Abstract M253

Changes in Temperature-Humidity Index and Number of Hot Days Related to Heat Stress of Dairy Cattle in Thailand

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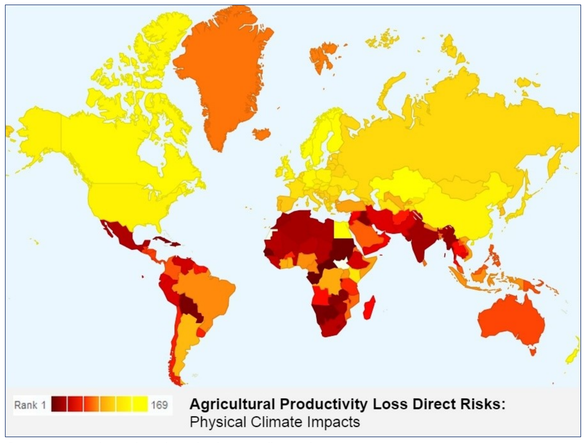
SUMMARY

Global climate is changing and becoming warmer. Higher ambient temperatures and humidity increase stress and lower dairy cattle production, particularly in tropical countries. Temperature-Humidity Index (**THI**) has been used to assess the risk of heat stress in dairy cattle. When **THI** exceeds 72, cows are likely to begin experiencing heat stress. The objective of this research was to characterize yearly changes in **THI** and number of days that **THI** exceeded 72 (**NHD**) in Thailand from 2002 to 2014. Average daily temperatures and relative humidity were measured in 17 meteorological stations located in 5 regions across Thailand (n = 78,713). Regions were Northern, Northeastern, Central, Eastern, and Southern. The overall yearly means and SD were 81.9 and 4.2 for **THI** and 361.5 d and 13.8 d for **NHD**, and the corresponding ranges were 58.7 to 93.2 for **THI** and 166 to 366 d for **NHD**. The **THI** and **NHD** were analyzed using a model that included year, region and interaction between year and region as fixed effects, and residual as a random effect. All fixed effects influenced **THI** and **NHD** (P < 0.01). Yearly LSM ranged from 79.3 (Northeastern-2011) to 84.1 (Central-2010) for **THI**, and from 315 (Central-2002) to 366 d (Southern-2012) for **NHD**. Trends across years were non-significant for **THI** (b = -0.003 units/yr; P = 0.93) and for **NHD** (b = 0.39 d/yr; P = 0.34). However, larger fluctuations in **THI** existed from 2009 to 2014 than from 2002 to 2008 (81.3 to 83.3 units vs. 81.5 to 82.4 units). Conversely, **NHD** showed similar ranges in both periods (349 to 364 d/yr vs. 341 to 357 d/yr). The LSM for **THI** and **NHD** were higher in the Central (82.1 units and 354 d/yr), Eastern (83.1 units and 363 d/yr), and Southern (82.8 units and 361 d/yr) regions than in the Northeastern (80.7 units and 344 d/yr) and Northern (80.7 units and 346 d/yr) regions. Although increasing trends in **THI** and **NHD** did not occur during the years of the study, variability in **THI** increased since 2009. *Regional effects indicated that more comprehensive strategies for reduction of heat stress in dairy cattle may be needed in the Central, Eastern, and Southern Thailand than in the Northern and Northeastern parts of the country.*



Source: www.cgdev.org/page/mapping-impacts-climate-change

INTRODUCTION

Global climate is changing and it is manifesting itself through various kinds of environmental changes. Extreme droughts, high ambient temperatures, heat waves, floods, and freak storms have occurred across the globe. Changes in climate are also affecting dairy cattle in Thailand, particularly cows kept in open barns. Fluctuations in high ambient temperatures and humidity are causing stress that can have a negative impact on normal living and levels of production of dairy animals.

The Temperature-Humidity Index (**THI**), a combination of ambient temperature and relative humidity, has been used to classify levels of comfort and stress zones of animals. In dairy cattle production, **THI** values are categorized into mild stress (72 to 80), moderate stress (81 to 90) and severe stress (above 90). *If **THI** values exceed 72, cows are likely to begin experiencing heat stress* (Armstrong, 1994)

The weather in Thailand is tropical, where ambient temperatures and relative humidity are generally high. In addition, Thailand has two monsoons every year (TMD, 2014), the northeastern monsoon (October to February) and southwest monsoon (May to October). Commercial dairy farming in Thailand began in 1957. Dairy cattle are raised and kept in open barns. To produce high volumes of milk, Holstein (*Bos taurus*) and to a lesser extent other European dairy breeds (Brown Swiss, Jersey, Guernsey, Red Dane) were used to upgrade local cattle of primarily *Bos indicus* origin. Currently, most dairy cows in the Thai dairy cattle population (91%) are crossbreds and have a Holstein fraction higher than 87.5%. High temperatures and humidity in different regions of Thailand fall within the range of stressful **THI** values for dairy cattle. Thus, the objective of this research was to characterize yearly changes in **THI** and number of days that **THI** exceeded 72 (**NHD**; number of hot days) in Thailand from 2002 to 2014.

