the most critical ones. The number of patients with heat stroke rises dramatically when the temperature

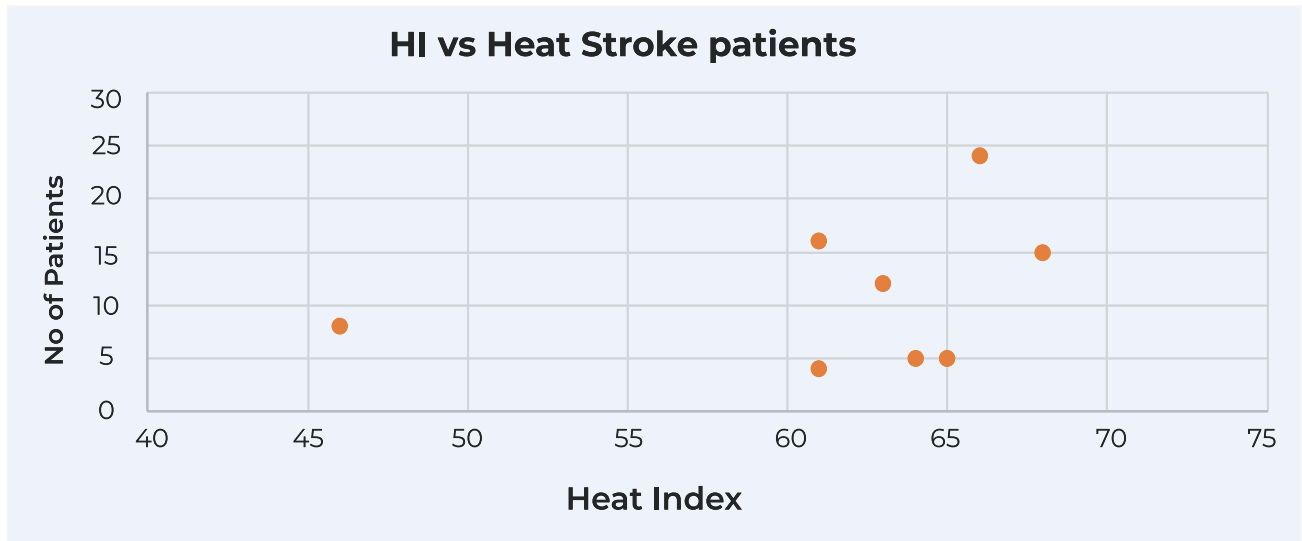
exceeds 39°C and HI is 55. Compared to the whole heatwave period, the number of the affected is higher between March and May (Figures 9 and 10).

Figure 9: Maximum temperature and heat index impact on heat stroke patients



Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

**Figure 10: Impacts on heat stroke patients due to increase in heat index**

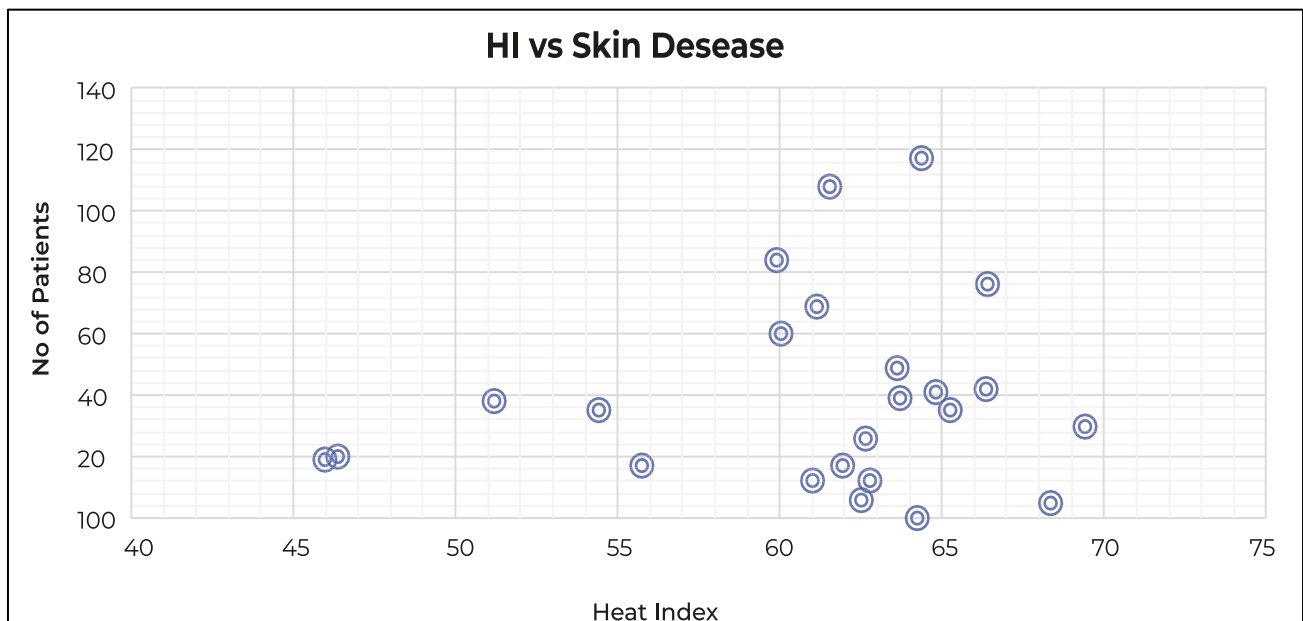


Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

During the summertime, high temperatures and direct sunlight with ultraviolet rays play a key adverse role in skin diseases like rash, skin cancer, bumps, etc. Severe sweating, discomfort, loss of skin moisture, and rapid fluctuation in body temperature caused by heatwaves result in

significant skin disorder impact. Skin diseases increase severely when the HI exceeds 60 (Figure 11). The number of patients with skin disease-related symptoms increases critically between March and May, almost by around 10% in comparison to the period between June to August.

**Figure 11: Heat index impacts on skin diseases**



A significant number of diarrhoea cases are reported when the HI is over 45 from March to August. The scenario worsens when HI exceeds 60. Diarrhoea impacted 60% of patients during the March-May period, whereas 40% were impacted during the heatwave period between June and August. Several issues can affect migraines and headaches, where heatwave is critical in worsening the scenario. The number of patients with such problems increases critically when the HI is above 60. Around 10% of migraine and headache patients are higher in June-August than March-May. A detailed analysis of the health impact of extreme heat is illustrated in the annexe (section 11.4). Overall, the number of patients critically increases when the HI exceeds 55 in Rajshahi. Heat stroke, asthma or breathing/respiratory issues,

skin diseases, headache/migraine, diarrhoea, and other health issues come into effect when HI is over 55, indicating severe impacts on human health with increases in HI. Based on the health impact assessment employing heat index for highly impacted health issues, the impact starts when HI crosses 50 and when HI exceeds 55 rapid increases are observed. 85% of the samples of heat-related cases impact between the HI of 55 and 70. Hence, this study recommended HI 55 as a proxy for the impact threshold. Based on the result of the KII with different stakeholders, it can be pointed out that the health impact of heatwaves, along with extreme temperatures, affects the livelihood of marginal people, especially those who are living in slums and congested areas and have significantly poor socio-economic status.

## 7 Triggers and Thresholds

### 7.1 Heat Index

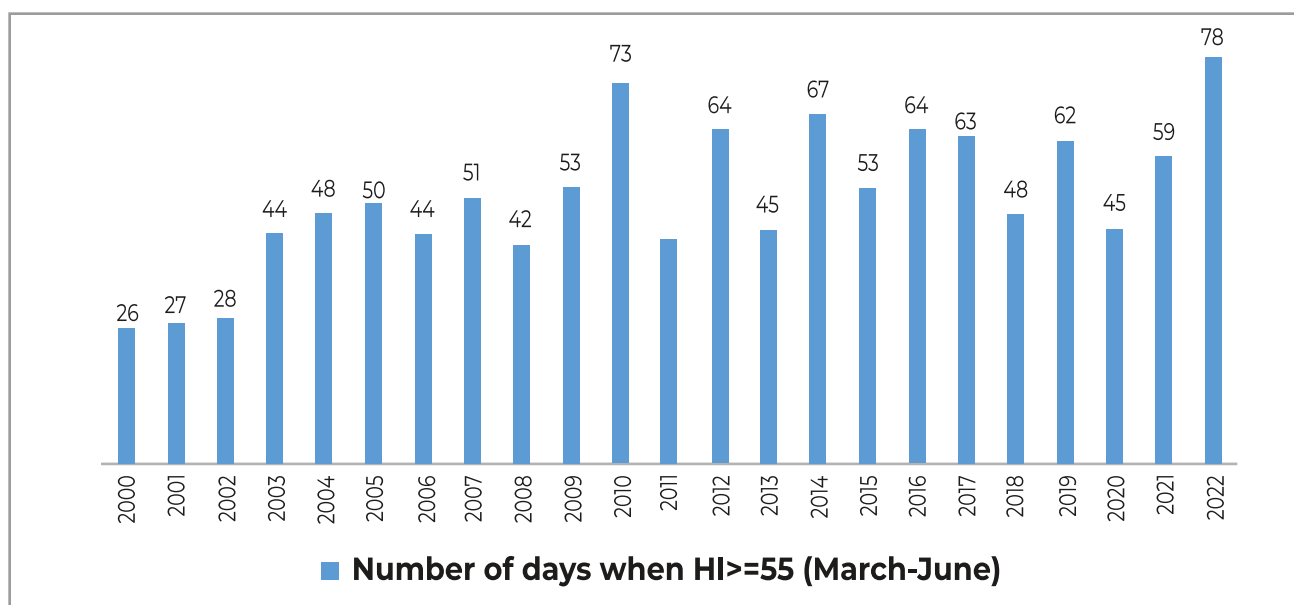
The heat index (HI) represents the temperature that humans experience when relative humidity is factored in with the actual air temperature (NOAA, 2022). By analysing the HI, we can gain insights into how warm it feels to the average person in the current weather conditions. The heat index is proportionately linked to both air temperature and relative humidity.

The BMD has not developed any heat index-based heatwave standard. However, through examining the data on heat index and its effects on health, it has been

determined that the impact starts when HI crosses 50 but increases rapidly when HI exceeds 55 (as mentioned in section 6).

The literature review and daily temperature analysis in the previous sections have confirmed that the peak summer months of Rajshahi are March, April, May, and June (from Table 1). To identify the years when the HI surpasses the extreme danger level (i.e., above 55), HI analysis has been computed for the months of the years between 2000 and 2022.

**Figure 12: Number of days with HI at extreme danger level (i.e., above 55) during the peak summer months (from March to June) between 2010 and 2020**



Source: Author's illustration based on data obtained from BMD

Based on the chart above, it can be inferred that during the peak summer months (from March to June), 7 of the 22 years (i.e., 2010, 2012, 2014, 2016, 2017, 2019 and 2022)

had more than 51% of the days (more than 60 days on average) the HI exceeded the extreme danger level (i.e.,  $HI \geq 55$ ).

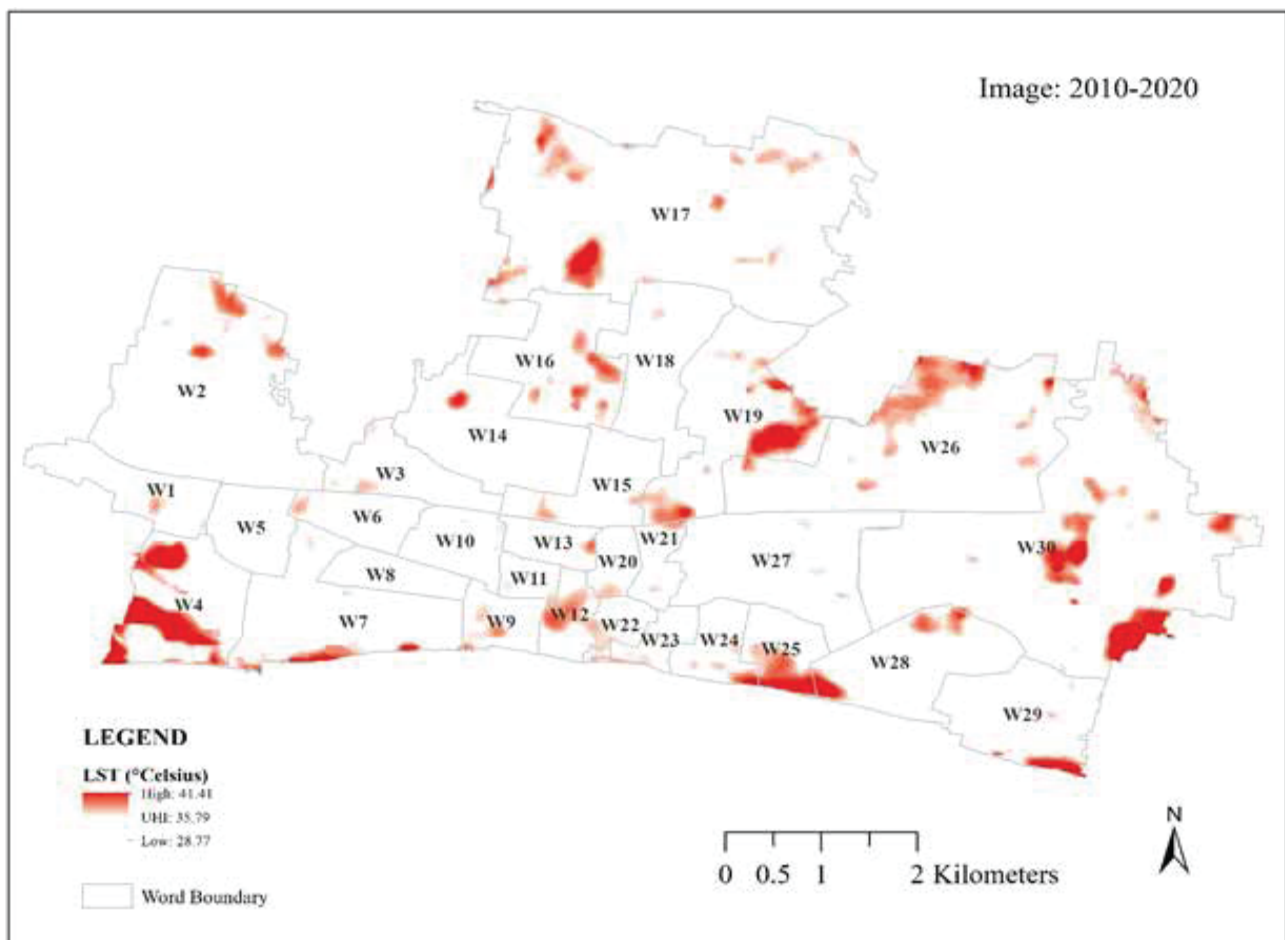
## 7.2 Heat Island

Heat island, also known as Urban Heat Island (UHI), refers to locations or regions that have elevated temperatures compared to the surrounding areas (Jabbar et al., 2023). This temperature difference arises from factors like concentrated heat release from buildings, vehicles and industrial activities. The presence of built-up structures such as roads, buildings and pavements contributes to the absorption of heat during the day, which is then released at night, ultimately raising the overall temperature of the city.

Individuals who work outdoors or on the ground, roofs or roads, as well as those residing in slums or on the streets, are particularly susceptible to the adverse effects of UHIs.

To detect urban heat islands, the land surface temperature (LST) of Rajshahi was analysed using satellite images (refer to Section 11.3 for LST calculation specifics).

**Figure 13: Heat Island with ward boundary of Rajshahi City (RCCC, 2022)**

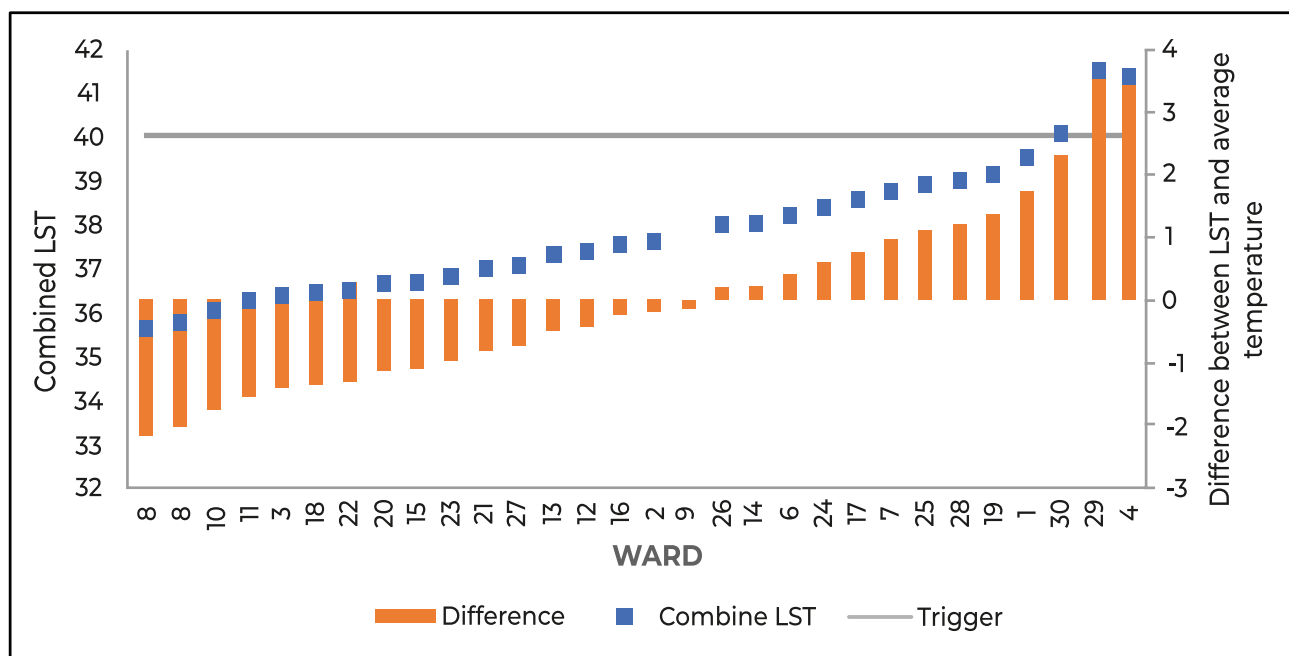


Source: Subedi et.al, 2022.

