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# Detection and Analysis of Extreme Heat Events in the Chuadanga District of Southwestern Bangladesh †

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**Abstract**

Chuadanga in southwestern Bangladesh is among the country's hottest areas, yet it is unclear whether its heat risk is rising. This study combined daily maximum temperature (Tmax) and relative humidity from the Bangladesh Meteorological Department (BMD) station (1990–2024), MODIS Land Surface Temperature (LST), and a survey of 50 low-income outdoor workers. Heat waves followed the BMD definition (≥3 consecutive days with Tmax ≥ 36 °C), close to the station's 90th percentile (36.4 °C); intensity was assessed with severity classes and a heat index. The station recorded 171 spells and 1670 hot days. Annual hot days showed no significant trend ($p = 0.733$) but peaked at 84 days in 1992 and 2023 and 83 in 2024; severe or extreme days made up 25.3% of hot days in 2024, against 16.7% in 1992. Monsoon-season hot days increased significantly ($p = 0.017$). Danger-class heat index days rose by 15.2 days per decade, mainly in June–September. Terra LST differed from station Tmax by 3–4 °C, whereas afternoon Aqua LST was within 0.5 °C on average. All residents perceived worsening heat; 40% reported hospitalization. Results are for one station and suggest a heavy and increasingly dangerous heat burden, supporting worker protection and early warning.

**Keywords:** heat wave; hot days; MODIS land surface temperature (LST); Mann–Kendall trend; occupational heat stress; climate perception; early warning systems

## 1. Introduction

Heat waves are becoming more frequent, longer and hotter worldwide, and this rise has been accelerating since the 1950s [1]. Their causes are only partly understood, involving global warming, air circulation, landform and hydrology [2]. The human cost is severe: extreme heat raises illness and death and reduces the capacity for physical work. Nearly half of the world's population and more than one billion workers are exposed to high heat [3], and heat strain sharply cuts the manual work capacity of outdoor workers [4].

South Asia is among the regions most affected by climate change [5], and the 2022 pre-monsoon heat waves showed how severe such events can become [6]. Recent studies link these extremes to a northward shift of upper-level winds [7], upper-air wave activity combined with drying soils [8], and persistent subtropical high-pressure systems [9]. The health toll is profound: the 2010 heat wave caused more than 1300 deaths in Ahmedabad, India, and the 2015 heat wave more than 1200 deaths in Karachi, Pakistan [10]. Bangladesh is densely populated, has low coping capacity and is among the most heat-vulnerable countries in South Asia. Pre-monsoon (March–May) extreme heat threatens public health,

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livestock, the energy sector, agriculture and outdoor workers [11]. Annual mean outdoor wet bulb globe temperature (WBGT) derived from ERA5 rose by 0.08–0.5 °C per decade across Bangladesh during 1979–2021, with more days of high and extreme heat-illness risk [12]. The western districts, including Rajshahi, Chuadanga, and Jashore, are the hottest areas [11,13].

Chuadanga ranks among the country's five hottest stations for 1990–2019 [13], and a local media report placed its April 2024 peak at 43.7 °C, the highest in 29 years [14]. Yet the long-term direction of change is unclear. A multi-station analysis for 1991–2021 reported a decline in pre-monsoon days with Tmax ≥ 36 °C at Chuadanga, significant only at the 90% level [11], but heat has intensified sharply across South Asia since 2022 [6,15]. We therefore extend the record to 1990–2024 and examine total hot days and days in each severity class.

Three broader limitations complicate heat wave detection in Bangladesh. First, no single definition applies everywhere, since thresholds and durations vary [16,17]. In India, for example, a study using Indian Meteorological Department criteria applied three different daily maximum temperature thresholds, above 40 °C for plains, 37 °C for coastal areas and 30 °C for hilly regions [18]. The World Meteorological Organization (WMO) states that no universally accepted definition exists and that national service set thresholds to suit local climate; about 60% of WMO Members use absolute thresholds to define heat waves [19]. Percentile-based indices, such as the warm spell duration index, instead require at least six consecutive days above the calendar-day 90th percentile [19]. The Bangladesh Meteorological Department (BMD) uses a fixed threshold, Tmax ≥ 36 °C, for at least three days. At Chuadanga, the 90th, 95th, 97th and 99th percentiles of daily Tmax for 1990–2024 are 36.4, 37.55, 38.5 and 40.2 °C, respectively, close to the BMD class limits (36, 38 and 40 °C). The BMD thresholds therefore behave like high-percentile thresholds, so we keep them and add counts of all hot days and of severe and extreme days as indicators of frequency and intensity. Second, ground stations are sparse, so satellite data are needed for spatial patterns; MODIS Land Surface Temperature (LST) offers broader coverage, but it is a skin temperature observed at fixed overpass times, mainly under clear skies, so it differs from air temperature [20–23]. Third, few studies have combined station records, satellite data and residents' perceptions for Chuadanga.

This study addresses these gaps with three lines of evidence: (i) a 35-year station record of heat wave frequency, duration and intensity; (ii) MODIS LST, checked against station temperatures and used only for seasonal and spatial context; and (iii) a survey of 50 low-income residents aged 40 and above who are regularly exposed to heat outdoors.

