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Assessment of the temperature and humidity index (THI) to facilitate the establishment of a ruminant rearing system in Bangladesh

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ABSTRACT

The objective of this study was to assess the temperature-humidity index (THI) values in the selected regions of Bangladesh for the suitability of ruminant rearing. Data on monthly temperatures and relative humidity were collected from the Bangladesh Meteorological Department (BMD) for a 27-year time period (1995–2022). The study region's data indicated that the hottest area was west central region and hottest month was June. In comparison, the coolest area was northwest region and coolest month was January. The northwest region had no heat stress from November to February, mild heat stress from March to May and October, as well as moderate heat stress from June to September. In the northeast region, mild heat stress occurred from March to May, October, and November, and moderate heat stress from June to September. December to February were comfortable, March, October, and November were mild heat stress, and April through September were moderate heat stress in the west central region. In the east central region, mild heat stress occurred in March to April, October, and November, and severe heat stress in May to September. In contrast to the west central region, which showed moderate heat stress during the rainy season, most other seasons showed mild heat stress. Thus, heat stress periods might vary depending on regional meteorological scenarios. Animals faced heat stress (THI > 72) or a warning signal due to a progressive increase in temperature and humidity indices over months and years of investigation. When THI levels are high, especially in July and August, livestock farmers must emphasize various herd management techniques to limit the risk of milk production and quality concerns, disease prevalence, and reproductive performance. The findings of the present investigation suggest heat stress mitigation measures for Bangladeshi ruminant farmers.

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Introduction

The suitable climate condition is a crucial factor in the management of livestock, irrespective of specific husbandry method used. It is important to provide a conducive and pleasant environment for ruminant farming. The suitable climate condition improves animal metabolism and homeostasis, maximizing Animal Welfare and herd productivity when animals exhibit their genetic traits in a pleasant environment. However, climatic evaluations are conducted as a part of the planning process of farming for the livestock farmers (Nwobodo *et al*., 2022). Climatic conditions may affect physiological and behavioural reactions in this situation. When temperature and humidity indices are high (THI above 72) they cause thermal stress that leads to changes in the biological functions of these animals. These changes include alteration in food intake, enzymatic reactions, hormonal secretions, as well as immune status, all of which can have an effect on productivity indices (da Silva *et al*., 2023).

Heat stress is defined as a state in which the body of an organism is subjected to an inordinate amount of heat that surpasses its capacity to eliminate heat and preserve regular physiological processes. Ruminant physiology as well as production performance are adversely affected by heat stress. Ruminants that are subjected to heat stress may exhibit symptoms including hyperthermia, tachypnea, and alterations in behavior such as shade-seeking as well as decreased activity (Silva *et al*., 2023, Dos Santos *et al*., 2021). Besides, ruminant ability to release the heat stored in their body is hampered by the rise in ambient temperature and humidity. This raises the body's core temperature and may result in regulatory dysfunctions such as altered enzyme activity. Heat stress may impair food metabolism enzymatic activities, such as nutrient digestion and absorption, reducing food intake and feed conversion efficiency (Dos Santos *et al*., 2021).

Heat stress also has an effect on the hormones that control thermoregulation and the immunological response in ruminants. Temperature may alter hormones such as cortisol, which is generated through the adrenal gland in reaction to stress and affects the immunological system of animals. This may result in a weakened immune system and an increased vulnerability to illness and infection (Mota-Rojas *et al*., 2021). Research on thermal comfort in ruminant production under various climatic conditions is conducted using indices that assess diverse impacts and correlate with physiological and behavioral characteristics of these animals (McManus *et al*., 2022, Silva *et al*., 2022).

One of the most significant agricultural industries in our country is ruminant farming. Heat stress causes a drop in milk production in cows by 10-25% and exposes them to a variety of diseases (Tao *et al*., 2011). Furthermore, heat stress increases somatic cell count in cow milk (Smith *et al*., 2013). So, farm animals should be protected from heat stress.

Temperature and humidity have a significant impact on livestock farming and are major contributors to global warming. Due to global climate change, several challenges are being encountered in different locations of Bangladesh (Hossain *et al*., 2022). Different indices are employed to assess the level of heat stress experienced by livestock. However, the temperature-humidity index (THI) value is the most often utilized metric in this regard (Kibar *et al*., 2018). The THI index is a single metric that represents the combined effect of air temperature and relative humidity on heat stress levels. This index was created as an air safety tool to monitor and mitigate losses caused by heat stress in animal production (Çayl and Arslan, 2022). It is critical to assess THI values and calculate impact levels at the regional level in order to protect farm animals from these harmful conditions. Despite substantial study done elsewhere, there is a shortage of studies evaluating THI values, specifically in relation to ruminant rearing under the environmental conditions of Bangladesh. Therefore, the objective of this study was to assess the critical THI in order to determine the heat stress conditions for ruminat rearing in Bangladesh. Consequently, this study establishes the initial data that can be used for future investigations.