The above figure shows the LST from 2010 to 2020 which indicates that specific city wards (ward numbers 4, 7, 19, 25, 28, and 30) experience more heat hotspots with elevated temperatures than other wards. This could be attributed to various factors such as the dense concentration of built-up structures, the conversion of water bodies into developed areas, the minimal vegetation cover, and the proximity of char land, especially in wards 7 and 25 (Subedi et.al, 2022).

Further, to quantify the UHI effect, we compared the LST of combined wards from 2010 to 2020 and a trigger threshold of 40°C . The trigger threshold of 40°C was selected based on its relevance to human health and safety in Rajshahi (Section 6)<sup>5</sup>. This analysis will help indicate the temperature difference between the urban and rural areas and help identify areas that consistently experience temperatures above the threshold. The following figure shows the UHI effect.

**Figure 14: UHI effect**



*Source: Author's illustration based on data obtained from Landsat satellite images.*

Based on the graph, it is evident that certain wards, such as wards 4, 29, and 30, are experiencing significantly higher levels of urban heat and can be classified as particularly hot. These wards have been identified as high-priority areas for interventions to reduce the UHI effect. The mean difference from the average temperature (of combined LST, which is 36.5°C) is also shown in Figure 18, which represents the degree to which the temperature of a particular

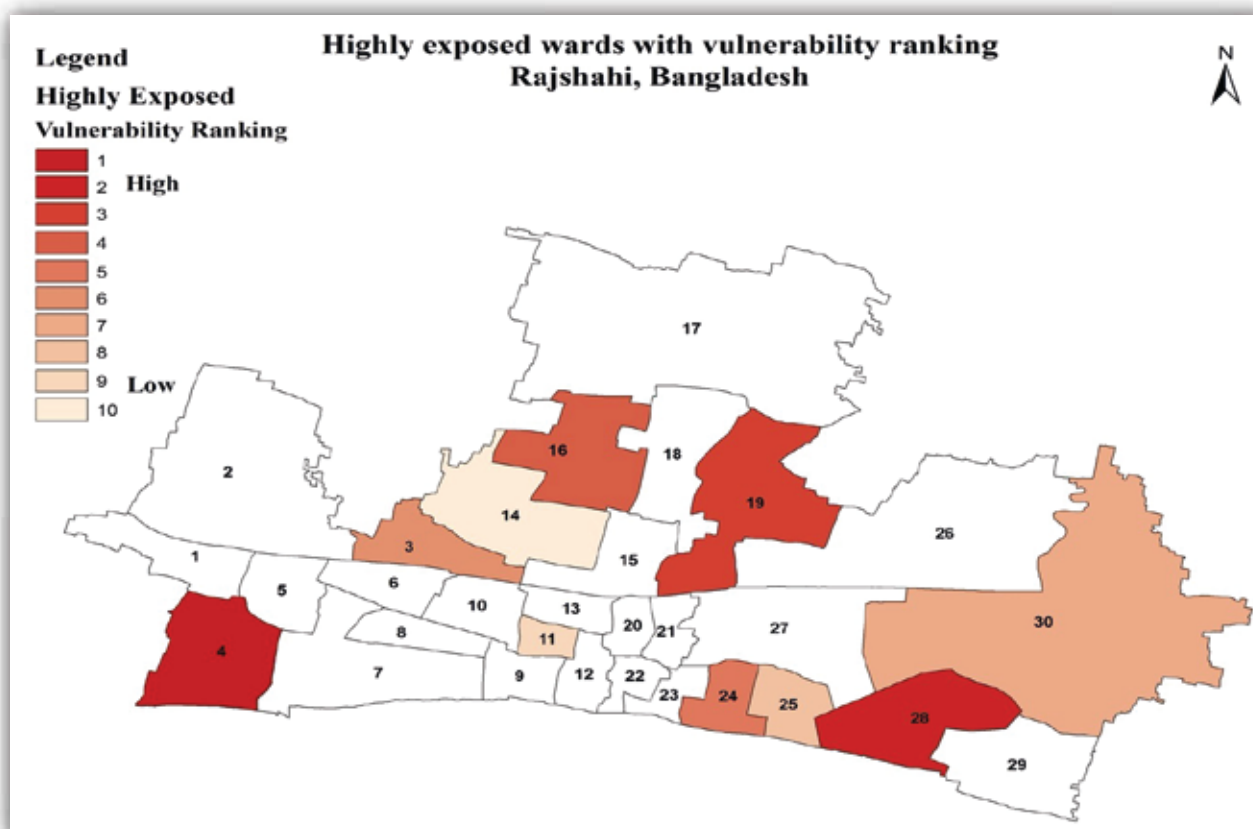
ward deviates from the typical temperature for that region.

Furthermore, a vulnerability ranking in the highly exposed wards has been conducted to determine their degree of vulnerability. As a result, depending on available resources and capacity, the respective city authority and other emergency service providers can prioritise actions before or during a heatwave that are indispensable if a heatwave reaches the threshold in Rajshahi.

<sup>5</sup> The significance of choosing 40°C as a threshold is explained in Section 5.3.



**Figure 15: Highly exposed to heatwave wards with vulnerability ranking**



Source: Author's illustration (adopted from the Subedi et.al, 2022).

The analysis interprets that ward 4,16,19 and 28 are highly vulnerable, followed by wards 24, 3, 30, 25, 11 and 14. It suggests that in addition to the preparedness measures for imminent heatwaves or actions during a

heatwave, long-term and policy-level interventions to reduce urban heat risks are also critical, especially in wards 4, 28, 19 and 24.

### 7.3 Stages of Trigger for Activation of Early Action

Triggers are determined by two factors: one is an extreme event (based on temperature), and the other is a potential impact (based on heat index). The following two-stage triggers have been proposed for anticipatory action of heatwave in Rajshahi City:.

**1. Pre-activation trigger<sup>6</sup>:** This trigger will be activated 5-7 days before the expected heatwave event. The criteria for this trigger are:

- Forecast temperature likely (>50% chance) to exceed 40°C and anticipated to remain more than 5 days,
- Heat Index (HI) likely (>50% chance) to cross 55.

**2. Activation trigger:** This trigger will be activated 2-3 days before the expected heatwave event<sup>7</sup>. The criteria for this trigger are:

- Forecast temperature highly likely (>75% chance) to exceed 40°C and remain above for 5 days,
- Heat Index (HI) is highly likely (>75% chance) to cross 55

These two-stage triggers will help in taking anticipatory measures in advance to mitigate the potential impact of the heatwave on the city and its inhabitants.

<sup>6</sup> When the pre-activation trigger conditions are met, it serves as an early warning that a potential heatwave is on the way. At this point, precautionary measures can be taken to prepare for the heatwave's potential impact, especially by relevant authorities and stakeholders.

<sup>7</sup> If the pre-activation trigger is met but the activation trigger is not, it indicates that the risk level has not risen to the level of a highly likely heatwave event. In such cases, authorities or relevant stakeholders can continue to closely monitor the situation and maintain a high level of preparedness. They might think about taking some precautionary measures instead of launching full-scale actions reserved for the activation trigger.

Heatwaves have wide-ranging social, physical, and economic consequences on human life and livelihood. Studies have shown that the impact is more pronounced in communities based on age, physical disabilities, and financial condition. Individuals living below the poverty line are at a greater risk of suffering from the heatwaves due to inadequate access to essential services such as healthcare, housing, and infrastructure (i.e., electricity, water, etc.). Therefore, understanding the impacts and interventions required

during heatwaves is critical for alleviating people's suffering. The following section represents the impacts and needs mentioned by the people who have been interviewed and the analysis of the collected information based on the FbF and AA criteria. Furthermore, it suggests feasible interventions considering the capacity, costs, benefits, etc. through multi-criteria decision-making using AHP (Analytical Hierarchy Process).

## 8.1 People Who Are Disproportionately Affected by Heatwave

Heatwaves have a disproportionate impact on certain groups of people, including those who are outdoor workers, the elderly, children, pregnant women, individuals with chronic medical conditions, and those who are economically disadvantaged. Heatwaves are mostly hard on people directly exposed to the sun and face extreme temperatures, like manual labourers. The weather directly affects their income as their livelihood depends on their work outside.

Elderly individuals, for instance, are more susceptible to heat-related illnesses due to age-related changes in the body's thermoregulatory system, decreased thirst sensation, and chronic medical conditions. Similarly, children may be more vulnerable to heatwaves due to their smaller body size and greater heat production than adults (559 million children are currently exposed to high heatwave frequency and expected to impact all global child population of 2.02 billion by 2050, n.d.).<sup>8</sup> Pregnant women may also be at greater risk due to the physiological changes that occur during pregnancy, making it more difficult for the body to regulate

temperature. Individuals with chronic medical conditions related to heart, respiratory system, or diabetes, are at increased risk of heat-related illnesses due to their underlying health conditions. Furthermore, poor people are more likely to work in the outdoor environment and lack access to cooling facilities (housing and other amenities), which increases their health risk from heat stress and makes them vulnerable to heatwaves. School students are also vulnerable to heatwaves as they are more exposed to outside due to their education curriculum and most school infrastructure accommodates large numbers of students with fewer facilities

Based on the position above and previous studies, five groups were identified for further analysis, which are elderly, disabled and chronically ill people, outdoor workers, pregnant women or lactating mothers, individuals residing in slums and school students as these groups of people are disproportionately affected by heatwaves.

## 8.2 Critical Impacts Due to Extreme Heat on the Vulnerable Groups

To develop effective interventions, it is crucial to understand the critical impacts heatwaves have on vulnerable groups. The previous approach identified areas that are particularly susceptible to heatwaves analysing the heat island, land surface temperature vulnerability index etc. where factors such as socioeconomic status, physical vulnerability, and capacity were prioritized. Based on that analysis, we

selected the wards that are heatwave hotspots to identify the impacted groups for our focus group discussions (FGDs). During these FGDs, we recorded information about each group's experiences, the impacts they faced, their local adaptation processes, and suggested interactions. Each group was found to have critical impacts, and the following information will inform our efforts to develop effective interventions.

<sup>8</sup> <https://www.unicef.org/press-releases/heatwaves-report>

### **8.2.1 Outdoor Workers**

Individuals who work outdoors are particularly vulnerable to heat-related health issues, such as headaches, dizziness, breathing difficulties, dehydration, and high blood pressure. These symptoms can manifest as early as the first day of a heatwave and can become more severe over time. In addition, outdoor workers often lack access to drinking water while on the job. As their income is directly tied to the weather

conditions, extreme weather can significantly reduce their earnings, with income dropping by as much as 50-60% during a heatwave. This financial strain can exacerbate their vulnerability, leading them to take out loans to cover their basic needs and forego necessary medical care. Overall, the combination of physical and financial stressors places outdoor workers at heightened risk during heatwaves.

### **8.2.2 Elderly, Chronically Ill, Disabled Person**

The elderly, chronically ill, and disabled individuals are especially vulnerable during heatwaves as the extreme heat exacerbates their health conditions such as blood pressure, hypertension, asthma, and other illnesses like mental illness. Additionally, elderly people's bodies are unable to resist heat. They typically spend most of their time at home, but their living conditions can worsen as their houses may lack heat resistance and often have roofs of sheets of tin that make the indoors unbearable on a hot day. Additionally, power outages are more frequent during heatwaves, making it even more challenging for them. These individuals mostly have to

depend on others for their daily needs, including food and medical care, which can become significantly challenging during the heatwave period given the financial strain on the family members that they are dependent on. Ultimately, the combination of pre-existing health conditions, inadequate living conditions, and limited resources make the elderly, chronically ill, and disabled individuals highly vulnerable to the impacts of heatwaves, especially medications that reduce the body's ability to thermoregulate.

### **8.2.3 Poor Communities Residing in the Slums**

The community group included individuals living in slums below the poverty line, for whom we conducted FGDs. These individuals reported that their living conditions were extremely poor, with most of their housing made of sheets of tin and bamboo which offer little protection from the heat. The lack of ventilation in

their kitchens makes it difficult to cope with the heat. Moreover, with their low income, paying high electricity bills puts additional financial strain on them. These individuals tend to avoid seeking medical care as much as possible due to the high cost of hospital visits, which can exceed 2000-3000 BDT per visit.

### **8.2.4 Pregnant Women, Lactating Mothers and Children**

Pregnant and lactating women reported experiencing a range of health issues during heatwaves, including sickness, vomiting, loss of appetite, skin diseases and headaches. They also reported feeling fatigued easily, while their children often fall ill with various illnesses such as fever, diarrhoea, and vomiting. New-born babies and little children have limited capacity to resist heat. To make matters worse, families often prioritize medical

expenses over food, compromising the mother's and child's nutritional needs. Many of these women are not well-informed about the precautions that can help reduce the impacts of heatwaves. Additionally, those from low-income families often lack access to drinking water and heat-resistant housing materials, which makes their living conditions even more unbearable.

### **8.2.5 School Children**

During heatwaves, students struggle to concentrate on their lessons, and their study time is often reduced. They also tend to perform poorly on exams during this time. Although many students fall sick during morning assemblies, schools do not have an adequate medical backup to deal with these situations. As a result, sick

students are usually sent back home. Schools often lack basic amenities such as electric fans, steady power supply, cold-water filters and additional rooms to deal with the heatwaves. All of these factors significantly impact the well-being of the students.

### 8.3 Heat Stress Concerning Livelihoods and Other Aspects of Social Life

Heat stress can have social and indirect impacts that extend beyond financial or medical losses, and it is important to examine these impacts. The following are some of the significant effects on the livelihoods and social lives of the people:

- During heatwaves, vulnerable groups may overlook their health issues and avoid seeing a doctor due to the expense of medicine and tests, leading to more severe health problems and diseases.
- Financial constraints on vulnerable groups may force them to sacrifice their food requirements for medical expenses, and the reduction in income due to the heatwave can lead to malnutrition.
- Extremely low-income families may prioritize three meals a day over study requirements, which can harm their educational outcomes.
- Income reduction and increased medical expenses can lead to debt, pushing people with

low income further into poverty and vulnerability.

- The physical and mental growth of the children is harmed, leading to their developmental deficiencies.
- Students may experience a lack of concentration and reduced productivity during this time.
- Women may be unable to leave their homes due to safety concerns, even if their houses become extremely hot, leading them to suffer from power outages and high indoor temperatures.

So, the impacts of heat stress go beyond just financial or medical losses. Vulnerable groups are particularly susceptible to indirect impacts such as reduced productivity, malnutrition, indebtedness, loss of quality of life, etc. Addressing these social impacts is crucial in developing effective strategies to mitigate the effects of heat stress and build more resilient communities.

### 8.4 Suggested interventions by the vulnerable groups

The impacts and interventions mentioned and suggested by each group during FGDs have been identified and ranked as per their preference (individual tables are in Annex 11.5 section). The summarized version from the individual groups is the following matrix (Table 6) mentioning the interventions by the vulnerable groups that they proposed during FGDs. The number represents the number of groups who mentioned these impacts as well as suggested

that particular intervention. The ranking of the interventions also classifies the interventions which may be considered for Anticipatory Actions (AA) and other ones that may be defined as long-term preparedness DRM programmes. Furthermore, some interventions are also classified as AA and DRM both. The anticipatory actions are the actions which are feasible and effective actions after the impact forecast and event i.e., within the lead time.





## 8.5 Analysis of the proposed interventions

The findings from focus group discussions (FGDs) and key informant interviews (KIIs) have been utilised.