## 2. Materials and Methods

### 2.1. Station Data and Heat Wave Definition

Daily maximum temperature (Tmax) for 1990–2024 was obtained for the Chuadanga station from BMD. A heat wave spell followed the BMD definition of at least three consecutive days with Tmax ≥ 36 °C, retained as the national operational definition [19]. Following WMO advice to describe events by magnitude, duration and extent [19], magnitude was measured with the BMD severity classes (mild, 36–38 °C; moderate, 38–40 °C; severe, 40–42 °C; extreme, >42 °C), duration by spell length, and frequency by the number of spells and hot days (days with Tmax ≥ 36 °C). Intensity was compared between years using the share of severe and extreme days among hot days. Trends were tested with the Mann–Kendall test and Sen's slope; spell onset month was also examined.

### 2.2. Study Area

Chuadanga District (23.64° N, 88.84° E) lies in southwestern Bangladesh, far from the Bay of Bengal and exposed to hot westerly air from Peninsular India (Figure 1). Daily

records were available only from the Chuadanga BMD station, so the results describe one point, which earlier multi-station studies place in the hot western belt of Bangladesh [11,13].

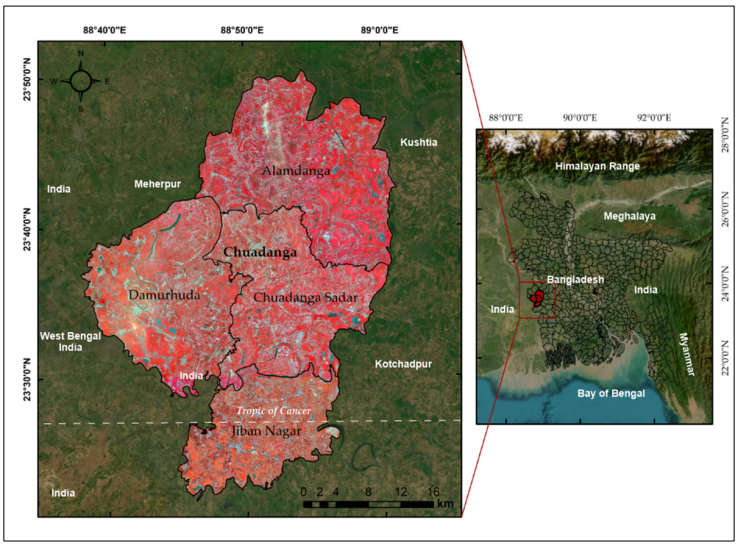



**Figure 1.** Study area map of Chuadanga District, located in southwestern Bangladesh.

### *2.3. MODIS LST Validation*

Monthly daytime LST (0.05°, about 5 km) from MOD11C3 (Terra, 2000–2024; about 10:30 local time) and MYD11C3 (Aqua, 2003–2024; about 13:30) was regressed against BMD mean Tmax for April of each year (Terra $n = 25$; Aqua $n = 22$) and for each month of 2024, with $R^2$ and mean bias reported [20–24]. LST, a clear-sky skin temperature, was used only for seasonal and spatial context.

### *2.4. Heat Index*

Humidity was included through the heat index (HI), computed for each day of 1990–2024 (12782 days) from daily mean air temperature and relative humidity [25], using the Rothfusz regression with National Weather Service adjustments [26,27]. Days were classed as Caution (26.7 to <32.2 °C), Extreme Caution (32.2 to <39.4 °C), Danger (39.4 to <51.7 °C) or Extreme Danger (≥51.7 °C) [27]. Yearly class counts were tested with Mann–Kendall and Sen's slope.

### *2.5. Public Survey*

A structured questionnaire was administered to 50 low-income residents (informal-sector workers, following the ILO definition) aged 40 years or above, with regular outdoor exposure. It covered perceptions of heat waves, the hot season, causes, and health and livelihood impacts. The survey was conducted in October 2025 and June 2026, after the end of the station records, but it captures changes recalled over 40 or more years, overlapping 1990–2024; results were therefore compared qualitatively.

## 3. Results

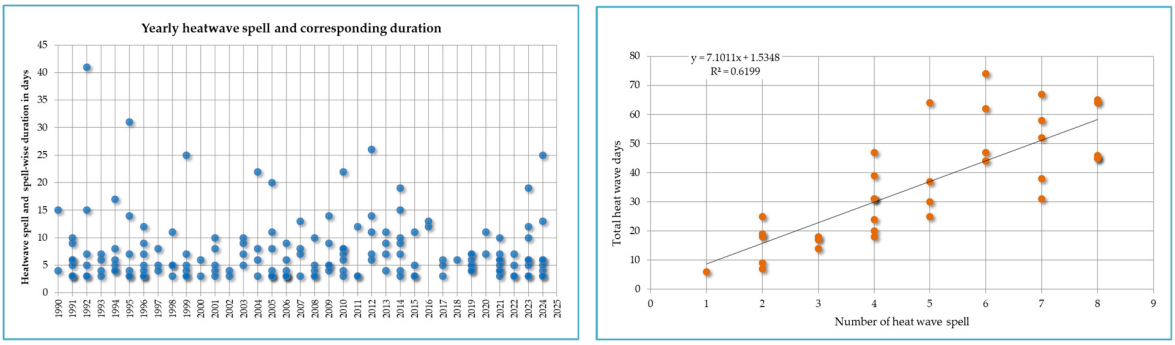
### *3.1. Heat Wave Climatology and Trend at Chuadanga Station (1990–2024)*

