Assessment of Extreme Temperature Changes in Chauk Township, Central Myanmar, Using Remote Sensing and GIS

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ABSTRACT

Myanmar remains highly vulnerable to the impacts of climate change, with recent data highlighting a significant shift in temperature patterns. In early 2024, Chauk, a town in the Magway Region, was among the hottest globally, experiencing record temperatures up to 48.2°C. This study focuses on Chauk, examining the extreme temperature trends from 2009 to 2024 and their socio-economic implications. Utilizing remote sensing and GIS technologies, the research employs satellite imagery from the USGS, selected for its minimal cloud cover, and the Single Channel Method to calculate Land Surface Temperatures (LST). The study incorporates both primary data from field surveys and interviews with local residents, and secondary data from satellite images. The analysis reveals a significant increase in LST, with mean temperatures rising from 31.71°C in 2009 to 35.125°C in 2024. The study also highlights the health impacts of these rising temperatures, including increased incidences of heatstroke, dehydration, and respiratory issues. The extreme heat, particularly the record temperatures of April 2024, has already resulted in approximately 100 fatalities. Economically, the heightened temperatures adversely affect labor productivity, especially in agriculture and construction, and exacerbate food insecurity due to reduced crop yields. Additionally, the increased demand for cooling drives up utility costs, further straining the local economy. The findings underscore the urgent need for comprehensive climate adaptation strategies. Recommendations include enhancing healthcare infrastructure to manage heat-related health issues, developing community awareness programs, and implementing policies to mitigate the economic impacts of extreme temperatures. By adopting these measures, Chauk Township can improve its resilience to climate change and safeguard its residents from future heatwaves.

Keywords: Chauk Township, remote sensing, land surface temperature (LST), climate change, socio-economic impacts.

Introduction

According to the earth observatory of National Aeronautics and Space Administration (NASA), the global warming is the usually rapid increase in Earth's average surface temperature over the past century due to the greenhouse gases released as people burn fossil fuels. (http://earthobservatory.nasa.gov/GlobalWarming). IPCC reported that "Managing the risks of extreme events and disasters to advance climate change adaptation" provides evidence from observations gathered since 1950 of changes in certain climate extreme (IPCC 2012). In addition, Myanmar has been ranked among the top of the three countries of most affected that by extreme climate change within 1992 and 2011 by the Global Climate Risk Index (2013) which measures the extent to which countries were affected by the impacts of weather related events (MOST, 2013). LST observations acquired by remote sensing technologies have been used to assess the Urban Heat Island (UHI), to develop models of LST exchange, and to analyze the relationship between temperature and LULC changes in urban areas (Voogt and Oke, 2003) recent studies have addressed the relationship between LST and surface characteristics such as vegetation indices (Carlson *et al.*, 1994; Owen *et al.,* 1998). Cities are characterized by increased air and surface temperatures as compared to their rural surroundings. This so called Urban Heat Inland (UHI) effect is caused by the specific urban structure, the set of physical features which can be described by land-use patterns and other structural indicators, such as the degree of surface sealing (Thinh *et al.,* 2002).

Figure 1. Extreme Temperature in Chauk

Myanmar remains one of the most vulnerable countries to the impacts of climate change and variability. In a recent Eldorado weather report from May 4, 2024, several cities in Myanmar were removed from the list of the 15 hottest cities globally. This is a significant shift from earlier in the year, when Chauk, located in the Magway Region, consistently ranked among the top three hottest cities worldwide.

Figure 1 illustrates the summer time of Chauk area. On April 28, 2024, the Department of Meteorology and Hydrology (DMH) reported unusually high daytime temperatures across Myanmar, with Chauk reaching a staggering 48.2°C. By April 30, three Myanmar cities were still listed among the 15 hottest globally, with Chauk holding the second position at 46°C. Notably, Chauk recorded its highest April temperature in 56 years, reaching 48.2°C, according to the country’s weather office.

Aim and Objectives

The primary aim of this study is to investigate the impact of socioeconomic conditions during the hottest months. The specific objectives are:

- To examine the Land Surface Temperature (LST) of the study area.
- To observe changes in LST over time.
- To analyze the effects of extreme weather on health and socioeconomic conditions.

