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| Research Article |

Noon-Time Thermal Comfort in a Tropical, Hot-Humid Climate City in the Philippines

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Abstract: Climate change and urbanization will rapidly increase land surface temperatures in cities with tropical, hot-humid climates. Understanding how this increase affects the individual human requires gauging current thermal comfort levels. This study uses the Modified Physiologically Equivalent Temperature (mPET) model to quantify noon-time thermal comfort within the Dumaguete city center. Twenty locations were investigated. These areas were organized based on the overhead cover in each location: Green Cover (GC) for locations with vegetation providing shade, Artificial Cover (AC) for locations with cover made of artificial or constructed materials, and Sparse Cover (SC) for areas with direct sun exposure. mPET calculated for both the GC and AC locations all fall below the 44.09°C limit for Moderate Heat Stress. However, most SC locations exceed said limit, indicating Strong Heat Stress. SC locations within urban canyons exhibited the highest mPET of all locations, corresponding to the highest heat stress levels. Wind velocity reduced mPET on all locations, affecting AC areas the most. Mean Radiant Temperature (T_{mrt}), which accounted for the heat radiated by the infrastructure around an area, had the greatest influence on mPET. This study has found that thermal comfort is greatly affected by the density of infrastructure surrounding a location. Specifically, tall buildings close to each other reflect and concentrate heat towards the ground level, greatly degrading thermal comfort for pedestrians. These results could help inform future zoning laws, encourage the use of vegetation as overhead cover for footpaths, and advocate urban designs which capitalize on wind to ventilate populous areas.

Keywords: Thermal Comfort, Hot-Humid Climate, mPET

INTRODUCTION

Rapid urbanization and climate change has manifested hotter temperatures in densely packed, highly populous cities. This temperature increase is now recognized as the Urban Heat Island (UHI) phenomenon, the effects and intensities of which are being investigated by researchers in many of the big cities in developed countries. However, very few cities in the South-East Asia have been investigated similarly, if at all. In the Philippines, the effects of UHI have only been thoroughly investigated in two regions: Metro Manila (Dul-loog & Galingan, 2019; Landicho & Blanco, 2019; Pereira & Lopez, 2004) and Cebu City (Cañete et al., 2019; Cortes et al., 2022; Shih & Dy, 2013).

UHIs affect the apparent temperatures or felt heat levels within afflicted areas (Ren et al., 2023) However, the lack of investigation also results in a lack of understanding on the effects of UHI on humans. Investigating the mentioned effects is critical as the increasing temperatures derived from climate change and urbanization subject more people heat-related health risks (Estoque et al., 2020) These health risks are even higher at noon-time, when temperatures are at the highest (Basu & Wu, 2024; Kjellstrom et al., 2024; Koerniawan & Gao, 2015).

Currently, there is a general need for large cities in South-East Asia to deurbanize. It was found that, while urbanization and economic development have a direct relationship, the said relationship is non-linear. This means that continued urbanization of large cities does not guarantee economic development (Nguyen & Nguyen, 2018). As such, small and medium sized cities have been the subject of recent urbanization efforts (Rob & Talukder, 2013). However, it was also found that urban development in South-East Asia is not rationally planned, being driven instead by social and political factors rather than logical economic planning. This results in unsustainable and destructive practices which put the immediate environment of the developing city as well as the residents at great risk (Abd Rahman et al., 2020; Arfanuzzaman & Dahiya, 2019). It can be surmised then that due to these factors, small and medium sized cities in the region would develop UHIs.

An observation of the weather and climate trends in the Philippines reveals that the country is heavily affected by Climate Change (PAGASA, 2018) Specifically, temperatures have been increasing in the Philippines since 1951. The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) reported in 2018 that the country is experiencing an average 0.1°C increase in temperature per decade. Similarly, the annual minimum temperatures have been increasing by 0.15°C per decade, while annual maximum temperatures have been increasing by 0.05°C per decade in the same period. Records show that urban areas experience a temperature increase of 0.25°C per decade while rural areas experience 0.16°C per decade (Manalo et al., 2022).

These increases in temperature do not only mean hotter day-times and higher electricity bills. Temperature increases contribute to health issues. In Vienna, Austria, increases in temperature were linked with increased hospitalization and mortality rates (Muthers et al., 2010). In the same vein, higher than normal temperature indices have been correlated to adverse pregnancy outcomes in Ahvaz, Iran (Dastoorpoor et al., 2021). All over the globe, an increase in temperature, be it sudden or gradual, has contributed significantly to the rise of heat-related disorders and mortalities (Basu & Wu, 2024). Felt heat has been increasingly sharply in South and South-East Asia over the last three decades, and this increase is bound to continue due to climate change (Kamal et al., 2024). Very few studies on the effects of increased temperatures on specific aspects of human health in the Philippine setting are published, but there is a general awareness of the health effects of Climate Change (Lu, 2016).

For workers and urban communities, this increase in temperature not only affects mortality, but also workplace productivity and safety. It has been found that, in South-East Asia, the increase in ambient and felt temperature at noon to the afternoon reduces work efficiency and labor productivity, as well as sharply increasing the risk of contracting heat-related illnesses (Kjellstrom, 2016; Kjellstrom et al., 2024). There have been various mitigation strategies to counter the noon to afternoon peak in temperature. Studies have been conducted which advocate for worker breaks during these high temperature timeframes as means to keep productivity at optimum levels (Kjellstrom et al., 2013; Takakura et al., 2017). However, as these studies are economic in nature, their methodology in quantifying noon-time felt heat and the investigation into the contributing factors of heat stress lack depth.

This research, therefore, aims to investigate the air temperature, relative humidity, sky view factor, and wind velocity in various key areas in a medium-sized city in the Philippines. Using the modified Physiologically Equivalent Temperature (mPET) model, the mentioned factors can be used to provide a quantitative assessment of the noon-time felt heat levels in a medium-sized city with a tropical, hot-humid climate.

Area of Investigation

Dumaguete city, a medium-sized city in the central region of the Philippines, was chosen as the area of study because of its geographic and economic properties. The city has access to both an active airport and seaport which facilitates trade and transport to all parts of the country. The city was named as one of the best places to retire in the world by Forbes Magazine, and is considered a good spot for retirement and work-from-home employment by citizens of the Philippines (McCarthy, 2015; SunStar Cebu, 2024). Much of the city's developed area is located near the coastline. a Thus, a plan has been proposed for the future urbanization and expansion of the city through the reclamation of a fraction of its coastline, with many community leaders and local scientists advocating against it (Abalos, 2021; Bello, 2022; Juanillo, 2021; Pal, 2021). As such, the city is a prime subject for future urbanization efforts, possibly developing an urban heat island in the near future.

The city experiences a tropical, hot-humid climate. A weather station operated by PAGASA is located in the Dumaguete city airport, and is the primary source of meteorological information in the city. The yearly average mean temperature is 27.9 °C, with the average max temperature measured at 30.9 °C, and the average minimum temperature measured at 27.9 °C, with the average relative humidity at 81%. Wind at ground level generally blows from the North-East, with an average speed of 2 meters per second. The total rainfall for the city totals at 1322.6 millimeters per year, with an average rainfall of 110.22 millimeters per month. Average yearly cloud cover is 6 oktas, with the lowest amount of cloud cover occurring in April and May, which are the summer months (Climatology and Agrometeorology Division, 2020).

Apparent Temperature

Apparent Temperature—also referred to as "felt temperature" or "thermal comfort"—arises from many different factors. These factors include, but are not limited to: air temperature, relative humidity, air velocity, barometric pressure, percentage of skin covered by clothing, energy expenditure of test individual, age, and many others (Steadman, 1979a, 1979b). In big cities, even land use, urban design, and population density contribute to the felt heat levels and thermal stress that an individual experiences (Cruz et al., 2021; de la Rosa, 2020; Orbon et al., 2019; Ouyang et al., 2024; Zander et al., 2018). Such complexity has given rise to many different approaches and models to the quantification of apparent temperatures (Zhao et al., 2021). Most of these models, however, operate on the concepts of heat balance and heat exchange. Although different in approach, these models are statistically correlated, enough so that the results of one model are near or near-identical to the results of another (Zare et al., 2019).