Materials and Methods

Study area and data

Bangladesh is located between 20° 34′ N and 26° 38′ N latitude and 88° 01′ E and 92° 41′ E longitude. The climate in Bangladesh is humid subtropical with high humidity and considerable seasonal rainfall changes. Bangladesh is located in the tropical monsoon zone, and its climate is characterized by high temperatures, abundant rainfall, and high humidity, with somewhat marked seasonal fluctuations (Alam *et al*., 2023). This study was carried out in the four regions of Bangladesh namely Northwest (NW) region, Northeast region (NE), West Central (WC) region and East Central (EC) region (Fig. 1). This study was conducted using observational data obtained from the Bangladesh Meteorological Department (BMD). The climatic data were recorded during the period of 1995 to 2022 at 17 different BMD stations. The BMD stations in the northwestern, northeastern, western central, and eastern central regions of Bangladesh are Bogura, Dinajpur, Rangpur, and Syedpur in the northwest; Mymensingh, Srimangal, and Sylhet in the northeast; Chuadanga, Faridpur, Ishurdi, Jessore, Rajshahi, and Tangail in the western central region; and Chandpur, Cumilla, Dhaka, and Madaripur in the eastern central region.

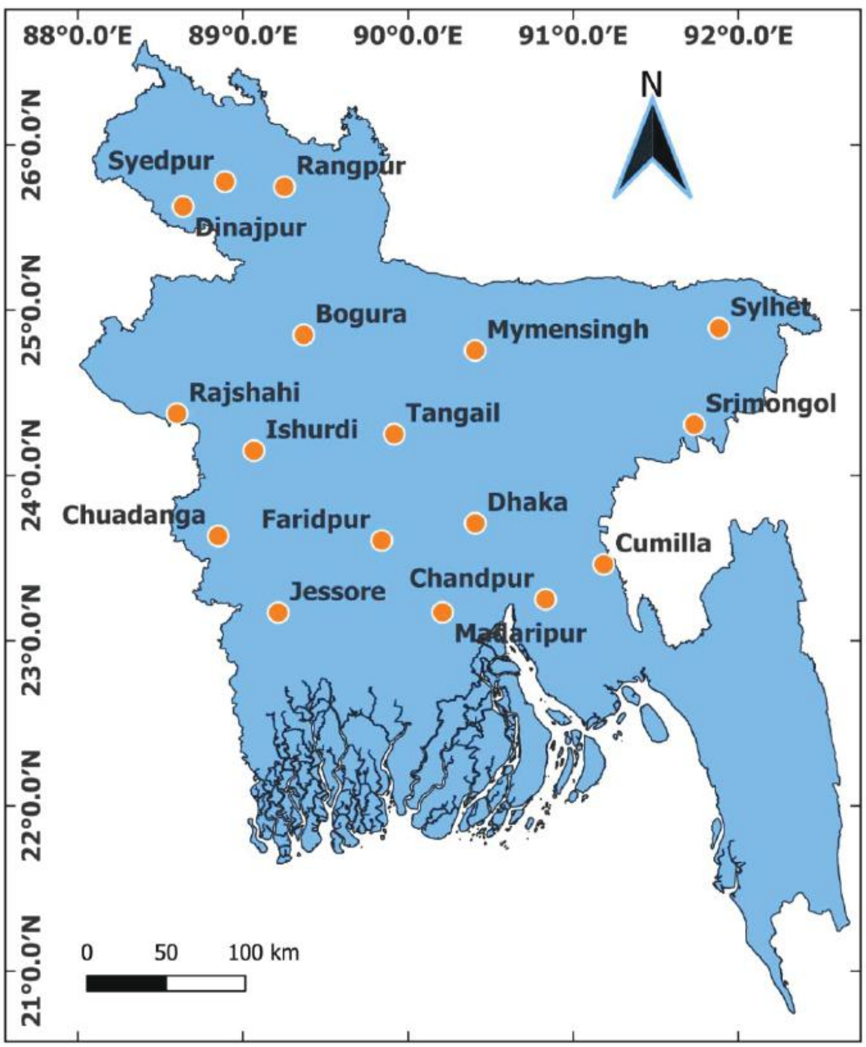

Fig. 1. The geographical positions of the study area.