Study Area

Chauk, located in central Myanmar’s Magway region, is known for its arid climate, being part of the country's rain shadow zone. Due to its geographic location, Chauk experiences high annual temperatures. The extreme weather recorded in 2024, which set new records, makes this location particularly relevant for the study. (Figure 2).

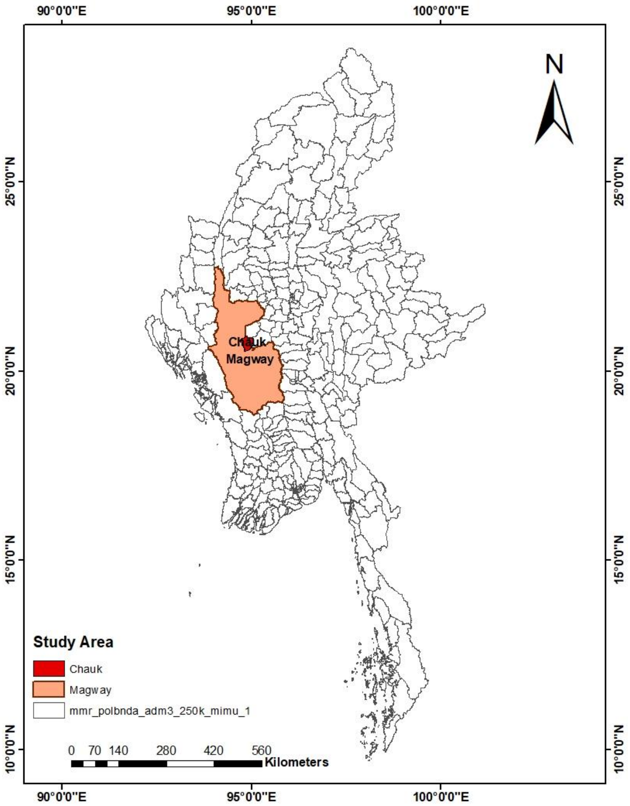

Figure 2. Location of Study Area

Data, Materials, and Methodology

This study utilizes both primary and secondary data. Primary data were collected through field surveys and interviews with local residents during periods of extreme weather. Secondary data were sourced from satellite images provided by the United States Geological Survey (USGS), chosen for their minimal cloud cover. Table 1 outlines the characteristics of the satellite images used, spanning from 2009 to 2024. Research involved using phone records for data collection, computer software for writing and analysis, and ArcGIS for processing satellite images. Both quantitative and qualitative methods were employed to assess LST and its socioeconomic impacts. In-depth interviews and discussions via Viber with local residents and government officials provided valuable insights into the ground realities during extreme weather events. The Single Channel Method was applied to analyze LST data from 2009, 2014, 2019, and 2024. Table 1 shows the acquisition of Landsat Satellite Image L5 TM (2009), and Landsat Satellite Images L8 Operational Land Images (OLI)/TRIS (2014, 2019, and 2024).

Table 1 Acquisition of Landsat Satellite Images L5 TM (2009), and L8 OLI/TIRS (2014, 2019, and 2024)

Date	Landsat Product ID	Path/ Row	Cloud Cover	Image Quality
27-3-2009	LT05_L1TP_134046_20090327_20200828	134/46	5.0	7
25-3-2014	LC08_L1TP_134046_20140325_20200911	134/46	0.98	9
8-4-2019	LC08_L1TP_134046_20190408_20200829	134/46	0.22	9
5-4-2024	LC08_L1TP_134046_20240405_20240412	134/46	3.59	9

Source: Earth Explore, United States of Geological Survey (USGS)

LST was retrieved from the thermal infrared band (TIR) of Landsat TM 5. This band has a spatial resolution of 120 m but was resampled to the same 30 m resolution as the land use and land cover data. Firstly, the Digital Numbers (DNs) of band 6 are converted to radiation luminance (R_{TM6}, m W cm^{-2} sr^{-1}) by the following formula,

$$R_{TM6} = \frac{V}{255}\,(R_{max} - R_{min}) + R_{min}$$

Where, R_{TM6} is the spectral radiance, V represents the Digital Number of band 6 received by the sensor, R_{max} is the minimum DN; R_{min} ($Wm^{-2}\ sr^{-1}\mu m^{-1}$) are the minimum and maximum detected spectral radiance, (R_{max} =1.896, R_{min} =0.1534 ($mW^{*}\ cm^{-2*}sr^{-1}$)).