The difference therein lies on the sensitivity of the models on specific environmental factors when it comes to heat balance and heat exchange. Depending on the specific focuses and assumptions, a model may be more sensitive to changes in one factor over the other (Charalampopoulos, 2019). This, in turn, makes different models more suited to specific climates or to the study of different relationships more than others. As such, the findings made using the different models are all equally valid, provided that they are used in contexts that they are best suited in.

Another factor why one model for the calculation of apparent temperature may be favored over the others is the ease of use. In the Philippines, the Heat Index model developed by Steadman in 1979 is used precisely for this reason (PAGASA, 2023). The Heat Index model requires only the temperature of the air and the humidity of the area that is being studied to give a reasonably accurate figure for the apparent temperature (Rothfusz, 1990). As the Philippines is an archipelago, Steadman's Heat Index model is a convenient method to provide apparent temperatures to Filipinos who may be facing different microclimates. It must be noted, however, that the Heat Index model is developed for the American climate. As such, many of the assumptions made for the model to be as accessible as it is are based on American climate trends, physiology, clothing standards, and culture (Rothfusz, 1990; Steadman, 1979a, 1979b). Steadman's Heat Index model, although convenient, is not well-suited for the Philippine context.

PET and mPET

As most apparent temperature models were developed in Europe and America in the mid-to-late 20th Century, times and places which are very different from the modern Philippines climatically, there is no one model that is best-suited for the outdoor environments with the hot-humid South-East Asian climate. Attempts have been made to update Steadman's Heat Index model and to make it more applicable to other types of climates (Lu & Romps, 2022), but it still is not the best option. While there exists a thermal comfort model specifically made using data from South-East Asia, including data from the Philippines, the model is used to determine indoor thermal comfort (Nguyen et al., 2012; Parkinson et al., 2020; Toe & Kubota, 2013). Therefore, the said model, while geographically relevant, cannot be used for this study.

Of all the available and accessible apparent temperature models, very few have been extensively modified to suit the hot-humid climate. Two of the models which have been modified for the hot-humid climate are the Physiological Equivalent Temperature (PET) (Koerniawan & Gao, 2015; Lin & Matzarakis, 2008), as well as its recent development, the Modified Physiological Equivalent Temperature (mPET) models (Lin et al., 2019). In fact, there are already published studies pioneering the use of PET in understanding thermal comfort levels in places with tropical, hot-humid climates, such as Australia (Abdollahzadeh & Biloria, 2021), Taiwan (Lin & Matzarakis, 2008; Ouyang et al., 2024; Yu et al., 2020), Indonesia (Koerniawan & Gao, 2015), India (Bal & Matzarakis, 2022), as well as the Philippines (de la Rosa, 2020). It has also been found that in warm climates, mPET has the highest correlation coefficient to body temperature compared to similar models for thermal comfort (Abbasi et al., 2024). All these prove the utility of the PET and mPET models when studying thermal comfort in the Philippines.

PET was first developed by Mayer and Höppe in 1986. It is based on Höppe's 1984 work on modeling human energy balance to investigate theinteraction of heat within the human body. The Munich Energy-balance Model for Individuals (MEMI)—the result of Höppe's investigation—then became the central pillar for the PET and mPET models. Both PET and mPET operate on a system of three equations (Chen & Matzarakis, 2018; Mayer & Höppe, 1987):

$$H + R + C + E_D + E_{Sw} + E_{Re} + L = 0 \qquad \text{(MEMI)} \qquad (1)$$

$$F_{CS} = A_{DU} V_B \rho_B c_B (T_c - T_{sk}) \tag{2}$$

$$F_{SC} = \frac{A_{Be}}{R_{cl}} (T_{sk} - T_{cl}) \tag{3}$$

where H is the internal heat flux produced by metabolism, R is the net radiation of the body, C is the convective heat transfer, E_D is the latent heat flux by diffusion of water vapor, E_{Sw} is the latent heat flux by evaporation of sweat, E_{Re} is the latent heat flux due to respiration, L is the sensible heat flux due to respiration, F_{CS} is the heat flux from the core of the body to the skin, A_{DU} is the surface area of the skin (in m^2), V_B is the blood flow density from core to skin (in $s^{-1}m^{-2}$), ρ_B is the density of blood (in $\frac{kg}{l}$), c_B is the specific heat capacity of blood (in $\frac{J}{kgK}$), T_c is the core temperature (in °C), T_{sk} is the mean skin temperature (in °C), F_{SC} is the heat flux from the skin to the outer layer of the clothing, A_{Be} is the area of the clothed body (in m^2), R_{cl} is the heat transfer resistance of the clothing (in $\frac{m^2K}{W}$), and T_{cl} is the surface temperature of the clothing (in °C).

The MEMI equation, Eq. 1, is a model of how energy, in the form of heat, is produced in (through metabolism) and expelled out of the body (through perspiration and respiration). A balance must be maintained between the rate in which the body produces heat and the rate in which said produced heat is expelled out. Essentially, the parameters of MEMI must be equal to zero when added altogether so that a human body can maintain an ideal body temperature. F_{CS} from Eq. 2, on the other hand, describes how the heat from inside the human body is distributed from the core to the skin through blood circulation. Paired with it is F_{SC} from Eq. 3 which describes the heat transfer from the skin onto the clothing that is worn by an individual.

Scientists from the Deutscher Wetterdienst (German Weather Service) have developed two free and open-access software (named "RayMan" and "SkyHelios") that are able to calculate PET and mPET using only these measurements (Matzarakis et al., 2018):

- Date and Time
- Geographic Data (Longitude, Latitude, and Altitude)
- Sky View Factor (SVF)
- Air Temperature (in °C)
- Vapor Pressure (in hPa) or Relative Humidity (in %)
- Wind Velocity (in $\frac{m}{s}$)
- Cloud Cover (in oktas)
- Personal Data (height and weight)
- Clothing Coverage and Activity

The above measurements, when used in the RayMan software, would output PET and mPET modeled apparent temperatures. However, since both PET and mPET were developed to be used in the European climatic context, the range of temperatures corresponding to physiological stress levels cannot be applied to all climates.

The work of Lin was the first to contextualize PET for hot-humid climates (Lin & Matzarakis, 2008), but there is still a need to localize PET for different countries and for different peoples (Binarti et al., 2020). As such, the works of Ribeiro et al. (2022) and Kotharkar et al. (2024) are necessary. Their results shifted the temperature ranges for PET many degrees higher for each stress and sensation level. Through survey and direct measurement of meteorological data, the two studies found that people native to tropical, hot-humid climates exhibit higher resistances for hotter temperatures, but lower resistances for colder temperatures.

Subsequent development of the PET model resulted in a PET algorithm that allows easy use for non-temperate climates, such as hot-dry and hot-humid climates (Lin et al., 2019), without the need to re-frame the PET thermal ranges. This improvement on PET is called the Modified Physiologically Equivalent Temperature (mPET) model (Chen & Matzarakis, 2018) which is now more sensitive to different climatic contexts. As such, the apparent temperature calculated through mPET would more accurately reflect the felt heat of an individual who is used to specific climates (Chen et al., 2020). Furthermore, it was found that mPET is more sensitive to the human body's physiological responses to physical exertion and work, making mPET more accurate in quantifying apparent temperature for an active test human (Ouyang et al., 2025). The mPET model, therefore, is an appropriate model to investigate apparent temperatures in the Philippine context.

Table 1. PET range for European and tropical climates

Physical Sensation	Temperature Range		Physiological Stress
	European Climates (Matzarakis et al., 1999)	Tropical Climates (Kotharkar et al., 2024)	
Very Hot	>41°C	>50.01°C	Extreme Heat Stress
Hot	35°C - 41°C	44.09°C - 50.01°C	Strong Heat Stress
Warm	29°C - 35°C	38.17°C - 44.09°C	Moderate Heat Stress
Slightly Warm	23°C - 29°C	32.25°C - 38.17°C	Light Heat Stress
Neutral	18°C - 23°C	26.33°C - 32.25°C	No Stress
Slightly Cool	13°C - 18°C	20.41°C - 26.33°C	Light Cold Stress
Cool	8°C - 13°C	14.49°C - 20.41°C	Moderate Cold Stress
Cold	4°C - 8°C	8.57°C - 14.49°C	Strong Cold Stress
Very Cold	<4°C	<8.57°C	Extreme Cold Stress

METHODOLOGY

The methodology for this study is patterned after similar researches done in locations with tropical, hot-humid climates (Koerniawan & Gao, 2015; Kotharkar et al., 2024; Lin et al., 2019; Ribeiro et al., 2022; Yu et al., 2020). In particular, the methodologies of Koerniawan & Gao (2015), Kotharkar et al. (2024), and Ribeiro et al. (2022) provided the blueprint for this study's methodology.