MATERIALS AND METHODS

The dataset consisted of 78,713 daily records of average temperatures (**AT**; ºC) and relative humidity (**RH**; %) collected from January 1, 2002 to December 31, 2014 at 17 meteorological stations of the Thai Meteorological Department (TMD) located across five regions of Thailand. These five regions were:

1) **Northern (NT):** 3 stations; 17.5 to 36.1 ºC for **AT** and 64 to 81% for **RH;** 250 to 400 m above msl (mean sea level); mostly hilly and mountainous.
2) **Northeastern (NE):** 5 stations; 18.7 to 35.2 ºC for **AT** and 66 to 80% for **RH;** 140 to 250 m above msl; high level plain in the west sloping down towards the east.
3) **Central (CT):** 4 stations; 21.2 to 36.2 ºC for **AT** and 69 to 79% for **RH**; 2 to 8 m above msl; large low level plain.
4) **Eastern (ET):** 3 stations; 22.3 to 36.2 ºC for **AT** and 71 to 81% for **RH;** 50 to 150 m above msl; mostly plains and valleys.
5) **Southern (ST):** 2 stations; 22.8 to 34.1 ºC for **AT** and 48 to 97% for **RH;** 50 to 80 m above msl; long ridge of western mountains.

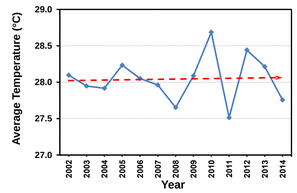
(OEPP, 2000)

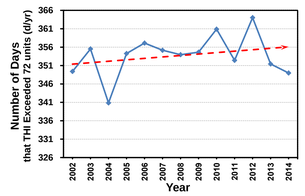
The **THI** were calculated using the **AT** and **RH** information from all regions by the formula **THI = (1.8 × AT + 32) – (0.55 – 0.55 × RH) × (AT – 26)** (NOAA, 1979). Then, the number of days that **THI** exceeded 72 (**NHD**; 221 records) were counted for each year of the particular stations. Yearly mean and standard deviation (SD) were calculated for **AT**, **RH**, **THI** and **NHD** in all regions. Means, SD, minima, and maxima were used to describe the distribution of these traits. Each trait was analyzed using a linear model that contained year, region, and interaction between year and region as fixed effects, and residual as a random effect. Least squares means (LSM) of **AT**, **RH**, **THI** and **NHD** were estimated for each year, region and interaction between year and region subclass. The estimated LSM for **AT**, **RH**, **THI** and **NHD** for pairs of regions were compared using Bonferroni t-tests. Year LSM for each trait were plotted against years, and also used to compute regression coefficients of **AT**, **RH**, **THI** and **NHD** on year.

RESULTS AND DISCUSSION

The yearly means and SD in Thailand from 2002 to 2014 were 27.87 ºC (SD = 2.57 ºC) for **AT**, 73.70 % (SD = 9.63 %) for **RH**, 81.91 units (SD = 4.18 units) for **THI** and 361.46 d/yr (SD = 13.84 d/yr) for **NHD**. Values ranged from 14.60 to 35.50 ºC for **AT**, from 29 to 99 % for **RH**, from 58.66 to 93.18 units for **THI**, and from 166 to 366 d for **NHD**.

All fixed effects influenced **AT, RH, THI** and **NHD** (P < 0.01). Yearly LSM ranged from 26.6 ºC (North-2011) to 29.2 ºC (Central-2010) for **AT**, from 60.5 % (Central-2004) to 79.6 % (Eastern-2013) for **RH,** from 79.3 units (Northeastern-2011) to 84.1 units (Central-2010) for **THI**, and from 315 d (Central-2002) to 366 d (Southern-2012) for **NHD**. The **THI** LSM values computed in all Thai regions were higher than the threshold of 72 units when cows are likely to begin experiencing heat stress. Further, nearly all **THI** values here were higher than those reported under temperate European climate conditions (40.8 to 79.9 units from May 2010 to October 2012) by Schüller *et al.* (2014). The values of **THI** and **NHD** in all regions of Thailand suggested that dairy cows were under stressful conditions most days of each year from 2002 to 2014.