Standard Landsat 8 data products provided by the USGS EROS Center consist of quantize and calibrated scaled Digital Numbers (DN) representing multi-spectral image data acquired by both the OLI and Thermal Infrared Sensor (TIRS). First, the digital numbers of TIRS band data were transform OLI and TIRS band data was converted to Top of Atmosphere (TOA) spectral radiance using the radiance re-scaling factors provided in the metadata file with the following equation,

$$L_{\lambda} = M_L\, Q_{cal} + AL$$

Where, L_{λ} means TOA spectral radiance and M_L is band specific multiplicity re-scaling factor from the metadata, *AL* indicates for band specific additive re-scaling factor from the metadata and Q_{cal} can be Quantize and calibrated standard product pixel values. Brightness temperature (T_b) is the microwave radiation radiance traveling upward from the top of Earth's atmosphere. The calibration process has been done for converting thermal DN values of thermal bands of TIR to T_b. For finding T_b of an area the TOA spectral radiance of (L_λ) was needed.

The second step, the radiation luminance of the all satellite images were converted to at-satellite brightness temperature in Kelvin, T (K), using the following formula for all Landsat images.

$$Tb = \frac{K_2}{In\,(\frac{K_1}{L_\lambda} + 1)}$$

Where, T_b defines the meaning of the effective at satellite brightness temperature in Kel vin (K), L_λ is TOA spectral radiance and K_1 and K_2 are the band specific thermal conversion c onstant from metadata (per-launch calibration constants). Table 2 distinguished the respective value of band conversion constant from metadata.

Table 2. The Value of Band Specific Thermal Conversion Constant from metadata

Sensor	K_1 (watt/ (m^2 x ster x µm))	K_2 (watt/ (m^2 x ster x µm))
Landsat 5 TM	1260.56	607.76
Landsat 8 OLI	BAND_10 = 774.8853	BAND_10 = 1321.0789
	BAND_11 = 480.8883	BAND_11 = 1201.1442

The calculated radiant temperatures were corrected for emissivity by using the NDVI. Thresholding the NDVI images into two general vegetation and non-vegetation classes, and assigning emissivity values of 0.95 and 0.92 to them respectively produced emissivity images for each date (Nichol, 1994). The emissivity corrected LST were computed according to (Artis and Carnahan, 1982), (Nichol, 2005) and (Weng *et al.,* 2004) as:

$$\text{LST} = \frac{T_B}{1 + \left(\lambda \times \frac{T_B}{\text{p}}\right) \ln \varepsilon}$$

Where, T_B is at-satellite brightness temperature (K), w (**λ**) indicated wavelength of emitted radiance (wavelength of emitted radiance) (11.5 µm), and P can calculate from the formula of h*c / s (σ) (1.438* 10^{-2} m K). H is Planck's constant (6.626* 10^{-34} J S), S defines the Boltzmann constant (1.38* 10^{-23} J/K), C means velocity of light (2.998* 10^{-8} m/s), the value of P is 14380.

Results and Discussion

Analysis on the LST and NDVI

For this study, satellite imagery was collected for four periods: 2009, 2014, 2019, and 2024 ensuring that each image was acquired on dates as close to one another as possible and with cloud cover below 10%. The Land Surface Temperature (LST) was calculated using the Single Channel Method, leveraging data from Landsat 5 and Landsat 8 satellites. The imagery was captured at a standardized time of 10:36:41 Myanmar Standard Time, corresponding to the scene center time of 04:06:41. This temporal consistency allows for a reliable comparison of LST across the four specified years. Image processing revealed a gradual increase in LST over the period from 2009 to 2024, as illustrated by the results in Figure 3 and Table 3. This trend highlights a significant rise in temperatures over the years, indicating an ongoing escalation in land surface temperatures.