Identifying the summer, rainy and winter seasons

The months of the year were divided into three seasons: summer, rainy and winter. In a year, the summer, rainy, and winter seasons are March-June, July-October, and November-February, respectively (Al Mahmud *et al*., 2015).

Calculation of Temperature and Hamidity Index (THI)

The temperature and humidity index (THI) for all months and years of each period was calculated at the weather stations using the air temperature, dew point temperature, and relative humidity readings. The THI were calculated using the following formula adopted from da Silva *et al*., 2023.

$$THI = (0.8 \times T) + (RH \div 100) \times (T - 14.4) + 46.4 \quad (1)$$

Where, T is the dry-bulb temperature (^{o}C), while RH is the relative air humidity (%).

In order to evaluate the severity of heat stress in ruminants (cattle, sheep, and goats), the model proposed by Armstrong, (1994) was used. The scale of severity was as follows: 72 denoted no stress, 72-78 mild stress, 79-88 moderate stress, and 89-98 severe stress.

Statistical analysis

The values of the minimum, average, and maximum THI were calculated using the equation no. 1 in the excel sheet. Fig. 2, 3 and 4 were created by using software R studio (Version 4.3.1).

Results and Discussion

Analysis of variations in the values of the minimum, average, and maximum THI data may reveal recent climatic trends. Fig. 2 illustrates the variation in the minimum THI values across different months in Bangladesh. From October to May, the THI values remained within a range that is considered comfortable for animals, indicating an absence of heat stress. The lowest THI recorded during this period was 52, while the highest was 72, across all study locations. In contrast, the months of June to September showed mild heat stress, with THI values between a lower value of 73 and a higher value of 75. Even when the temperature and season are good, da Silva costa *et al*., (2010) and Polli *et al*., (2020) found that the wind speed is very important for heat comfort because it helps the Santa Inês sheep lose heat through convection (Sejian *et al*., 2018). Consequently, any alterations in wind speed or other climatic factors can directly or indirectly impact the animals, leading to a state of stress and discomfort, even in favorable temperature and seasonal conditions.

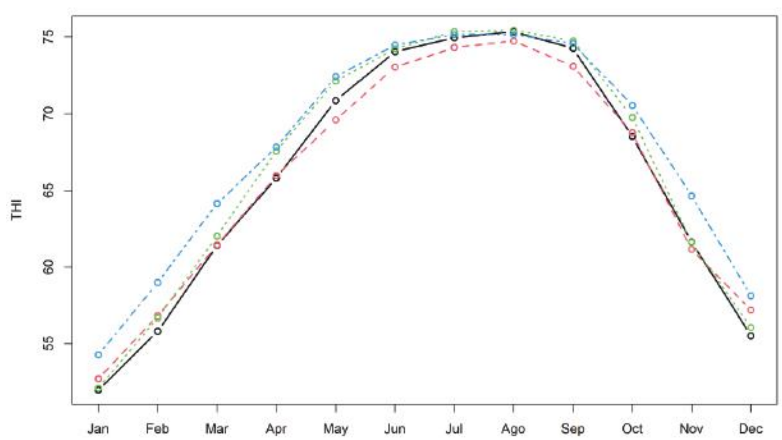

Fig. 2. Monthly minimum temperature and humidity index for the northwest (NW), northeast (NE), west central (WC), and east central (EC) from January to December, for the period from 1995 to 2022. [THI <72 indicates without stress; 72–78 indicates mild or mild stress; 79–88 indicates moderate stress; 89–98 indicates severe stress (Armstrong, 1994). Jan, January; Feb, February; Mar, March; Apr, April; May, May; Jun, June; Jul, July; Ago, August; Sep, September; Oct, October; Nov, November; Dec, December]

Fig. 3 illustrates the variance of the average THI, where the months of December to February indicated a comfort zone in all study locations of Bangladesh. The months of October, November, March, and April exhibited signs of mild to moderate thermal stress, as seen by fluctuations in the THI ranging from 72 to 79. In contrast, the period from May to September recognized moderate thermal stress, with THI values ranging from 77 to 81. Additionally, January had the lowest and July and August had the highest monthly average THI reported between 1995 and 2022. November to February were stress-free in the northwest area, March to May and October were mild thermal stress, and June to September was moderate thermal stress. The northeast region had a comfort zone from December to February, mild thermal stress from March to May, October, and November, and moderate thermal stress from June to September. December to February were comfortable in west central area, March, October, and November were comfortable and April to September were moderate thermal stress. December to February were comfortable in east central area, March to April, October, and November were comfortable and May to September were moderate thermal stress. Consistent with the findings of the present study, Akyuz *et al*., (2010) observed that dairy cattle experienced heightened heat stress over the period ranging from mid-May to October. Notably, the THI surpassed 72 during these months. According to a study conducted by Yaslıoğlu and İlhan (2016), the months of July and August saw the greatest decline in milk production in the provinces of Çanakkale, Bursa, and Balıkesir. Isik *et al*., (2016) reported that due to Antalya's location in a hot and humid climate zone, where temperature and humidity are at their highest between June and September, the THI values for dairy cattle have reached dangerous levels, particularly along the coast line.