According to BMD, a heat wave event is defined as three or more consecutive days with Tmax ≥ 36 °C, with consecutive qualifying days counted once as a single spell. Days were classified as mild, moderate, severe, or extreme according to fixed temperature ranges, without regard to duration. In this study, "heat wave" refers strictly to multi-day spells, whereas single extreme days are classified as "hot days". Over the 35-year record, Chuadanga

experienced 171 heat wave spells, totaling 1243 heat wave days, plus a further 427 hot days that fell outside a qualifying spell, i.e., ≥36 °C but less than 3 consecutive days. In total, 1670 hot days have occurred in 35 years in this district. The sections below describe how often the heat wave spells occurred, how long they lasted, how many total hot days occurred each year and how intense those days were.

### 3.1.1. Chronological Heat Wave Spells

Chuadanga experienced about five spells a year on average, though the number varied from year to year. Annual counts ranged from 1 to 8 spells (Figure 2a), with 1991, 1996, 2023 and 2024 reaching the upper end of this range with 8 spells. Figure 2a shows that most years had several short-duration spells, while in a few years a long-duration spell stands out from the rest. Correlation between spell number and total heat wave days or spell duration indicates linear increasing trend (Figure 2b).

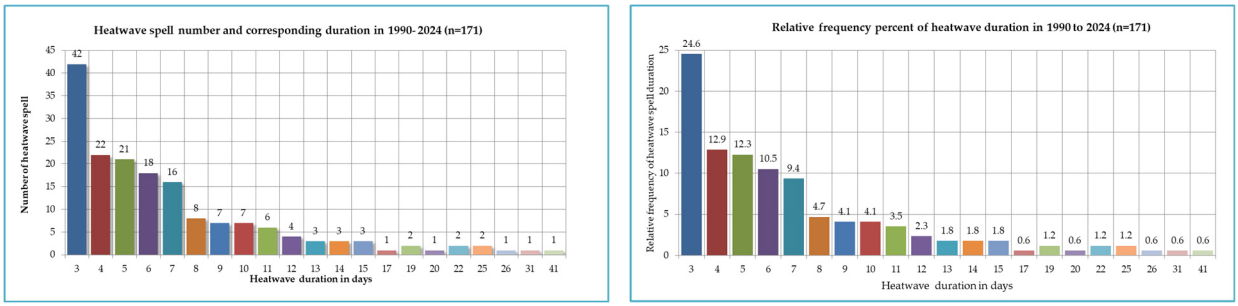



(**a**) (**b**)

**Figure 2.** (**a**) Yearly heat wave spells and corresponding spell duration in 1990–2024. (**b**) Correlation between number of heat wave spells and total heat wave days.

### 3.1.2. Frequency Distribution of the Heat Wave Spells

Heat wave duration ranged from 3 to 41 days, but short spells dominate the distribution (Figure 3a). Spells of 3 days account for 42 events and spells of 4–7 days for 77 events. As duration increases, spells become fewer: 8–10 days, 22 spells; 11–15 days, 19 spells; and 17–26 days, 9 spells. Only one spell of 31 days and one of 41 days were observed in the 35-year dataset. In relative terms (Figure 3b), 3-day spells make up 24.6% of all spells, 4–7 days 45.0%, 8–10 days 12.9%, 11–15 days 11.1% and 17–26 days 5.3%. The 31-day spell in 1995 and the 41-day spell in 1992 each make up 0.6% of the total. The distribution is therefore dominated by short spells. Spells longer than 15 days are rare, but they have a stronger impact on livelihoods, ecosystems, and water and energy demand than short spells.

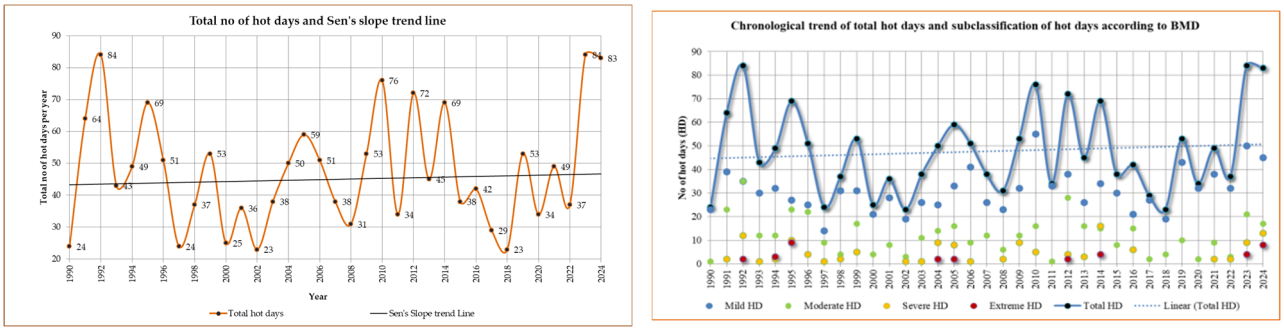



(**a**) (**b**)

**Figure 3.** (**a**) Absolute frequency distribution of spell duration ($n$ = 171). (**b**) Relative frequency (%) distribution of spell duration in 1990–2024 ($n$ = 171).