**Table 7: Analysis of the proposed interventions based on cost, lead time and institutional capacity**

| Sl. | Interventions                   | Cost                                                                                                                                                                                                                                                                                 | Lead Time | Institutional Capacity (BDRCS' Experience) | Rationale and source                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | Medical Camp with free medicine | 50,000 BDT for medicine (considering a camp is set for 10 days only during a heatwave and serves about 50 people daily with 100 Tk worth of medicine per person).<br>150,000 BDT for a tent of about 450 sq ft. to accommodate 50-70 people for the medical camp and cooling centre. | 2-3 Days  | H (Yes)                                    | The medical symptoms generally appear after 2-3 days of a heatwave. This intervention can be taken after the start of a heatwave, preferably within 3-days of the start of a heatwave, considered as an early action. The camp should be planned to continue for at least 5 days from the first day of the setup to help the affected people.<br>In Dhaka EAP, they have an MoU with BMD and executed 7-14 medical camps, so they simulate the IC material.<br>Common health issues like increased blood pressure, skin rashes, gastric issues, etc. were mentioned in the FGDs. A 100 BDT worth of medicines per person is approximately enough to treat such health issues.<br>(15 Feet by 30 Feet Customized Tent, n.d.) |
| 2.  | Financial support               | 2500 BDT per family during a heatwave period                                                                                                                                                                                                                                         | 2-3 Days  | H (Yes)                                    | On average, families of 4-5 members are found to take loans for the same amount in a heatwave period due to reduced income. As an early action, before the start of a heatwave, unconditional cash support of this amount would save them from the credit burden.                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 3.  | Solar fan or charger fan        | 7,500-20,000 BDT worth of solar panels per household for supporting one or two fans or lights.<br>4,000-5,000 BDT per charger fan                                                                                                                                                    | 1 Day     | M (Yes, but small-scale interventions)     | Although there is strong evidence found about the harmful effects of a fan during a heatwave when the indoor temperature gets higher than 35°C (Fraser Health 2022), a charger fan or solar fan was a popular suggestion among the FGD participants. One fan per family would be enough (Daraz, n.d.) (Solar Panel Price in Bangladesh, n.d.). This intervention should be taken early for vulnerable groups considering as a preparatory action for an upcoming heatwave                                                                                                                                                                                                                                                   |

|    |                                                                                                   |                                                                                                                          |          |                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4. | Prior alerts through the Miking system                                                            | 1000 BDT per day rent for sound system                                                                                   | 1 Day    | H (Yes)                                                                                             | <p>This intervention should make the public aware of an ongoing heatwave and the precautionary measures. It should be taken before and during a heatwave so that vulnerable people can take measures themselves for protection from the negative impacts.</p> <p>For that, sound systems can be used for miking and placed on vehicles like rickshaws and auto-rickshaws, which cost around this amount.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 5. | Establishing tube wells for drinking water                                                        | 1,00,000-2,50,000 BDT based on various factors                                                                           | 2 Days   | H (Yes)                                                                                             | <p>The participants in the FGDs mentioned deep tube wells in their respective areas to provide safe and cold water for consumption, which can be considered an early (preparedness) action and needs to be performed only once.</p> <p>In the cited document they mention the price of installing a tube well. The cost varies according to the depth, soil condition, labour cost etc. ([No Title], n.d.)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 6. | Cooling space                                                                                     | 10,000-15,000 BDT air cooler inside tents. Electricity cost can be 200-300 BDT per day for a 150-300 watt single cooler. | 3-5 Days | L (New intervention - Vans are difficult in terms of accessibility, so tents are suggested instead) | <p>Tents with air coolers is a feasible approach, suggested by the participants, to create a cooling space or centre for the people nearby. This should be set up early which may take 3-5 days to set up as a preparedness action for an upcoming heatwave. An air cooler would be enough to sufficiently cool a tent and it's a low-cost feasible intervention. (Vision, n.d.)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 7. | Attach board as a false ceiling under the tinned roof and modify kitchens for better ventilation. | 14,000 BDT for a single household (400 sq. ft)                                                                           | 5-7 Days | L (New intervention)                                                                                | <p>Houses that have roofs with sheets of tin get very hot inside during the daytime, especially on a hot day when the inside temperature gets higher than the outside. Attaching a false ceiling is a viable option to prevent this occurrence as it'd prevent the heat, produced by the hot tin sheet, from entering the house directly.</p> <p>Also, the kitchens of poor households are very small and lack ventilation. As a result, heat produced during cooking time can't escape. Modifying existing kitchens of those people with improved ventilation systems will help them, especially the women of the household. This intervention should be taken before an anticipated heatwave as preparedness action, particularly in vulnerable areas.</p> <p>False ceiling materials cost 28 BDT per sq. ft., and an estimated total cost is about 14,000 BDT (pwd, n.d.) per household, inclusive of the labour cost.</p> |

|    |                                                     |                                                                                                                                                |          |                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|----|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8. | Cooling space & cooling water filter in the schools | 25,000 BDT per water filter with cooling function (with 3-litre cold water per hour capacity).<br>100 Tk/ month electricity cost for extra fan | 1-2 Days | L (New Intervention) | This intervention was mentioned by the school students. Some schools have safe drinking water without a cooling function, some schools don't even have a water filtration system. In schools with only a water filtration system, water gets very hot in the water container or the water line during heatwaves. Therefore, water filters with both purification and cooling functions solve every school's drinking water problem and can give the students relief during a heatwave. The price of installing that is sourced from this website (Hot / Cold / Warm Auto Water Purifier Dispenser Price in Bangladesh, n.d.) |
|----|-----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Source: Author's illustration based on data obtained from BDRCS and Various websites for price.

\*\*\* (Institutional Capacity Scale; H= High, M=Medium, L= Low)

This table gives the whole idea about cost, lead time and institutional capacity.

This study also analyses tentative cost and benefit estimation based on KII and secondary sources for the GRC/BDRCS to make decisions on selecting the intervention. Besides, this analysis has been used in the AHP present the cost obtained from Table 7 and the

direct and indirect benefit of the proposed interventions. This cost is collected from KII with some of the people from FGD, the approach was more like a qualitative approach, not a rigorous action.

**Table 8: Cost-benefit analysis of the interventions**

| Sl. | Interventions                             | Cost                                                                                                                                                                                                                                                                           | Direct Benefit                                                                                                                                                                                             | Indirect Benefit                                                                                                                               |
|-----|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | Medical Camp with free of charge medicine | 50,000 BDT/10 days (considering a camp is set for 10 days only during a heatwave and serves about 50 people daily with 100 Tk worth of medicine per person)<br>150,000 BDT for a tent of about 450 sq ft. to accommodate 50-70 people for the medical camp and cooling centre. | 1500 BDT/season<br>Their medical expense varies from 2000-5000 BDT and accessible medical help reduce upcoming bigger problems                                                                             | 1000 BDT/week; reduction of income due to sickness during heatwave will be reduced.<br><br>1000 BDT/week; they won't be required to take loans |
| 2.  | Financial support                         | 2500 BDT per family during a heatwave period                                                                                                                                                                                                                                   | 2000+1000 BDT/season worth benefits to the family.<br>Health issues will be reduced, medical expenses will be reduced, and they won't be required to take loans for health causes or income reduction etc. | Income reduction due to illness will reduce                                                                                                    |

|    |                                                                    |                                                                                                                                   |                                                                                                                                    |                                                                                                                                                                                                                                                                                    |
|----|--------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 3. | Financial Help (food, fruits, and others)                          | 2500 BDT per Family during Heatwave                                                                                               | 4500 BDT/week; they won't be required to take loans, they are not required to pay the interest, compromise their food baskets etc. | 1000 BDT/season; health condition improvement,                                                                                                                                                                                                                                     |
| 4. | Solar fan or charger fan                                           | 7,500-20,000 BDT worth of solar panels per household for supporting one or two fans or lights.<br>4,000-5,000 BDT per charger Fan | 3000 BDT /season; worth of medical expenses may be reduced; they are not required to compromise their food basket                  | 150 BDT/day worth; income reduction won't occur Because they mentioned that when they get sick, they cannot work which causes this amount of loss. So, During the season, they can get about 1500 BDT worth of benefits.                                                           |
| 5. | Prior alerts through the Miking System                             | 1000 BDT per day rent for a sound system.                                                                                         | 2000 BDT/ per family. They can be prepared for upcoming days. Can take precautions, thus their health issues may get less severe.  | Fewer health issues mean less income reduction.                                                                                                                                                                                                                                    |
| 6. | Establishing Tube wells                                            | 1,00,000-2,50,000 BDT based on various factors                                                                                    | 6000 BDT / season Improve access to drinking water,                                                                                | Their health issues like dehydration and water-borne diseases will reduce due to quality full drinking water, income reduction will reduce.                                                                                                                                        |
| 7. | Attach Board under Tin-roof and improve ventilation of the kitchen | 14,000 BDT for a single household (400 sq. ft)                                                                                    | 3000 BDT/ season worth saved due to Health issues reduction and quality of life will increase.                                     | They get sick due to extreme heat, some of them deliver food, and outdoor workers also get sick because they cannot rest properly when they are at home. So if this intervention can reduce those sufferings, it may increase their income                                         |
| 8. | Cooling Space & Cold-water filter in the school                    | 25,000 BDT per water filter 3 Liter cold water/ hour<br>100 Tk/ month electricity cost for extra Fan                              | 11000 BDT/ season being sick due to extreme heat in the school.                                                                    | Loss of concentration and attendance in the school will be reduced. as well as the incidents of heat stroke in school may not happen. Also, Most students who feel senseless during a heatwave will get relief through this intervention.<br>1000 BDT worth of benefit indirectly. |

Source: Author's illustration based on data obtained from FGDs

All the information discussed in the previous parts needs to be summarized based on which experts scored the interventions considering which one is more important in comparison to others and the criteria to be considered are social acceptability, institutional capacity, technical feasibility and positive economic returns. The positive economic return needs to be considered to see if an intervention benefits the beneficiaries more than the cost of execution. For this, the benefit-cost ratio is calculated by summing up all direct and indirect benefits to be divided by the total cost. The positive value represents that it has a positive economic return. After this pair-wise ranking (Annex:

12.2), the AHP was used to rank the interventions. Only feasible interventions (Table 9), based on the expectation of vulnerable groups and FbF/AA, were proposed for the AHP ranking. The proposed interventions are medical camp and free medicine, financial help, providing prior warning, cooling space, solar fan or charger fan, retrofitting heat-resistant materials such as boards to be attached under tin-roof, cooling room, and cold-water filter for school. The following table is the compiled version of the previous information (Table no: 6,7,8) and benefit-cost ratio: (Table 9)

**Table 9: Compiled information on the criteria defined for AHP**

| Criteria and Reference                        | Unit                                                                              | 1.<br>Medical Camp and Free Medicine | 2.<br>Financial Help   | 3.<br>Prior Warning | 4.<br>Colling Space   | 5.<br>Solar Fan or Charger Fan                               | 6.<br>Attach Board Under Tin-Roof | 7.<br>Colling room & Cold-water filter for school |
|-----------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------|------------------------|---------------------|-----------------------|--------------------------------------------------------------|-----------------------------------|---------------------------------------------------|
| Socially Acceptable (Demand bashed)           | Number of FGD                                                                     | 12                                   | 11                     | 10                  | 8                     | 11                                                           | 8                                 | 2                                                 |
| Technically Possible (Time requirement)       | Day                                                                               | 3                                    | 2.5                    | 1                   | 4                     | 1                                                            | 6                                 | 1.5                                               |
| Institutionlly Capable (previous experience)  | H= High, Have Experience<br>M= Medium, In small scale<br>L= Low, New Intervention | H                                    | H                      | H                   | L                     | M                                                            | L                                 | L                                                 |
| Positive Economic Return (benefit-cost ratio) | Tentative BC ratio per Family                                                     | $(1500+2500+1000+1000)/2000=3$       | $(4500+1000)/2500=2.2$ | $2000/1000=2$       | $3000/(15300/20)=3.9$ | $4500/(4000/3)=3.37$<br>(Charger fan)<br>$4500/(7500/6)=3.6$ | $3000/(14000/10)=2.14$            | $2000/(25,000/15)+100=2.13$                       |

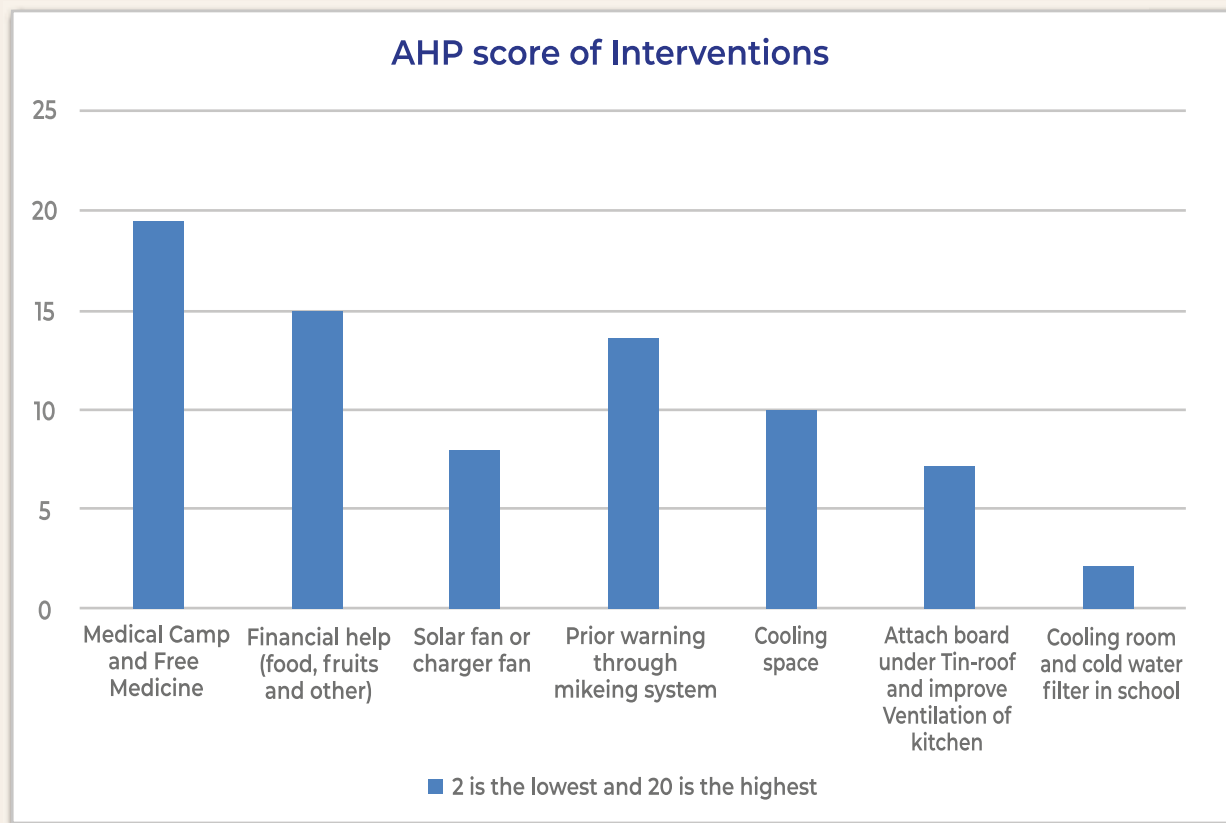
Source: Author's illustration based on previous tables and calculation

The scores of each matrix have been calculated with the weightage of each criterion and row average of

each intervention and finally, the AHP score is obtained and presented in a bar chart (Figure 16) below:



**Figure 16: AHP score of each intervention**



*Source: Author's illustration from AHP ranking score*

## 8.6 Detailed analysis for the execution of the proposed early actions

The following table represents the extensive costs per intervention, volunteer requirements, and the number of people who will benefit from the intervention. This will help GRC, BDRCS and local authorities to make decisions regarding executing the interventions.

In the previous study, of RCCC about identifying heatwave hotspots of Rajshahi, four vulnerable wards have been identified. On average, according to the registered voter list, among the 20,000 households

2300 households in each ward have an income below the poverty level. To address these conditions, 10-12 camps combined with medical camps and cooling spaces are proposed for those four wards within a close proximity of the communities. The scale and number can be re-evaluated based on the requirements of the beneficiaries considering the economic conditions and the locations.