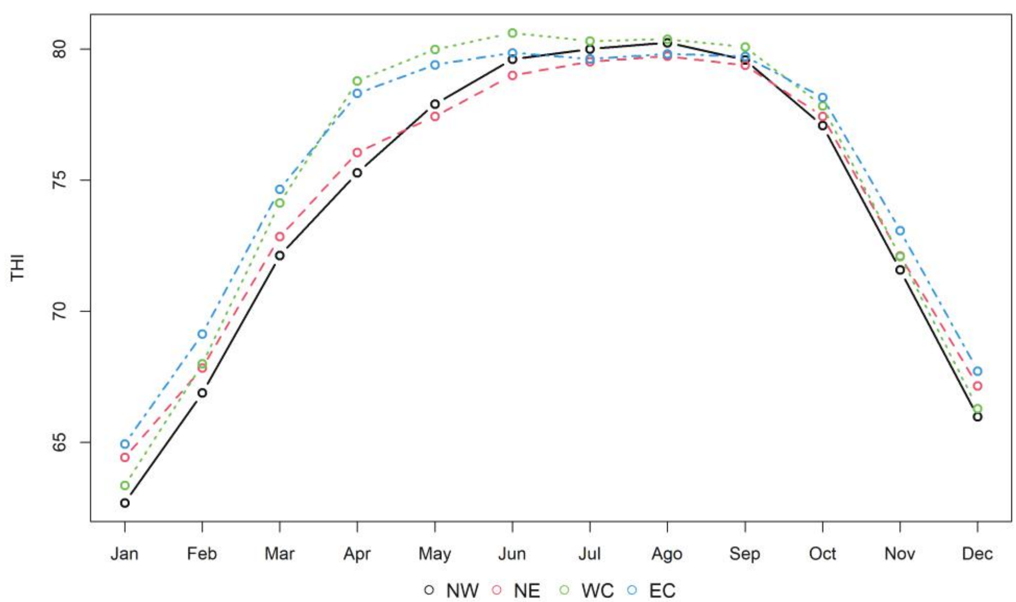

Fig. 3. Monthly average temperature and humidity index for the northwest (NW), northeast (NE), west central (WC), and east central (EC) from January to December, for the period from 1995 to 2022. [THI <72 indicates without stress; 72–78 indicates mild or mild stress; 79–88 indicates moderate stress; 89–98 indicates severe stress (Armstrong, 1994). Jan, January; Feb, February; Mar, March; Apr, April; May, May; Jun, June; Jul, July; Ago, August; Sep, September; Oct, October; Nov, November; Dec, December]

Heat stress has a greater impact on dairy cattle than cold stress (Serdar, 2018). Cows subjected to heat stress have a shorter estrus duration, a lower pregnancy rate, and more early embryonic fatalities (Avendao-Reyes *et al*., 2010). Heat stress reduces dry matter consumption, weight increase, and milk production in cows. Furthermore, there is an increased chance of getting the illness (Serdar DU, 2018). According to Kadzere *et al*., (2002), milk yield can drop by 33% above 35°C and 50% above 40°C. The same researchers noted that a THI of 70 or less is considered appropriate. Conversely, animals confined in environments characterized by a high THI face challenges in heat dissipation due to exposure to temperatures surpassing their tolerance threshold. As a result, they experience thermal stress, and the amount of endogenous heat generated exceeds the capacity for cooling. Consequently, the heat shock induces an elevation in body temperature, leading to indices surpassing the reference values (Bernabucci*et al*., 2010, Min *et al*., 2019, Correa-Calderón *et al*., 2022). Azevêdo *et al*., (2009) postulated that animals subjected to this particular categorization of THI may experience a decline in their reproductive potential, particularly when exposed to heat stress conditions resulting from THI levels over 72, as indicated by the findings of this study (Fig. 5). The variation in the maximal THI values were illustrated in Fig. 4 across different months in Bangladesh. The months of December and January showed mild thermal stress with variations of lower THI (75) and higher THI (78) in all study locations of Bangladesh. From February to November, there was observable evidence of stress levels ranging from moderate to severe thermal, as indicated by fluctuations in the THI within the range of 79 to 95. The THI results observed in various regions of Bangladesh are comparable to those identified by Lima *et al*., 2021. They found that THI value above 80 during the months of August to September for the city of Amapá, indicating a state of moderate stress. Notably, such elevated THI levels have been associated with adverse effects on animal fattening, as well as an increased incidence of respiratory problems and stress in cattle.