### 3.1.3. Trend of Hot Days over 35 Years

Total hot days (HD) are all the days with temperatures ≥36 °C. The Sen's slope line in Figure 4a rises only slightly, from about 43 days in 1990 to about 47 days in 2024. The Mann–Kendall test indicates that this small rise is not statistically significant ($S = 25$, $Z = 0.341$, $p = 0.733$, $\tau = 0.042$). Sen's slope is 0.1 days per year, which adds up to about 3.4 extra hot days over the 35 years. Overall, the number of hot days at the station has stayed almost the same over the record, with large year-to-year changes.




(**a**) (**b**)

**Figure 4.** (**a**) Total number of hot days (HD) per year (1990–2024) with Sen's slope trend line. (**b**) Chronological trend of total annual hot days, with severity sub-classification (mild/moderate/severe/extreme).

The lowest count was 23 days, in both 2002 and 2018. The highest was 84 days, in 1992 and 2023, and 2024 was nearly as high at 83 days. Other clear peaks appeared in 1995 (69 days), 2010 (76 days), 2012 (72 days) and 2014 (69 days). Most high years were followed by a sharp drop, so the record shows strong year-to-year variability and does not move steadily in one direction (Figure 4b).

Hot-day counts alone do not show how intense the heat was, so the severity classes were also examined. In 2022, 32 of 37 hot days were mild. By 2023, every class had grown (mild 50, moderate 21, severe 9, extreme 4), and 2024 was similar (mild 45, moderate 17, severe 13, extreme 8). The three peak years had almost the same number of hot days but different intensities: severe and extreme days made up 16.7% of hot days in 1992 and 15.5% in 2023, but 25.3% in 2024. Earlier peaks were made up mostly of milder days; for example, 2010 (76 days) had 55 mild days and almost no extreme ones. The only earlier year with a comparable number of extreme days was 1995 (about 9); the 8 extreme days recorded in 2024 are the highest count since then. Heat in 2024 was therefore more intense than in 1992, even though the hot-day counts were alike.

### 3.1.4. Trends of Total Pre-Monsoon and Monsoon Hot Days

Pre-monsoon (March–May) hot days show a non-significant decreasing trend for 1990–2024 ($S = -68$, $Z = -0.95$, $p = 0.341$, $\tau = -0.114$, Sen's slope = −0.33 days/year). Monsoon-season (June–September) hot days show a statistically significant increase in 1990–2024 ($S = +168$, $Z = 2.38$, $p = 0.017$, $\tau = 0.282$, Sen's slope = +0.33 days/year) (Figure 5).

### 3.1.5. Characteristics of Heat Wave Onset Dates

Heat wave spells usually begin between March and June. The trend line in Figure 6 moves from about April in 1990 to about May in 2024, indicating a modest delay in onset over time. A few starts fall well outside this usual window: some spells began very early,

around February in 2005 and 2006, while others began late, in September 1992, October 2010, and August 2023. Several spells since 2019 have also begun as late as June–July.

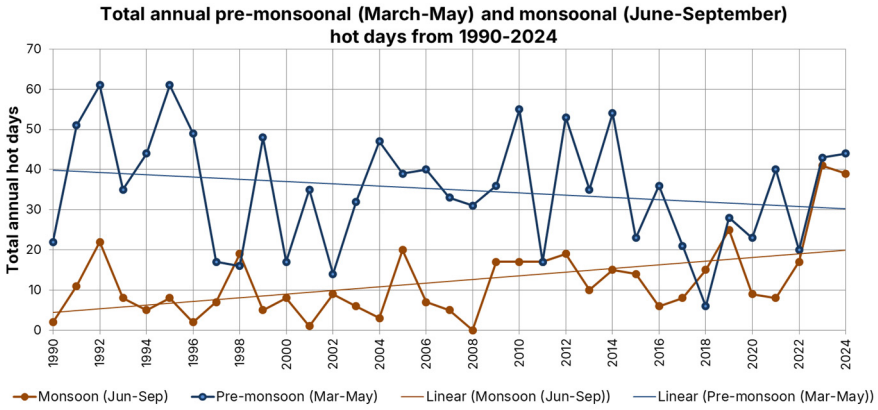



**Figure 5.** Trends of total annual pre-monsoon (March–May) hot days and monsoon (June–September) hot days in 1990–2024.