**Table 10: Total Cost, Volunteer Requirements, and Beneficiaries**

| SI. | Interventions                                                                             | AHP Score | Volunteer Requirements       | Total Cost per Intervention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Beneficiaries (Total Population)              |
|-----|-------------------------------------------------------------------------------------------|-----------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| 1.  | Medical Camp and Free Medicine for 50-70 people per camp. Total around 10-12 camps        | 19.52     | 3-4 Volunteer for each camp: | <ul style="list-style-type: none"> <li>• 250 sq Tent in total 12 camps: <math>75,000 \times 12 = 900,000</math> BDT (one-time cost)</li> <li>• Medicine cost for 50 people each day for 5 days <math>50 \times 12 \times 5 \times 100 = 300,000</math> BDT</li> <li>• Cost of the fan using a generator: <math>3000 \times 12 = 36,000</math> BDT</li> <li>• Drinkable water facility cost: <math>50 \times 5 = 250</math> liter; <math>13 \times 50 \times 12 \times 5 = 39,000 + 1000 = 40,000</math> BDT</li> <li>• One duty doctor Cost: <math>3000 \times 12 = 36,000</math> BDT</li> <li>• One medical Assistant Cost: <math>1000 \times 12 = 12,000</math> BDT</li> <li>• Volunteer cost: <math>500 \times 4 \times 12 = 24,000</math> BDT</li> </ul> |                                               |
| 2.  | Unconditional Cash Grant of 2500 BDT per household in the slums                           | 15.06     | 10-15                        | <ul style="list-style-type: none"> <li>• Women Headed Vulnerable Households in four communities:</li> <li>• <math>2500 \times 8,000 = 20,000,000</math> BDT per Season</li> <li>• Volunteer cost: <math>15 \times 500 \times 2.5 = 18,750</math> BDT</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                               |
| 3.  | Prior Warning in all four vulnerable communities                                          | 13.72     | 2 Volunteer per community    | <ul style="list-style-type: none"> <li>• Miking cost in four communities for 3 days: <math>8000 \times 4 \times 3 = 96,000</math> BDT</li> <li>• Cost of volunteering for miking in the community <math>8 \times 500 = 4,000</math> BDT</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | $2000 \times 4 = 8,000$ households per season |
| 4.  | Cooling Space in all four vulnerable communities                                          | 9.98      | 3-4 Volunteer for each camp  | <ul style="list-style-type: none"> <li>• Cooler cost in 12 Camps: <math>15,000 \times 12 = 180,000</math> BDT (one-time cost)</li> <li>• Electricity cost for 6 days: <math>500 \times 12 \times 6 = 36,000</math> BDT per season</li> <li>• Drinkable Water facility cost: <math>50 \times 5 = 250</math> liter; <math>13 \times 50 \times 12 \times 5 = 39,000 + 1000 = 40,000</math> BDT</li> <li>• Volunteer Cost: <math>500 \times 4 \times 12 = 24,000</math> BDT</li> </ul>                                                                                                                                                                                                                                                                           | 40,000 people per season                      |
| 5.  | Solar Fan or Charger Fan for each low-income household in all four vulnerable communities | 8.09      | 10.15                        | <ul style="list-style-type: none"> <li>• For Lactating mother of four vulnerable communities; <math>5000 \times 200 \times 4 = 4,000,000</math> BDT (one-time cost)</li> <li>Volunteer Cost: <math>15 \times 500 = 7,500</math> BDT</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | $200 \times 4 = 800$ households per season    |
| 6.  | Attach Board under Tin-roof for each low-income household in all four communities.        | 7.21      | 10.15                        | <ul style="list-style-type: none"> <li>• Only for households having elderly and disabled people <math>14,000 \times 150 \times 4 = 8,400,000</math> BDT (one-time cost)</li> <li>• Volunteer Cost: <math>15 \times 500 \times 7 = 52,500</math> BDT</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | $150 \times 4 = 600$ households per season    |

|                    |                                                                                  |      |     |                                                                                                                                                                                                              |                 |
|--------------------|----------------------------------------------------------------------------------|------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| 7.                 | Cooling room and Cold-water filter in 12 Schools of four vulnerable communities. | 2.13 | 3-4 | <ul style="list-style-type: none"> <li>• Extra Fan, electricity and Cold-water filter cost for each school: 25,000*12 = 300,000 BDT (one-time cost)</li> <li>• Volunteer Cost: 500*12 = 6,000 BDT</li> </ul> | 12,000 students |
| <b>Total Cost=</b> |                                                                                  |      |     | <b>21,466,750 BDT</b>                                                                                                                                                                                        |                 |

Source: Author's illustration based on field survey

\*\*\*[1-3 intervention = high priority, 4-7 intervention= medium priority]

### 8.6.1 Proposed Interventions for First-stage Execution

Resources are limited as well as execution of many interventions can be mismanaged so phase phase-wise approach will be efficient for achieving the goal. Considering the cost, volunteer requirements and beneficiary conditions, three actions are proposed as high priority and as a first-stage intervention:

1. Set up medical camps with free-of-cost medicine
2. An unconditional cash grant of 2500 BDT per household in the slums
3. Provide prior warning in all four vulnerable communities.

Criteria like social acceptability, technical feasibility, institutional capacity, and positive economic return were also considered while determining these three interventions to be a high priority for the 1st stage. The 2nd stage should be started after building the capacity and awareness through the prior stage, for which four interventions are proposed:

1. Set up cooling space for vulnerable communities
2. Solar fan or charger fan distribution to most vulnerable households
3. Modify houses by attaching false ceilings under the roofs with sheets of tin.
4. Establish cooling rooms and water cooling filters in schools

These interventions haven't been explored in detail while preparing this report.

A brief plan for executing each intervention in the 1st stage is described below:

**Medical camp and free medicine:** Establishing 10-12 medical camps in suitable locations in proximity to the four vulnerable wards targeting 50-70 people per camp

is a suitable plan for this intervention. It can be arranged for five days starting on the 1st day of the heatwave. The second or third day is usually the threshold for tolerance mentioned by the vulnerable groups when they start to feel sick and have symptoms of diseases, as mentioned by the participants of the FGDs. A 250 sq feet tent for the camp would be enough to serve 50 to 70 people each day. In those tents, an electric fan with a generator for electricity and a drinkable water facility will be available. One duty doctor and a medical assistant are proposed along with three to four volunteers per camp to handle the crowd and distribution of facilities. As a result, this intervention will be able to help 3000-5000 people per activation.

**Unconditional Cash Grant of 2500 BDT per household in the slums:** During FGDs, the participants emphasized that they are forced to take loans from money lenders at high interest rates due to their reduced income during heatwave periods. These loans amount to about 2000-2500 BDT to support their daily family needs. As these groups of people live on daily earnings, a reduction in work hours or not being able to work due to illnesses causes them to sacrifice their daily meals. An unconditional cash grant will be a great relief for them to prevent them from the burden of debt. Women-headed families are proposed as the primary target group due to their high concern for the nutrition needs of their children. On average, 2000 households can be reached in each vulnerable ward and 10-15 volunteers would be required to support this intervention. This intervention should be initiated before a heatwave.

**Prior Warning in all four vulnerable communities :** A prior warning that makes them aware of the upcoming heatwaves and precautionary measures they could take can reduce their suffering. Spreading the information using a miking system on vehicles around

the communities is the most suitable system at the local level. Similar activities were taken by the NESCO or WASA as per the response from the participants during FGDs. Word of mouth is found to be very common among these communities as they share this kind of information with other who misses it. Miking should start three days before a heatwave is anticipated to start. Each community would require two sets of miking systems in a vehicle and two volunteers on each vehicle. This low-cost intervention will benefit not only the people with low incomes but also all people from all economic classes to prepare for the upcoming heatwaves.

## 8.7 Key Actors for AA Project Implementation

The roles of the different actors are critical for the Anticipatory Actions (AA) in general and heat actions in particular. These actors can extensively support limiting the adverse impact of heatwaves, building the resilience of individuals, and enhancing the adaptation capacity of the communities. The roles and responsibilities of stakeholders should be clearly defined, with no overlapping duties. Therefore, all the pre-identified stakeholders are divided into three groups - Primary, Secondary and Tertiary actors.

The primary actor is the foremost institution responsible for leading the implementation of the proposed early actions. Each respective institution will also lead in communication and coordination with other stakeholders to roll out the early actions for the targeted communities.

Ideally, two or a maximum of three institutions can be considered secondary actors who will take a critical role in supporting the primary actor to implement the proposed early actions. They can collaborate with the primary actors to provide support in terms of technical, resources and other administrative facilitation to ensure all the targeted groups get the benefits effectively.

The tertiary actors can be anyone who can collaborate with the team consisting of primary and secondary actors by providing support related to various facilitation and knowledge sharing, monitoring and evaluation, and leveraging additional resources to scale up the operations by ensuring successful implementation of the respective early actions. The tertiary actors are integral groups for effectively implementing the early actions.

Based on the outputs from the KIs and stakeholders' validation workshop, the below table showcases how the different actors can take accountability to formulate the AA for the heatwave in Rajshahi City:

**Table 11: Actor Analysis for effective implementation of the AA for heatwave in Rajshahi**

| Sl. | Early Actions                                        | Primary Actor                                                          | Secondary Actors                                                                                                                                                                                   | Tertiary Actors                                                                                                                                                               |
|-----|------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | <b>Medical Camp with Free Medicine</b>               | Rajshahi City Corporation (health department)                          | <ul style="list-style-type: none"> <li>• Civil Surgeon office, Rajshahi Medical College &amp; Hospital,</li> <li>• BDRCS</li> </ul>                                                                | BDRCS, WHO, UNICEF, DMC, WDMC and Other NGOs, Information Department, Directorate General of Health Services, Local Government                                                |
| 2.  | <b>Cooling Space/shelter</b>                         | Rajshahi City Corporation (Secretariat and Engineering Department)     | <ul style="list-style-type: none"> <li>• BDRCS,</li> <li>• District Relief and Rehabilitation Office (DRRO)</li> <li>• Ward Disaster Management Committee (Standing Orders on Disaster)</li> </ul> | Engineering Department (Rajshahi City Corporation), Rajshahi Development Authority, Northern Electricity Supply Company Limited, Rajshahi Development Authority, WASA, UNICEF |
| 3.  | <b>Financial Help (for food, fruits, and others)</b> | Rajshahi City Corporation (Secretariat department, Revenue department) | <ul style="list-style-type: none"> <li>• -BDRCS,</li> <li>• -District Relief and Rehabilitation Department (District Commissioner Office)</li> </ul>                                               | Department of Social Service, Ward Councillors (RCC), Ward Disaster Management Committee, World Bank, Asian Development Bank, NGOs, UNDP                                      |

|    |                                                                                |                                                                               |                                                                                                                                                                                                    |                                                                                                                                                                               |
|----|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4. | <b>Solar fan or charger fan</b>                                                | Rajshahi City Corporation (Secretariat department and Engineering department) | <ul style="list-style-type: none"> <li>• DRRO</li> <li>• BDRCS</li> </ul>                                                                                                                          | Ward Disaster Management Committee, Government of Bangladesh, NGOs                                                                                                            |
| 5. | <b>Prior alerts through the Miking System</b>                                  | Rajshahi City Corporation (Secretariat and Engineering Department)            | <ul style="list-style-type: none"> <li>• BDRCS,</li> <li>• District Relief and Rehabilitation Office (DRRO)</li> <li>• Ward Disaster Management Committee (Standing Orders on Disaster)</li> </ul> | Engineering Department (Rajshahi City Corporation), Rajshahi Development Authority, Northern Electricity Supply Company Limited, Rajshahi Development Authority, WASA, UNICEF |
| 6. | <b>False ceilings under tinne-roof and improved ventilation of the kitchen</b> | Rajshahi City Corporation (Secretariat department and Engineering department) | <ul style="list-style-type: none"> <li>• BDRCS</li> <li>• Rajshahi Development Authority (RDA)</li> </ul>                                                                                          | Ward Disaster Management Committee, Government of Bangladesh, NGOs                                                                                                            |
| 7. | <b>Cooling Space and Cold-water filter in the Schools</b>                      | District Education Office (Primary & High School)                             | <ul style="list-style-type: none"> <li>• BDRCS</li> <li>• Water Supply and Sewerage Authority (WASA)</li> </ul>                                                                                    | Department of Public Health and Engineering, School Management Committee, Government of Bangladesh Engineering Department, Local Community, NGOs                              |

## 9

## Early actions through Social Protection: What are the opportunities?

The following section guides the opportunities for leveraging existing national social protection systems to build and improve the overall resilience of vulnerable groups in Rajshahi City to heatwaves.

Social protection comprises of policies and programs aimed at protecting individuals from risks across the lifecycle to mitigate poverty and inequality (ILO, 2017). While traditionally social protection has been used to address risks during an individual's lifetime (like job loss, work accidents, and ageing), it is now increasingly being considered a tool for building climate resilience. The role of social protection in addressing major socio-economic challenges arising from climate change is becoming more evident, thereby necessitating the need to link social protection and

national climate change responses (Costella et al., 2021). Based on a quick literature review and key informant interviews with the Department of Social Services/Welfare (DSS) at the district level reveal that there are neither any social protection programmes aimed at addressing the impacts of heatwaves nor a City Heatwave Plan. This presents a unique opportunity to understand the feasibility of using social protection schemes for heatwaves, and to analyse whether some of these schemes and their components can be used for taking early actions.

While there are several schemes active in the Rajshahi City corporation area, a few schemes are most relevant for anticipatory action against heatwaves which are:



1. Old Age Allowance (OAA) by the Department of Social Services (DSS) under the Ministry of Social Welfare (MoSW)
2. Disability Allowance (DA) by the DSS under the MoSW
3. Gratuitous Relief (GR) – an emergency relief programme by the Ministry of Disaster Management and Relief (MoDMR)
4. Dalit Harijans Allowance by the DSS under the MoSW (for Road and Drain Cleaners)

It is to be noted that the suggestions made are only indicative, and in-depth consultations and assessments should be done involving key stakeholders in Rajshahi City to understand the feasibility of the options proposed.

**The Old Age Allowance (OAA)** is an unconditional cash transfer programme, and was found to be relevant due to two reasons:

- a) in the literature review and interviews conducted, the elderly people have been identified to be one of the most vulnerable groups to heatwave impacts in Rajshahi.
- b) the uptake, popularity, and coverage of OAA is one of the highest among all social protection programmes available in the city of Rajshahi.

The OAA scheme beneficiaries in Rajshahi could receive support in the following ways:

- a) Anticipatory cash top-up: additional funds could be provided to OAA beneficiaries based on heatwave forecasts. This would enable them to purchase small fans during the heatwave period.
- b) Horizontal expansion of the OAA scheme: The OAA scheme could be temporarily extended to include new beneficiaries who reach the eligible age within three months of a forecasted heatwave. This would involve targeting men aged 64 and women aged 61. Quick registrations could be facilitated through self-registration via SMS.
- c) Communication and awareness: The contact information of OAA beneficiaries is available, allowing for early warning messages to be sent through established channels. During a recent heatwave period, health officials have already communicated advisements to individuals, to stay indoors, stay hydrated, and shop in the

evening, using the directory. Collaborative efforts between BDRCS and DSS can raise awareness about potential impacts and preventive measures using WHO heatwave recommendations adjusted for the local context of Rajshahi.

**The Disability Allowance (DA)** is a means-tested cash transfer programme that could be used for early action support in Rajshahi:

- a) Similar to OAA, additional cash can be provided to the beneficiaries as a top-up to cover expenses for fans or air conditioners during the heatwave.
- b) To ease self-registration for persons with disabilities during summer, the DA programme's design could be temporarily adjusted where staff or volunteers could verify registrations through door-to-door visits based on online/SMS requests, scheduled in the early mornings and late evenings.

**The Gratuitous Relief (GR)** program, administered by the Ministry of Disaster Management and Relief (MoDMR), can potentially support informal workers at risk from heatwaves. A compensation amount can be determined by calculating the expected duration of a heatwave and the resulting potential income losses. BDRCS can support the informed decision-making process by conducting rapid studies to gather income and workday loss data.

**The Dalit Harijans Allowance** by the DSS under the MoSW can provide additional support to marginalized informal workers in Rajshahi City affected by extreme heat.

The DSS in Rajshahi provides one-time support for patients with adverse health conditions like Liver Cirrhosis, Cancer, Kidney issues, Stroke, Paralysis, and now even heat stroke. Public awareness about this support for heat-related illnesses is crucial, requiring appropriate messaging from DSS offices. Conducting an impact analysis study in Rajshahi can estimate the financial requirement for supporting heat stroke cases based on past heatwave crises. BDRCS colleagues can advocate for extending the allowance to cover heat strokes and assist in communicating eligibility messages to individuals at risk.

For all the schemes mentioned here, adjustments to the common parameters can be made to tweak the

programme design to determine the timing of delivering the assistance. Using historical forecast data, the average duration of the heatwave period in Rajshahi can be traced, and potential adjustments can be made to give the cash transfer in advance of this period.

In addition, the following recommendations can be implemented to ensure comprehensive actions addressing heatwave impacts in Rajshahi:

1. Collaborate with the district government to map overlaps between program beneficiaries and vulnerable populations, especially those living in informal slums, and provide necessary support.
2. Explore the options to share beneficiary data from DSS with BDRCS and other NGOs to facilitate cash support and other assistance.
3. Utilize existing channels, such as radio and television, in cooperation with the Ministry of Health and BMD, to popularize the modifications to social protection schemes and disseminate tailored messages regarding heatwave support.
4. Address challenges in digitizing beneficiary data, improving data accuracy, and enhancing knowledge and awareness of the recipients related to the entitlements and renewal requirements.
5. Conduct a message dissemination workshop among the Working Group on AA to present study results and explore collaboration opportunities among the agencies working with vulnerable communities.

6. Advocate for work-from-home solutions during heatwaves and support early warning message dissemination. This recommendation is particularly relevant to sectors such as communication, finance, business activities, defence, public administration, and education.
7. Advocate for research on the link between heatwaves and drought, and the impacts on productivity and livelihoods. Utilize existing research as a foundation and encourage universities and BMD to analyse compounding risks and impacts.
8. Implement adaptation measures like insulating household roofs, cooling the community shelters, providing cooling water stands, and greening the urban spaces.
9. Engaging with the disaster-affected people to explore the use of funds allocated for rehabilitation in consultations with the disaster and relief department under the district commissioner's office.

