EVALUATING THE OUTDOOR THERMAL COMFORT CONDITIONS IN URBAN VILLAGES OF KUALA LUMPUR

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EVALUATING THE OUTDOOR THERMAL COMFORT CONDITIONS IN URBAN VILLAGES OF KUALA LUMPUR

ABSTRACT

Urban villages (kampungs) are distinctive products of rapid urbanization and massive rural to urban migration, located within cities and surrounded by high rise buildings. These urban villages have still kept their own design patterns and characteristics. Kuala Lumpur (KL) still has some traditional urban villages that have not been replaced by contemporary residential projects due to the rapid modernization and urban growth. Although thermal comfort of outdoor urban spaces is an influential factor in residential behavior, there is a limited number of studies that have been conducted especially in KL city. On the other hand, this is a significant factor in increasing the use of outdoor spaces and preserve traditional conditions. This study measures and reports a quantitative research of the field measurements and simulates the collected data from experimental study via the Rayman and ENVI-met softwares. The purpose of this simulation is to evaluate the outdoor thermal comfort in both shaded and unshaded areas in urban villages in hot and humid climate. Three different areas of KL city namely Kampung Baru, Kampung Melayu Kepong, and Kampung Sungai Penchala were chosen based on geographically location in regards with clarifying differences in the environment surrounding, identification of natural environments such as vegetation, material and surface, and the level of density. Physiological Equivalent Temperature (PET) and Mean Radiant Temperature (Tmrt) indices were used to explore the functional spaces of the selected areas towards identifying the climatological condition in outdoor spaces and the significant environmental values to achieve a higher level of quality of life. The findings of field measurement results show that among the shaded areas, Kampung Melayu Kepong recorded the coolest weather at 11:00 am with 27.7°C while the warmest was the Kampung Baru at 16:00 pm with 34.9 °C; whereas, in unshaded areas Kampung Melayu Kepong with 30.5 °C and Kampung Sungai Penchala with 37 °C were coolest and warmest respectively. In terms of wind speed, Kampung Melayu Kepong recorded the fastest speed with 3.28 m/s blew from the southeast. Kampung Melayu Kepong and Kampung Sungai Penchala have the highest measured relative humidity of 78%, and coolest temperature of 27.7°C, and 26.2°C respectively. According to ENVI-met simulation in the shaded area, the coolest kampung was Kampung Melayu Kepong with 25.59 °C; whereas, the warmest was Kampung Baru with the highest recorded temperature of 34.8 °C. In addition, the highest temperature in the unshaded area measured was Kampung Baru with 35.38 °C, and the lowest temperature was in Kampung Melayu Kepong recorded 30.12 °C. In summary, the results show that the higher relative humidity percentage decreases temperature. Moreover, this research proposes some effective technological and specialized suggestions on the appropriate design to promote outdoor thermal comfort satisfaction, mitigation of heat in hot and humid context and having a better quality of life.

Keywords: urban village, outdoor thermal comfort, ENVI-met, shaded/unshaded area

ABSTRAK

Kampung bandar adalah produk tersendiri hasil daripada perbandaran pesat dan penghijrahan luar bandar ke bandar, terletak di bandar-bandar dan dikelilingi oleh bangunan yang tinggi. Kampung bandar ini masih mengekalkan corak dan ciri reka bentuk mereka sendiri. Kuala Lumpur (KL) masih mempunyai beberapa kampung tradisional yang belum digantikan oleh projek kediaman kontemporari kerana pemodenan pesat dan pertumbuhan bandar. Walaupun keselesaan terma ruang luar bandar adalah faktor yang berpengaruh dalam tingkah laku penduduk, kajian yang telah dijalankan di kawasan ini, khususnya di bandaraya KL adalah terhad. Sungguh pun begitu, ia merupakan faktor penting dalam meningkatkan penggunaan ruang luar dan mengekalkan keadaan tradisi. Kajian ini mengukur dan melaporkan penyelidikan kuantitatif dan pengukuran lapangan dan mensimulasikan data yang dikumpulkan dari kajian percubaan melalui perisian Rayman dan ENVI-met. Tujuan simulasi ini adalah untuk menilai keselesaan terma luaran di kedua-dua kawasan yang teduh dan tidak teduh di kampung-kampung bandar dalam iklim panas dan lembap. Tiga kawasan berbeza di KL iaitu Kampung Baru, Kampung Melayu Kepong, dan Kampung Sungai Penchala dipilih berdasarkan pelbagai pembolehubah seperti suhu, radiasi matahari, kelembapan relatif, kelajuan angin, arah angin dan faktor pandangan langit pada dua hari yang berlainan. *Physiological Equivalent Temperature (PET)* dan *Mean Radiant Temperature (Tmrt)* digunakan untuk meneroka ruang fungsional kawasan-kawasan terpilih kearah mengenalpasti keadaan iklim di ruang luaran dan nilai-nilai alam sekitar yang penting untuk mencapai tahap kualiti kehidupan yang lebih tinggi. Penemuan hasil pengukuran lapangan menunjukkan bahawa di antara kawasan yang teduh, Kampung Melayu Kepong merekodkan cuaca paling dingin pada pukul 11:00 pagi dengan 27.7 darjah sementara yang paling panas adalah Kampung Baru pada jam 16:00 malam dengan 34.9 darjah; sementara di kawasan tidak teduh, di Kampung Melayu dengan 30.5 darjah dan Kampung Sungai Penchala dengan 37 darjah masing-masing paling sejuk dan paling hangat. Dari segi kelajuan angin, Kampung Melayu Kepong mencatat kelajuan terpantas dengan tiupan 3.28 m/s dari tenggara. Kampung Melayu Kepong dan Kampung Sungai Penchala mempunyai kelembapan relatif tertinggi 78%, dan suhu paling sejuk 27.7 darjah dan 26.2 darjah. Menurut simulasi ENVI-met untuk kawasan yang teduh, kampung paling dingin ialah Kampung Melayu Kepong dengan 25.59 darjah; sedangkan yang paling panas adalah Kampung Baru dengan suhu rekod tertinggi 34.8 darjah. Disamping itu, suhu tertinggi di kawasan tidak teduh yang diukur adalah Kampung Baru dengan 35.38 darjah, dan suhu terendah di Kampung Melayu Kepong yang mencatatkan 30.12 darjah. Ringkasnya, hasil menunjukkan bahawa peratusan kelembapan relatif yang lebih tinggi menurunkan suhu. Selain itu, penyelidikan ini mencadangkan beberapa petunjuk berteknologi dan khusus yang berkesan bagi reka bentuk yang sesuai untuk menggalakkan kepuasan keselesaan terma luaran, pengurangan haba dalam konteks iklim panas dan lembap dan mempunyai kualiti kehidupan yang lebih baik.

Kata kunci: kampung bandar, keselesaan terma luaran, ENVI-met, kawasan teduh /tak teduh

To my beloved parents

Who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

To my lovely fiancé; Dr. Shin To Amiri

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LIST OF SYMBOLS AND ABBREVIATIONS

UHI	:	Urban heat island
TPC	:	Thermal Perceptions Classification
PET	:	Physiological equivalent temperature
TMRT	:	Mean radiation temperature
SVF	:	Sky view factor
ET	:	Effective temperature
SET	:	Standard effective temperature
PMV	:	Predicted mean vote
GR	:	Global radiation
WBGT	:	Wet-bulb globe temperature index
S	:	Solar radiation
RH	:	Relative humidity
TA	:	Air temperature
AT	:	Apparent temperature
CD	:	Cloud cover
ATC	:	Air temperature change
WS	:	Wind speed
WD	:	Wind direction
V	:	Air velocity
H/W	:	Height/width
CLO	:	Clothing
FPM	:	Feet/minute
TME	:	Physical Activity
HPA	:	Hectopascal

UBL	:	Urban Boundary Layer
UCL	:	Urban canopy layer
UCZ	:	Urban Climate Zone
LCZ	:	Local Climate Zone
RSL	:	Roughness Sub Layer
MRA	:	Malaya reservation area
UM	:	University of Malaya
KL	:	Kuala Lumpur
UNDESA	:	United Nations Department of Economic and Social Affairs
UVG	:	Urban Village Group
ASHRAE	:	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
VCWC	:	Village Security Working Committee
MPS	:	Mosque Parish System

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Over the decades, Kuala Lumpur (KL) city has been confronted with an enormous and significant level of urban spatial expansion. Having such a level of rapid urban transformations in a tropical context creates challenges for achieving an outdoor thermal comfort level preferred by the inhabitants. One of the challenges that will be considered in this research is environmental parameters in the outdoor urban spaces, which affect human comfort. In an urban environment, the human thermal comfort of urban microclimatic represents the level of satisfaction of inhabitants, which closely relates to perceptions and preferences towards the way people use outdoor spaces. The level of comfort is felt under a 'stable state', which means an acceptable range for thermal comfort based on the ASHRAE standard 55, (2004), formerly known as the American Society of Heating, Refrigeration and Air-Conditioning Engineers. When the temperature rises in human body more than the standard level according to the state of comfort; human sensation recognizes and reacts to their ecological warm condition (Evans, 1984). Physical elements such as air quality, urban design of outdoor spaces and their arrangement in an environment play an important role in human thermal comfort. It is important to have knowledge about climate in developing the urban design and planning, which has been discussed in many studies (e.g. Svensson & Eliasson, 2002; Eliasson, 2000; Papparelli, Kurban, & Cunsulo, 1996).