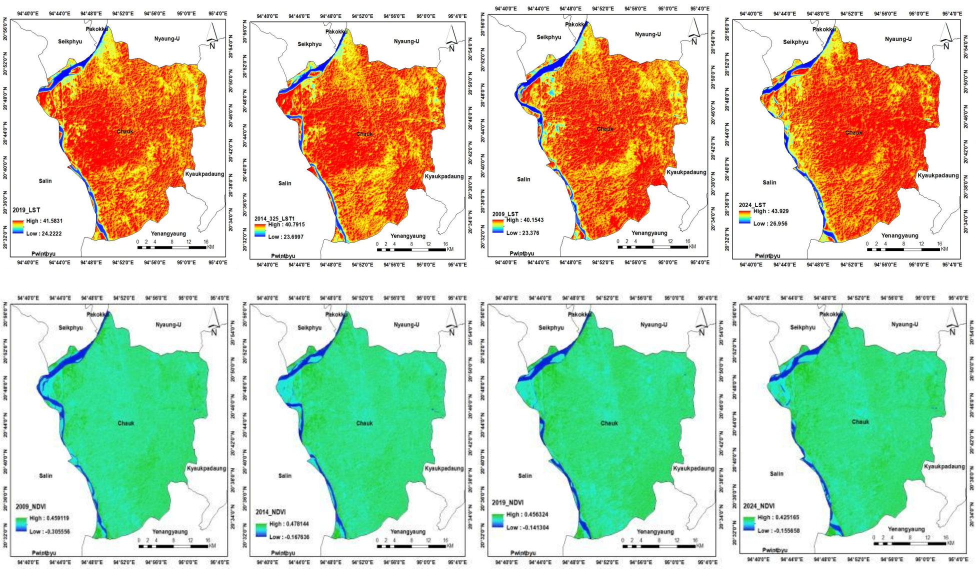

Figure 3. LST and NDVI conditions of Chauk (2009, 2014. 2019, and 2024)

Source: results of image processing

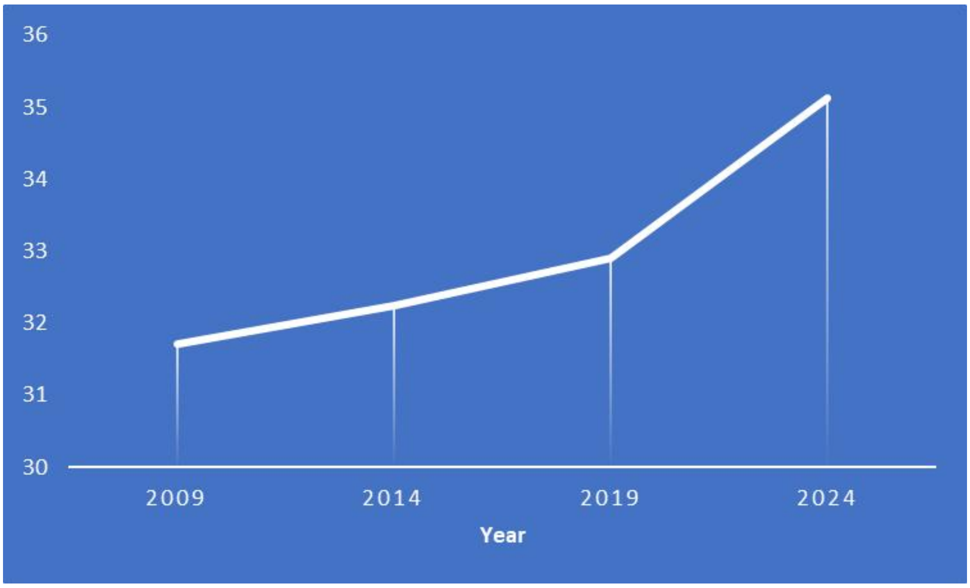

Figure 4. Mean LST of Chauk (2009, 2014, 2014 and 2024)

Figure 3 and Table 3 present data on Land Surface Temperature (LST) and the Normalized Difference Vegetation Index (NDVI) for Chauk Town during the summer months across four distinct years for 2009, 2014, 2019, and 2024. Analysis of the data reveals a clear upward trend in both minimum and maximum temperatures over this period. Specifically, the mean LST has progressively increased from 31.71°C in 2009 to 35.125°C in 2024. In 2014, the mean LST was 32.24°C, and by 2019, it had risen to 32.9°C. This gradual rise in temperature indicates a significant warming trend in Chauk Town over the past 15 years. The increasing mean LST reflects broader climatic changes impacting the region, as detailed in the temperature and vegetation index data provided in Figure 3 and Table 3.