For any of these modifications to be adopted into a social protection scheme, both the availability of the funds and the active humanitarian actors present at the time must be considered as the pre-determined and agreed threshold. In the meantime, advocacy is necessary at the district level, as well as the national level, on the importance of formally recognizing 'heatwaves' as a recurrent disaster that Rajshahi and Bangladesh are at risk from.

## 10

## Conclusion

In conclusion, the feasibility report for Rajshahi City provides valuable insights into addressing heatwave impacts and minimizing their effects on the community. Through field investigations and participatory exercises, the report identifies vulnerable wards and groups, assesses the impact of heatwaves, and proposes interventions to connect social protection systems with early warning and early action. The analysis considers infrastructure requirements, technological advancements, and potential collaborations with stakeholders, ensuring the practicality of the project. The study highlights the importance of implementing anticipatory actions,

disaster risk management measures, and a combination of both to effectively mitigate heatwave risks. Anticipatory actions such as medical camps, financial assistance, food distribution, and cooling spaces can help address immediate needs during heatwaves.

Although the study focused on using forecast-based finance for early action, the findings revealed that investing in productive assets to create livelihoods can help build the long-term coping capacity of households to shocks, beyond just providing cash or other reliefs. Disaster risk management interventions, including improving infrastructure, providing

livelihood opportunities, and enhancing awareness, can also contribute to long-term resilience. Considering operational costs and volunteer requirements, the report emphasizes the need for phased implementation of interventions. It recommends prioritizing medical camps, unconditional cash grants, and early warnings in the initial phase, followed by cost-effective measures such as providing cooling spaces, installing fans, and improving infrastructure in subsequent phases.

Furthermore, the study highlights the lack of existing social protection programs specifically addressing heatwave impacts in Rajshahi City. It underscores the opportunity to leverage social protection schemes such as Old Age Allowance, Disability Allowance, and emergency relief programs to provide relevant assistance during heatwaves. Connecting social protection systems with early warning and early action can enhance the overall response and support vulnerable communities effectively. Additionally, research on the link between heatwaves, drought, productivity, and livelihood impacts should be encouraged, with a particular emphasis on compounding risks. Implementing adaptation measures like installing insulations, cooling the community shelters, and greening the urban spaces can further enhance resilience.

The study suggests that RCC will take a leading role in implementing early actions to reduce the heat impacts on vulnerable communities. They will link the AA with their existing mandates, plans and policies for

the sustainability of the initiative. BDRCS, being an auxiliary body to the government, will support RCC and other concerned authorities to provide all forms of community mobilization, engagements and additional humanitarian support. Furthermore, the support of the BMD, DRRO, Rajshahi Medical College & Hospital, RDA, and WASA will be critical for the effective implementation of the AA. This collaborative effort can strengthen existing services, improve emergency support, and facilitate the application of safety net recommendations.

To ensure comprehensive actions, the report provides additional recommendations, including collaboration with the district government, data sharing between relevant agencies, tailored messaging through media channels, digitization of beneficiary data, awareness workshops, advocacy for changing working hours and encouraging work-from-home solutions, research on heatwave impacts, and implementation of adaptation measures.

In conclusion, the feasibility report underscores the feasibility of developing anticipatory actions for heatwaves in Rajshahi and emphasizes the importance of collaborative efforts, stakeholder engagement, and targeted interventions to effectively address heatwave impacts. By implementing the recommended measures and connecting social protection systems with AA, Rajshahi can enhance its resilience and minimize the overall impact on the community during heatwave events.

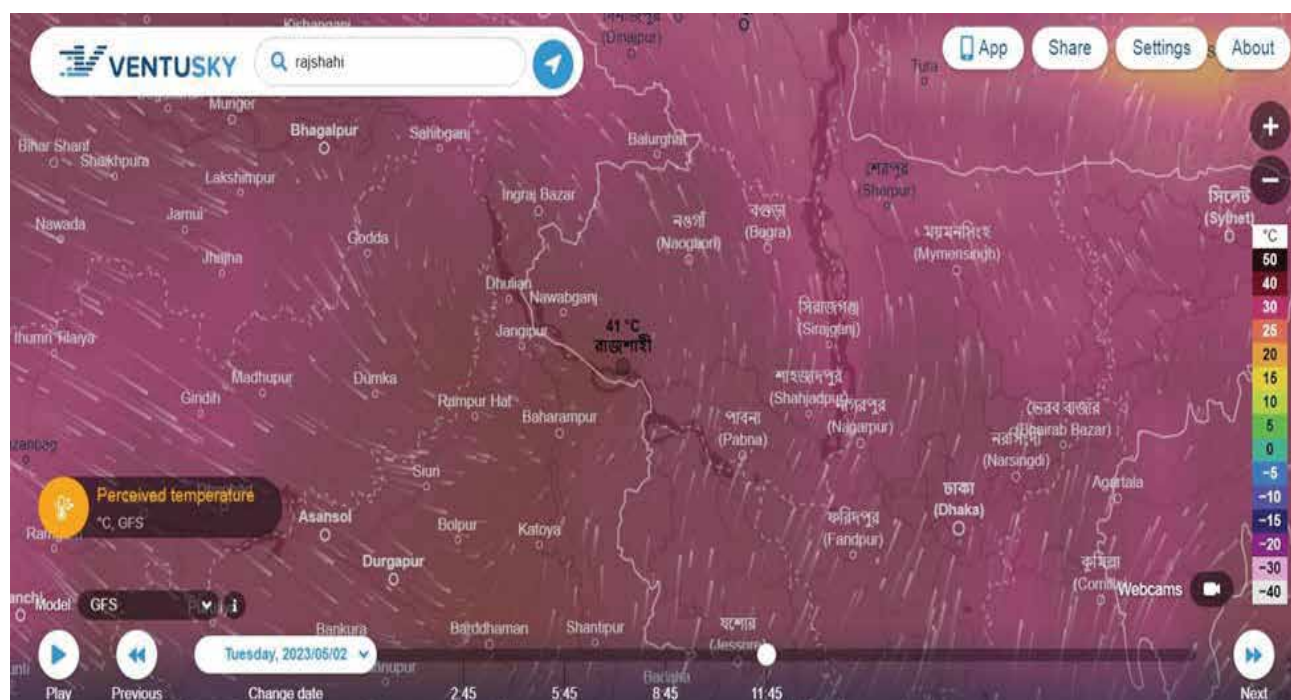
# ANNEX



### 11.1.1 Global Level

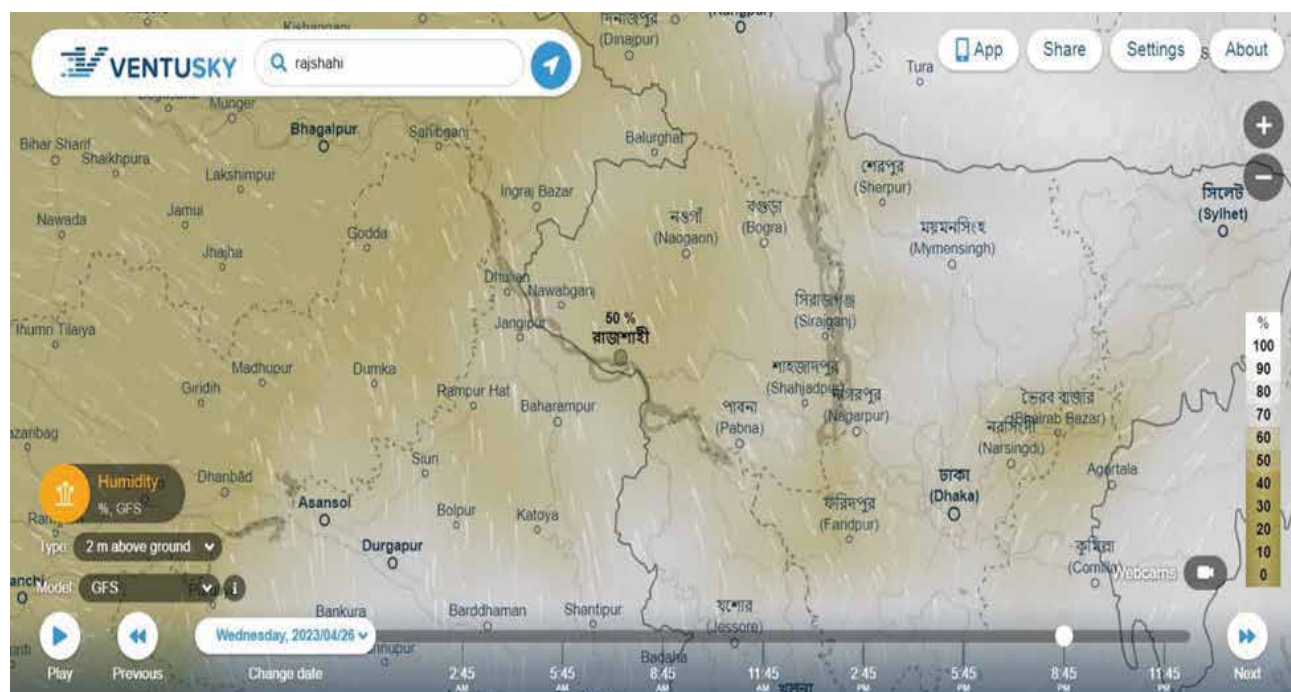


Figure 19: Temperature forecast at the global level in the GFS model



Source: Ventusky website

Figure 20: Humidity forecast at the global level in the GFS model



Source: Ventusky website

### 11.1.2 Local/national level

**Figure 21: Temperature and humidity forecast at local/national level in WRF model by BMD ahead of 7 days**



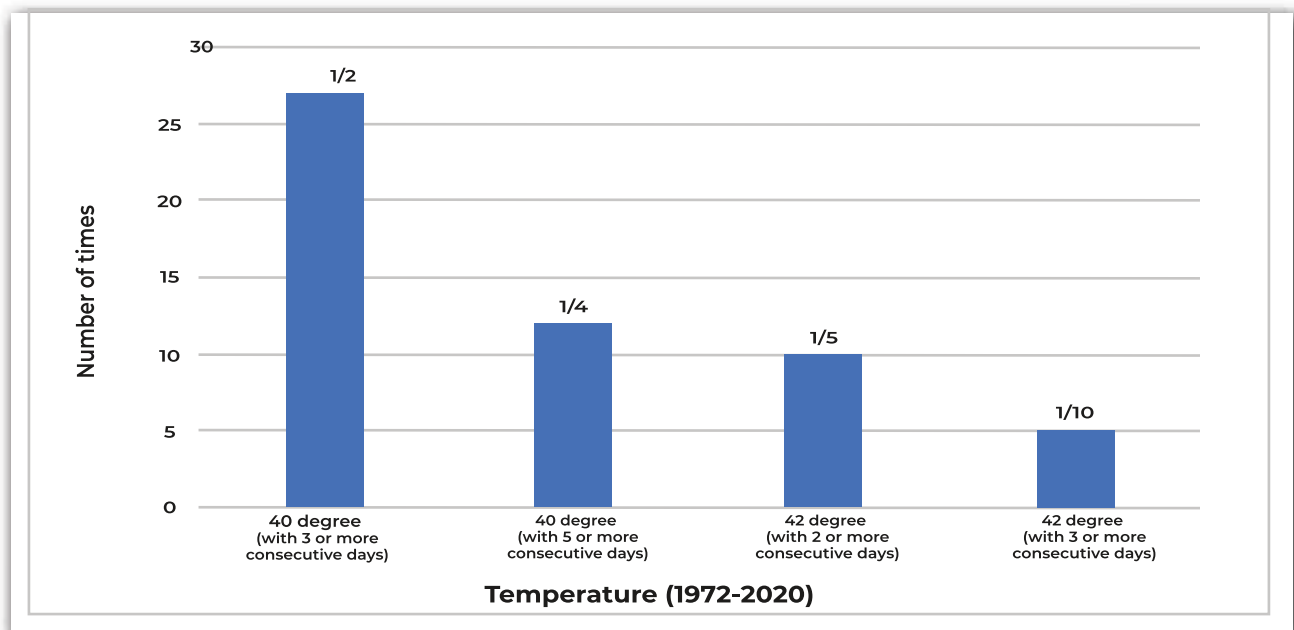
### 11.1.3 Return Period

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

The return period indicates how frequently extreme temperatures occur, such as temperatures exceeding 40°C in the case of Rajshahi. Analysis of the historical data reveals that the return period for temperatures of 40°C or higher for a period of three or more consecutive days is once every two years, while for a

period of five or more consecutive days, it is once every four years. Similarly, the return period for temperatures of 42°C or higher for a period of two or more consecutive days is once every five years, while for a period of three or more consecutive days, it is once every ten years.

**Figure 22: Return period.**

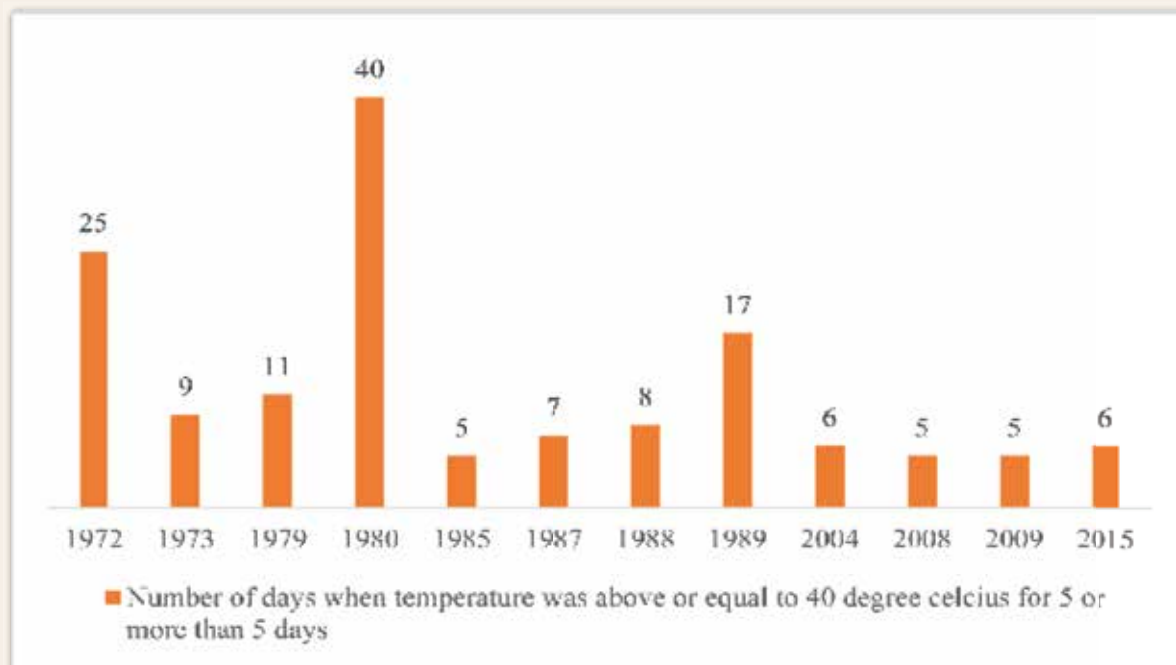


### 11.1.4 Consecutive Days of the Trigger Thresholds

The following Figures 26 and 27 illustrate the duration of the maximum temperature being equal to or above 40°C for five or more consecutive days and being equal to or above 42°C for two or more consecutive days, respectively. The figures reveal that a total of 12 events of the maximum temperature being equal to or above 40°C for five or more consecutive days have occurred;

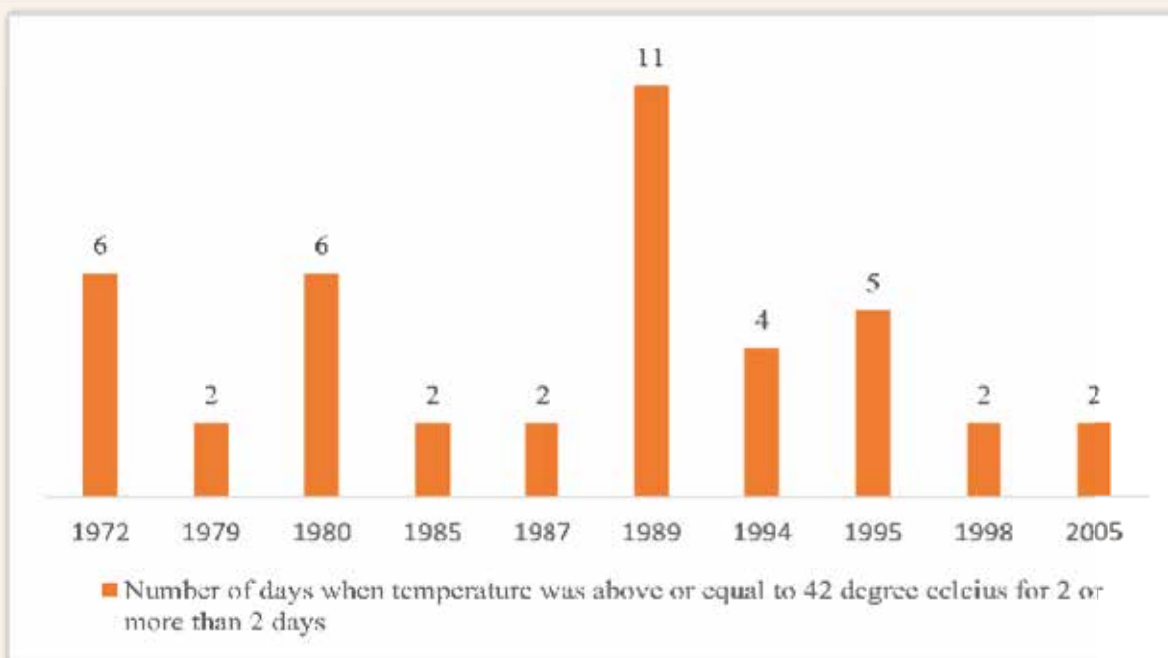
the most recent occurrence being in 2015. Similarly, there have been 10 events with the maximum temperature being equal to or above 42°C for two or more consecutive days; the most recent occurrence being in 2005. This analysis was also helpful in determining the frequency of the trigger thresholds.