With the creation of urban spaces from urbanization, KL city faces higher density and increasing human activity. Therefore, spaces in urban areas become more compacted with surrounding high-density development and as a result, this has created Urban Heat Island (UHI). Urban open spaces are ever more important since more people living there than in rural areas. Thus, urban spaces, such as green spaces, squares, or parks can bring economical, ecological, environmental, and social benefits to cities and are crucial for healthy urban living (Nouri & Costa, 2017). Climate change is the main concern of urban areas, which is associated to the UHI effect (Akbari & Kolokotsa, 2016). UHI indicate the higher air temperatures in urban areas in compare to their rural areas. It is the common reaction to many uncontrollable and controllable factors that could be collected as temporary effect variables, such as cloud cover and air speed (Hsieh & Huang, 2016). This may result in permanent variables, for example building, green areas, and urban materials and sky view factor geometry (Synnefa, Dandou, Santamouris, Tombrou, & Soulakellis, 2008; Zoulia, Santamouris, & Dimoudi, 2009), and cyclic effect variables, such as anthropogenic heat sources, solar radiation, climate conditions (Taha, 1997). Even though the effect often reduced by the size of the city, UHI phenomenon affect small cities (Castaldo, Pisello, Pigliautile, Piselli, & Cotana, 2017; E. Vardoulakis, Karamanis, Fotiadi, & Mihalakakou, 2013) and be worse by heat waves (Pyrgou, Castaldo, Pisello, Cotana, & Santamouris, 2017a, 2017b). Vegetation and open land in urban areas are substituted with roads, buildings, and other infrastructures so that spaces turn from permeable to impermeable with low and dry solar reflectance (Emmanuel & Fernando, 2007). Whenever urban spaces become warmer than the suburban spaces, the great influence on the thermal comfort of our outdoor spaces and urban congested spaces can be observed (Stewart and Oke, 2012). An urban heat island is a name given to describe the characteristic warmth of both the atmosphere and surfaces in cities (urban areas) compared to their (non-urbanized) surroundings. The heat island is a example of unintentional climate modification when urbanization changes the characteristics of the earth's surface and atmosphere. Having a moderate UHI with sustainable measures caused the energy building to reduce and improving human comfort (S. U. E. Grimmond, 2007; Steemers, 2003). Thus, it is shown that there is a correlation between the UHI intensity with human activity, density of building, urban structures, the use of high absorbing materials, and lack of greenery spaces in urban areas as influential factor in the level of comfort (T. Oke, Johnson, Steyn, & Watson, 1991). Urban villages on the other hands, are a distinctive product of rapid urbanization and massive rural to urban migration as a universal phenomenon. (Chung and Geertman 2013). These villages in contrast to the urban areas are the better condition in the level of thermal comfort. UHI effect can be seen closer to city center due to the high temperature in contrast the urban villages within the cities. In this research, micro-class factors in urban villages in KL, as well as studies on the reduction of UHI phenomenon regarding the characteristics of urban villages, are examined. All these issues mentioned above could be influential on the level of thermal comfort.

It can be seen that, the UHI phenomenon happens in the urban areas, in contrast with the suburban areas. The discomfort conditions with negative impacts of those issues in different layers of the KL city (urban boundary layer and canopy layer) caused the higher temperature. This study evaluates the thermal comfort in the urban areas within the cities. This study evaluates the thermal comfort in the urban areas within the cities considering the parts of those more similar environmental features to suburban areas.

1.2 Research Gaps

The majority of researches relevant to outdoor thermal comfort has been done in Taiwan. (Hwang & Lin, 2007) conducted a study to investigate the outdoor thermal comfort range for Taiwanese people (Hwang & Lin, 2007). Additionally, there are other areas considered for outdoor thermal comfort research and studies such as school campus (Shih, Lin, Tan, & Liu, 2017), urban parks (C.-H. Lin, Lin, & Hwang, 2013), public square (Huang, Lin, & Lien, 2015; T.-P. Lin, 2009), and a rural traditional settlement (S.-R. Yang & Lin, 2016) based on the current climate conditions. In Taiwan, the thermal air temperature increase rate is 0.81 °C every 25 years in plain area under the climate change influence (C. Y. Lin et al., 2015). There is another research conducted by Hwang (Hwang, Lin, & Huang, 2017) on the future urban heat island intensity (UHII) difference projection in central Taiwan. The findings revealed that the UHII will increase to a maximum of 5.8 °C during 2075–2099 and, 476.9% increase in residential cooling energy use.

A large volume of thermal comfort research has been conducted in Malaysia. It is very limited or no looking at thermal comfort in urban villages. For example, Sheikh Ahmad Zaki (2017) conducted a study on student's adaptive behavior and comfort of temperature at UTM University in Malaysia and Kyushu University in Japan. Results shows the mean operative temperature in Japan was 25.1ºC in free running model (FR), in contrast Malaysia was 25.6ºC. In addition, the mean operative temperature in mechanical cooling model (CL) were 25.6, 26.2 degree in Malaysia and Japan respectively. The following study carried out by Abu Bakar, A., and Mohamed B. Gadi (2016) on thermal comfort in KL. They have done the survey through 126 students as a sample and the filed measurement of environmental climate parameters. Abubakar, A, and Mohammed, B. said that thermal comfort is a tool for measuring and study on quality weather of environment. The results of their survey show the strong proved in the context of the study between correlation and relationship of the thermal comfort and thermal sensation.

Anting conducted a study on five kinds of cool pavements (high albedo) in Malaysia (Anting et al., 2017). The findings revealed that porcelain tiles could reduce surface temperature approximately 6.4°C compared to asphalt. Because of inter reflections; vertical surfaces high albedo could increase the received radiation on vertical surfaces. For instance, 0.8 albedo could result in an increase of 259 kWh/m2/year solar gain on east façade compared to 67 kWh/m2/year on the roof (de Lemos Martins, Adolphe, Bastos, & de Lemos Martins, 2016). However, the application of cool paving materials should be examined in combination with the urban morphology (SVF) and their thermophysical properties. Simulation results with the ENVI-met model showed that the application of cool paving materials in areas with high values of SVF may lead to worse thermal comfort conditions in daytime (Karakounos, Dimoudi, & Zoras, 2018).

There is a lack of studies evaluating thermal comfort in urban villages in the context of KL city. It is important to investigate the thermal comfort in these areas because (i) these sites are rich in culture and heritage values; (ii) a significant percentage of population occupies these areas because of its lower cost of accommodation. They created a community in need of functional outdoor spaces to improve the quality of life and; (iii) these areas are primarily covered with vegetation and the vegetation is significantly capable of cooling the surrounding microclimate and can be used as a thermal comfort strategy in key areas in the urban center. In addition, most of them have successfully maintained the characteristics of the traditional village called the 'Kampung', therefore, redevelopment in these areas has been restricted in an attempt to maintain the cultural and social values of the place. Moreover, minimizing the effectiveness of UHI requires investigating the current strategies of controlling the level of the temperature of the city.

1.3 Recent Thermal Comfort Studies

An increase in urban density can have adverse impacts on human health and wellbeing. The body temperature of the human should be maintained at approximately 37°C (Hensen, 1990). The exchange of heat is done due to radiation, evaporation, conduction, and convection. The outside is also causing changes in body temperature in physiological function (Amindeldar, Heidari, & Khalili, 2017; Jendritzky, de Dear, & Havenith, 2012). Therefore, outdoor entertaining activities such as cycling and walking are beneficial for psychological health and human physiological. However, in summer and winter climatic situations, the majority of urban residents tend to remain indoors rather than venture outside. Besides, the air conditioning development is another encouraging factor to keep people to stay inside. In consequence, human ability to resist sickness is reduced and human adaptive ability to the natural surroundings is intimidated (Chen & Ng, 2012). Increasingly, these drawbacks to spending large amounts of time indoors are recognized and many urban residents have begun to engage in outdoor activities and lifestyles (Amindeldar et al., 2017). Meanwhile, the people spend more time outdoors so less energy is used on artificial indoor cooling and heating.

An extensive body of research explores different aspects of outdoor thermal comfort in a variety of climatic conditions around the world. Amindeldar and Chen have conducted an overall review of research in this field (Amindeldar et al., 2017; Chen & Ng, 2012). Some of these researches investigate both human thermal sensation and the range of adaptive behaviors in a variety of outdoor spaces under different climatic conditions (Ahmed, 2003; Givoni et al., 2003; Nikolopoulou & Lykoudis, 2006; Nikolopoulou & Steemers, 2003; Spagnolo & De Dear, 2003). Other researches focus on the geographical, characteristic and cultural differences that influence human outdoor thermal comfort and perception of comfort (Zhao, Zhou, Li, He, & Chen, 2016). Evidently, the importance of outdoor thermal comfort in high-density cities is increasingly recognized as having a significant influence on pedestrian safety, comfort and outdoor behavior (Grimmond et al., 2010).

Additionally, comfortable micrometeorological situations increase the time that people spend outdoors results to savings energy because the use of air conditioners is reduced (Lai, Guo, Hou, Lin, & Chen, 2014). The microclimate effect on human health should also be considered (Kovats & Hajat, 2008). Some researchers showed that when air temperature goes very high, the death rate increase (Hajat & Kosatky, 2010; Robine, Cheung, Le Roy, Van Oyen, & Herrmann, 2007; Robine et al., 2008; Salata et al., 2017; Vanos, Warland, Gillespie, & Kenny, 2010).