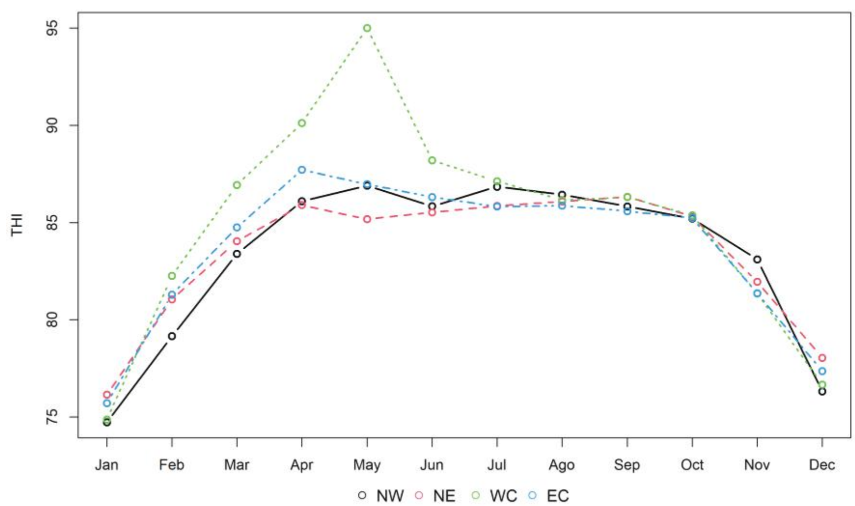

Fig. 4. Monthly maximum temperature and humidity index for the northwest (NW), northeast (NE), west central (WC), and east central (EC) from January to December, for the period from 1995 to 2022. [THI <72 indicates without stress; 72–78 indicates mild or mild stress; 79–88 indicates moderate stress; 89–98 indicates severe stress (Armstrong, 1994). Jan, January; Feb, February; Mar, March; Apr, April; May, May; Jun, June; Jul, July; Ago, August; Sep, September; Oct, October; Nov, November; Dec, December]

Table 1. Yearly minimum THI in northwest region (NW), northeast region (NE), west central (WC) region, and east central (EC) region of Bangladesh, for the period from 1995 to 2022

Year	NW	NE	WC	EC
1995	52	53	53	54
1996	55	55	55	57
1997	54	57	53	55
1998	54	55	55	57
1999	55	56	55	58
2000	55	55	55	58
2001	53	54	53	55
2002	57	57	57	59
2003	52	54	52	56
2004	55	57	55	58
2005	55	56	56	58
2006	56	56	54	57
2007	54	54	53	56
2008	56	57	56	58
2009	57	57	56	59
2010	54	55	53	56
2011	53	54	52	55
2012	53	54	52	55
2013	52	53	52	55
2014	56	56	55	57
2015	56	58	56	59
2016	55	56	55	58
2017	55	56	55	57
2018	53	56	52	56
2019	55	56	54	57
2020	56	57	56	58
2021	56	53	56	58
2022	56	57	57	59

*Green color indicates without stress

Table 1 displays the minimum THI values for the years 1995 to 2022. Based on (Armstrong, 1994) findings, the study locations in Bangladesh exhibited a range of minimum THI values that were within the comfort zone. Notably, there were variations found in both lower (52) and higher (59) THI values.