In general, the methodology can be broken down into three phases: data gathering, processing and calculation, and statistical analysis. The data gathering phase includes the identification of the areas to be investigated, as well as the collection and organization of data taken from the said locations. The data gathered is then processed in the processing and calculation phase, leading to the calculation of mPET for each location. In the data analysis phase, both the gathered and calculated data are organized and compared to each other through a linear regression analysis. The results from the analysis are reported and interpreted in the latter parts of this paper. Figure 1 contains a summarized flowchart of the processes involved in this methodology.

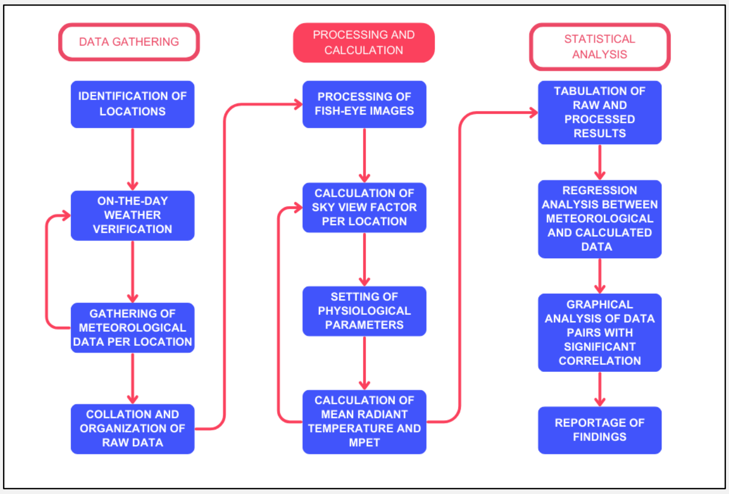

Figure 1. A flowchart summary of the steps taken in this study's methodology.

Sampling Locations

As there is no definition of what constitutes Dumaguete's city-center, the area encompassed in Figure 2 was considered the primary area of interest for this study. The borders were chosen as the area within contains most of the public offices and spaces, places of commerce, schools, public transport terminals, and areas with high foot traffic in the city.

Twenty key areas within Dumaguete's city-center, where foot traffic is high, were selected as areas of investigation. These places included but were not limited to: school entrances and exits, department stores, markets, places of commerce, hospitals, bus and jeep terminals, road-crossings, and others. The 20 areas selected are as follows:

1. (KH) Katipunan Hall, Silliman University - 9° 18' 46.05" N, 123° 18' 26.56' E
2. (CSC) Cang's Shopping Complex - 9° 18' 56.66" N, 123° 18' 8.19" E

3. (SUMC) Silliman University Medical Center - 9° 19' 1.90" N, 123° 18' 14.40" E
4. (NOHS) Negros Oriental High School - 9° 18' 49.47" N, 123° 18' 7.52" E
5. (NORSU) Negros Oriental State University - 9° 18' 44.78" N, 123° 18' 10.00" E
6. (WCES) West City Elementary School - 9° 18' 33.58" N, 123° 18' 16.81" E
7. (PNB) Philippine National Bank, Silliman Branch - 9° 18' 36.35" N, 123° 18' 19.87" E
8. (NORECO) Negros Oriental II Electric Cooperative - 9° 18' 34.03" N, 123° 18' 19.99" E
9. (LSP) Lee Super Plaza - 9° 18' 28.70" N, 123° 18' 27.26" E
10. (PNP) Dumaguete City Police Station - 9° 18' 24.62" N, 123° 18' 16.82" E
11. (HCH) Holy Child Hospital - 9° 18' 22.82" N, 123° 18' 24.79" E
12. (JPS) Jeepney Terminal, Sibulan - 9° 18' 22.59" N, 123° 18' 21.14" E
13. (MPD) Public Market Pedicab Drop-off - 9° 18' 17.38" N, 123° 18' 20.71" E
14. (MDG) Public Market Dry Goods Stalls - 9° 18' 19.29" N, 123° 18' 22.91" E
15. (MF) Fruit Market - 9° 18' 16.91" N, 123° 18' 24.45" E
16. (JPB) Jeepney Terminal, Bacong - 9° 18' 13.15" N, 123° 18' 24.68" E
17. (CHO) City Health Office - 9° 18' 17.14" N, 123° 18' 35.87" E
18. (CTO) City Treasurer's Office - 9° 18' 20.33" N, 123° 18' 35.49" E
19. (SPE) Seaport Passenger Entrance - 9° 18' 44.83" N, 123° 18' 36.82" E
20. (SPG) Seaport Gate/Lo-oc Barangay Hall - 9° 18' 50.40" N, 123° 18' 36.60" E

KH, NOHS, NORSU, and WCES are schools situated within the study bounds. Collectively, they account for around 25,000 students from elementary to postgraduate levels. The total number of students enrolled in schools in Dumaguete city amount to a population of about 35,000 (Tilos, 2022).

SUMC and HCH are hospitals with both in-patient and out-patient facilities. They operate a total of around 300 beds for the treatment of patients (Cruz, 2022).

CSC, PNB, NORECO, LSP, MDG and MF are places of commerce. Specifically, MDG and MF are part of the central marketplace of Dumaguete city, while CSC and LSP are shopping malls. PNB is a local branch of the national bank of the Philippines and NORECO is the local electric cooperative providing power and electrical services in the area.

PNP, CHO, and CTO are government offices. PNP is the local police station. CHO is the city's health office which includes multiple government operated out-patient clinics, also doubling as the offices for the health and sanitation related government operations. CTO is the office which accommodates and processes the payment of taxes and fees for government services.

JPS, MPD, JPB, SPE, SPG are terminals for public transportation. JPS and JPB are transport terminals for public utility vehicles going north and south of Dumaguete city. MPD is the main hub for pick-up and drop-off for transport into the central marketplace of the city. SPE and SPG are the entrance and exit gates for the sea port of Dumaguete city.

These areas were organized into 3 categories depending on the type and amount of cover found in location. Green Cover (GC) refers to areas with direct green cover, usually in the form of tree canopies. Artificial Cover (AC) were areas with man-made shading infrastructures in the form of walkway canopies, tall walls, tall buildings, roofs, and others. Sparse Cover (SC) areas were locations where there was no cover of any form, exposed directly to the sun.

Instruments and Data Collection

A time frame of 11:00 AM to 2:00 PM was observed during the data gathering process to accurately capture noon-time data. Atmospheric data was gathered using a La Crosse EA-3010U handheld anemometer and PASCO PS-2154 6-in-1 weather sensor. The PASCO PS-2154 was powered by a PASCO Airlink Interface. It was then connected, by Bluetooth, to a smartphone with the SPARKVue Data Collection and Analysis software installed.

Fish-eye pictures of the sky were taken to evaluate the Sky View Factor for each location. Twelve on-the-spot measurement attempts were made for the air temperature, relative humidity, and wind velocity for an hour, each attempt taken at five-minute intervals. For each measurement attempt, the date and time were noted, together with the study area's latitude and longitude. On-site data were collected from October 10, 2023 to November 10, 2023.