On the other hand, there is a limited number of thermal comfort scales (da Silveira Hirashima, de Assis, & Nikolopoulou, 2016; Din et al., 2014; Kántor, Égerházi, & Unger, 2012; Krüger, Rossi, & Drach, 2017; T.-P. Lin & Matzarakis, 2008; Pantavou, Santamouris, Asimakopoulos, & Theoharatos, 2014). Din conducted for the Malaysian people, proposed categories as "uncomfortable" and "somehow comfortable" or "discomfort" index (Din et al., 2014; Song & Wu, 2018). Kántor emphasized on the various Physiologically Equivalent Temperature (PET) thermal sensation ranges between Hungary and Taiwan (Kántor, Unger, & Gulyás, 2012). He determined thermal sensation classes for the warm months of Taiwan covered the 'slightly cool' to 'warm' domains, while they included categories from 'neutral' to 'hot' in Hungary. The neutral zone locates not only at higher PET values, but it is significantly wider in Taiwan (21–33°C; 12°C wide) than in Hungary (17–22.5°C; 5.5°C wide) meaning that Taiwanese people react less intensively to the changes of the thermal environment around the neutrally perceived conditions.

Lin carried out a study to evaluate future outdoor heat stress condition by using the wet-bulb globe temperature index (WBGT) (C.-Y. Lin, Chien, Su, Kueh, & Lung, 2017). The findings showed that heat stress condition is in danger level (WBGT > 31°C) in summer at the end of the 21st Century. Outdoor thermal risk areas assessment of future thermal comfort is based on shading orientation in a traditional settlement. Outdoor shading strategies in changing climate were planned in Taiwan, Taipei (TP), Taichung (TC), and Kaohsiung (KH), in the past four decades (1971–2010) based on the synthesis reasoning from the outdoor thermal stress, the users' spatial and temporal distributions, and the vulnerability of users (Huang, Yang, Matzarakis, & Lin, 2018). Therefore, assessing future outdoor thermal environment variation is very important. There should be formulate adaptation strategies to increase the level of comfort in an outdoor thermal comfort in climate changing to help people.

Many studies conducted and propose effective method to moderate high temperatures based on building materials, building layouts, roofs, pavements, and landscape environments (Din et al., 2014; Kántor, Unger, et al., 2012; Krüger et al., 2017; T.-P. Lin & Matzarakis, 2008; Pantavou et al., 2014). Vegetation is one of effective ways to decrease hot temperatures in summer. Trees in particular, have better influence to reduce the hot temperatures than grass since they have more shade to decrease radiant temperature (Golasi, Salata, de Lieto Vollaro, & Coppi, 2017).

Comfort and microclimate are also affected by street canyon geometry. Thessaloniki carried out a case study to simulate models for a preliminary analysis the influence of canyon orientation and aspect ratio (Chatzidimitriou & Yannas, 2016). The findings showed that the most comfortable conditions take place in N-S oriented canyons of high or medium aspect ratio in summer whereas E-W oriented canyons should be improved, for example, more shading on exposed north side. In summer afternoon, deep canyons showed more comfort than wide canyons although there is no differences at night (Chatzidimitriou & Yannas, 2016).

In Melbourne, pedestrian thermal comfort and urban development demonstrate increasing tree canopy coverage, which is from 40% to 50%. These planning strategies were shown to examine its impact on improving thermal comfort in hot weather. Higher aspect ratios, deeper canyons, and lower sky view factors contribute to decrease the mean radiant temperatures level (42ºC–64ºC) in future. Increased building height scenario also improved PET by 3ºC – 4ºC, however, the mean radiant temperatures decreases by increasing the use of tree canopy coverage about 1ºC – 2ºC (Jamei & Rajagopalan, 2017).

Some researches assessing urban measures for hot climates in a moderate climate condition revealed the fundamental factors of microclimatic effects. For example, a variety of that play an important role in the area or the place covered with grass provides a lower temperature in comparison to the brick pavement in an open space. Furthermore, the PET difference between grass and brick pavement is from 0.1 to 8°C ranges, with an average of 6°C (Kleerekoper, Taleghani, van den Dobbelsteen, & Hordijk, 2017).

Thus, this study examined the various mitigation strategies performances such as cool pavement, cool roofs, more urban vegetation, and combination of them by comparing the current configuration of the site with an asphalt ground surface. Therefore, in the canopy layer, determining an UHI cause an increase in the air temperature of 3.6◦C – 5◦C (Salata, Golasi, de Lieto Vollaro, & de Lieto Vollaro, 2015; Salata et al., 2017). Current research of thermal effects examined three methods, such as the use of low albedo materials, the addition of trees and green spaces within urban areas. Low albedo materials considerably decrease the ground surface temperature of narrowest canyons due to the significant solar obstruction. Trees may provide significant direct solar radiation protection as a complete surface shields and act as a fence to reflected solar radiation

The integrated modeling also used to investigate how different spatial trees arrangements in neighborhoods influence on their cooling effects. Therefore, a study conducted by (Wu & Chen, 2017) in a residential neighborhood with high-rise buildings in Beijing (Wu & Chen, 2017). The ENVI-met microclimate is simulated with time resolution, location, and with field measurement data. The findings revealed that various spatial arrangements had distinguished effects on capturing shortwave radiation that cause different air temperature. For instance, trees that are exposed to solar radiation had stronger cooling influence compared to trees in the shadow of surrounding buildings. The findings showed the importance of trees spatial arrangement on cooling of residential neighborhoods.

H.M.P.I.K. Herath et al, (2018) conducted a study to explore the urban green effect on microclimatic condition improvement in hot and humid urban area and assessing the best appropriate strategy by modeling with ENVI-met microclimatic software (V4) (Herath, Halwatura, & Jayasinghe, 2018). The ENVI-met calibration procedure is done via the software modeling and a real ground monitoring procedure to select urban situation. R-squared (R^2) values for three different types of surface such as cement, asphalt, and grass were 0.81, 0.78, 0.92 for 1.5 m and 0.96, 0.91, and 0.88 for near ground (0m), respectively. Therefore, the ENVI-met model can be used effectively to increase the city's thermal conditions in warm and humid conditions in Sri Lanka. I.Karakounos in 2018 carried out a study to explore how mitigation techniques in a dense urban environment influence on outdoor thermal comfort and microclimate parameters in Serres, Greece in a hot summer day (Karakounos et al., 2018). ENVI-met model simulation was used based on outdoor thermal comfort conditions and microclimatic for the daytime period 6.00 am–20.00 pm at the 1.8 m height from the ground. That study tested three parameters, which were surface temperature, air temperature, and mean radiant temperature (Tmrt). The findings showed that the use of cool paving materials in areas with high Sky View Factor (SVF) values may result to worse thermal comfort conditions during daytime due to the high value of Tmrt, it should be carefully considered.

Castaldo conducted an outdoor microclimate monitoring in various areas of Perugia as small-sized historical city, Italy. The findings showed that air temperature increase up to 5°C in urban neighborhood during night time regards to the suburban green area. In addition, the newly developed city of urban surrounding is hotter, up to 2°C compared to the same suburban zone (Castaldo et al., 2017).

Outdoor environment can be significantly affected by overheating of the city. In urban areas, high summertime temperatures decline the outdoor comfort conditions and have negative impact on citizens’ health, and also it increasing the stress to exposed populations (Santamouris et al., 2017). The ambient temperatures upsurge, increases the demand for energy for cooling adding more pressure to the electricity network during peak hours (Pyrgou et al., 2017a). Thus, in order to create the urban life quality, the urban microclimate investigating is very important (Busato, Lazzarin, & Noro, 2014; Van Hove et al., 2015).

Appropriate public areas are designed to make cities livable and attractive. Specific adaptation and mitigation technologies is suggested by the scientific community to respond to the impact of urban warming (Norton et al., 2015). The two main groups of mitigation technologies are green infrastructures to increase shading and evapotranspiration in the urban environment (Gunawardena, Wells, & Kershaw, 2017; Hoelscher, Nehls, Jänicke, & Wessolek, 2016; Rahman, Moser, Rötzer, & Pauleit, 2017) and cool materials that is considered by high thermal emittance capability and high solar reflectance to decrease the solar radiation absorption in the urban area (Rosso et al., 2015; Santamouris et al., 2017).

One of the main roles of vegetation such as green roofs, parks, vertical greeneries is to decrease the temperature gap between urban and neighboring regions. Over 30% of typical is established by urban areas pavements (Akbari & Matthews, 2012). The majority part of these surfaces are paved by cement or asphalt, and green or cool material is implemented to modify suitable urban components (Salata et al., 2015). According to Klemm, street greenery has a strong effect on outdoor thermal comfort from a psychological and physical perspective in moderate climates (Klemm, Heusinkveld, Lenzholzer, & van Hove, 2015). Likewise, Saaroni, Pearlmutter, and Hatuka represent a mainly favorable thermal comfort perception between individuals in urban parks of Mediterranean weather, because of their satisfaction with the park visual attractiveness (Saaroni, Pearlmutter, & Hatuka, 2015).