**Figure 23: Number of days when temperature was above or equal to 40°C for five or more than five consecutive days**



Source: Authors Illustration based on BMD data

**Figure 24: Number of days when the temperature was above or equal to 42°C for two or more two consecutive days**



Source: Authors Illustration based on BMD data

## 11.2 Heat Index Calculation

The National Oceanic and Atmospheric Administration (NOAA) has developed a heat index, which is based on a combination of air temperature and relative humidity and is expressed in Fahrenheit. This formula is commonly used for heat index calculations worldwide (NOAA). To determine the heat index, the following equation developed by NOAA was used.

$$\text{Index Heat} = -42.379 + (2.04901523 \times T) + (10.14333127 \times rh) - (0.22475541 \times T \times rh) - (6.83783 \times 10^{-3} \times T^2) - (5.481717 \times 10^{-2} \times rh^2) + (1.22874 \times 10^{-3} \times T^2 \times rh) + (8.5282 \times 10^{-4} \times T \times rh^2) - (1.99 \times 10^{-6} \times T^2 \times rh^2)$$

where,  $T$  = temperature in Fahrenheit and  
 $rh$  = relative humidity

Initially, the temperature in degrees Celsius ( $^{\circ}\text{C}$ ) was converted to degrees Fahrenheit, and the formula was applied to calculate the heat index. Subsequently, the heat index obtained in degrees Fahrenheit was converted back to degrees Celsius.

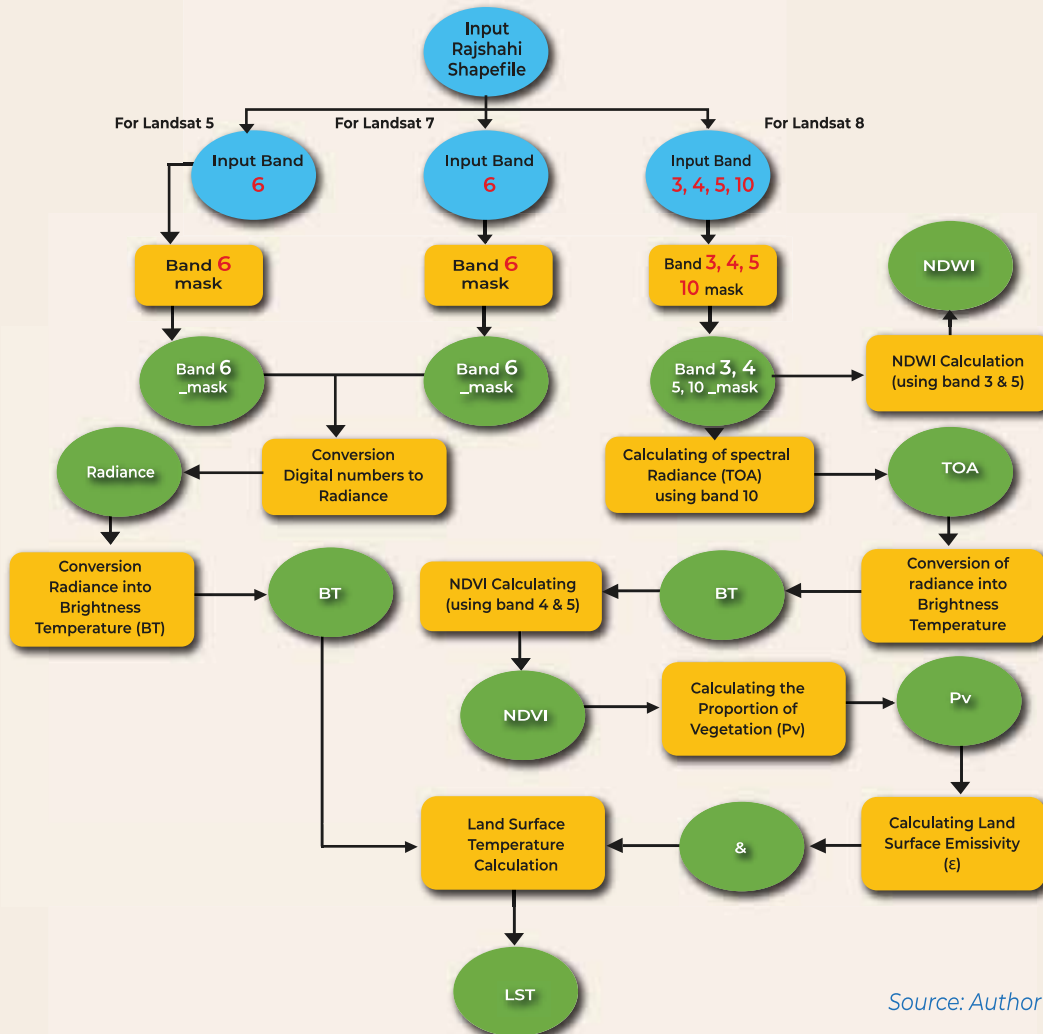
## 11.3 Heat Island Calculation

### 11.3.1 Land Surface Temperature

Land surface temperature (LST) mapping aims to demonstrate a flexible and straightforward conceptual framework relying upon satellite thermal data that shows surface temperature trends and variability and areas at high risk (i.e., areas with high temperature compared to surrounding).

The calculation of LST from satellite imagery was done using Landsat 8 OLI-TIRS sensor images. It's important to note that LST is not the same as air temperature included in daily weather reports. To calculate LST, a model was developed in the ArcGIS model builder that combines different tools. The formula used for LST calculation was adopted from various studies (Orhan et. al, 2014; Orhan et.al, 2016). The LST is a crucial variable in identifying the UHI effect. The following figure shows the LST calculation model.

Figure 25: LST calculation model

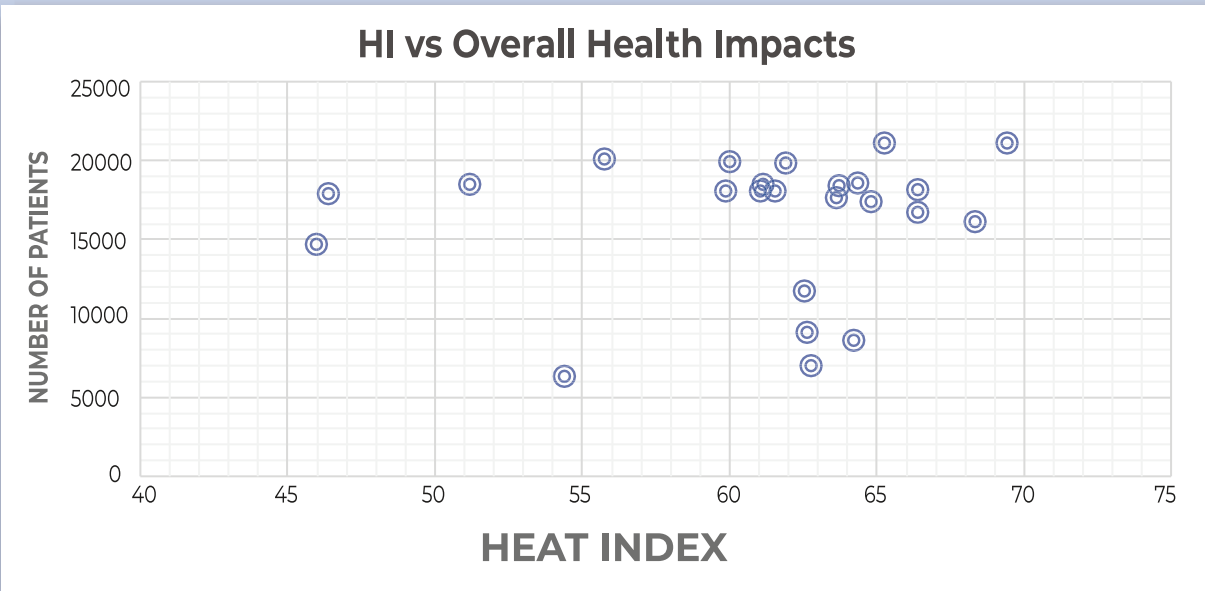


Source: Author illustration

# 11.4 Health Impacts by Heat Index Variability

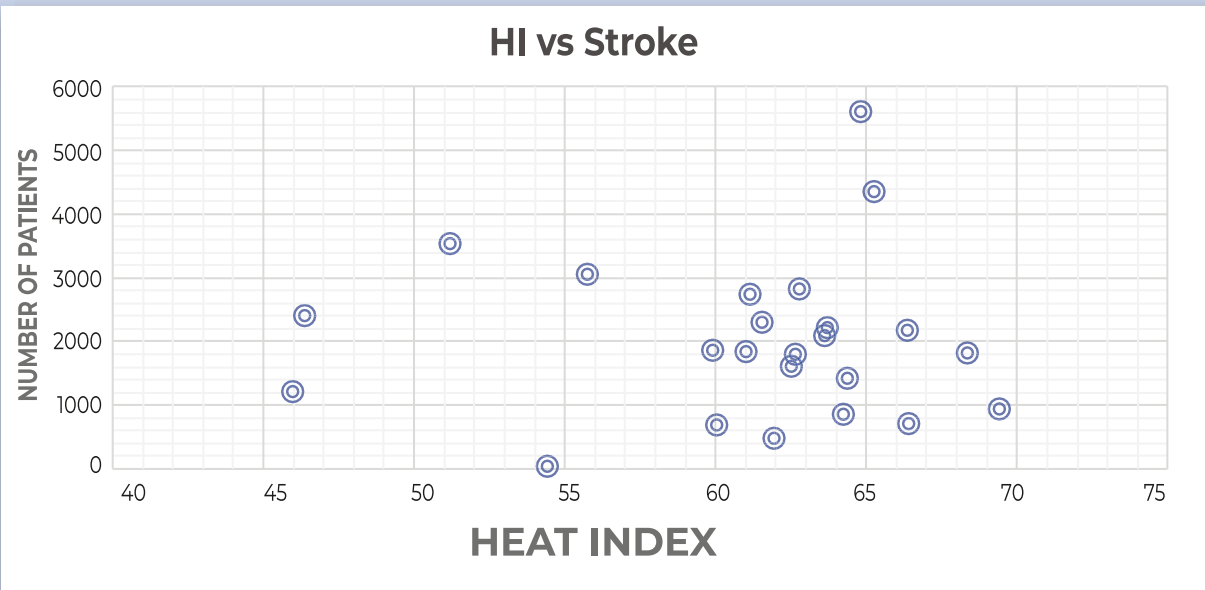
These analyses and statistics are described in the sections on health impacts. A few figures are presented here that indicate the effects of heat index (HI) and temperature on individual diseases.

**Figure 26: Heat Index impact on overall adverse health issues during the heatwave period (2019–2022)**



Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

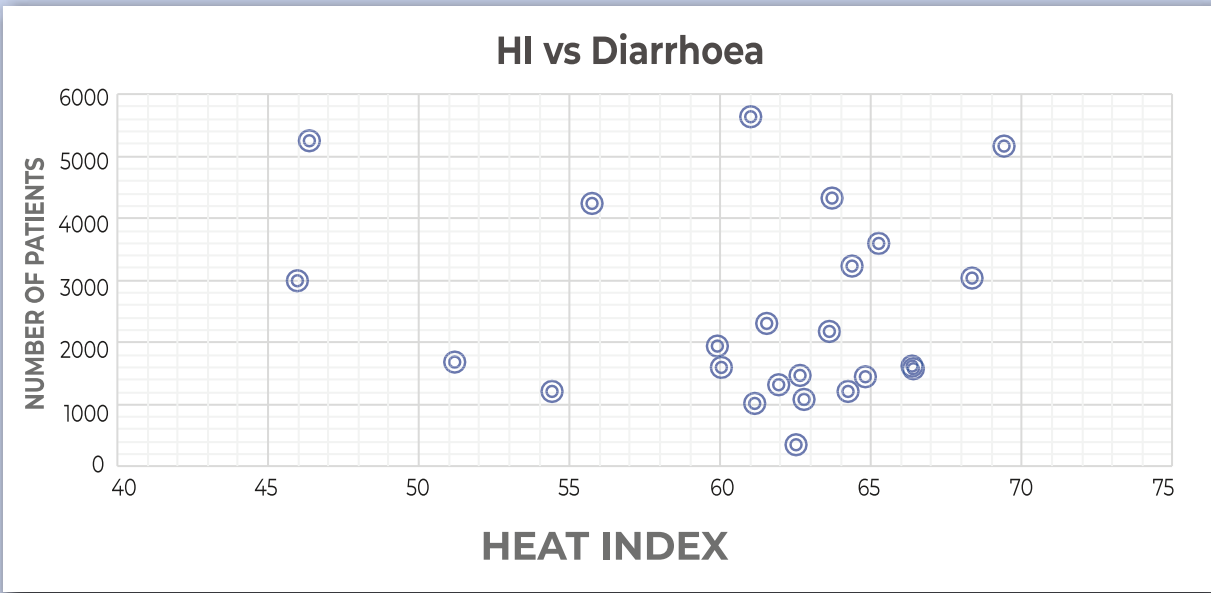
**Figure 27: Heat Index impact on stroke during 2019–2022.**



Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

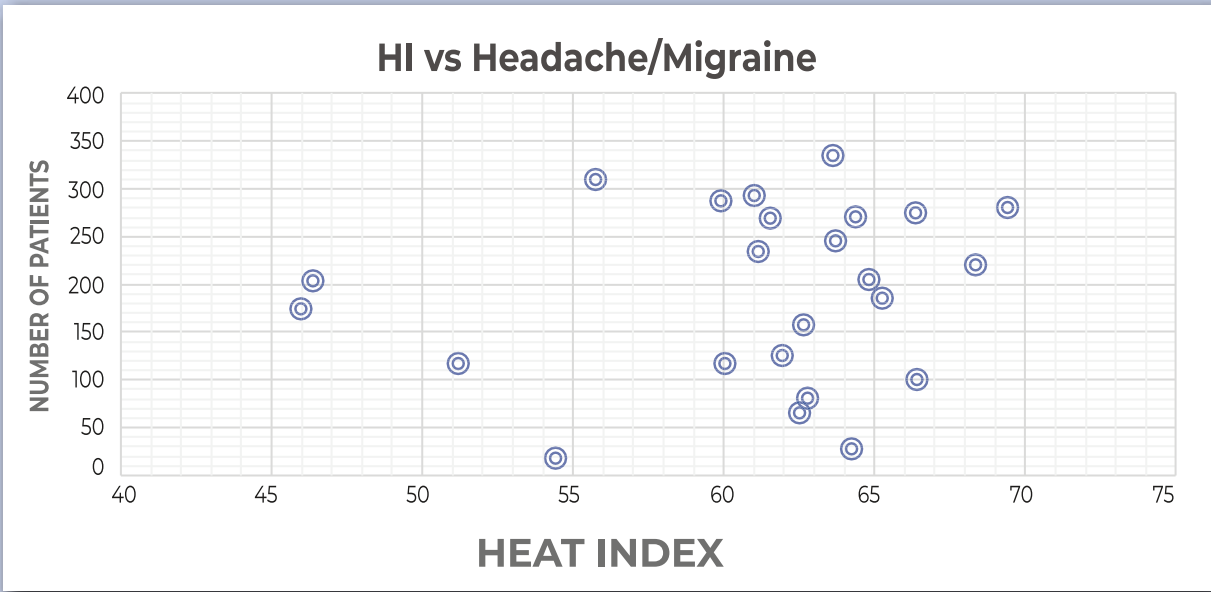


Figure 28: Heat Index impact on diarrhoea during 2019–2022



Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

Figure 29: Heat Index impact on headache and migraine during 2019–2022



Sources: Data collected from Divisional Director (Health) Office Rajshahi, and compiled by authors, 2023.

## 11.5 Impacts and Interventions Suggested by the Vulnerable Groups

The impact and intervention matrix of each vulnerable group are presented below, as well as the ranking of interventions.