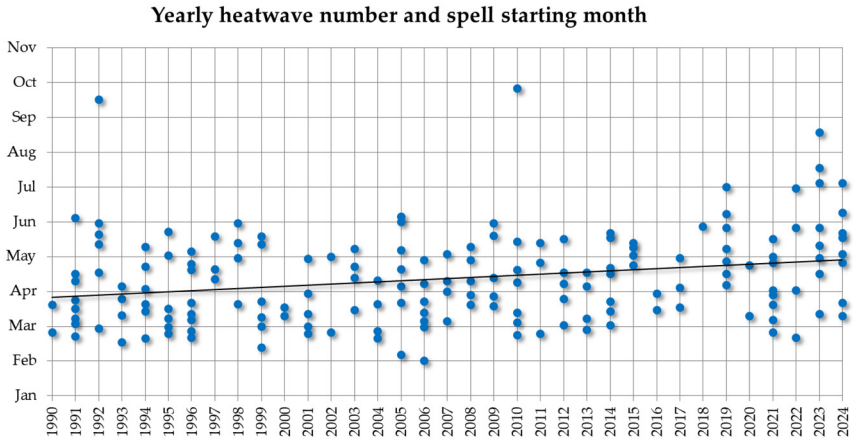



**Figure 6.** Long-term shift in heat wave spell onset month over 35 years from 1990 to 2024.

### *3.2. Heat Index and the Effect of Humidity*

Including humidity, the heat index (HI) reached at least the Caution class 226.5 days per year on average (about 62% of the year), with no trend in this total ($p = 0.49$). What changed was the mix of classes (Figure 7). Danger and Extreme Danger days rose by 15.2 days per decade ($\tau = 0.49$, $p < 0.001$), from 58.7 days per year in 1990–1999 to 98.6 in 2020–2024, while Extreme Caution days fell by 11.5 days per decade ($p < 0.001$) and Caution days showed no significant change ($p = 0.29$). The year 2024 had the most Danger days (116) and the only Extreme Danger day of the record (53.7 °C on 10 June).

Danger days occurred from March to October, with about 75% in June–September; June (16.1 days), July (13.5) and August (13.0) had the most. Their increase was significant in June, July, August and September (+2.2 to +3.8 days per decade) but not in April or May ($p > 0.75$), which agrees with the rise in monsoon-season hot days (Section 3.1.4). Humidity explains this contrast: from June to August, the mean air temperature is 30–31 °C but the HI is 39–40 °C because relative humidity is 82–86%, whereas in March the two differ by only 1.5 °C.

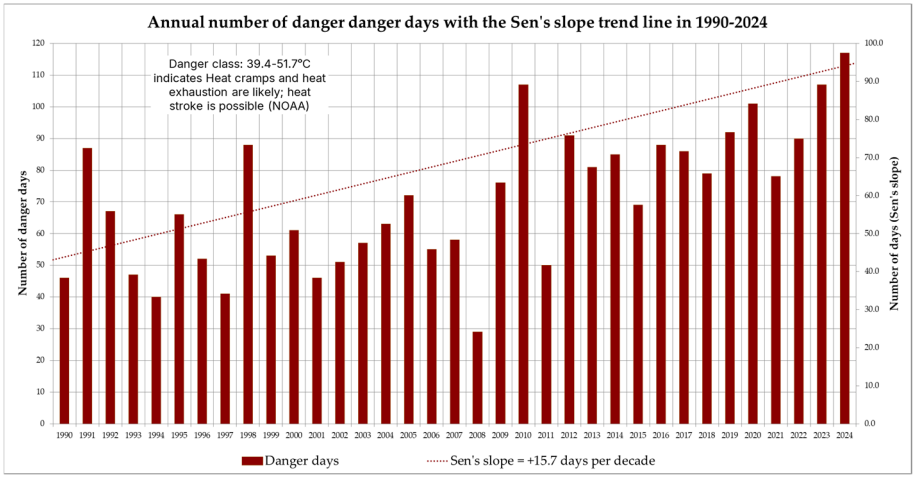



**Figure 7.** Annual number of Danger and Extreme Danger heat index days in Chuadanga, 1990–2024, with the Sen's slope trend (+15.2 days per decade).

### *3.3. Comparison of Monthly MODIS Daytime LST with BMD Station Observations*

MODIS Land Surface Temperature (LST) measures ground skin heating, whereas Bangladesh Meteorological Department (BMD) stations record air temperature 1.2–2 m above ground. Consequently, while related, the two metrics differ physically. A comparison of monthly daytime LST and BMD maximum air temperature (Tmax) across 2000–2024 (April) and all 12 months of 2024 demonstrates that LST accurately captures seasonal progression ($R^2$ = 0.881), rising from January until reaching its peak in April, before declining through the monsoon. However, year-to-year variation in April showed a weaker correlation ($R^2$ = 0.553), confirming that LST reflects broad seasonal cycles rather than daily heat waves or fine-scale annual variations.