Table 2. Yearly average THI in northwest region (NW), northeast region (NE), west central (WC) region, and east central (EC) region of Bangladesh, for the period from 1995 to 2022

Year	NW	NE	WC	EC
1995	74	74	75	75
1996	74	75	75	76
1997	72	74	74	75
1998	74	75	75	75
1999	75	75	76	76
2000	74	74	75	75
2001	74	74	75	75
2002	74	74	75	75
2003	74	74	75	75
2004	74	74	75	75
2005	74	74	76	76
2006	75	75	76	76
2007	74	74	75	75
2008	74	74	75	75
2009	75	75	76	76
2010	75	75	76	76
2011	74	74	75	75
2012	74	74	75	75
2013	74	74	75	75
2014	74	75	75	75
2015	74	74	75	75
2016	75	75	76	76
2017	71	72	72	73
2018	74	74	75	75
2019	74	75	75	76
2020	74	75	75	76
2021	75	75	76	76
2022	75	75	76	76

*Blue color indicates mild or mild stress; Green color indicates without stress

Table 2 presents the presence of mild thermal stress indicators across all study locations in Bangladesh during the period from 1995 to 2022, except 2017, when the NW region showed within the comfort zone. It was observed that the years of 1999, 2005, 2006, 2009, 2010, 2016, and 2019-22 demonstrated the highest mild heat stress level. Similar to the findings of this study, Rosanova *et al*., (2020) found THI in the northern State of Tocantins between 75 and 78. This finding could help with the implementation of strategies that reduce the heat stress experienced by bovines in relation to handling, welfare, as well as animal behavior. In another study, Lima *et al*., (2019) observed at THI average in Barbalha in the state of Ceará in the Northeast region of Brazil and found that they ranged from 77 to 82 in November. Mild stress (72–82) and moderate stress (79–88) were used to describe this time. From January to April, the THI was mostly around 76, which indicates that the environment was mild to moderately stressful.

Table 3. Yearly maximum THI in northwest region (NW), northeast region (NE), west central (WC) region, and east central (EC) region of Bangladesh, for the period from 1995 to 2022

Year	NW	NE	WC	EC
1995	87	85	90	87
1996	86	85	88	86
1997	85	84	87	85
1998	86	85	87	86
1999	85	86	89	87
2000	85	84	86	84
2001	86	85	87	86
2002	84	85	85	84
2003	85	85	88	86
2004	85	84	89	87
2005	86	85	88	86
2006	85	85	87	85
2007	87	85	88	86
2008	85	85	88	87
2009	86	85	89	87
2010	85	85	90	87
2011	85	85	86	85
2012	85	85	86	85
2013	86	86	87	85
2014	86	86	95	88
2015	85	85	88	86
2016	86	86	89	86
2017	81	80	81	80
2018	86	86	87	86
2019	86	86	88	86
2020	86	86	86	85
2021	86	86	88	87
2022	87	86	88	86

*Yellow color indicates moderate stress; Red color indicates severe stress

Table 3 illustrates the presence of moderate to severe heat stress throughout all study areas in Bangladesh for the period ranging from 1995 to 2022. In the year of 2017 lowest variance of THI (81) was found in the northwest region, while the highest variance of THI (95) was recorded in west central region in 2014 in all years of the study. The elevated THI was a consequence of the fact that the mean temperature in western central region in 2014 was greater than in prior years. Nevertheless, the years 1995, 1999, 2004, 2009, 2010, 2014, and 2016 had severe levels of stress in the west central region, as signaled by the fluctuations in the THI which were recorded as 90, 89, 89, 89, 90, 95, and 89 is indicative of global warming. This is consistent with a study by Costa *et al*., (2010) in the municipality of Porto Velho-RO of western Brazil, which has a dry and humid tropical climate with characteristics similar to those of the regions studied. There was an observation of severe thermal stress for animals exposed to the sun at certain times of the day, and this can be related to high humidity and low wind speed in the area, affecting herd productivity indices.

Many studies have revealed that harmful effects occur below THI values of 72, the starting limit of heat stress, and above 77, where feed intake drops quickly and even deaths begin (Armstrong, 1994). The lowest, highest, and average THI values were determined as 26, 79, and 58.5 in a study carried out by Serdar DU, (2018) in a dairy cattle farm in Bursa, Turkey. The 70 THI value was reached in May and occasionally exceeded this level until October. It was stated that during this time, milk production dropped. For three years, the study discovered 268 days (49.6%) of THI 70 or above on 540 days between May and October. Wheelock *et al*., (2010) found that cows at THI 65 and above had significantly lower milk yields. Bouraouni *et al*., (2002) found that July (71.45) as well as August (71.37) milk production dropped by 0.41 kg per unit rise in THI of 69 and above. Collier *et al*., (2011) calculated a daily milk production reduction of 2.2 kg between 65 and 73. Brügemann *et al*., (2012) found that milk production increased after THI 30, remained stable, and decreased after 60, while Linvill and Pardue, (1992) found that THI above 65 caused heat stress.