### 11.5.1 Pregnant Women and Lactating Mothers

Pregnant women and lactating mothers are more vulnerable to the effects of intense heat due to their unique physical conditions, as discovered through two conducted FGDs. They suffer from dehydration, headaches, digestive issues, and skin conditions, which affect not only their health but also their children. Financial constraints and power shortages worsen their condition. The women suggest financial assistance, food and fruit baskets, medical camps, free medicine, and advance notice of heatwaves through a

microphone system to alleviate their suffering. They also propose interventions like solar-powered or charging fans, improved ventilation in their homes, and tube wells for drinking water. The table shows the impact and interventions suggested by lactating mothers and pregnant women, ranked by their demand. These interventions address the issues faced by these vulnerable groups, and their implementation would significantly improve their health and well-being.

**Table 12: Lactating Mother/Pregnant women**

| Location                 | Impact/ Interventions                                                                         | Ranking of the interventions     |              |                   |                          |               |                                                  |                                                         |                         |                                        |              |
|--------------------------|-----------------------------------------------------------------------------------------------|----------------------------------|--------------|-------------------|--------------------------|---------------|--------------------------------------------------|---------------------------------------------------------|-------------------------|----------------------------------------|--------------|
|                          |                                                                                               | 1                                | 2            | 3                 | 4                        | 5             | 6                                                | 7                                                       | 8                       | 9                                      | 10           |
|                          |                                                                                               | Financial Help during a heatwave | Medical Camp | Free Distribution | Solar fan or Charger fan | Cooling Space | One-time Monetary to attach Board under Tin-roof | One-time Monetary to improve ventilation of the kitchen | Establishing Tube wells | Prior alerts through the Miking System | Fruit Basket |
| Ward No : 04 (Community) | 1. Pregnancy-related sicknesses: vomiting, lacking a taste for food, headaches, skin diseases |                                  | X            | X                 |                          |               |                                                  |                                                         |                         |                                        |              |
|                          | 2. Child health issues: digestion problems, irritation, vomiting,                             |                                  | X            |                   |                          |               |                                                  |                                                         |                         |                                        |              |
|                          | 3. Discomfort in cooking in the kitchen                                                       |                                  |              |                   |                          | X             |                                                  | X                                                       |                         |                                        |              |
|                          | 4. Excess heat inside the Tin-roofed house                                                    |                                  |              |                   |                          |               | X                                                |                                                         |                         |                                        |              |
|                          | 5. Income reduction                                                                           | X                                |              |                   |                          |               |                                                  |                                                         |                         |                                        |              |
|                          | 6. Increased medical expenses                                                                 |                                  | X            | X                 |                          |               |                                                  |                                                         |                         |                                        |              |
|                          | 7. Load shedding                                                                              |                                  |              |                   | X                        | X             |                                                  |                                                         |                         |                                        |              |
|                          | 8. Lacks the access to drinking water                                                         |                                  |              |                   |                          |               |                                                  |                                                         | X                       |                                        |              |
|                          | 9. Do not get prior alerts                                                                    |                                  |              |                   |                          |               |                                                  |                                                         |                         | X                                      |              |

| Location                       | Impact/ Interventions                                                                         |                                  |              |                   |                          |               |                                                  |                                                         |                         |                                        |              |
|--------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------|--------------|-------------------|--------------------------|---------------|--------------------------------------------------|---------------------------------------------------------|-------------------------|----------------------------------------|--------------|
|                                |                                                                                               | 1                                | 2            | 3                 | 4                        | 5             | 6                                                | 7                                                       | 8                       | 9                                      | 10           |
|                                |                                                                                               | Financial Help during a heatwave | Medical Camp | Free Distribution | Solar fan or Charger fan | Cooling Space | One-time Monetary to attach Board under Tin-roof | One-time Monetary to improve ventilation of the kitchen | Establishing Tube wells | Prior alerts through the Miking System | Fruit Basket |
| Ward No: 01 (Maternity Clinic) | 1. Pregnancy-related sicknesses: vomiting, lacking a taste for food, headaches, skin diseases |                                  | X            | X                 |                          |               |                                                  |                                                         |                         |                                        |              |
|                                | 2. Child health issues: digestion problems, irritation, vomiting,                             |                                  | X            | X                 |                          |               |                                                  |                                                         |                         |                                        |              |
|                                | 3. Discomfort in cooking in the kitchen                                                       |                                  |              |                   |                          |               |                                                  | X                                                       |                         |                                        |              |
|                                | 4. Excess heat inside the Tin-roofed house                                                    |                                  |              |                   |                          |               | X                                                |                                                         |                         |                                        |              |
|                                | 5. Food Rots quickly                                                                          |                                  |              |                   |                          |               |                                                  |                                                         |                         |                                        |              |
|                                | 6. Increased medical expenses                                                                 |                                  | X            | X                 |                          |               |                                                  |                                                         |                         |                                        |              |
|                                | 7. Load shedding                                                                              |                                  |              |                   | X                        |               |                                                  |                                                         |                         |                                        |              |
|                                | 8. Do not get prior alerts                                                                    |                                  |              |                   |                          |               |                                                  |                                                         |                         | X                                      | X            |

### 11.5.2 Community (especially slum/ heatwave hotspots)

The study conducted two FGDs in slum communities in Ward nos. 19 and 24 to understand the impact of high heat on vulnerable individuals. Participants in these groups reported experiencing serious health issues during the summer, such as high blood pressure, fever, cough, headache, suffocation, breathing problems, allergies, prickly heat, and dehydration. They also reported a significant drop in daily revenue and work productivity during heatwaves. The community members requested various interventions, such as medical camps with free medication, a shelter to escape the heat, financial assistance to add a board as false ceiling under their roofs with sheets of tin, and a

tube well for clean drinking water. They also requested solar fans or charging fans to combatting heat during load shedding and high-power bills. Participants preferred receiving prior warnings through a miking system, SMS, or awareness building to help them prepare for the heatwave. The impact and interventions suggested by lactating mothers and pregnant women were also included in the study. The table ranks the interventions based on demand. Overall, the interventions proposed in the study aim to reduce the suffering of vulnerable individuals during heatwaves and increase their preparedness for future occurrences.

**Table 13: Community**

| Location    | Impact/ Interventions                                                                           | Ranking of the interventions |                            |               |                                  |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|-------------|-------------------------------------------------------------------------------------------------|------------------------------|----------------------------|---------------|----------------------------------|--------------------------------------------------|---------------------------------------------------------|-------------------------|--------------------------|----------------------------------------|---------------------------------|-----------------------------|
|             |                                                                                                 | 1                            | 2                          | 3             | 4                                | 5                                                | 6                                                       | 7                       | 8                        | 9                                      | 10                              | 11                          |
|             |                                                                                                 | Medical Camp                 | Free Medicine Distribution | Cooling Space | Financial Help during a heatwave | One-time Monetary to attach Board under Tin-roof | One-time Monetary to improve ventilation of the kitchen | Establishing Tube wells | Solar fan or Charger fan | Prior alerts through the Miking System | Prior alerts through SMS, Phone | Awareness-Building Training |
| Ward No: 24 | 1. Health Issues: Blood Pressure, Breathing problems, skin diseases, Headaches                  | X                            | X                          |               |                                  |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 2. Income Reduction                                                                             |                              |                            |               | X                                |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 3. Increased Medical Expense                                                                    | X                            | X                          |               |                                  |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 4. Kitchen space inside the House                                                               |                              |                            | X             |                                  |                                                  | X                                                       |                         |                          |                                        |                                 |                             |
|             | 5. Load-shedding & High Electricity Bill                                                        |                              |                            | X             |                                  |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 6. Drinking water scarcity                                                                      |                              |                            |               |                                  |                                                  |                                                         | X                       | X                        |                                        |                                 |                             |
|             | 7. Do not get Prior alerts                                                                      |                              |                            |               |                                  |                                                  |                                                         |                         |                          |                                        | X                               | X                           |
| Ward No: 16 | 1. Health Issues: Blood Pressure, Breathing problems, skin diseases, Headaches, Fever, Asphyxia | X                            | X                          |               |                                  |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 2. Income Reduction                                                                             |                              |                            |               | X                                |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 3. Increased Medical Expense                                                                    | X                            | X                          |               | X                                |                                                  |                                                         |                         |                          |                                        |                                 |                             |
|             | 4. Kitchen space inside the House                                                               |                              |                            |               |                                  |                                                  | X                                                       |                         |                          |                                        |                                 |                             |
|             | 5. Excess heat inside the Tin-roofed house                                                      |                              |                            | X             |                                  | X                                                |                                                         |                         |                          |                                        |                                 |                             |
|             | 6. Load-shedding                                                                                |                              |                            |               |                                  |                                                  |                                                         |                         | X                        |                                        |                                 |                             |
|             | 7. Drinking water scarcity                                                                      |                              |                            |               |                                  |                                                  |                                                         | X                       |                          |                                        |                                 |                             |
|             | 8. Do not get Prior alerts                                                                      |                              |                            |               |                                  |                                                  |                                                         |                         |                          | X                                      | X                               | X                           |

### 11.5.3 Elderly, Chronic ill, Disabled Person

Two FGDs were conducted to identify the impact and suggested interventions for the elderly, chronically ill, and disabled people during a heatwave. These groups already suffer from various health issues such as headaches, blood pressure, and breathing problems, and the heatwave exacerbates their problems. They cannot afford extra medical care or medicines due to the reduction of their income by 40-50% during this time. Their houses and kitchens are not heat-resistant, which adds to their suffering. Frequent load shedding occurs during the time of extreme heat, and they cannot afford to buy solar fans or charger fans. They suggested cooling spaces in their community, but

women are not fond of the idea as they prefer resting in common courtyards, which stay relatively cooler than the house. They also mentioned establishing deep tube wells as the water level is lowered during a heatwave, and the supply of water from the corporation contains a high iron content. They suggested prior warning through miking systems to be prepared for the hazard and reduce additional health issues. They also suggested establishing small businesses or providing domestic animals to be self-dependent. The interventions suggested by them are ranked as per their demand in the following table. Financial help, medical camps, and free medicines can reduce their suffering during a heatwave.

**Table 14: Elderly, Chronically Ill and Disabled Person**

| Location    | Impact/ Interventions                                                             | Ranking of the interventions |                            |                                                  |                                                         |                                  |                          |               |                         |                                        |              |                  |                                             |
|-------------|-----------------------------------------------------------------------------------|------------------------------|----------------------------|--------------------------------------------------|---------------------------------------------------------|----------------------------------|--------------------------|---------------|-------------------------|----------------------------------------|--------------|------------------|---------------------------------------------|
|             |                                                                                   | 1                            | 2                          | 3                                                | 4                                                       | 5                                | 6                        | 7             | 8                       | 9                                      | 10           | 11               | 12                                          |
|             |                                                                                   | Medical Camp                 | Free Medicine Distribution | One-time Monetary to attach Board under Tin-roof | One-time Monetary to improve ventilation of the kitchen | Financial Help during a heatwave | Solar fan or Charger fan | Cooling Space | Establishing Tube wells | Prior alerts through the Miking System | Fruit Basket | Deep Motor pumps | Providing Domestic animal or small business |
| Ward No: 24 | 1. Health issues: exhaustion, discomfort, cough, breathing issues, headaches etc. | X                            | X                          |                                                  |                                                         |                                  |                          |               |                         |                                        |              |                  |                                             |
|             | 2. Income Reduction                                                               |                              |                            |                                                  |                                                         | X                                |                          |               |                         |                                        | X            |                  | X                                           |
|             | 3. Increased Medical Expenses along with day-to-day medicine                      |                              |                            |                                                  |                                                         | X                                |                          |               |                         |                                        |              |                  | X                                           |
|             | 4. Excess heat inside the Tin-roofed house                                        |                              |                            | X                                                |                                                         |                                  |                          |               |                         |                                        |              |                  |                                             |
|             | 5. Load- shedding                                                                 |                              |                            |                                                  |                                                         |                                  | X                        | X             |                         |                                        |              |                  |                                             |
|             | 6. Drinking water scarcity                                                        |                              |                            |                                                  |                                                         |                                  |                          |               | X                       |                                        |              | X                |                                             |
|             | 7. Do not get Prior alerts                                                        |                              |                            |                                                  |                                                         |                                  |                          |               |                         | X                                      |              |                  |                                             |
| Ward No: 16 | 1. Health Issues: Blood Pressure, Skin disease, Furuncle,                         | X                            | X                          |                                                  |                                                         |                                  |                          |               |                         |                                        |              |                  |                                             |
|             | 2. Income Reduction                                                               |                              |                            |                                                  |                                                         | X                                |                          |               |                         |                                        | X            |                  |                                             |
|             | 3. Increased Medical Expense                                                      |                              |                            |                                                  |                                                         |                                  |                          |               |                         |                                        | X            |                  |                                             |



|  |                                            |  |  |   |   |  |   |  |  |   |  |  |  |
|--|--------------------------------------------|--|--|---|---|--|---|--|--|---|--|--|--|
|  | 4. Discomfort in cooking spaces            |  |  |   | X |  |   |  |  |   |  |  |  |
|  | 5. Excess heat inside the Tin-roofed house |  |  | X |   |  |   |  |  |   |  |  |  |
|  | 6. Load-shedding                           |  |  |   |   |  | X |  |  |   |  |  |  |
|  | 7. Do not get Prior alerts                 |  |  |   |   |  |   |  |  | X |  |  |  |

### 11.5.4 School Student

During extreme heatwaves, students often suffer from various health problems that can impact their ability to focus and perform well in their studies. For instance, high temperatures can cause skin diseases, dehydration, headaches, and other health issues that can make attending classes uncomfortable and difficult. Some students may even faint during

morning assembly due to the intense heat. Particularly, proper medical facilities to address the health needs of their students. In the event of sickness, students are often sent back home, which can result in missed classes and a loss of learning opportunities. The following table represents the impacts on them and the ranking of their suggested interventions.

**Table 15: School Students**

| Location                           | Impact/ Interventions                                    | Ranking of the interventions |                            |               |                   |                         |                          |                                  |                                  |                                        |                                 |                  |
|------------------------------------|----------------------------------------------------------|------------------------------|----------------------------|---------------|-------------------|-------------------------|--------------------------|----------------------------------|----------------------------------|----------------------------------------|---------------------------------|------------------|
|                                    |                                                          | 1                            | 2                          | 3             | 4                 | 5                       | 6                        | 7                                | 8                                | 9                                      | 10                              | 11               |
|                                    |                                                          | Medical Camp                 | Free Medicine Distribution | Cooling Space | Cold water filter | Establishing Tube wells | Solar fan or Charger fan | Shedding between School Building | Financial Help during a heatwave | Prior alerts through the Miking System | Prior alerts through SMS, Phone | Deep Motor pumps |
| Ward No-16<br>(Male- Female Mixed) | 1. Health Issues: Skin disease, Furuncle, Dehydration,   | X                            | X                          |               |                   |                         |                          | X                                |                                  |                                        |                                 |                  |
|                                    | 2. Concentration issuers                                 | X                            |                            | X             |                   |                         |                          |                                  |                                  |                                        |                                 |                  |
|                                    | 3. Drinking Water Scarcity in School                     |                              |                            |               |                   | X                       |                          |                                  |                                  |                                        |                                 | X                |
|                                    | 4. Load shedding                                         |                              |                            |               |                   |                         | X                        |                                  |                                  |                                        |                                 |                  |
|                                    | 5. Income reduction of family                            |                              |                            |               |                   |                         |                          |                                  | X                                |                                        |                                 |                  |
|                                    | 6. Do not get Prior alerts                               |                              |                            |               |                   |                         |                          |                                  |                                  | X                                      | X                               |                  |
|                                    | 1. Health Issues: Dehydration, acne, hair fall, Headache | X                            | X                          | X             |                   |                         | X                        |                                  |                                  |                                        |                                 |                  |
|                                    | 2. Health issues during Menstruation                     | X                            | X                          | X             |                   |                         |                          |                                  |                                  |                                        |                                 |                  |

|                             |                                 |  |  |   |   |  |   |  |   |   |   |  |  |
|-----------------------------|---------------------------------|--|--|---|---|--|---|--|---|---|---|--|--|
| Ward No-19<br>(only Female) | 3. Coldwater scarcity in School |  |  |   | X |  |   |  |   |   |   |  |  |
|                             | 4. Concentration issues         |  |  | X |   |  | X |  |   |   |   |  |  |
|                             | 5. Load shedding                |  |  |   |   |  | X |  |   |   |   |  |  |
|                             | 6. Income reduction of Family   |  |  |   |   |  |   |  | X |   |   |  |  |
|                             | 7. Do not get Prior alerts      |  |  |   |   |  |   |  |   | X | X |  |  |

### 11.5.5 Outdoor Workers (Rickshaw pullers, Day labourers etc.)

The most vulnerable group during extreme weather conditions are outdoor workers, such as rickshaw pullers and day labourers, who cannot afford to take time off work. They suffer from health problems like headaches, breathing difficulties, dehydration, and skin diseases due to their exposure to high temperatures. They cannot afford medical facilities and demand free medical camps and essential medicines like gastric influx, blood pressure, fever cold, saline, and glucose. Cooling spaces during work breaks and financial assistance, such as food baskets, would be helpful. Their houses are usually made of tin sheet roofs, which make them very hot during the day. They need one-time monetary assistance to attach a board

or other heat-resistant materials to their homes. They also lack access to drinking water and electricity and suffer from load shedding and high electricity bills. The establishment of tube wells and solar fans can reduce these problems. Prior warnings and awareness building about preventive measures for heatwaves are essential for them. Miking systems in the community and the use of mobile phones and social media platforms can provide prior warnings. Overall, the provision of medical facilities, cooling spaces, financial assistance, the establishment of tube wells, and prior warnings can alleviate the suffering of outdoor workers during a heatwave.