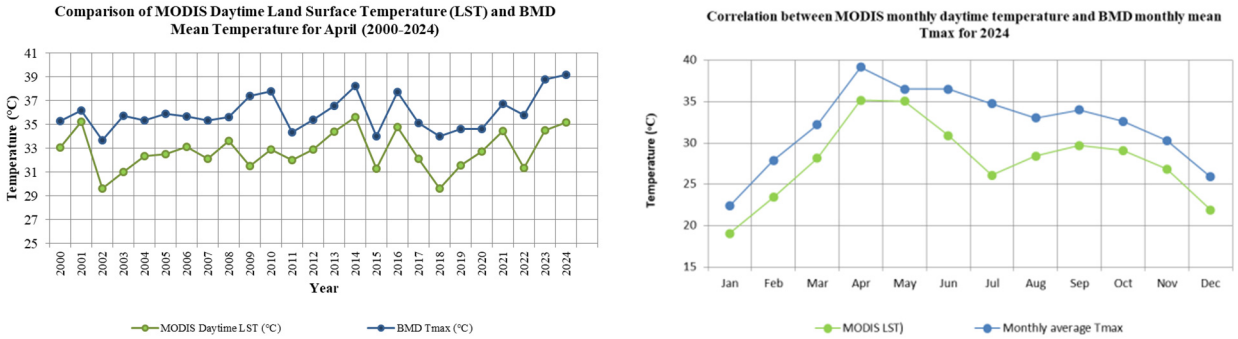
The two datasets also exhibit distinct seasonal offsets (Figure 8, Table 1). In 2024, Terra LST was lower than mean Tmax in every month by an average of 4.3 °C, with the largest disparities occurring in June and July, when monsoon cloud cover, rain, and soil moisture cooled the ground surface. Terra daytime LST was also lower than BMD Tmax every April from 2000 to 2024. These biases are partly a matter of timing, as Terra passes overhead around 10:30 local time, well before the peak afternoon air temperature. Aqua passes at about 13:30 and showed much better agreement: for April 2003–2024, the mean bias was +0.05 °C ($R^2$ = 0.606), and the three hottest Aprils at the station (2024, 2023 and 2014) were among the five warmest in the Aqua record. For 2024, Aqua gave $R^2$ = 0.873 and a mean bias of −0.43 °C, although July and August had no usable values. Year-to-year agreement for April remained only moderate for both satellites.

**Table 1.** Summary of MODIS LST-BMD regression results for the two comparisons.

| Comparison | Data Used | $R^2$ | Mean Bias (°C) |
|---|---|---|---|
| Terra April vs. BMD Tmax | April only, 2000–2024, 25 values | 0.553 | −3.19 |
| Terra 2024 vs. BMD Tmax | Monthly, 12 values | 0.881 | −4.29 |
| Aqua April vs. BMD Tmax | April only, 2003–2024, 22 values | 0.606 | +0.05 |
| Aqua 2024 vs. BMD Tmax | Monthly, 10 values | 0.873 | −0.43 |

Two further features of the product limit the comparison. First, a satellite observes a given place only at its overpass times, and the monthly product is built from clear-sky observations only [21]; cloudy days, which are common in the monsoon, are missing, so monthly LST may lean toward clearer days. Second, the station gives a point measurement of air temperature, while an LST pixel represents the average surface temperature over an

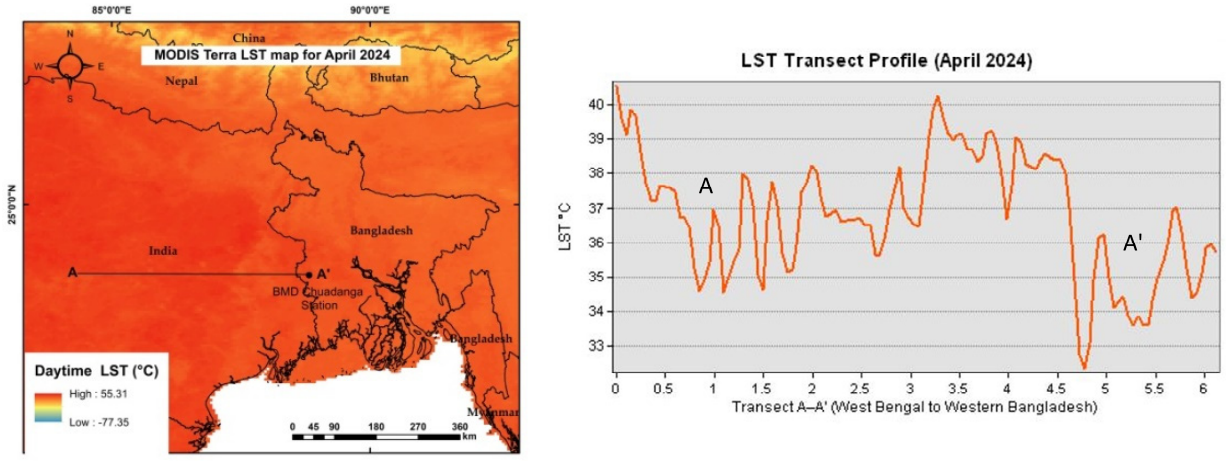
area of about 5 km. For these reasons, LST was not used to detect heat waves or to estimate air temperature, and the bias is reported as a systematic offset without correction. The afternoon Aqua overpass lies closer to the time of daily maximum temperature, which explains much of its smaller bias, and its missing monsoon months show the effect of clear-sky sampling.




(**a**) (**b**)

**Figure 8.** MODIS Terra daytime LST compared with BMD station temperature. (**a**) April values for 2000–2024 ($n = 25$), with BMD mean maximum temperature. (**b**) Monthly values for 2024 ($n = 12$), with the BMD monthly mean of Tmax. In both panels the two records rise and fall together, but LST is not equal to station air temperature.

Figure 9b shows LST along a profile line for April 2024, generally higher in the west, over India, and lower toward Bangladesh. This matches the westward pattern reported by Dastour et al. [28], who found that maximum air temperature fell with increasing longitude in March and May. Such maps show where surface heating is stronger, but a single month is not a trend for Chuadanga District. These results should be read with caution: the samples are small ($n = 12$–$25$), no held-out data were tested, and LST is a skin temperature that cannot replace air temperature without season- and site-specific corrections. Therefore, MODIS LST is best used for seasonal and spatial patterns, while BMD records remain the reference for identifying heat waves.