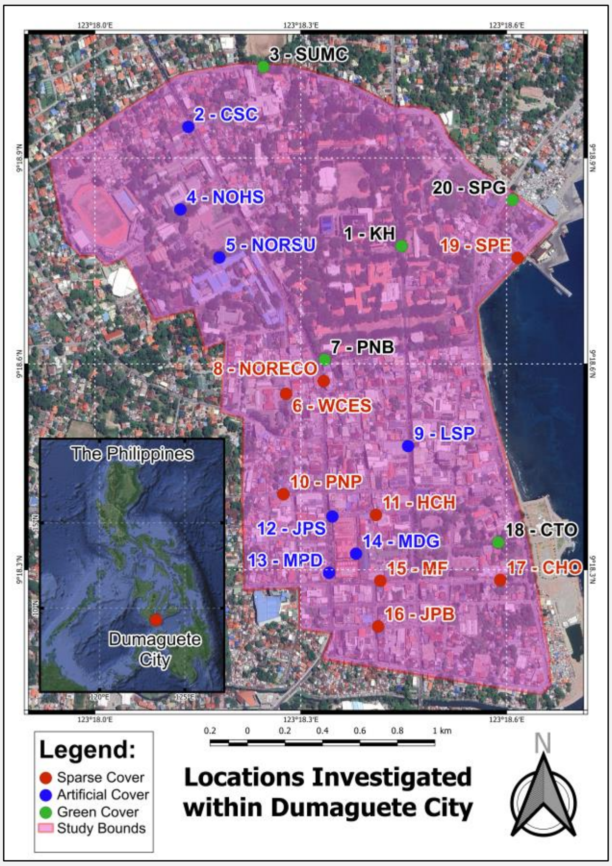

Figure 2. Dumaguete's city-center and the locations investigated, color coded into GC (Green), AC (Blue), and SC (Red).

Other Considerations

The physiological considerations were first standardized per age group and sex before the data was fed into the RayMan software. Only the median legal working age 40 years old was considered. Biological sex was considered for the calculations due to the fact that the significant difference in height and weight for the average male and female Filipino would affect the calculations for apparent temperature. For males, the height used was 1.67 meters with a body-mass of 66.1 kilograms. For females, the height used was 1.54 meters with a body-mass of 58.3 kilograms (del Prado-Lu, 2007; FNRI-DOST, 2015). For clothing and activity, regular work clothes (i.e. a shirt with a pair of pants and shoes) correspond to a factor of 0.7, while walking had an activity level of 110 W/m^2 (Yu et al., 2020).

Using the RayMan Pro software, the tabulated data were processed to calculate for the mPET levels and repeated for each sex and age. For ease and efficiency, the tabulated data were fed into the software using a formatted text (.txt) file. This process was reiterated for each of the study areas. All calculated mPET levels were compiled and organized for analysis.

Potential Limitations

Measurements were only taken on days with fair weather, when there were no low-pressure areas or high-pressure areas near Negros Island. On average, October and November has about 11 to 13 rainy days per month. Furthermore, there are between 9 to 13 days with thunderstorms on the said months (Climatology and Agrometeorology Division, 2020). As such, no measurements were taken during days with rain or intense heat. This was done so that the measurements were taken on days with average weather conditions, not during periods of weather extremes.

Data Analysis

Pairs of the organized datasets were then subjected to the Pearson Correlation Coefficient analysis. This analysis returned a decimal value (*r*) between 0.00 and 1.00 which revealed the strength of the correlation between the said data. A guide on the interpretation of the correlation coefficient is in Table

2. Pairs of parameters with moderate to strong correlations were graphed and subjected to linear regression.

Table 2. Pearson Correlation Coefficient table used for this study based on regression correlation coefficients for biomedical studies (Schober et al., 2018)

Correlation Coefficient	Interpretation
0.00 - 0.10	Negligible Correlation
0.10 - 0.39	Weak Correlation
0.40 - 0.69	Moderate Correlation
0.70 - 0.89	Strong Correlation
0.90 - 1.00	Very Strong Correlation

RESULTS AND DISCUSSION

Sky View Factor (SVF)

Sky View Factor (SVF) is the first grounding factor when it comes to the evaluation of apparent temperature. It dictates the classification of the location being investigated, as well as being central to the calculation of other related values down the line.

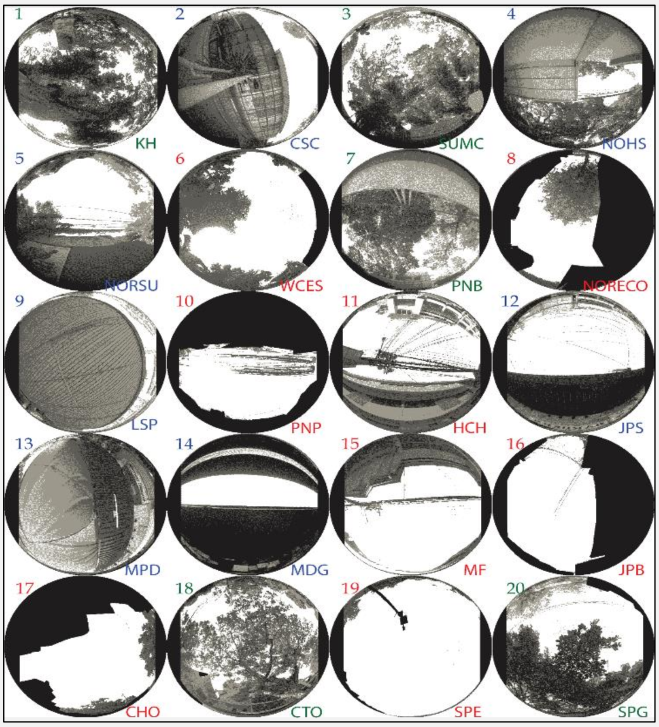

Figure 3. Fish-eye images of the locations investigated, processed through the RayMan software for SVF calculations, and color coded into GC (Green), AC (Blue), and SC (Red). Numerical values for SVF are recorded in Table 3.

Of the 20 locations selected for investigation, five were identified to be in the Green Cover (GC) category. These areas are Katipunan Hall (KH), the Philippine National Bank (PNB), and the Silliman University Medical Center (SUMC).

Seven areas were classified under the Artificial Cover (AC) category. These areas included schools and establishments for trade and commerce. Both the Negros Oriental High School (NOHS) and the Negros Oriental State University (NORSU) were classified under this category. Cang's Shopping Complex (CSC), which is nearby both NOHS and NORSU, is also classified as an AC area. Apart from CSC, NOHS, and NORSU, four of the seven areas within the category were situated well-within the urbanized Dumaguete city-center.

The eight remaining areas were identified to be Sparse Cover (SC) areas. This grouping of areas is the most diverse as it includes a school (West City Elementary School - WCES), a hospital (Holy Child Hospital - HCH), government offices such as the Dumaguete City Police Station (PNP) and the City

Health Office (CHO), as well as areas of transport and commerce such as the Negros Oriental II Electric Cooperative (NORECO), Fruit Market (MF), Jeepney Terminal bound for Bacong (JPB), and the Seaport Passenger Entrance (SPE).

It is within reason to assume that SC areas are representative of the street-side walkways of the Dumaguete city-center, as artificial covers aren't always present and old-growth trees with expansive canopies are disruptive to urban infrastructure. Of the 20 locations selected, 8 locations were classified as SC areas, accounting for 40%—the majority—of the areas investigated.

Each of the individual fish-eye images were fed into the RayMan software to extract numerical SVF values for the locations. Corrections to the fish-eye images were done in the RayMan software due to color erasure and lens flare.

SVF values represent how exposed an area is to the sky overhead. They are in decimals from 0.000 to 1.000 depending on the fraction of the sky visible on the ground level. For ease of use and understanding, the decimal can be thought of as how much of the sky that a person standing on the area sees. The closer the SVF value is to 1.0, the more the area is exposed to the sky. Table 3 contains a compilation of the SVF values measured from the fish-eye images taken at each location.