According to Derkzen, the viewpoint of people on climate change adaptation and advantages originated from temperate climate strategies (Derkzen, van Teeffelen, & Verburg, 2017). Morakinyo conducted a research on the role of green roofs in outdoor temperature and reducing cooling demand in numerous climates with various urban densities (Morakinyo, Dahanayake, Ng, & Chow, 2017). The findings of their study showed that green roofs are mostly operational in hot-dry climate, whereas the minimum efficiency is in the temperate climates. Instead, according to Morakinyo, the greening of 30–50% of facades in high-density urban locations provide daytime pedestrian thermal comfort improvement in tropical climate by at least one thermal class (Morakinyo et al., 2017). Consequently, outdoor microclimate mitigation strategies aims to enhance pedestrians comfort perception and living quality (Acero & Herranz-Pascual, 2015; Chen & Ng, 2012; Lee, Mayer, & Chen, 2016).

The human outdoor thermal well-being and perception is influenced by personal characteristics, such as income (Scopelliti et al., 2016), anthropometric variables (Kruger & Drach, 2017), personal background (Pisello et al., 2017) and morphological and meteorological factors (Jamei & Rajagopalan, 2017). According to Nouri and Costa (2017), the main microclimatic risk factors in numerical analysis and coupled experimental that can influence pedestrian thermal comfort in a square. Instead, Chatzidimitriou carried out a research on the effect of specific urban morphologies and design parameters for example, landscape elements, street, and building geometry on pedestrian thermal comfort in the summer of cities (Chatzidimitriou & Yannas, 2016). The high influence of soil and trees humidity and the pavement albedo contrasting effects was specifically emphasized. Kleerekoper investigated the influence of various urban changes on thermal comfort of pedestrians in terms of PET (Kleerekoper et al., 2017). The findings of their research showed that strategies effect on mean radiant temperature and wind speed could result in greater temperature effects. On the other hand, strategies affecting relative humidity and air temperature are operational on a wider scale as well.

Research works by Makaremi, GhaffarianHoseini (2012) is concerned on thermal comfort situations of shaded outdoor environments in tropical climate in University Putra Malaysia (UPM) campus, Malaysia. Although this study was about the shaded outdoor environments in UPM campus, it more focused on local and international students as the respondents of study. Meanwhile, the PET thermal comfort index was used to evaluate the thermal comfort situations in chosen spaces. Findings of the field measurement indicate that the acceptable range of thermal comfort exists from (9-10 am) and (4-5 pm) and (10-11 am). In the shade, it also reduces the amount of discomfort because of the high levels of exposure to the sun when the comfort level is reduced from 11:00 am to 16:00 pm. The conclusion of field study shows that the participants tolerate warm thermal spaces but the local participants could accept much higher PET values than those defined as thermal comfort classification for (sub) hot and humid climate (Makaremi, Salleh, Jaafar, & GhaffarianHoseini, 2012). In another study, on the heat island phenomenon in Singapore City, Wong and Yu (2005) found the cooling effects of the city green areas were reflected not only in vegetated areas but also in the surrounding areas, particularly at the leeward side of the green area. Johansson and Emmanuel's study in Sri Lanka also confirmed that the land cover of the city center, which had more hard cover, brought more thermal discomfort when compared with rural areas (Johansson & Emmanuel, 2006).

Rabiatul Adawiyah Nasir (2012) carried out research on adaptive and perceptive mechanisms of outdoor thermal comfort in shaded green spaces in Malaysia. Figure 1.1 shows the results of the measured PET through using Rayman Model. The conclusion revealed that 2.1% of PET was hot, 66.4% slightly warm, 19.9% warm, and 11.6% comfortable. Therefore, the PET range was between 20.8 and 39.70°C that represents the warm zone. The thermal comfort level is illuminated using an apparent temperature (AT), which is calculated from Ta and h. AT indicating better understanding of the value that how Malaysians adjust to tropical outdoors situation. The AT captured in the study has shown in Figure 1.2. The AT range was between 27.2°C and 36.7°C and the comfortable range was between 20°C and 29°C. Thus, the conclusion revealed that the condition during measurement days was in the "some discomfort" range, which when occurred in hot weather, the body produced sweat that cooled the body as it evaporated and made some discomfort situation (Nasir, Ahmad, & Ahmed, 2012).

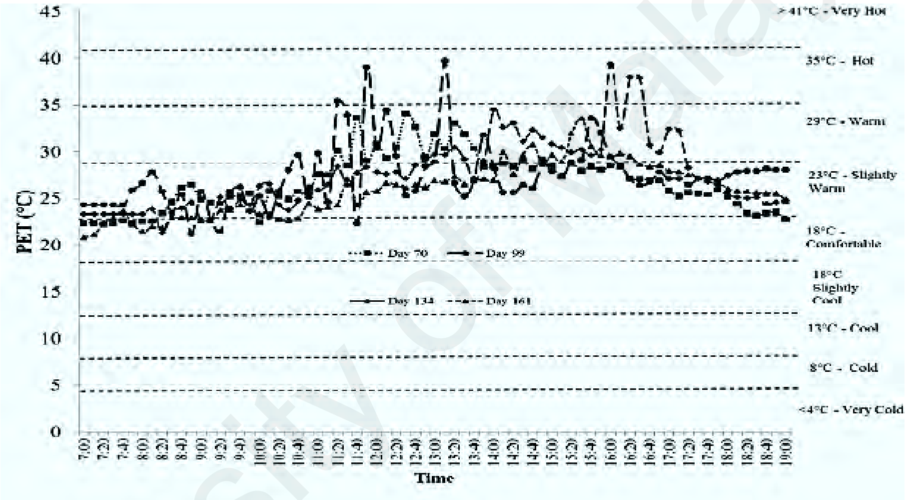


Figure 1.1: Calculated Physiological Equivalent Temperature (PET)
Source: Nasir, Ahmad, & Ahmad, 2012

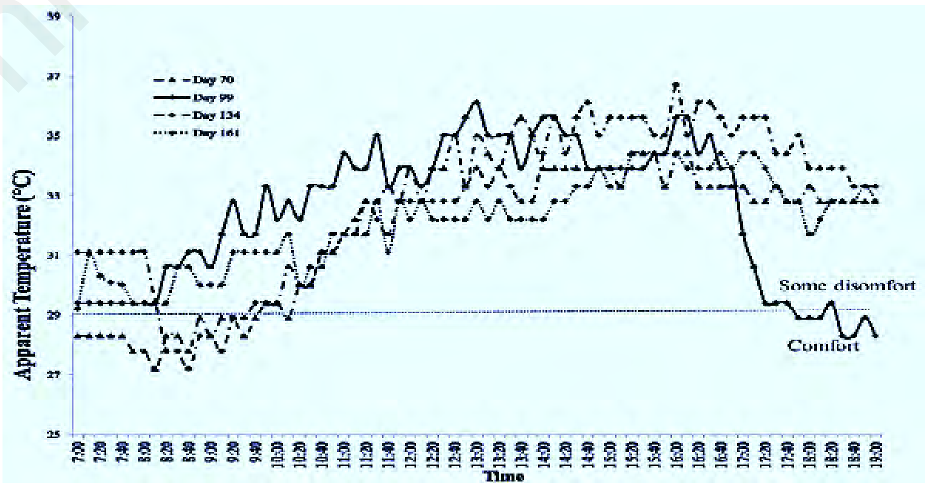


Figure 1.2: Apparent Temperature (AT)
Source: Nasir, Ahmad, & Ahmad, 2012

Malaysia experiences a climate of humid and hot temperature throughout the year. The climate in KL has small temperature variation monthly. The highest temperature is on February or on March in which the hottest temperature is about 32°C to 33°C. In contrast, the coolest month is December in which the lowest temperature is about 23°C to 24°C (Omar, 2009). Urban regions change the surrounding climates physically by affecting the temperatures compared with rural spaces at their border.

Brian conducted a comparative study on the increasing temperature produced by the global warming phenomenon which is produced by the UHI effect (Bledsoe & Watson, 2001). In this study, he contends that the global warming predict an increase in temperature from 3.5°F to 6°F over the next century, while large urban areas are measured to be 6°F to 8°F warmer than their surrounding rural regions (Elsayed, 2012; Shahidan, 2011) . With an raising rate at 0.25°F to 2°F in each decade,, the UHI influence of quick developing in metropolitan areas in Malaysia might be double after 50 years (Elsayed, 2012).

1.4 Problem Statement

KL city is facing a rapid urban transformation in recent years and most of rural environments in this context have been replaced by modern urban areas. Thus, urban villages are generated within the city as a fruit of this change. Looking into this issue, it is evident that buildings and in particular houses and their surrounded outdoor spaces as one of the main constituents of urbanized areas have an immense effect on the lives of their occupants. However, the lack of studies on thermal comfort of outdoor urban spaces in KL, and on the other hand, the limitation of studies which have looked at thermal comfort of outdoor urban spaces in KL, present the significant need towards exploring the local attributes of urban villages embodying major sustainable values. Moreover, Existence of outdoor thermal discomfort in such urban villages results in negative impacts on occupants' health, use of outdoor spaces, and their walkability (Yusuf et al., 2014). Likewise, this research draws attention to the following points:

(a) Modernization and urban growth in KL city and the surrounding urban areas has resulted in traditional urban villages being replaced by contemporary residential, commercial and mega-development projects (Brookfield, Hadi, & Mahmud, 1991).