Table 4. Minimum, maximum and average THI in summer season in northwest region (NW), northeast region (NE), west central (WC) region, and east central (EC) region of Bangladesh, for the period from 1995 to 2022

Region	Minimum THI	Maximum THI	Average THI
Northwest	68	86	76
Northeast	68	85	76
West central	69	90	78
East central	70	86	78

*Green color indicates without stress; Yellow color indicates moderate stress and Blue color indicates mild or mild stress; Red color indicates severe stress

Table 4 displays the variance of the THI during the summer season. The minimum THI values indicate the comfort zone in all the regions under consideration. On the contrary, the average THI displayed mild thermal stress levels, while the maximum THI demonstrated moderate thermal stress levels, with the exception of the west central region which showed the highest THI value of 90, indicating a severe thermal level of stress. However, research shows that when the THI value approaches 60, the milk production in dairy cattle decreases. Ilhan, (2018) projected that the summer season is the most dangerous time for cattle heat stress in Turkey's Marmara region. Although THI produces troubles for dairy cattle when it exceeds 72 (Ermetin *et al*., 2023), it is important to take precautions to minimize the THI effect in hot and humid summer season.

Table 5. Minimum, maximum and average THI in rainy season in northwest region (NW), northeast region (NE), west central (WC) region, and east central (EC) region of Bangladesh, for the period from 1995 to 2022

Region	Minimum THI	Maximum THI	Average THI
Northwest	73	86	79
Northeast	73	86	79
West central	74	86	80
East central	74	86	79

* Blue color indicates mild or mild stress and Yellow color indicates moderate stress

Table 5 presents the variance of the THI throughout the rainy season, with the lowest THI values indicating a mild degree of stress across all regions examined in the study. On the contrary, the maximum THI was associated with moderate thermal stress, while the average THI was indicative of mild thermal stress. However, it is notable that the west central region reported the greatest THI value of 80, which suggests a state of moderate thermal stress. This finding aligns with the research conducted by (da Silva *et al*., 2023) in the Humaitá municipality of Amazonas, Brazil. The study was conducted during the rainy season in January, and a THI of 75 was recorded. This value suggests a range of mild stress but is still being identified as an alert scenario for dairy cattle.

Table 6. Minimum, maximum and average THI in winter season in northwest region (NW), northeast region (NE), west central (WC) region, and east central (EC) region of Bangladesh, for the period from 1995 to 2022

Region	Minimum THI	Maximum THI	Average THI
Northwest	66	83	74
Northeast	66	83	74
West central	66	85	75
East central	68	84	75

*Green color indicates without stress; Yellow color indicates moderate stress and Blue color indicates mild or mild stress

The variability of the THI during the winter season shown in Table 6, with the smallest THI values indicating the absence of stress levels across all regions investigated in the study. On the contrary, the maximum THI indicates a state of moderate thermal stress, while the average THI reflects a condition of mild thermal stress. Indeed, it can be concluded that the winter season does not present a significant risk for farm animal production in relation to the THI. the overall health of animals (da Silva *et al.,* 2023). da Silva *et al*. (2023) also conducted a research in three capitals (Manaus, Bos Vista, and Rio Branco) in Brazil's northern area, which has a mostly hot and humid climate. According to their findings, the average THI in Bos Vista and Manaus exhibited negative asymmetry, with 72-78 suggesting mild stress and 79-88 indicating moderate stress. Furthermore, a comparison of the THI indices across

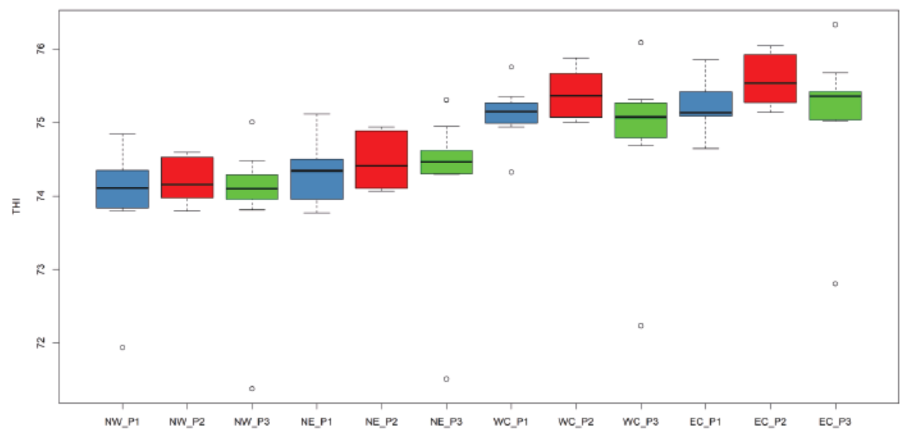

Fig. 5. Box plot of average THI by regions (NW, Northwest; NE, Northeast; WC, West central & EC, East central) in each period (P1=1995 to 2002; P2=2003 to 2010, and P3=2011 to 2022)

states and periods revealed that Bos Vista had the highest THI index, followed by Manaus, with Rio Branco having the lowest index.