Although, Malhi and Wright (2004) showed that the tropics had warmed at a mean rate of 0.26 ºC per decade since 1970s, trends for **AT** (b = 0.003; P = 0.89) and for **RH** (b = 0.08; P = 0.20) from 2002 to 2014 here were near zero. However, yearly **AT** LSM tended to have wider fluctuations in the last six years (2009 to 2014; 27.51 to 28.69 ºC) than during the first seven years of the study (2002 to 2008; 27.65 to 28.23 ºC).

Similarly, trends across years were non-significant for **THI** (b = -0.003 units/yr; P = 0.93) and for **NHD** (b = 0.39 d/yr; P = 0.34). However, larger fluctuations in **THI** LSM existed from 2009 to 2014 (81.3 to 83.3 units) than from 2002 to 2008 (81.5 to 82.4 units). Conversely, **NHD** showed similar ranges in both periods from 2009 to 2014 (349 to 364 d/yr) and from 2002 to 2008 (341 to 357 d/yr). **THI** LSM values were highly correlated with **AT** LSM (r = 0.98; P = 0.0001) but not with **RH** LSM (r = 0.03; P = 0.92). Although increasing trends in **THI** did not occur during the years of the study, variability in **THI** increased since 2009. This variability was likely associated with El Niño–Southern Oscillations (ENSO) that are a primary factor for temperature fluctuations in large areas of Southeast Asia.

Most of the highest regional LSM were found in Eastern Thailand for **AT** (28.57 ± 0.02 ºC), **RH** (76.60 ± 0.08 %), **THI**, (83.10 ± 0.04 units) and **NHD** (363.23 ± 2.95 d/yr), whereas most of the lowest LSM were found in Northeastern Thailand (27.31 ± 0.02 ºC for **AT**, 71.90 ± 0.06% for **RH**, 80.66 ± 0.03 units for **THI**, and 344.22 ± 2.12 d/yr for **NHD; Table 1**).

The LSM for **THI** and **NHD** were higher in the Central, Eastern, and Southern regions than in the Northeastern and Northern regions (**Table 1**). These differences seemed to be associated with distance from the sea shore, where areas closer to the sea were warmer (Central, Eastern, and Southern regions) than areas farther from the sea (Northeastern and Northern regions).

All regions in Thailand had LSM for **THI** higher than 72 units indicating that the weather in all regions of the country created stressful conditions to dairy cows. The LSM values for **NHD** from all regions indicated that dairy cows experienced an average of 344 stressful days per year (10 months) from 2002 to 2014. These results indicated the need for more comprehensive strategies to reduce heat stress of dairy cattle in the Central, Eastern, and Southern regions than in the Northern and Northeastern regions of Thailand.

FINAL REMARKS

- *Although an increasing trend in **THI** did not occur from 2002 to 2014, variability in **THI** increased since 2009*
- ***THI** and **NHD** were affected by region, year and year x region interaction*
- ***THI** LSM were higher than 72 units in all regions of Thailand, creating stressful conditions for dairy cows throughout the year*
- ***NHD** values indicated that cows in all regions of Thailand experienced stressful conditions (**THI** > 72) for over 10 months of the year*
- *More comprehensive strategies for reduction of heat stress in dairy cattle may be needed in the Central, Eastern, and Southern regions than in the Northern and Northeastern regions of Thailand*

Table 1 Least squares means of average temperature (**AT**), relative humidity (**RH**), Temperature-Humidity Index (**THI**) and number of days that **THI** exceeded 72 units (**NHD**) by region of Thailand (2002 to 2014)

Region	Parameter			
	AT (ºC)	RH (%)	THI (Unit)	NHD (d/yr)
Northern	27.29 ± 0.02[c]	73.65 ± 0.08[c]	80.72 ± 0.03[c]	345.95 ± 2.71[bc]
	(14,050)[1]	(22,863)	(14,243)	(39)
Northeastern	27.31 ± 0.02[c]	71.90 ± 0.06[d]	80.66 ± 0.03[c]	344.22 ± 2.12[c]
	(22,863)	(23,506)	(23,311)	(65)
Central	28.60 ± 0.02[a]	73.74 ± 0.07[c]	82.06 ± 0.03[a]	353.85 ± 2.34[ab]
	(18,755)	(18,644)	(18,591)	(52)
Eastern	28.57 ± 0.02[a]	76.60 ± 0.08[a]	83.10 ± 0.04[a]	363.23 ± 2.95[a]
	(13,138)	(13,128)	(13,146)	(39)
Southern	28.42 ± 0.02[b]	76.11 ± 0.09[b]	82.84 ± 0.04[b]	361.46 ± 3.31[a]
	(9,421)	(9,492)	(9,422)	(26)

[a, b, c, d] Least squares means within the same row with different superscripts differ (P < 0.05);

[1] Number of records

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