(b) Many rural areas have been replaced by the modern urban areas and affected by the UHI from the urban center, i.e. the thermal comfort in functional outdoor spaces in urban villages are affected by the Kampong's proximity to an urban center.

(c) Considering the negative impacts of UHI on different layers of the KL city, urban villages, with their special use of vegetation, and building materials might be a promising solution for cooling down the urban spaces. Nevertheless, it is primarily important to first explore the possibilities to further cool down the urban village outdoor spaces (Elsayed, 2012).

(d) Very limited studies have been looked at the thermal comfort of outdoor urban spaces in KL, and among these limited studies, thermal comfort conditions of outdoor spaces in the urban villages have been neglected. The existence of outdoor thermal discomfort in the urban villages may results in lack of quality of life, negative impacts on health, fewer outdoor activities, less walkability.

1.5 Research Aim

This study investigates outdoor environmental parameters of thermal comfort (wind speed and direction, solar radiation, relative humidity, and air temperature) and other influential elements such as; type of vegetation, sky view factor, geographical location, and shading level in three selected urban villages in Kuala Lumpur quantitatively. Furthermore, the level of human thermal comfort in every selected kampungs was also measured and analyzed.

The study accordingly, proposes some solutions based on heat mitigation strategies, provides possibilities to improve the thermal comfort conditions of outdoor spaces in urban villages of KL for improving the users' outdoor activities and quality of life.

1.6 Research Questions and Objectives

The followings are the list of the research questions and objectives that are used to lead this research toward achieving the aim of this study.

1.6.1 Research Questions

Below questions are answered by the research objectives and help this study to achieve its aim.

1. What is the thermal comfort condition of the urban spaces in the selected urban villages in Kuala Lumpur (KL)?
2. What is the impact of the embedded physical elements in the studied outdoor spaces of urban villages in KL on their thermal comfort?
3. What is the solution or technical guideline to improve the outdoor thermal comfort of urban villages in KL?

1.6.2 Research Objectives

To achieve the research aim and answer the research questions of this study, the following research objectives are derived and investigated.

1. To investigate the thermal comfort condition of outdoor spaces in selected urban villages in Kuala Lumpur (KL).

2. To evaluate the impacts of shading in the outdoor spaces of urban villages on their thermal comfort.
3. To recommend design solutions and technical guidelines for enhancing the outdoor thermal comfort of urban villages in KL.

1.6.3 Research Hypotheses

(a) The outdoor environment influences outdoor human thermal comfort.

(b) The level of thermal comfort has a relationship with UHI inversely. High level of temperature causes UHI in urban centers, which has a negative effect on thermal comfort in the adjacent urban villages in Kuala Lumpur. Those urban villages, which are closer to the urban center, are hotter. Closer urban villages to the urban center are affected more by UHI, in contrast with the urban villages far from the urban center, which are cooler with better thermal comfort level as described by the environmental parameters measured during the fieldwork.

(c) Urban villages with more shading coverage can cause a cooling effect on the microclimate due to the greenery increment.

The above-formulated hypotheses will be verified in the discussion chapter of this research.

1.7 Significance of the Study

The results of this study will provide a better understanding of the general thermal environment in outdoor urban spaces in KL city's urban villages, which can be applied to other urban spaces to improve thermal comfort and minimize the UHI effects. This study also has a significant impact on the understanding of thermal adaptation on, outdoor thermal comfort in functional spaces in urban villages, and by extension in the urban center's public spaces.

This study concentrates on outdoor thermal comfort and the different level of comfort in the influencing parameters among the urban villages in KL. Urban designers and planners to design more comfortable thermal environments in KL and other similar urban contexts can adopt the study findings. It is also useful in improving outdoor thermal condition in developing new cities. The study has further identified efforts in improving UHI mitigation strategies in tropical climates by assessing the potential optimum cooling effect in three selected urban villages using the physical properties of surface materials and measuring the thermal comfort parameters. The manners in which this study contributes are highlighted below.

(a) This study offers a new way of understanding the conception of Malaysian urban planning and designing to planners, architects, landscape architects, and government by considering the importance of surface material selection, and microclimatic variables during designing urban area using the observation of physical elements in the urban villages. This understanding is significant for opening a new perspective and capability according to the technical aspects of the types of albedo and the characteristics of the surface materials used in the case studies for minimizing the effect of UHI. By having a better understanding of the environment, nature, and figures, the urban planner can allocate effort in planning and arrange better urban spaces to maximize the cooling potential of both aspects.

(b) The findings of this study give fundamental information on the comfort level of outdoor thermal for the selected area of urban villages throughout daytime peak hours that can be further applied for KL as the city area.

(c) The findings also can contribute in enhancing the strategies in UHI mitigation to find better solutions for improving the urban quality of life in the present and the future.

1.8 Research Scope and Limitations

In this section, limitations and scope of the research are discussed. Highlighting limitations of the study is important for further researches and ensures the validity of future works. This study focuses on the objective assessment of outdoor thermal comfort in functional spaces in the selected case studies in urban villages of Kuala Lumpur (KL), identifies the most influential parameters that affect UHI, and hinders the sustainability of the functional spaces. Some of the parameters considered in this study are wind speed and direction, solar radiation, relative humidity, air temperature, type of vegetation, sky view factor, geographical location, and shading level. Furthermore, an in-depth discussion on the albedo of the materials is elaborated in this study. The change of energy balance of the human body by the change of microclimatic conditions, a detailed investigation of the vegetation type and foliage and urban design is beyond the scope of this study due to the limitation in time and cost of this study.

Last but not least, when assessing all microclimate parameters, which represent outdoor thermal comfort, all parameters are examined based on the single variable as divergent to the overall thermal sensation. Therefore, in further study, the individual parameter assessment should be considered for overall thermal sensation, which is affecting the findings and results.

Due to the lack of time of data gathering, based on Nasir etal. (2013) data gathered only for two days for every each of kampungs, and totally six days for all locations. Although more days of data gathering gives better understanding on the analysis, Current absorbed data are scientifically satisfied the aim of this research objectives.

1.9 Research Structure

This thesis is organized into five chapters. The followings are short descriptions of the entire chapters.

Chapter 1 provides some information about the background of the work that has been carried out in this thesis. Then the research gap in the field of this study is reviewed and the problem of this research is stated. The aim and objectives of this research are followed by significances of this study, research scope, and limitations. The structure of this thesis is elaborated in the next section.

Chapter 2 gives a background of this research via reviewing a state-of-the-art literature. The review starts from the urbanization and urban quality, microclimate and local climate zone, and discusses the layer of urban spaces, the effect of UHI on the urban open spaces, the explanation of reduction of heat through the strategies, and then their relations with human activities and outdoor thermal comfort. Further, it assesses urban villages (Kampung) in different outdoor urban spaces in KL through various conditions, which gives better understanding of the level of thermal comfort.

Chapter 3 illustrates the exhaustive methodology of this thesis. The analysis of Tmrt and PET indices used in this study, is carried out via Rayman software and ENVI-met simulation. This research uses quantitative filed study to measure outdoor thermal comfort conditions in hot and humid tropical climate in different urban spaces in KL city. The Rayman Model is used to select the most influential parameters on thermal comfort in the selected urban villages.

Chapter 4 presents the primary results of the investigation via Rayman Model, including PET and Tmrt. Field measurement explanation and computer software modeling programs (the Rayman Model) are used to assess the most influential parameters in the outdoor environment. The differences of meteorological characteristics and thermal comfort among the contexts are figured out through the ENVI-met modeling. Outdoor thermal comfort assessments are discussed together in this chapter in order to provide in-depth explanation of the estimation. In addition, the reported analysis is supported with existing literature.

In chapter 5, discussion and outcomes from the analysis correlation between the data analysis of field measurements in select case study areas. This chapter reports the outcomes analysis the Rayman Model and ENVI-met simulation data of determine the level of comfort in each case studies and validation of

In chapter 6, a framework for improving the level of outdoor thermal comfort condition is proposed based on a case study of urban villages within KL. Moreover, this chapter reports the outcomes and findings of the thesis along with the contributions of this research. It also provides some recommendations for future works and further studies in this field.

CHAPTER 2: URBAN VILLAGES OPEN SPACES AND OUTDOOR THERMAL COMFORT

2.1 Introduction

This chapter gives a background of this research via reviewing a state-of-the-art literature. The review starts from the urbanization and urban quality, microclimate and local climate zones, and discusses the layers of urban spaces, the effect of UHI on the urban open spaces, the explanation of reduction of heat through the strategies, and then their relations with human activities and outdoor thermal comfort. Further, it studies urban villages (Kampungs) in different outdoor urban spaces in KL in various conditions, which gives a better understanding of the level of thermal comfort.

In this chapter, Section 2.1 presents a short introduction to this chapter. After then, a discussion on urbanization, urban quality, and the importance of urban space's quality for residents and visitors in creating an environmental ambiance that is essential for life outdoors are presented in Section 2.2. Section 2.3 reports the relationship between urbanization and microclimatic. Section 2.4 describes urbanization of KL and the phenomenon of urban village within the urbanization. Section 2.5 presents a review on urbanization in Malaysia and the UHI phenomenon. In addition, UHI in the global scale and in Malaysia is discussed. Different types of UHI are identified before moving on to the UHI studies based on temperature in tropical climates. Section 2.6 gives more details about qualities of a successful urban space. In Section 2.7 explains the thermal Comfort evaluation in urban open spaces. Section 2.8 talks about comfort and the importance of outdoor life. Section 2.9 summarizes the chapter.