(**a**) (**b**)

**Figure 9.** Spatial pattern of MODIS daytime LST. (**a**) LST map of the region for April 2024; line A−A′ marks the profile path from India, West Bengal (A), to western Bangladesh, Chuadanga District (A′). (**b**) LST along line A−A′ for April 2024, generally higher in the west and lower toward the east. LST is ground-surface temperature, not air temperature.

### 3.4. People Perceptions and Health Burden of Extreme Heat ($n = 50$)

A public survey evaluated community perceptions of heat waves among 50 low-income, long-term outdoor workers ($n = 50$) in Bangladesh's Chuadanga District. To assess changes in local weather over time, sampling targeted adult residents with at least 40 years of continuous residency. Participants—comprising farmers, day laborers, rickshaw pullers, traffic police, fishermen, construction workers, hawkers, small shop owners, and office workers—were drawn from urban (54%), suburban (22%), and rural (24%) areas. On average, respondents spent 10 h daily outdoors (ranging from 4 to 15 h), lacked air conditioning, and experienced frequent power outages. These findings reflect personal recollections and lived experiences; these are quantitative self-reports rather than direct meteorological or medical measurements.

To our knowledge, this study presents the first community survey on heat waves in Chuadanga and all 50 respondents reported intensifying heat waves, rating severity at an average of 8.50/10 (Table 2)—aligning with rural findings in Rajshahi and Khulna [29]. Chuadanga residents identified May, June, and September as peak months, reflecting a broader extreme-heat window than reported in Rajshahi [30] or Dhaka [31]. Consistent with earlier findings identifying outdoor workers as highly vulnerable [30,31], 66% of respondents experienced reduced work capacity, and 40% reported hospitalization due to heat-related illnesses. Regarding attribution, Chuadanga participants primarily blamed deforestation (40%) and fate (38%), contrasting with the literature emphasizing urban heat island (UHI) effects and regional ecological changes [29–31].

**Table 2.** Key survey metrics on heat wave perception and health burden.

| Metric | Value |
|---|---|
| Heat waves perceived as increasing | 100.0% ($n = 50$) |
| Mean severity rating | 8.50/10 (intolerable) |
| Hospitalized due to extreme heat | 40.0% ($n = 20$) |
| Reduced work productivity | 66.0% ($n = 33$) |
| Hottest months | May 68%; June, September 66%; August 64%; April 56%; July 50%; March 14% |
| Perceived causes | Deforestation, Fatalistic, Drying water bodies, Climate change |

## 4. Discussion

Over 1990–2024, Chuadanga recorded 171 heat wave spells, about 5 a year, with yearly counts from 1 to 8. Most spells were short: about 70% lasted 3–7 days. Spells longer than 15 days were rare, but they strain livelihoods, water and energy demand. Annual hot days (Tmax $\geq$ 36 °C) rose only slightly (Sen's slope = 0.1 days per year, $p = 0.733$). The record moves in cycles, with high years such as 1992, 2010, 2012, 2023 and 2024 usually followed by sharp drops. Pre-monsoon hot days fell slightly ($p = 0.341$), in the same direction as the decline reported by Rahman et al. [11]. After 2021, however, monsoon and post-monsoon hot days rose sharply. Monsoon hot days averaged 10.5 days a year in 1991–2021 but 32.3 days a year in 2022–2024, which lifted the monsoon trend to a significant level ($p = 0.017$). This recent rise is not visible in the earlier record that ends in 2021 [11]. Hot days jumped from 37 in 2022 to 84 in 2023 and 83 in 2024.

The strong 2023–24 El Niño (Oceanic Niño Index, ONI, peak +2.06) [32] may have contributed, as hot days in 2024—as in 1992, 1995 and 2010—occurred in the year after an El Niño peak. Yet, 2023 began before El Niño developed, and El Niño years tend to bring above-normal monsoon rain in Bangladesh [33], so its role cannot be separated from warming here. We did not analyze humidity or rainfall in relation to El Niño, so the suggestion that El Niño suppressed monsoon humidity and raised temperatures cannot be tested with our data and should be checked in future work.

Counts alone hide a change in intensity. In 2024, 25.3% of hot days were severe or extreme, against 16.7% in 1992 and 15.5% in 2023, although all three years had 83–84 hot days, and the 8 extreme days in 2024 are the most since 1995. Recent South Asian heat has been linked to shifting winds, drying soils and persistent high-pressure systems [7–9], but our data cannot determine which process was responsible here. Part of the rise may have also come from a fixed threshold catching more days as the climate warms [34]. The usual onset of heat waves has shifted from April in 1990 to May in 2024, and a few spells began between July and October. Residents named May, June and September as the hottest months, a wider window than March–May, which fits this later start.

Including humidity gives a clearer signal of rising intensity than temperature alone. Danger-class heat index days rose by 15.2 days per decade, from 58.7 to 98.6 days per year between 1990–1999 and 2020–2024, although the total number of warm days did not change, and the rise was confined to June–September. This agrees with the significant increase in monsoon-season hot days and with residents' view that the hot season now includes June and September. From June to August, the heat index is 8–9 °C above the monthly mean air temperature, so temperature alone understates the risk to outdoor workers. The heat index assumes shade and light wind, and sunshine can add several degrees [27], so conditions in open fields may be worse than reported. These results support the use of humidity in local warning thresholds.