Table 3. Areas investigated for noon-time thermal comfort and the meteorological data gathered per location, organized into the three categories

Cover Type	Location	SVF	T_a	Relative Humidity	Wind Velocity
GC	KH	0.174	32.1 ± 0.2 °C	68.8 ± 0.6 %	0.7 ± 0.4 m/s
	SUMC	0.210	32.1 ± 0.2 °C	66.2 ± 0.6 %	0.4 ± 0.4 m/s
	PNB	0.085	33.8 ± 0.2 °C	55.4 ± 0.5 %	1.2 ± 0.2 m/s
	CTO	0.231	33.9 ± 0.1 °C	52.9 ± 0.7 %	0.8 ± 0.2 m/s
	SPG	0.333	33.5 ± 0.5 °C	55.0 ± 0.8 %	0.4 ± 0.3 m/s
AC	CSC	0.188	32.0 ± 0.4 °C	63.6 ± 0.7 %	0.7 ± 0.3 m/s
	NOHS	0.108	33.2 ± 0.2 °C	63.1 ± 0.8 %	0.7 ± 0.2 m/s
	NORSU	0.355	33.3 ± 0.1 °C	63.1 ± 1.2 %	0.0 ± 0.0 m/s
	LSP	0.057	32.9 ± 0.1 °C	58.8 ± 0.4 %	0.8 ± 0.5 m/s
	JPS	0.458	32.2 ± 0.4 °C	57.2 ± 0.8 %	1.5 ± 0.3 m/s
	MPD	0.012	33.9 ± 0.3 °C	56.4 ± 1.2 %	0.0 ± 0.0 m/s
	MDG	0.224	33.2 ± 0.3 °C	55.6 ± 0.5 %	0.0 ± 0.0 m/s
SC	WCES	0.567	34.9 ± 0.3 °C	57.2 ± 0.6 %	0.1 ± 0.1 m/s
	NORECO	0.319	37.1 ± 0.1 °C	55.5 ± 1.1 %	0.7 ± 0.2 m/s
	PNP	0.433	37.7 ± 0.2 °C	52.7 ± 1.7 %	1.1 ± 0.2 m/s
	HCH	0.407	34.1 ± 0.2 °C	58.6 ± 1.2 %	0.0 ± 0.0 m/s
	MF	0.622	35.0 ± 0.6 °C	55.8 ± 1.8 %	1.3 ± 0.3 m/s
	JPB	0.552	37.2 ± 0.3 °C	51.2 ± 1.9 %	1.2 ± 0.6 m/s
	CHO	0.504	34.6 ± 0.3 °C	56.0 ± 1.8 %	1.0 ± 0.2 m/s
	SPE	0.873	34.0 ± 0.4 °C	55.7 ± 1.1 %	0.8 ± 0.4 m/s

Average SVF value for GC areas is 0.207. For the AC areas, the average is 0.200. Highest are the average SVF value of SC areas, at 0.535.

Worthy of note is close proximity of the SVF values for both the GC and AC areas. Tree canopies are natural covers, and as such provide a great deal of shade and coverage on the ground level. This is reflected by the SVF values for the GC areas, which range from 0.085 to 0.333. For the AC areas, the SVF ranges from 0.012 to 0.458, for similar reasons.

NORECO (0.319), HCH (0.407), and PNP (0.433), despite being classified as SC areas, have lower SVF values due to being located within urban canyons, which are areas enclosed on two or more sides with buildings which are two stories or taller. The geometry of the surrounding infrastructure in the said areas can be seen in both Figure 3. Although these areas have SVF values comparable to some of the AC and even GC areas, they lack overhead cover. SPE (0.873) has the exact opposite situation. The area is comparatively open as it is directly on the Dumaguete City coastline.

Modified Physiologically Equivalent Temperature (mPET)

mPET is calculated through the RayMan Pro software, using the meteorological measurements in Table 3. Table 4 contains the modified PET range for tropical climates used to evaluate mPET in this study.

Table 4. Calculated mean radiant temperature (T_{mrt}) and mPET for the areas investigated

Cover Type	Location	T_{mrt}	mPET		Physiological Stress (Heat Stress)
			Females	Males	
GC	KH	44.3 ± 0.4 °C	39.0 ± 0.8 °C	38.4 ± 0.7 °C	Moderate
	SUMC	49.2 ± 0.3 °C	41.3 ± 1.1 °C	40.6 ± 1.1 °C	Moderate
	PNB	52.0 ± 1.9 °C	41.7 ± 0.9 °C	40.9 ± 0.9 °C	Moderate
	CTO	48.7 ± 1.7 °C	40.9 ± 0.6 °C	40.1 ± 0.6 °C	Moderate
	SPG	51.4 ± 2.9 °C	42.6 ± 1.7 °C	41.7 ± 1.6 °C	Moderate
AC	CSC	47.1 ± 0.9 °C	39.7 ± 1.0 °C	39.1 ± 1.0 °C	Moderate
	NOHS	49.9 ± 0.3 °C	41.7 ± 0.5 °C	40.9 ± 0.5 °C	Moderate
	NORSU	49.9 ± 0.5 °C	43.2 ± 0.3 °C	42.4 ± 0.3 °C	Moderate
	LSP	51.8 ± 0.3 °C	41.7 ± 0.9 °C	40.9 ± 0.9 °C	Moderate
	JPS	49.1 ± 0.8 °C	39.1 ± 0.9 °C	38.5 ± 0.8 °C	Moderate
	MPD	50.9 ± 0.6 °C	43.5 ± 0.2 °C	42.6 ± 0.2 °C	Moderate
	MDG	52.1 ± 0.2 °C	43.7 ± 0.2 °C	42.8 ± 0.2 °C	Moderate
SC	WCES	60.3 ± 0.6 °C	48.3 ± 0.7 °C	47.2 ± 0.6 °C	Strong
	NORECO	60.6 ± 0.9 °C	48.3 ± 0.8 °C	47.2 ± 0.8 °C	Strong
	PNP	59.3 ± 0.7 °C	47.4 ± 0.6 °C	46.3 ± 0.6 °C	Strong
	HCH	59.2 ± 3.2 °C	47.7 ± 1.5 °C	46.6 ± 1.4 °C	Strong
	MF	55.9 ± 0.7 °C	44.1 ± 0.6 °C	43.2 ± 0.5 °C	Moderate
	JPB	58.6 ± 1.8 °C	46.9 ± 1.6 °C	45.8 ± 1.5 °C	Strong
	CHO	53.5 ± 0.7 °C	43.1 ± 0.7 °C	42.2 ± 0.7 °C	Moderate
	SPE	55.1 ± 1.5 °C	43.6 ± 1.5 °C	42.8 ± 1.4 °C	Moderate

The mPET values calculated through the RayMan Pro software is collated in Table 4. Most obvious is the fact that the calculated mPET values for females are noticeably higher than the equivalent mPET values for males. The physiological difference between the average Filipino male and female leads to the disparity of their felt heat levels. In the cooler Green Cover (GC) and Artificial Cover (AC) areas, this difference can vary as little as 0.5°C, jumping up to about 1.0°C on the hotter AC locations. This disparity can be attributed to physiological differences between Filipino females and males (Stolwijk, 1980). More specifically, Filipino males are both taller and heavier than Filipino females.

It can also be seen that all the average mPET values for the GC and AC are below the 44.09°C threshold for "Moderate Heat Stress." Lower mPET readings in Katipunan Hall (KH), Silliman University Medical Center (SUMC), and Philippine National Bank - Dumaguete City, Silliman Avenue Branch (PNB)—all three areas surrounded by dense foliage—could signify a connection between green spaces and thermal comfort within an urban area. More specifically, green spaces reduce heat stress to tolerable levels even during noon time, when temperatures are at their peak. This is consistent with the findings of studies done in the Philippines which found that green spaces reduce the effects of the urban heat island effect (Cañete et al., 2019; Cruz et al., 2021).

For the AC areas, the mPET values are relatively close to each other. The lowest mPET values in the AC areas are in the Cang's Shopping Complex (CSC) and the Jeepney Terminal for Sibulan (JPS). Both locations also have the lowest Mean Radiant Temperatures (T_{mrt}) for the AC areas. Both areas are relatively open with an almost constant light breeze blowing through. As such, the low T_{mrt} values and open surroundings of both locations result to lower mPET values and better thermal comfort on site.