**Table 16: Outdoor workers (Rickshaw pullers, Day labourers etc.)**

| Location                   | Impact/ Interventions                                            | Ranking of the interventions |                            |                                  |               |             |                                            |                                                  |                         |                          |                                        |                             |                  |                                    |
|----------------------------|------------------------------------------------------------------|------------------------------|----------------------------|----------------------------------|---------------|-------------|--------------------------------------------|--------------------------------------------------|-------------------------|--------------------------|----------------------------------------|-----------------------------|------------------|------------------------------------|
|                            |                                                                  | 1                            | 2                          | 3                                | 4             | 5           | 6                                          | 7                                                | 8                       | 9                        | 10                                     | 11                          | 12               | 13                                 |
|                            |                                                                  | Medical Camp                 | Free Medicine Distribution | Financial Help during a heatwave | Cooling Space | Food Basket | Providing upper shade for the driving seat | One-time Monetary to attach Board under Tin-roof | Establishing Tube wells | Solar fan or Charger fan | Prior alerts through the Miking System | Awareness-Building Training | Deep Motor pumps | Providing Domestic animal or small |
| Ward No-24<br>(20.02.2023) | 1. Health Issues: Headache, Blood Pressure, Breathing difficulty | X                            | X                          |                                  | X             |             |                                            |                                                  |                         |                          |                                        |                             |                  |                                    |
|                            | 2. Scarcity of drinking water                                    |                              |                            |                                  |               |             |                                            |                                                  | X                       |                          |                                        |                             | X                |                                    |
|                            | 3. Load Shedding                                                 |                              |                            |                                  |               |             |                                            |                                                  |                         | X                        |                                        |                             |                  |                                    |
|                            | 4. Income reduction                                              |                              |                            | X                                |               |             |                                            |                                                  |                         |                          |                                        |                             |                  |                                    |
|                            | 5. Increased Medical Expense                                     |                              |                            | X                                |               |             |                                            |                                                  |                         |                          |                                        |                             |                  |                                    |
|                            | 6. Do not get Prior alerts                                       |                              |                            |                                  |               |             |                                            |                                                  |                         |                          | X                                      | X                           |                  |                                    |

|                                         |                                                                                        |   |   |   |   |   |   |   |   |   |   |  |   |   |
|-----------------------------------------|----------------------------------------------------------------------------------------|---|---|---|---|---|---|---|---|---|---|--|---|---|
| Ward No -19<br>(Mostly Rickshaw-Puller) | 1. Health Issues: Headache, Blood Pressure, Dizziness, Breathing issues                | X | X | X |   |   | X |   |   |   |   |  |   |   |
|                                         | 2. Income Reduction                                                                    |   |   | X |   | X | X |   |   |   |   |  |   |   |
|                                         | 3. Scarcity of Drinking water                                                          |   |   |   |   |   |   |   | X |   |   |  |   |   |
|                                         | 4. Increased Medical Expense                                                           |   |   | X |   |   |   |   |   |   |   |  |   |   |
|                                         | 5. Do not get Prior alerts                                                             | X | X | X |   |   |   |   |   |   | X |  |   |   |
| Ward No-24<br>(Mixed Male-Female)       | 1. Health Issues: Headache, Blood Pressure, Dehydration, Cold fever,                   | X | X |   | X |   | X |   |   |   |   |  |   |   |
|                                         | 2. Income Reduction                                                                    |   |   | X |   | X | X |   |   |   |   |  |   | X |
|                                         | 3. Increased Medical Expense                                                           | X | X | X |   | X | X |   |   |   |   |  |   |   |
|                                         | 4. Excess heat inside the Tin-roofed house                                             |   |   |   |   |   |   | X |   |   |   |  |   |   |
|                                         | 5. Load shedding                                                                       |   |   |   |   |   |   |   |   | X |   |  |   |   |
|                                         | 6. Scarcity of Drinking water                                                          |   |   |   |   |   |   |   | X |   |   |  | X |   |
|                                         | 7. Do not get Prior alerts                                                             |   |   |   |   |   |   |   |   |   | X |  |   |   |
| Ward No-24 24 Mixed                     | 1. Health Issues: Headache, Blood pressure, Dizziness, Breathing issues, Skin Diseases | X | X | X |   |   | X |   |   |   |   |  |   |   |
|                                         | 2. Income Reduction                                                                    | X | X | X |   | X |   |   | X |   |   |  |   |   |
|                                         | 3. Scarcity of Drinking water                                                          |   |   |   |   |   |   |   | X |   |   |  | X |   |
|                                         | 4. Increased Medical Expense                                                           | X | X | X |   |   |   |   |   |   |   |  |   |   |
|                                         | 5. 5. Do not get Prior alerts                                                          |   |   |   |   |   |   |   |   | X |   |  |   |   |
|                                         | 6. Load Shedding                                                                       |   |   |   |   |   |   |   |   | X |   |  |   |   |

## 11.6 Weights and Score of the AHP Method

### 11.6.1 Criteria and Weights

The decision criteria for AHP scoring, the interventions were evaluated based on being socially acceptable, technically and institutionally feasible, and having positive economic return. The importance of these

criteria has been calculated through the following matrix with the given score by the experts for each criterion given below:

**Table 17: Scoring of the criteria for AHP.**

| Criteria                 | Socially Acceptable | Technically Possible | Institutionally Capable | Positive Economic Return |
|--------------------------|---------------------|----------------------|-------------------------|--------------------------|
| Socially Acceptable      | 1.00                | 4.00                 | 3.00                    | 2.00                     |
| Technically Possible     | 0.25                | 1.00                 | 1.00                    | 2.00                     |
| Institutionally Capable  | 0.33                | 1.00                 | 1.00                    | 1.00                     |
| Positive Economic Return | 0.50                | 0.50                 | 0.50                    | 1.00                     |

Based on the matrix, the weight of these criteria is assigned based on expert judgment and the result is given below:

**Table 18: Weights of Criteria.**

| Criteria                 | Weights | Weights (%) |
|--------------------------|---------|-------------|
| Socially Acceptable      | 4.00    | 3.00        |
| Technically Possible     | 1.00    | 1.00        |
| Institutionally Capable  | 1.00    | 1.00        |
| Positive Economic Return | 0.50    | 0.50        |

### 11.6.2 Score of interventions

With the help of the summary and acquired data from the analysis the inventions scored by the experts as relative importance on a scale of 1 to 9, where; (1 = Equal importance, 3 = Moderate importance, 5 =

Strong importance, 7 = Very strong importance, 9 = Extreme importance and 2,4,6,8 = can be used to express intermediate values) thus, matrix has developed. The scores were given by the experts. These are the matrix of score of each criterion:

**Table 19: Alternatives for criterion socially acceptable**

| Alternatives                                                       | Medical Camp with Free Medicine | Financial Help | Solar Fan or Charger Fan | Prior Alerts through the Miking System | Cooling Space | Attach Board under Tin-roof and Improve Ventilation of the Kitchen | Cooling room and Cold-water Filter in School |
|--------------------------------------------------------------------|---------------------------------|----------------|--------------------------|----------------------------------------|---------------|--------------------------------------------------------------------|----------------------------------------------|
| Medical Camp with Free Medicine                                    | 1.00                            | 4.00           | 5.00                     | 3.00                                   | 4.00          | 7.00                                                               | 4.00                                         |
| Financial Help                                                     | 0.25                            | 1.00           | 4.00                     | 5.00                                   | 3.00          | 7.00                                                               | 3.00                                         |
| Solar Fan or Charger Fan                                           | 0.20                            | 0.25           | 1.00                     | 0.16                                   | 2.00          | 4.00                                                               | 3.00                                         |
| Prior Alerts through the Miking System                             | 0.33                            | 0.20           | 6.25                     | 1.00                                   | 0.25          | 0.13                                                               | 2.00                                         |
| Cooling Space                                                      | 0.25                            | 0.33           | 0.50                     | 4.00                                   | 1.00          | 6.00                                                               | 4.00                                         |
| Attach Board under Tin-roof and Improve Ventilation of the Kitchen | 0.14                            | 0.14           | 0.25                     | 7.69                                   | 0.17          | 1.00                                                               | 5.00                                         |
| Cooling Room and Cold-water Filter in School                       | 0.25                            | 0.33           | 0.33                     | 0.50                                   | 0.25          | 0.20                                                               | 1.00                                         |

**Table 20: Alternatives for criterion technically possible.**

| Alternatives                                                       | Medical Camp with Free Medicine | Financial Help | Solar Fan or Charger Fan | Prior Alerts through the Miking System | Cooling Space | Attach Board under Tin-roof and Improve Ventilation of the Kitchen | Cooling room and Cold-water Filter in School |
|--------------------------------------------------------------------|---------------------------------|----------------|--------------------------|----------------------------------------|---------------|--------------------------------------------------------------------|----------------------------------------------|
| Medical Camp with Free Medicine                                    | 1.00                            | 5.00           | 5.00                     | 6.00                                   | 3.00          | 7.00                                                               | 5.00                                         |
| Financial Help                                                     | 0.20                            | 1.00           | 0.33                     | 0.25                                   | 2.00          | 4.00                                                               | 7.00                                         |
| Solar Fan or Charger Fan                                           | 0.20                            | 3.03           | 1.00                     | 0.25                                   | 3.00          | 1.00                                                               | 3.00                                         |
| Prior Alerts through the Miking System                             | 0.17                            | 4.00           | 4.00                     | 1.00                                   | 4.00          | 6.00                                                               | 4.00                                         |
| Cooling Space                                                      | 0.33                            | 0.50           | 0.33                     | 0.25                                   | 1.00          | 5.00                                                               | 2.00                                         |
| Attach Board under Tin-roof and Improve Ventilation of the Kitchen | 0.14                            | 0.25           | 1.00                     | 0.17                                   | 0.20          | 1.00                                                               | 2.00                                         |
| Cooling Room and Cold-water Filter in School                       | 0.20                            | 0.14           | 0.33                     | 0.25                                   | 0.50          | 0.50                                                               | 1.00                                         |

**Table 21: Alternatives for criterion institutionally capable**

| Alternatives                                                       | Medical Camp with Free Medicine | Financial Help | Solar Fan or Charger Fan | Prior Alerts through the Miking System | Cooling Space | Attach Board under Tin-roof and Improve Ventilation of the Kitchen | Cooling room and Cold-water Filter in School |
|--------------------------------------------------------------------|---------------------------------|----------------|--------------------------|----------------------------------------|---------------|--------------------------------------------------------------------|----------------------------------------------|
| Medical Camp with Free Medicine                                    | 1.00                            | 3.00           | 4.00                     | 0.16                                   | 0.33          | 5.00                                                               | 4.00                                         |
| Financial Help                                                     | 0.33                            | 1.00           | 5.00                     | 0.33                                   | 3.00          | 4.00                                                               | 6.00                                         |
| Solar Fan or Charger Fan                                           | 0.25                            | 0.20           | 1.00                     | 0.11                                   | 3.00          | 3.00                                                               | 4.00                                         |
| Prior Alerts through the Miking System                             | 6.25                            | 3.03           | 9.09                     | 1.00                                   | 6.00          | 5.00                                                               | 5.00                                         |
| Cooling Space                                                      | 3.03                            | 0.33           | 0.33                     | 0.17                                   | 1.00          | 4.00                                                               | 3.00                                         |
| Attach Board under Tin-roof and Improve Ventilation of the Kitchen | 0.20                            | 0.25           | 0.33                     | 0.20                                   | 0.25          | 1.00                                                               | 3.00                                         |
| Cooling Room and Cold-water Filter in School                       | 0.25                            | 0.17           | 0.25                     | 0.20                                   | 0.33          | 0.33                                                               | 1.00                                         |



**Table 22: Alternatives for criterion positive economic return.**

| Alternatives                                                       | Medical Camp with Free Medicine | Financial Help | Solar Fan or Charger Fan | Prior Alerts through the Miking System | Cooling Space | Attach Board under Tin-roof and Improve Ventilation of the Kitchen | Cooling room and Cold-water Filter in School |
|--------------------------------------------------------------------|---------------------------------|----------------|--------------------------|----------------------------------------|---------------|--------------------------------------------------------------------|----------------------------------------------|
| Medical Camp with Free Medicine                                    | 1.00                            | 2.00           | 3.00                     | 4.00                                   | 3.00          | 5.00                                                               | 4.00                                         |
| Financial Help                                                     | 0.50                            | 1.00           | 2.00                     | 4.00                                   | 2.00          | 4.00                                                               | 3.00                                         |
| Solar Fan or Charger Fan                                           | 0.33                            | 0.50           | 1.00                     | 0.33                                   | 2.00          | 0.50                                                               | 4.00                                         |
| Prior Alerts through the Miking System                             | 0.25                            | 0.25           | 3.03                     | 1.00                                   | 2.00          | 4.00                                                               | 2.00                                         |
| Cooling Space                                                      | 0.33                            | 0.50           | 0.50                     | 0.50                                   | 1.00          | 3.00                                                               | 5.00                                         |
| Attach Board under Tin-roof and Improve Ventilation of the Kitchen | 0.20                            | 0.25           | 2.00                     | 0.25                                   | 0.33          | 1.00                                                               | 2.00                                         |
| Cooling Room and Cold-water Filter in School                       | 0.25                            | 0.33           | 0.25                     | 0.50                                   | 0.20          | 0.50                                                               | 1.00                                         |

## 11.7 AHP Ranking Validation by the Stakeholders

The proposed Anticipatory Actions were ranked based on a set of criteria and application of the AHP model, and the scores have been validated by the stakeholders in the validation workshop. The participants were from various govt. departments and organizations like WASA, RDA, UNDP, GRC, School Principals, etc. related to the study and divided into four mixed groups (7-8 participants in each group) to evaluate and rank the feasible early action measures for heatwave. The stakeholders are in four mixed

groups to discuss in detail whether the proposed intervention is relevant or not and also evaluate the criteria used for evaluation in the study. They evaluated the rankings of the interventions based on the institutional capacity and positive return and they also justified their suggested ranking.

Then those rankings were again run through the AHP model and found very well aligned with the proposed rank in the study. The outputs with comparison are shown in Table 23.

**Table 23: AHP ranking in validation workshops.**

| Interventions                                | AHP Ranking by the study team | Groups 1 | Groups 2 | Groups 3 | Groups 4 | Final Ranking (by the stakeholders) |
|----------------------------------------------|-------------------------------|----------|----------|----------|----------|-------------------------------------|
| Medical Camp with Free Medicine              | 1                             | 1        | 1        | 1        | 1        | 1                                   |
| Financial Help                               | 2                             | 3        | 4        | 2        | 2        | 2                                   |
| Solar Fan or Charger Fan                     | 5                             | 6        | 6        | 4        | 6        | 6                                   |
| Prior Warning                                | 3                             | 2        | 2        | 3        | 3        | 3                                   |
| Cooling Space                                | 4                             | 4        | 3        | 5        | 4        | 4                                   |
| Attach Board under Tin-roof                  | 6                             | 5        | 5        | 6        | 5        | 5                                   |
| Cooling Room and Cold-water Filter in School | 7                             | 7        | 7        | 7        | 7        | 7                                   |

Source: Prepared by the author as per suggestion and analysis.

The majority of stakeholders prioritized medical camps and free medicine, with unconditional cash grants being the second priority. However, Group 2 believes that people will become idle and dependent on monetary help. Prior warning through the miking system is ranked either second or third among all the groups, highlighting the importance of being aware of risks and precautions. Although cooling spaces are agreed upon by most stakeholders, opposing views were also found. While Group 2 regarded it as a great support for vulnerable people, Group 3 stated they may lack community values and misuse the assets of cooling space. Solar fans or charge fans are ranked sixth as most of the groups fear the beneficiaries may sell them instead of using them for their benefit. Attaching boards under tin roofs is ranked fifth, while cool rooms and water filters are ranked seventh. Many

stakeholders believe schools should implement these measures independently, as they will become more crucial in the future due to extreme heatwaves.

For combining the rankings of four groups the weighted average method was used where all groups were given equal weights to come to the final ranking. Except for two interventions (providing a solar Fan or charger fan and attaching board under the tin roof), the ranking of all other interventions is consistent among all four groups. In our analysis, the solar fan or charger fan was ranked fifth, and the attaching board under the tin roof was ranked sixth. However, the outcome of the validation workshop for providing a solar fan or charger fan was ranked sixth and attaching a board under the tin roof was ranked fifth. Overall, our ranking and stakeholders' ranking are similar and validated as very important.

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