2.2 Urbanization

Having a better living environments for improved urban quality and making new settlements match to human requirements result in creating towns, cities, and villages over time that highlight the needs of their residents based on comfort, economics, society, and culture (Shahidan, 2011). Development of the urban spaces in larger scales due to urbanization to achieve the requirements and needs of the residents, affects thermal comfort. Therefore, by changing the characteristics of urban spaces, the climate will be affected. In another word, increasing human-made changes on urbanized growth, causes harmful transformations on the natural ecosystem.

Urbanization can be defined as the process of land use transformations while people concentrated in cities and towns based on social modernization (Ren, Wang, & Liu, 2015). Through the rapid growth of social and economic development, considerable workforce tends to move from rural to urban-based industrial areas to find new positions and opportunities for a better future life. Recently, United Nations Department of Economic and Social Affairs (UNDESA, 2014) has presented a record that shows a significant increase in urban population throughout the world between the years of 1950, and 2014. For example, 30% of the world's population was urban in 1950 but this number has been increased to 54% by the end of 2014. Inconsequence, the human settlement pattern has transformed significantly, and an increase of urban economic activities causes creating unique negative ecological results such as carbon emission (Al-mulali, Sab, & Fereidouni, 2012; Wang, Chen, & Kubota, 2016). Furthermore, in these areas, higher temperatures 'islands' are established and on the other hand, temperatures in the central regions of cities have risen in comparison with their rural environments (Radhi et al., 2015). This temperature distinction is what establishes the UHI effect.

From 1990 to 2025, about 2.9 billion new urban populations expected to move to urban areas globally. There is a persisting need to control the results of global warming in metropolitan spaces and to pinpoint possible approaches and strategies to respond the climate change properly. (Elsayed, 2012). Sani proposed that the influence of UHI from urban areas is not limited to horizontal temperatures throughout the surface of the earth (Sani, 1991). It also effects on the vertical direction by the atmospheric area with far-reaching consequences (Elsayed, 2012). Other studies have also shown that thermal influences of a large city in the world can potentially extend up to 200 to 500 m and more. Environmental decline is constantly related to the development and human activities (Elsayed, 2012). Humans made a significant amount of heat over his activities and are an important source of its construction from industrial plants, transportation systems, and heating ventilation and air conditioning systems, which are set up for cooling internal environment in buildings (Elsayed, 2012).

2.3 Urbanization in Kuala Lumpur (KL)

Urbanization has been happening in 30 urban centers in Malaysia such as KL, and plays an important role in exchanging the urban air temperature display (Elsayed, 2012). There are 14 metropolitan regions in Malaysia with a population of over 75,000 people. KL city is the capital city of Malaysia with a population of 1,504,300 people, recognized as the greatest metropolitan area within the country (Elsayed, 2012).

2.3.1 Urban Villages

Urban villages are a distinctive product of rapid urbanization and massive rural to urban migration, are a universal phenomenon in many cities with strong economic growth (Chung, 2010; Hao, Geertman, Hooimeijer, & Sliuzas, 2013). It is evident that buildings and their surrounding outdoor context are the main constituents of urbanized areas with an immense effect on the lives of their occupants. Today, observing the rapid globalization and growth in KL city, many of traditional urban villages within and at the periphery of the city have been replaced by residential, commercial, and industrial projects; both small and large scale alike. In Malaysia, Malay kampung is modernity's significant other in the contemporary discourse.

The size and shape of the organization in Asian cities has drastically transformed the urban physical and socioeconomic landscape (Ujang & Aziz, 2016). Urban population in East Asia has increased 3% per year while urban land expansion reached 2.4% per year. This study investigates the human thermal comfort effect of UHI on urban villages in the KL. This study is necessary to determine how the surrounding urban development affects the villages. The most discussed urban village in KL is Kampung Baru sitting in the heart of the metropolitan region. The area has strong heritage values to the local community and urban residents in its periphery and across Malaysia.

A kampung is defined as a village or locality with 10,000 or fewer people under the leadership of Village Heads (Ujang & Aziz, 2016). The vernacular architecture and human scale have largely remained, with colorful low-rise wooden detached houses, kitchens, and cafes spilling out on to the streets with large soft-scape percentages, soft ground floor cover, and rich social life. The qualities imply a better microclimatic condition and improved urban quality to some aspects as compared to its urban counterpart.

Despite piecemeal development and extension of commercial and residential units, some of the traditional kampungs still look similar to their early years. With the rising land value, the area has been subjected to the real estate development scheme that would maximize the economic potential of the properties. Taking redevelopment steps implies a drastic change in the landscape of urban villages, which will ultimately begin to show UHI characteristics similar to that in the city areas. Another possibility, which is related to the current UHI situation and the existing literature, is that urban villages close to urban developments will be more affected by UHI as compared to those further away. However, the abundance of vegetative cover for shading will reduce the air temperature as compared to the use of buildings for shading with the less vegetative cover in the adjacent urban areas.

With a strong commitment from the government, a comprehensive development master plan was prepared for urban villages like Kampung Baru, Kampung Sungai Penchala, and Kampung Melayu Kepong. Despite the resistance, it seems preventing urban development in urban villages is inevitable on the current track. A strong incentive is needed by the government to maintain many existing characteristics within the status in these areas particularly those that help mitigate the UHI effect namely the large percentage of vegetative cover. Figure 2.1 shows an example of urban villages in Malaysia. The sites namely Kampung Baru, Kampung Sungai Penchala, Kampung Melayu Kepong were selected from the identified urban villages in the KL Metropolitan Area, and the outdoor thermal comfort is evaluated using the PET discussed in section 3 and 4. These results are compared to the city and possible physical UHI mitigation strategies are identified from the findings and the existing literature. The site selection will be further elaborated in the Methodology Chapter.

Figure 2.1: Urban village1: Kampung Baru, Urban village2: Kampung Melayu Kepong and Urban village3: Kampung Sungai Penchala
Source: Author

2.3.2 Concept of Urban Village and Life Quality

A part of an urban population is “urban village” population. This concept came from the combination of the basic features of the social, physical, and economic environments in the urban and village environment. Urban village is created based on rapid urbanization and economic development of cities (Yuting et al., 2010; Yan & Yves, 2011; Li & Li., 2011 & Pu et al., 2011). Figure 2.2 is shown these combinations of the village and urban environments basic characteristics to reveal the basic features of the "urban village" areas.

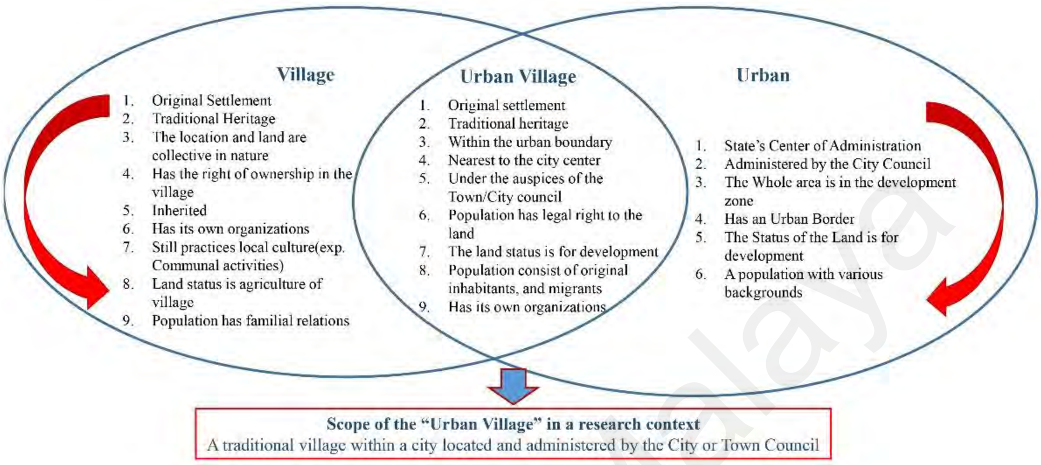


Figure 2.2: The Concept of Urban Village
Source: Yan & Yves, 2011

The formation of the "urban village" environment could be measured through its social (social relations, culture and local traditions as organizational structure), physical (land use, geographical position, it settlement and construction), and economic (status of the land, title of land, and current social economic activities) areas. There is a relationship between urban environment and life quality of urban village population. The urban growth of development has affected "urban village" population (Yan & Yves, 2011; Xie, 2005). However, the life quality of urban population depends on offered urban and infrastructure services (Haryati, 2010; Azahan et al., 2008; Yazid et al., 2015). Accordingly, urban development should be considered based on development of strategies and planning to improve the life quality of urban population.

The security of life quality and health guarantee are strong features of a city (Mansor, 2010; Azahan et al., 2008; Tammy, 1999; Yazid et al., 2015; Wim et al., 2009), since these are essential factors on social comfort and the level of satisfaction fleeing of people ni the city.