A majority of the Sparse Cover (SC) areas return mPET values classified as "Strong Heat Stress," with the exception of the Fruit Market (MF), City Health Office (CHO), and Seaport Passenger Entrance (SPE). These locations (MF, CHO, SPE) were also areas with open overhead covers and have the lowest T_{mrt} among the SC locations. The areas with "Strong Heat Stress" are located within urban canyons. Modern building materials typically reflect and store great amounts of heat(Cañete et al., 2019). As such, areas within urban canyons have higher T_{mrt}, and thus have higher mPET. This means that buildings situated close to each other exacerbate heat stress on the ground level. This idea was first found through simulation by Wang et al., and de la Rosa, but very few studies have verified this using actual field measurements (de la Rosa, 2020; Wang et al., 2022). Kotharkar et al. (2024) provided the first published investigation on the effects of urban density and human thermal comfort. However, their primary research objective was to reframe the PET range for a tropical, hot-humid environment. As such, their investigation did not delve deeply on the effect of dense urban spaces on thermal comfort. These studies are in contrast to those done by Ribeiro et al., and Yu et al., which were also done in urban settings with tropical, hot-humid climates, but the locations investigated were all wide, open spaces (Ribeiro et al., 2022; Yu et al., 2020). Direct sun exposure would directly increase mPET if only human intuition and lived experience is considered. However, it must be remembered that mPET is a result of meteorological factors and not just SVF.

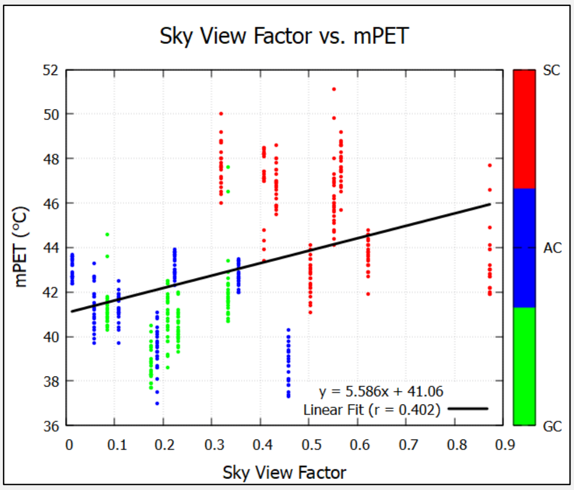

Figure 4. SVF and their corresponding mPET values, with a correlation coefficient of $r = 0.521$ indicates a moderate relationship. The colors indicate the type of overhead cover cover in which the datapoints were gathered: green for Green Cover (GC), blue for Artificial Cover (AC), and red for Sparse Cover (SC).

The Pearson correlation analysis between SVF and mPET returned a correlation coefficient of $r = 0.521$. This constitutes to a moderate, positive relationship between SVF and mPET. However, this correlation is not strong enough to warrant the assertion that higher SVF values would equate to higher mPET. This means that direct sun exposure may not be the only cause increasing mPET and heat stress. As seen in Figure 4, the type of overhead cover (SC, GC, AC) still influences mPET more directly compared to the numerical value of SVF. As was discussed prior, the geometry and density of urban infrastructure greatly affect the thermal comfort on the ground level.

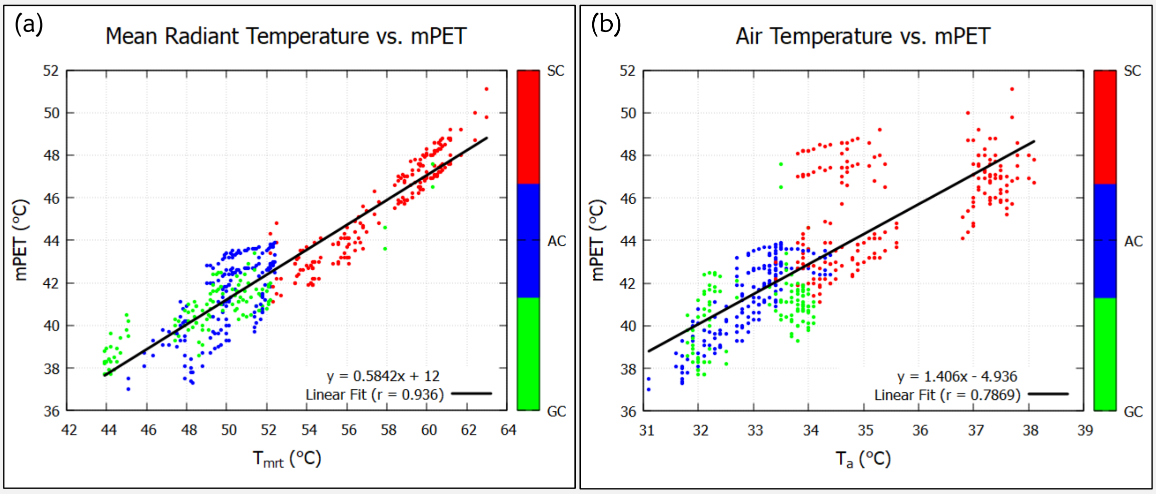

Figure 5. Same as with Figure 4, but with (a) T_{mrt} and mPET with a very strong relationship ($r = 0.936$) and (b) T_a and mPET with a strong relationship ($r = 0.787$).

Similarly, it can be asserted that greater exposure to thermal radiation would increase mPET. Figure 5 contains regression lines which are attempts to model the relationship between T_{mrt}, T_a, and mPET. While it is readily apparent that the relationship between T_{mrt} and mPEt is direct and linear, the spread of the datapoints in the T_a vs mPET scatterplot indicates that the effect of air temperature on mPET may not be as great as that of T_{mrt}. Correlation analysis between T_{mrt} and mPET returns a coefficient of $r = 0.936$, indicating a very strong, positive relationship. The same analysis done on T_a and mPET returns a value of $r = 0.787$, which constitutes a strong, positive correlation. Both factors influence mPET in substantial ways. However, the lower r value for T_a vs mPET may be due to the fact that air temperature itself is affected by mean radiant temperature. Therefore, T_{mrt} influences mPET more than T_a. This is because mean radiant temperature is a more direct manifestation of the heat present in the location investigated.

Since higher mean radiant temperatures are the result of both direct sun exposure and placement of the surrounding urban infrastructure in the location being investigated, it can be concluded that higher mPET values would also result from urban canyons. This result has first been found and contextualized to the Philippine climate by de la Rosa in 2020 (de la Rosa, 2020). However, the said research was only done in simulation, with minimal input from in-situ meteorological measurements. In 2024, Kotharkar and Dongarsane simulated thermal comfort in Indian cities with different urban geometries. They found that compact urban areas exhibit moderate heat stress throughout the day, while open areas tend to stay neutral for most of the day. However, they have also found that the software that they use, ENVI-met, tends to be unstable due to the complexity of the layout of cities in India (Kotharkar & Dongarsane, 2024). As such, this finding could serve as vindication to the observations and conclusions of de la Rosa, as well as real-world grounding to the results of Kotharkar and Dongarsane.

In the past, Relative Humidity (RH) was itself used as a measure of human thermal comfort. It was deemed inadequate however, as RH does not take into consideration human biological functions as well as human perception of heat (Steadman, 1979a). It was found that RH, or humidity in general, does not influence human thermal comfort greatly by itself. Rather, RH modifies how other meteorological factors are perceived by a test human (Steadman, 1979b). For example, an RH measurement of 50% would make ambient air with $T_a = 20°C$ be perceived as dry, but even with the same RH, ambient air with $T_a = 40°C$ is perceived to be humid (Steadman, 1979a). As such, RH may influence human thermal comfort in ways that are not immediately apparent.

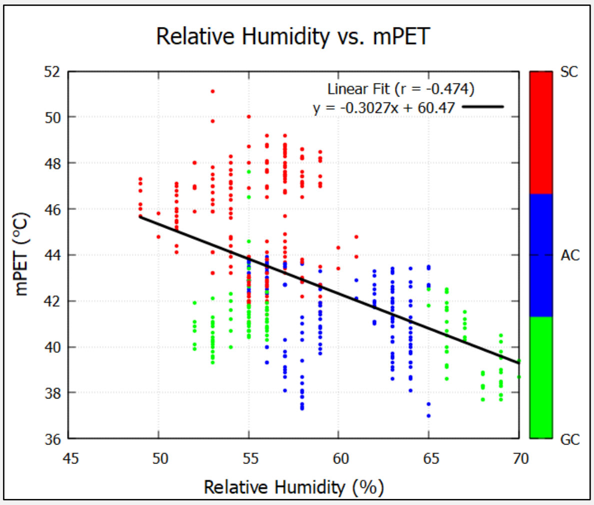

Figure 6. Same as with Figure 4, but with relative humidity and mPET. The correlation coefficient of $r = -0.474$ indicates a moderate relationship.