Animal welfare is negatively impacted by rising THI levels due to changes in feeding habits, higher activity, and less resting time (Ramón-Moragues *et al*., 2021). On warmer days, bovine animals were less active in the morning and more active in the afternoon (Meneses *et al*., 2021). Spanish researchers found that heat-stressed animals rested less, especially in the afternoon (Ramón-Moragues *et al*., 2021).

The variations in the THI in Fig. 5 throughout several research locations in Bangladesh and the disparities seen across these regions during different time periods. Furthermore, the study reveals that the greatest THI was seen in the east central area throughout the time span from 2003 to 2010. Conversely, the lowest THI values were recorded in the northwest region between 1995 and 2002. The regional average THI throughout each period falls within the range of 72-78, suggesting the presence of a mild heat stress that contributes to a decrease in

During the summer, cows walk more each day than they do in the winter. When alterations to feeding, rumination, or standing/lying habits are significant enough to require a more thorough assessment, further welfare problems are detected (Antanaitis *et al*., 2023). Literature reveals that cows take a break every day between 9 and 12 hours (Tullo *et al*., 2019). That equals to 22 to 30 minutes every hour. This behavior is used to assess cattle welfare since it is significantly impacted when the animals are agitated or uncomfortable (Tullo *et al*., 2019). Cows under heat stress stand more to evaporate heat through the skin (Provolo *et al*., 2009). Cow welfare is indicated by this behavior, which changes significantly when they are stressed or in discomfort. When heat stress happens, the duration of time spent resting per hour is reduced (Ramón-Moragues *et al*., 2021). According to present study, the THI values in our country's west central regions, particularly in the summer, are higher than the values determined in the other three regions. Actually, in every selected region of Bangladesh, THI levels decreased linearly in the winter, peaked in the summer, and increased linearly in the rainy season. Indeed, the THI values in summer were shown to be substantially higher than that of found in rainy and winter seasons. These results are comparable to those found by (Dantas *et al.,* 2007), who evaluated trends in climate data from 1991 to 2004 and determined climatological changes capable of influencing the THI and, as a result, inducing thermal stress in production animals. Based on THI values, it may be concluded that farm animal-rearing conditions fluctuate seasonally.

However, during periods of elevated environmental temperatures, it is crucial to modify livestock farming practices to mitigate the effects of heat stress. Possible adaptation measures may involve a combination of: (i) proactive alterations to the environment to decrease heat load and enhance heat dissipation, such as providing shade, improving ventilation, and utilizing fogging devices and fans; (ii) strategies to minimize the production of metabolic heat, such as adjusting feeding schedules and changing the type of feed (iii)ensuring balanced feeding and water requirements (iv) genetic selection promoting heat tolerance; (v) managing calving during specific seasons; and (vi) choosing more heat-resistant cattle breeds or other livestock species like goats. It will be helpful in preventing stress, and as a result, it will reduce losses in milk production and fertility (Ermetin *et al*., 2023, North *et al*., 2023)

Conclusion

The study locations of Bangladesh during 1995 and 2022 had significant monthly and annual THI differences. West central and east central had the highest average THI in 2016, and northwest had the lowest in 2017. West central area has the highest THI values in 2014 compared to other years. The monthly average THI variance was largest in west central in July and August and lowest in northwest in January. THI remains below the value of 72, thus animal farming is not at risk from December to February. In these months, when temperatures as well as humidity are elevated depending on THI values, herd management as well as shelter protections should be taken to avoid milk yield as well as quality, illnesses, and reproduction issues. Giving rations and selecting breeds that are resistant to heat and have high adaptability will be useful in protecting animals from heat stress. Additionally, planning shelter types for the west central region's climate and providing animals with conditions that reduce the adverse consequences of high humidity and temperatures will reduce heat and humidity stress, particularly during July and August.

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Author contributions

All authors contributed to the study's conception and design. Material preparation and analysis were performed by MSD Islam, AK Mondal, MR Auwul. The first draft of the manuscript was written by MSD Islam, AK Mondal, SHMF Siddiki, and reviewed and edited by MS Islam and MA Islam. All author have reviewed the final manuscript and given their consent of approval.

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Not applicable

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The authors declare that they have no conflict of interest.

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