2.3.2.1 Urban Village's Physical Environment

The physical environment of urban village could be considered based on its geographical location, its settlement, land use, and construction. The "urban village" geographical position is in urban environment, which is administrative, service and business centers because of rapid urban development. Therefore, "urban village" environment is a village area enclosed by the urban area and is located at the borders of the urban frontier (Yan & Yves, 2011; Li & Li, 2011). It is also enclosed by numerous urban infrastructure facilities for example industrial centers, hyper-malls, major roads, commercial centers, housing areas, business centers, and condominiums as urban facilities. The location of urban villages is within the land that has been considered as a development zone, comprising business, industrial, commercial, and housing zones. These three zones are planned to construct an attentive, elegant, and modern urban area, which has a direct influence on the "land-use" of "urban village" population that was earlier gazette for 'settlement' and 'agriculture' usage and in consequence the entire "urban village" environment develop. The planning and strategy of land-use are involved in changing of land use position. Moreover, it is significant in continuous and smooth urban development procedure (Malaysia, 2010).

One time, in China, livestock breeders, farmers, and small businessmen settled the "urban village." The development of urbans in the agriculture area by the government to develop the manufacturing, industrial, and urban facility sectors had led changes of land-use in major cities such as Shenzen and Guangzhou and turned these cities into modern and big cities. Urbans were depeleved very fast because of the construction of development zones as business, industrial, and housing zones. Therefore, land-use in the "urban village" was changed. In Malaysia, the urban development has created "urban village" settlement areas such as new villages, traditional villages, planned villages, and re-settlement environments. The population of urban village is the legitimate population with its land ownership rights. In the "urban village," the majority of the foundation of the environment structures have their own construction and are rarely inclined by surrounding traditions and cultures (Katiman, 2001; Abdul Hadi, 2004).

2.3.2.2 Urban Village's Social Environment

The urban development has a direct influence on the "urban village" population's social area. Urban development causes the population to emigrate from rural zones to cities to explore new opportunities that leads to the combination of urban social structure (Katiman, 2001; Abdul Hadi, 2004). For example, in China, the urban development had caused the immigrants moved to "urban village" areas because the rent rates were cheaper. This situation had caused security and prostitution problems (Siti Aminah el al., 2016; Li & Li, 2011; Yan & Yves, 2011). Local tradition and culture has an important influence in forming social identity. It is also creating a community to resist environmental modifications (Abdul Hadi, 2004). Mohammad Yusof (2011), carried out a study in an "urban village", Alor Setar, Kedah. The findings revealed that common visitations and work throughout special circumstances and attending religious sessions are significant reasons to determine the comfort of the "urban village" population. Tradition and culture are also important factors in determining of that population (Mohd Yusof et al. 2011)

In Malaysia, there are two lower level organizational structures, which are the Mosque Parish System (MPS) and the Village Security Working Committee (VCWC). The VCWC chairperson is chosen by federal government heads or the state authorities. In the meantime, Imam (head of the mosque) or Surau Chairperson who is selected by the district religious office heads of parish system are in the parish. The role of VCWC is more in the "urban village" environment that is followed by the imam's role. These two level organizational structures play an important role in confirming the stability and safety of the village.

2.3.2.3 Urban Village's Economic Environment

The economic environment of "urban village'" is one of main factor in emphasizing the conceptual definition of an "urban village." The policy of previous government was to give ownership to the population of "urban village" but nowadays, it has an authentic title on the land or residence in which they live. In the "urban village" environment, there is three type of land titles or ownership such as 99-year lease, permanent titles, and temporary titles based on the purpose, location, and position of the settlement.

In Malaysia, many populations have permanent titles, they have a 99-year lease or temporary titles in new villages. It means those who live in the re-settlement areas received permanent titles (Katiman, 2001). The land status in most "urban village" environments has been transformed to 'development areas' due to the zone expanding policy announced by the state governments and local authorities. Therefore, the "urban village" property was only for development projects (Malaysia, 2010).

2.4 Urbanization and Microclimate

According to Christensen 2005, urbanization is the process of covering a substantial portion of a land space with constructions or impervious pavements (Christensen, 2005). He also defined urban climate as the climate in and near urban environments. It is more or less humid, warmer, more reflected light and shadier than the climate of the nearby land areas. On the other hand, Allaby and Park defined urban climate as a residential climate affected by the presence of a city that can comprise of lower wind speeds, lower relative humidity, and higher rainfall (Dictionary of Environment and Conservation, (Allaby & Park, 2013). Therefore, climate influences on conditions of comfort in the most areas of the world, which are affected by urbanization (Shahidan, 2011). The landforms, landscape, and ground surfaces transform as result, the presence of new materials and construction increases cause significant changes in the climate of urban.

The primary components of urbanization including residential, commercial and industrial developments have created several dramatic human-induced modification to the landscape and natural ecosystem through the creation and use of impervious materials for landscaping comprising of rigid-edged rough structure blocks (Roth, 2007; Shahidan, 2011). Rapid industrialization and urbanization has caused deterioration of the urban environment.

Besides, the increasing numbers of buildings have pushed out greenery such as trees in urban open spaces that can significantly reduce the negative effect of urbanization in urban areas (Santamouris et al., 2001; Shahidan, Shariff, Jones, Salleh, & Abdullah, 2010).

A study by Karaca in Southern Istanbul showed a rising trend in urban temperatures (Karaca, Tayanç, & Toros, 1995). This is the most urbanized, industrialized and highly populated and area of the city where these phenomena have had negative impacts on the area's regional cooling. In a different study, the findings revealed that rapid urbanization had a significant impact on the change in the regional climate in Tokyo (Karaca et al., 1995; Mochida & Lun, 2008; Mochida et al., 1997). This gave rise to a plethora of environmental issues due to the replacement of earlier green vegetation area, ponds, and rivers with asphalt roads, pavements and artificial heat release, which are non-ideal ground surface conditions. Furthermore, (Ichinose, Shimodozono, & Hanaki, 1999), urbanization produced a warm bias of 2.8^{o}C based on the lowest air temperatures during 135 years' climate records for Tokyo (Shahidan, 2011; Tran, Uchihama, Ochi, &

Yasuoka, 2006). In Los Angeles, the maximum temperatures were over 2.5ºC higher than they were in 1920 and in Washington DC, a similar experience where temperatures raised by approximately 2ºC between 1871 and 1987 (Akbari, 2005; Akbari, Menon, & Rosenfeld, 2009). From the evidence above, it is clear that the changes brought about by urbanization have a negative shift in urban climate in cities around the world (Shahidan, 2011).

The built environment impact can be resulting from many factors such as the buildings construction use of new surface materials (concrete, asphalt, tiles), and the heat emission, pollutants, and moisture. Urbanization changes the land of the surface in urban environment remarkably, influencing radiative, atmosphere, thermal, roughness, moisture, emission (Oke, Johnson, Steyn, & Watson, 1991; Shahidan, 2011) that accordingly influence the overall urban life and quality. These transformations are described as below.

(a) Radiative modifications occur because of the presence of new surface materials that have a wide variety of albedo and emissivity principles than vegetation. Lack of shading elements such as vegetation and trees in urban space cause the radiative transformations to become uncontrollable and high that results to increase wall temperature and the ground surface, which influence the microclimate environment (Shahidan, 2011) .

(b) Compared to natural surfaces while the thermal mass of constructions is greater, a massive reservoir is provided for storing heat during daytime and will be released during nighttime. This procedure notably has higher influence on the nighttime temperature in urban spaces. In addition, it decreases ambient temperature via evapotranspiration (Shahidan, 2011).

(c) The efficient "sealing" can cause the moisture decrease for evapotranspiration because of the surface materials replacement such as asphalt, concrete, and pavement from vegetation and natural soil, which decrease the humidity of the urban areas.

(d) Due to the flexibility and rapid growth of barrier elements such as structures, permeability, and sharp edges, they can create positive and negative pressure variance on the barrier surface. This results in vortex shedding and flow separation while face to urban airflow. This influences the momentum, mass, and energy transportation away from the city areas. As a result, the instability in the city spaces will be rougher than the similar atmosphere throughout rural areas (Shahidan, 2011).

(e) The greenhouse and aerosols gases released influence the radiative change because they perform as concentration cores. Therefore, spare heat and water vapor from burning are added to the urban environment. Moreover, anthropogenic heat that are released by the fuels' combustion from stationary sources such as power generation or movable system such as buses, cars, transportation, and from animal or human metabolism act as extreme heat, increasing air temperature and warming the urban atmosphere (Roth, 2007).

2.4.1 Urban Micro Climate

Urban thermal comfort is defined and discussed in the context of urban climate, which reflects the dynamics in the surrounding atmosphere of a given urban setting. The growth of cities so far has turned each urban environment into a hierarchical structure of several different scales of neighborhoods, communities, and districts. The urban climate, heavily affected by local configurations and resident activities, also naturally follows the same hierarchy. Generally, three different scales can be assigned to urban climate conditions.

The microscale perspective of urban climate is also commonly referred to as the microclimate. It differentiates the temperature and airflow on every surface and object, varying in very short distances. Figure 2.3 is show the basic spatial dimension includes individual buildings, trees, streets, courtyards, gardens, etc. This microscopic differentiation determines that the source is dominated by immediate surfaces no greater than 0.5 km away, and the relevant processes are mainly radioactive, conductive, and convective sensible heat fluxes from walls and grounds. Control factors contributing to the microclimate profile are naturally fabric, structure, ground cover, metabolism, as well as weather and time of day or season (Adebayo, 1987). Microclimate sees its immediate applications in the studies of pedestrian bioclimatic, building, and indoor climate, and practical design. As the lowest scale of urban climate, many samples can be extracted and lots of detailed analysis can be conducted about relations between all the factors and outcomes.