Figure 6 contains a scatterplot comparing RH and mPET, as well as a linear regression which could describe their relationship. Correlation analysis between RH and mPET yields a coefficient of $r = -0.474$ which constitutes a moderate, negative relationship. However, considering the relationship between T_{mrt} and T_a with mPET, it is worthwhile to ask if mPET was reduced because of the increase in RH, or was mPET reduced because T_{mrt} and T_a were also reduced. Since the correlation strength between mPET with both T_{mrt} ($r = 0.936$) and T_a ($r = 0.787$) are much stronger than that with RH ($r = -0.474$), the latter assertion is the most probable. It was already found prior that RH can only modify human perception of heat, and is not as direct a factor in human thermal comfort compared to others.

In tropical, hot-humid climates, wind velocity plays a vital role in human thermal comfort (Wang et al., 2022). The sensitivity of the mPET model to wind velocity has been investigated (Matzarakis et al., 2016), but the findings have not been contextualized to the South-East Asian climate. It is therefore crucial to establish knowledge on how wind velocity affects mPET in tropical, urban locations.

Wind increases thermal comfort. As seen in Figure 7, there is a general decrease in mPET with stronger wind velocities. However, a single regression will be not able to describe the rate of decrease in mPET with increasing wind velocity. The disparities between the mPET in GC, AC, and SC areas creates a gap in the scatterplot which makes for very large variance if only a single regression line is used in interpreting the behavior of the data. As such, it is reasonable to perform regression and correlation analyses per overhead cover category.

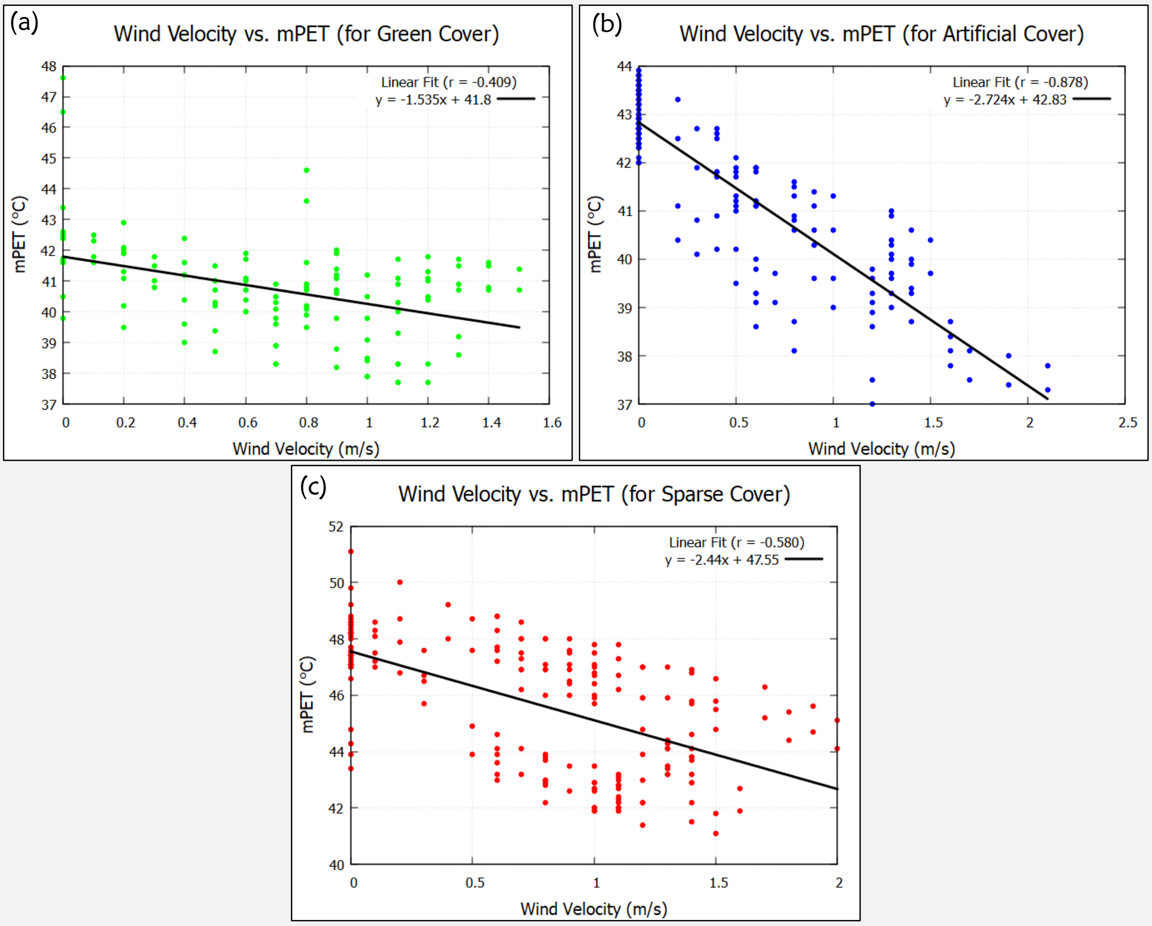

Figure 7. Same as with Figure 4, but with Wind velocity and mPET for (a) GC, (b) AC, and (c) SC locations. Both the GC ($r = -0.409$) and SC ($r = -0.580$) locations have correlation coefficients indicating a moderate relationship. However, AC locations have a coefficient of $r = -0.878$ which indicates a strong relationship.

Correlation analysis between Wind Velocity and mPET returned coefficients $r = -0.409$ for the GC areas, $r = -0.580$ for the SC areas, and $r = -0.878$ for the AC areas. The r values for GC and SC constituted to moderate, negative relationships. However, for the AC areas, the r value points to a strong, negative relationship. Based on the correlation coefficients alone, mPET in AC areas are the most affected by wind velocity. Examining the equations of the linear regression, however, reveals that wind greatly reduces heat stress for both AC and SC locations. In the case of AC, the slope of the line is -2.724, while the slope for the regression line for SC is -2.44. Both of these slopes mean that, for every 1 m/s of wind present, mPET in AC areas is reduced by 2.724 °C, and mPET for SC areas is reduced by 2.44 °C. It can therefore be said that the presence of wind is an optimal way of reducing mPET, and thus heat stress, in AC and SC areas.

The correlation coefficient (r = -0.409) and slope of the linear regression (m = -1.535) for GC areas point to the fact that wind is not as effective in reducing mPET in the said locations. This might be due to the vegetation in GC areas providing passive cooling through their biological functions and thus wind velocity would only have reduced effect on mPET. Conversely, as both AC and SC areas have no passive cooling from the surroundings, wind is one of the few ways in which mPET can be reduced. This is consistent with the findings of Abdollahzadeh and Biloria. Additionally, they state that urban canyons, if oriented properly, could leverage the natural wind patterns in a city as a way to reduce heat stress (Abdollahzadeh & Biloria, 2021).

Table 5. Pearson correlation coefficients for the meteorological factors taken into consideration for this study

	SVF	mPET	T_{mrt}	T_a	RH	Wind
SVF	1.00	0.402	0.521	0.404	-0.367	0.215
mPET	0.402	1.00	0.936	0.787	-0.474	-0.309
T_{mrt}	0.521	0.936	1.00	0.806	-0.588	-0.058
T_a	0.404	0.787	0.806	1.00	-0.675	0.171
RH	-0.367	-0.474	-0.588	-0.675	1.00	-0.229
Wind	0.215	-0.309	-0.058	0.171	-0.229	1.00

Other meteorological factors exist with the factors described prior. However, their effect on mPET, or in thermal comfort in general, may not be so significant or relevant. As such, the specifics of their relationships with each other were not discussed in detail. Table 5 contains the Pearson correlation coefficients for the meteorological factors used in this investigation. Pairs of parameters with correlation coefficients of $|r|=0.500$ and below were considered to have no significant relationship with each other.

Sky View Factor (SVF) and Mean Radiant Temperature (T_{mrt}) have a moderate, positive correlation. This is consistent with the fact that the more exposed a location is to the sun, the higher the T_{mrt}. However, locations within urban canyons exhibit higher temperatures due to the surrounding infrastructure storing and reflecting heat towards the ground level. As such, greater sun exposure does not automatically increase T_{mrt}.