Table 3. Minimum and Maximum of LST and NDVI of Chauk (2009, 2014. 2019, and 2024)

Title	2009		2014		2019		2024fro	
	Min	Max	Min	Max	Min	Max	Min	Max
LST	23.27	40.15	23.69	40.79	24.22	41.58	26.96	43.29
NDVI	-0.3	0.46	-0.17	0.47	-0.14	0.45	-0.15	0.45

Source: Results from image processing

Assessment of Extreme Temperature

The assessment of extreme temperature changes in Chauk Township, Central Myanmar, reveals significant health and economic impacts resulting from rising land surface temperatures. The study, utilizing remote sensing and GIS technologies, highlights the escalating temperature trends from 2009 to 2024. This decade-long analysis demonstrates a steady increase in mean LST, which has soared from 31.71° C in 2009 to 35.125° C in 2024.

Health Effects

Extreme temperatures in Chauk have profound health implications. According to the responses of interviews, elevated LST correlates with a higher incidence of heat-related illnesses such as heatstroke, dehydration, and respiratory problems. The intense heatwaves experienced in Chauk, particularly in April 2024 when temperatures reached up to 48.2°C, have already resulted in significant casualties, including approximately 100 deaths. Prolonged exposure to such extreme conditions exacerbates chronic health conditions, particularly among vulnerable populations such as the elderly, children, and those with pre-existing health issues. The local healthcare infrastructure struggles to cope with the surge in heat-related ailments, putting additional strain on medical resources.

Economic Consequences

The economic impact of extreme temperatures is also notable. Increased temperatures can lead to reduced labor productivity, particularly in sectors reliant on outdoor work such as agriculture and construction. In Chauk, which is already part of Myanmar's rain shadow zone, the intensified heat further stresses agricultural outputs, leading to lower crop yields and increased food insecurity. Additionally, the higher energy demand for cooling exacerbates utility costs for residents and businesses. This increased expenditure places a financial burden on households and affects the overall economic stability of the community. The rising temperatures in Chauk Township present serious challenges to both public health and the local economy. The findings underscore the need for enhanced climate adaptation strategies, including improved healthcare infrastructure, community awareness programs, and policies aimed at mitigating the economic impacts of extreme heat.

Conclusion

The assessment of extreme temperature changes in Chauk Township underscores the urgent need for comprehensive climate adaptation and mitigation strategies. The study reveals a troubling upward trend in land surface temperatures from 2009 to 2024, with the mean LST escalating from 31.71°C to 35.125°C. This rise in temperatures not only highlights the increasing severity of heatwaves but also illustrates the significant health and economic ramifications for the local community.

The health impacts of these rising temperatures are profound. Extreme heat, particularly the record-setting temperatures of 48.2°C in April 2024, has led to a marked increase in heat-related illnesses and fatalities. Vulnerable populations, including the elderly, children, and those with pre-existing health conditions, are at heightened risk. The local healthcare system is strained under the pressure of increased heat-related health issues, emphasizing the critical need for improved medical resources and community health initiatives.

Economically, the consequences are equally significant. The elevated temperatures have detrimental effects on labor productivity, particularly in outdoor-dependent sectors like agriculture and construction. The reduction in agricultural productivity exacerbates food insecurity, while increased energy demands for cooling contribute to higher utility costs, imposing a financial burden on both households and businesses. This economic strain further destabilizes the community's financial health and underscores the necessity for targeted economic support measures.

The findings of this study underscore the imperative for proactive climate adaptation strategies. Effective responses must include strengthening healthcare infrastructure, implementing community education programs on heat management, and developing policies that address the economic impacts of extreme temperatures. By integrating these measures, Chauk Township can enhance its resilience to climate change and better safeguard its residents against the escalating challenges of extreme heat.

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