MODIS Land Surface Temperature (LST) followed the seasonal cycle of station temperature closely in 2024 ($R^2 = 0.881$), but the April fit across 25 years was weaker ($R^2 = 0.553$). Terra LST differed from station temperature by about 3–4 °C because it measures the ground surface, not the air [23], and the satellite passes before the afternoon peak and observes mainly under clear skies. The afternoon Aqua pass was much closer to station Tmax (mean bias +0.05 °C in April and −0.43 °C in 2024), but its April fit across years was still only moderate ($R^2 = 0.606$). MODIS LST is therefore not a replacement for ground data. The profile for April 2024 shows heat rising from east to west, which may point to a regional climate influence on Chuadanga and other western districts. This covers one month only, so other years must be tested.

All 50 residents reported that heat waves are becoming more severe; the station record also shows more severe and extreme days in 2023–2024. The survey is therefore used here as evidence of lived experience and health burden, not as a measurement of heat. It was carried out in 2025–2026, after the station and satellite records ended, but it does not describe a single year: residents with 40 or more years of residence recalled long-term change, which overlaps the whole 1990–2024 record. Their view of worsening heat fits the recent rise in severe days and the significant increase in monsoon-season hot days, although the two sources cannot be compared statistically and recent hot years may weigh more in memory. The 40% hospitalization and 66% lost work capacity fit the heavy heat burden of outdoor workers elsewhere [4,35]. Only 16% named climate change as a cause, so further awareness efforts are needed. These results also match the call of the United Nations Office for Disaster Risk Reduction (UNDRR) for heat thresholds that reflect humidity, wind and persistence, for heat action plans that are practiced, and for protection of daily-wage workers who lose income when work stops [36]. Residents' preference for tree planting (46%) fits the UNDRR call for nature-based solutions [36]. Because respondents were aged ≥40 years, their reports may also reflect age-related changes on how heat is perceived, since thermal sensitivity declines with age [37] and older adults may underestimate their physiological heat strain, which can delay protective behavior and raise health risk [38]; prior awareness of climate change may further shape how experiences are interpreted. We did not stratify responses by age and cannot separate these effects, so the results are best read as perceptions of long-term outdoor workers rather than as measured heat exposure.

This study has limits. It rests on one station, so the results describe Chuadanga station and indicate, but do not prove, conditions across the district; WMO guidance also judges the extent of an event across several stations [19]. The BMD definition uses Tmax only; humidity enters through a daily heat index that assumes shade and light wind [27], and neither captures night-time heat or cumulative heat load. MODIS LST differs physically from air temperature and was used only for seasonal and spatial contexts. The survey is small, self-reported and limited to residents aged 40 and above.

## 5. Conclusions

Station, satellite and survey evidence show a heavy heat burden at Chuadanga, based on one BMD station. Annual hot days (Tmax $\geq$ 36 °C) had no significant long-term trend ($p = 0.733$) but varied strongly, and 2023 and 2024 (84 and 83 days) matched the 1992 peak. Intensity differed, however: severe and extreme days were 25.3% of hot days in 2024, against 16.7% in 1992 and 15.5% in 2023, and monsoon-season hot days increased significantly. With humidity included, Danger-class heat index days rose by 15.2 days per decade, from 58.7 to 98.6 days per year, and the first Extreme Danger day (53.7 °C) occurred in June 2024. Terra LST captured the seasonal cycle but was 3–4 °C below station Tmax, whereas afternoon Aqua LST was much closer; station data should still remain the heat wave reference. All 50 residents perceived worsening heat, and 40% reported hospitalization. Following the UNDRR ten actions to combat heat [36], we recommend the following:

- Local heat thresholds that include humidity and spell length, linked to a practiced heat action plan and an early warning system;
- Social protection and work-rest schedules with shaded rest points for daily-wage and outdoor workers;
- Nature-based measures, such as tree planting and canal restoration, which residents favored.

Future work should add neighboring stations, test percentile-based heat wave definitions alongside the BMD threshold, and validate MODIS LST with independent data.

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**Institutional Review Board Statement:** The public survey data cannot be shared. The survey was non-sensitive and anonymous in nature; no personal information was collected.

**Informed Consent Statement:** The survey data were generated and used in this research with the permission of the residents.

**Data Availability Statement:** The 35-year daily maximum temperature dataset was obtained from the Bangladesh Meteorological Department (BMD). The MODIS Terra monthly LST dataset was retrieved from the official USGS website. The primary survey dataset was generated by the first author (M.R.M.) with the consent of the participants.

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## Abbreviations

The following abbreviations are used in this manuscript:

| | |
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| BMD | Bangladesh Meteorological Department |
| LST | Land Surface Temperature |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| Tmax | Daily maximum temperature |
| WBGT | Wet bulb globe temperature |
| ILO | International Labor Organization |
| ONI | Oceanic Niño Index |
| UNDRR | United Nations Office for Disaster Risk Reduction |
| WMO | World Meteorological Organization |
| HI | Heat index |

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