Koerniawan & Gao (2015), as well as Wang et al. (2022), have proposed that dense urban structures inhibit wind. In the case of Koerniawan & Gao (2015), they have observed that locations with dense foliage in Indonesia’s urban parks tended to experience lower wind velocities on average. They did not, however, perform a statistical analysis on this assertion. However, Wang et al. (2022) simulated a typical urban block and found that, in certain orientations, wind effectively dies down before it can penetrate the core of the urban block due to turbulent flow. The correlation analysis done between SVF and wind velocity found in this study suggest that they have a weak relationship. However, it must be noted that SVF can be used as an estimate to urban density, it does not take into account the orientation of the surrounding infrastructure, as well as the direction and intensity of the wind. This may also be the reason why Koerniawan & Gao (2015) only made this assertion in writing, but did not provide rigorous numerical tests to prove it.

Like with Relative Humidity (RH) and mPET, RH exhibits moderate, negative relationships with T_a and T_{mrt}. However, it is known that RH changes due to many environmental factors, such as elevation and atmospheric pressure, thus the relationships of RH with T_a and T_{mrt} cannot be singled out.

Lastly, T_a and T_{mrt} have a strong, positive relationship. This is due to the fact that the source of heat of both parameters is the sun. As such, greater sun exposure raises both T_a and T_{mrt} concurrently.

Figure 8 contains a flowchart summary of the parameters which influence mPET. Considering the findings of this research, it was found that sun exposure and urban density are the primary factors which increase noon-time heat stress. Green spaces are the most optimal measure in reducing mPET. However, for locations which cannot accommodate greenery, the presence of wind is an efficient way to reduce heat stress.

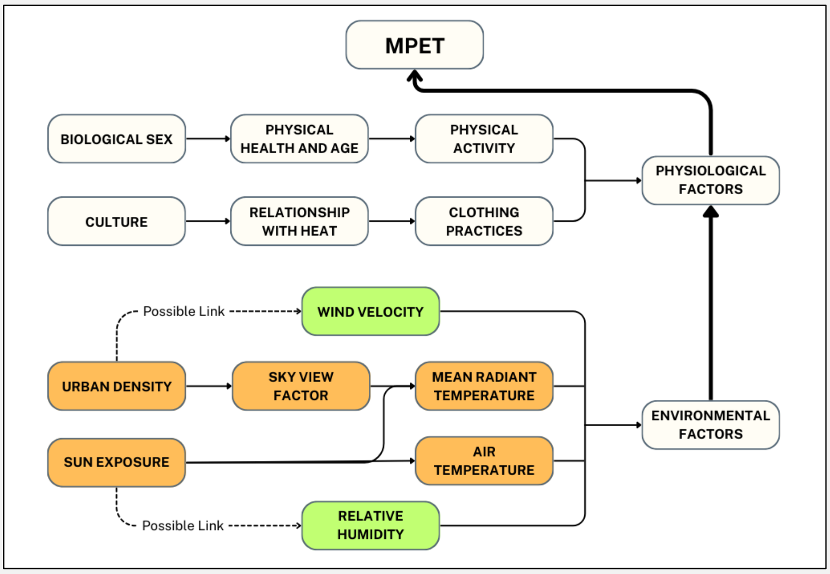

Figure 8. A flowchart summary of the factors which affect mPET. The factors in the orange boxes increase mPET, thus also increasing heat stress, while those in the green boxes decrease mPET, minimizing heat stress.

CONCLUSION

Cities located in tropical, hot-humid environments are becoming increasingly hotter due to climate change. It is, therefore, imperative that the effects of climate change in such settings are temporally and thoroughly investigated. One of the most common ways to contextualize climate change with urban landscapes is through the identification of Urban Heat Islands (UHI) and their intensities. The findings from UHI studies provides a numerical representation of the increasing heat levels within cities. However, UHI findings only reflect the heat levels of urban structures. Data from UHI studies ultimately do not reflect how humans perceive and are affected the increased temperatures.

To contextualize the effects of both climate change and UHI on human experience, the thermal comfort levels within the urban landscapes have to be investigated. A quantitative measure to gauge thermal comfort within urban spaces in tropical, hot-humid settings is the Modified Physiologically Equivalent Temperature (mPET) model. By individually and collectively analyzing the microclimatic variables (Sky View Factor, Air Temperature, Mean Radiant Temperature, Wind Velocity, and Relative Humidity) at certain locations of interest, mPET values can then be calculated through the RayMan Pro software provided by the German Weather Service. The calculated mPET values were then interpreted using a PET range developed by Kotharkar et al. (2024) to contextualize the thermal sensation a person may have when subjected to the microclimatic variables measured. This study is mainly focused on the calculation and contextualization the human thermal comfort levels within the urban Dumaguete city-center.

For each of the 20 locations investigated in the Dumaguete city-center, the type of overhead cover for each location was first identified. Five locations were identified to have Green Cover (GC), seven had Artificial Cover (AC), and eight had Sparse Cover (SC). The amount of overhead coverage was then quantified using their SVF. The SVF for each location affected the other microclimatic factors. Wind velocity could possibly be affected by SVF, with areas having higher SVFs generally having higher average wind velocities. However, this relationship requires further verification.

Both GC and AC areas had T_{mrt} that were considerably lower than the T_{mrt} for the SC locations. Even the highest average T_{mrt} value from the GC and AC areas (52.1°C) is lower by 1.4°C to 8.5°C compared to the average T_{mrt} values from the SC areas. It is, however, important to note that the SC areas with the lowest T_{mrt} values were relatively open areas with high SVFs. SC locations situated within urban canyons had mean radiant temperatures that were considerably higher due to the reflection of short-wave radiation and emission of long-wave radiation onto the ground level.

Consequently, all of the GC and AC areas stayed below the 44.09°C mPET threshold for "Moderate Heat Stress," comparatively low compared to the SC locations. Most of the SC areas exceeded the said threshold, staying within the "Strong Heat Stress" temperature range, except for three locations. The exceptions were also identified to have been the relatively open areas with lower T_{mrt}. As was identified prior, the SC areas with the highest mPET values were situated within urban canyons.

Through regression and Pearson correlation analyses, it was determined that T_{mrt} and T_a have the most influential relationship with mPET. That is, as T_{mrt} and T_a increase, mPET also increases. Similar tests were done to determine the general relationship between wind velocity and mPET, which resulted to different correlation coefficients for the different overhead cover classifications. Between GC, AC, and SC, mPET from the AC and SC locations were the most affected by wind velocity.

It can be concluded, therefore, that human thermal comfort in an urban setting with a tropical, hot-humid climate such as the city-center of Dumaguete City is affected not just by climatic factors like air temperature, relative humidity, sun exposure, and others, but also by urban architecture. The placement and geometry of buildings and other structures within a given space heavily influences the microclimatic variables in an area. Closely-packed buildings reflect and emit thermal radiation onto the ground level, while also inhibiting air flow. As such, higher levels of heat stress are experienced by individuals within urban canyons.

Considering the findings of this research, it is recommended that future urbanization efforts in South-East Asia consider integrating green spaces in their urban designs. These green spaces are the most effective measure in reducing ground-level heat stress for pedestrians. Locations designated for foot traffic should be decluttered and made less dense, so that built-up areas and infrastructure do not reflect and concentrate heat towards the foot traffic. Furthermore, urban designers should also leverage the natural wind patterns in an area as a tool to improve thermal comfort. Buildings and other infrastructure should not inhibit the flow of wind, or are designed such that they redirect wind to areas with large amounts of foot traffic or urban canyons.

The paradigm of future urbanization should be human-focused. As such, the researchers recommend future studies in the topic of human thermal comfort be done with urban design in mind. The conclusions and recommendations of this research can be used as basis for simulating proposed urban designs, or be basis for the redesign of existing urban spaces. Climate variability should also be taken into consideration, as climate change continues to impose weather extremes to many parts of the world, especially in South-East Asia. Finally, the methodology of this study can be used as a framework for researches on disaster risk reduction and mitigation strategies in urban areas.

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