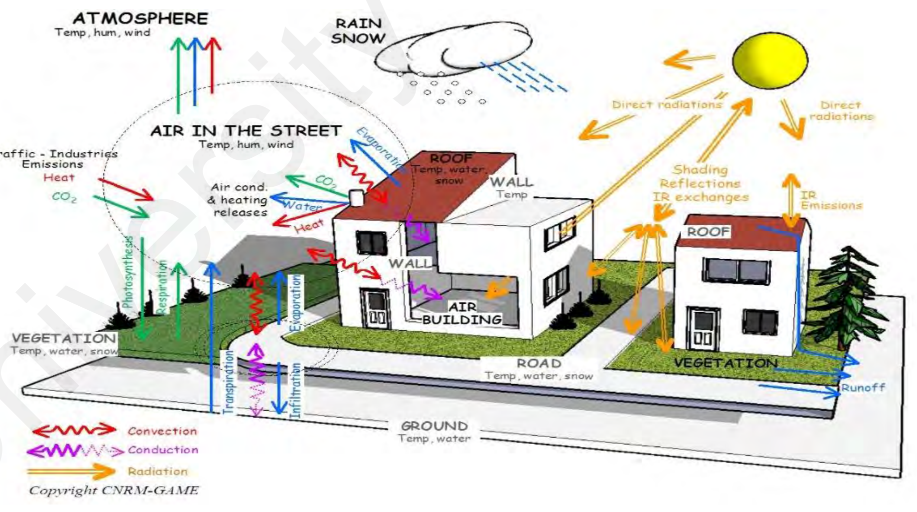


Figure 2.3: Three-dimensional description of microscale urban climate
Source: Adebayo, 1987

A layer beyond the micro scale of urban climate, the local scale examines the climate of neighborhoods in cities with similar urban development (surface cover, size, and spacing of buildings, activities, etc.). The standard climate station can be designed to monitor the local-scale urban climate. By definition, the local-scale signals are an integration of microclimate effects and typical spatial dimensions extend from one to several kilometers. Figure 2.4 is show a representative Urban Climate Zone (UCZ), Air Temperature (Ta) measurement usually comes from either climate stations or at the top of the Roughness Sub Layer (RSL) where turbulent mixing leads to sufficient blending of microscale effects (Barlow, 2014; Oke, 2002). In studying the local-scale climate, heat fluxes from roofs, chimneys, and the spatial average of surface-air volume should be considered. While weather and time of day or season also play a role in the micro-scale, the horizontal extent of UCZ should be controlled. Discussions of the local-scale urban climate could result in interesting applications regarding neighborhood climate and more sustainable urban design. This scale serves as a transition from the micro scale environment to the whole city perspective and is correlated with both the smaller and the larger scales.

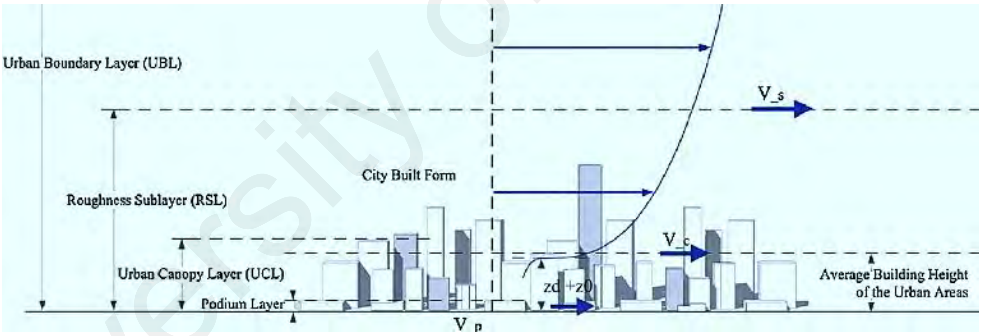


Figure 2.4: Example subject area of the local scale urban climate
Source: Edward Ng & et.al, 2011

Stepping up from the neighborhood level to the whole city, a spatial dimension typically appears covering tens of kilometers. This so-called meso-scale of urban climate is affected by both the city itself and the surrounding area. New processes that have to be considered in this scale including heat fluxes from the top of the RSL, entrainment of heat from above the Urban Boundary Layer (UBL), air mass advection from upwind, internal radioactive flux divergence, etc. as indicated in Figure 2.5. The vast scale also makes much more control factors relevant-city horizontal and vertical dimensions, weather and time of day, seasonal plant growth, snow cover, soil wetness, and space heating/cooling, emissions as a few examples. Applications of the meso-scale urban climate research can be found in UHI mitigation for heat waves, photochemistry of urban plume, suppression of storms, planning of urban layout, as well as many other fruitful areas (Oke, 2002). From the policy and strategy perspectives, the three scales of urban climate also lead to natural classifications.

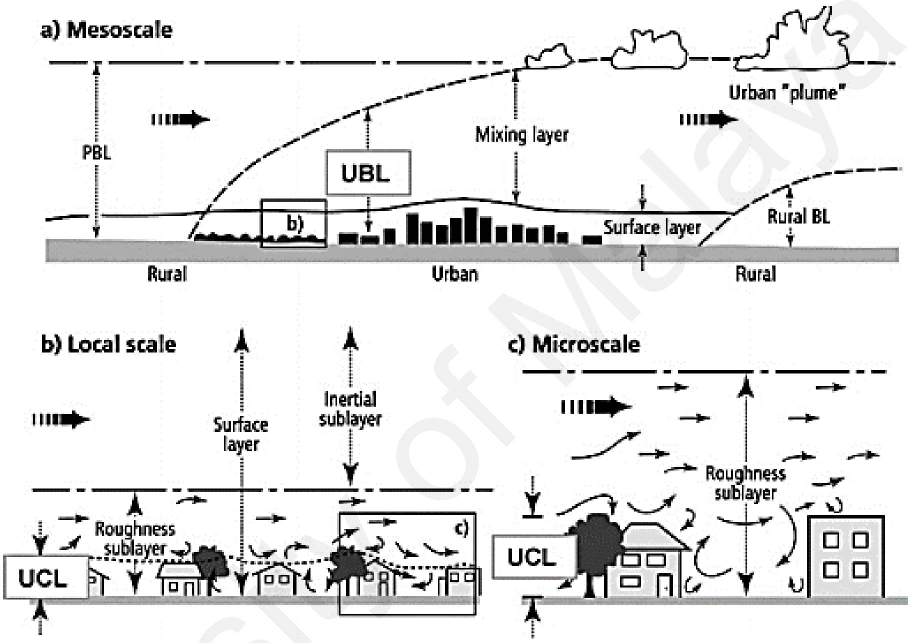


Figure 2.5: Schematic diagram of the urban boundary layer (UBL)
Source: Oke, 2002

For the physical target at the individual building/street level (facade and roof construction materials, design, and orientation), relevant policies, and strategies focus on building regulations/control. By moving toward designing larger urban area (arrangement of buildings, roads, and green spaces), policies and strategies, the work on the integrated design of the area and the climate in the neighborhood (around 10 up to 1000 meters) and its changes in urban suburbs become more important. As move up toward the larger physical subject of urban design (arrangement of buildings, roads, green space), policies and strategies, also shift to the more integral design of area action plan, and the climate at the neighborhood scale (around 10 to 1000 meters) and its sub-urban variations are of importance. Both individual building/street and neighborhood scales still belong to the realm of an urban design strategy and the local development framework. However, the bigger city as a whole, and its planning (including an arrangement of commercial, industrial, residential, recreational, and green space), calls for a more global policy consideration, namely the sub-regional and regional spatial strategy. The city and metropolitan climate scale extend from 1 to 50 kilometers; in this range, the UHI form and intensity plays a significant role in the climate formation and development. All the scales are therefore relevant for urban design and require extensive research for better understanding and modeling their own dynamics. Placing these climate scales in our context of thermal comfort, there are several atmospheric layers functioning across the scales.

2.4.2 Local Climate Zones (LCZ)

LCZs contain new and organized categorization of field locations in heat island researches. The category splits rural and urban landscapes to 17 standard classes that each of them described through structural and land cover properties affected the temperature of the air at screen height. The outcome proves that thermal differences exist among all LCZ classes, which are administered mainly by building spacing and height, tree density, previous surface fraction, and soil wetness. Consequently, local climate zones (LCZs) or dividing landscapes into structural and land cover classes is considered not only for the field site categorization in heat island studies but also it justifies the usage of inter-zone temperature difference ($\Delta TLCZ\ X-Y$) to measure the degree of heat island. In order to develop the LCZ system, other researchers might model and observe the climatic circumstances of its wide-ranging classes. They would examine field data collected from various rural and urban spaces to develop urban canopy models to establish predictive competence.

Standards are essential to ensure reliability and meaningful exchange of information throughout cultures, regions, and disciplines. The implementation of common symbols, scales, techniques, and terminology could assist urban climatologists to communicate more efficiently (Stewart & Oke, 2010). One part of standardization, which is rarely developed, is the categorization of field locations for urban heat island (UHI) studies. It is a traditional method used to design locations in the countryside and city as ‘rural’ and ‘urban’, with little attention to the local or micro features. Researchers hardly clarify the terms ‘urban’ and ‘rural’ or report the site metadata needed to measure (Sheppard et al., 2011). The limited use of such terms in the heat island related literature results in misunderstanding about the actual experience and land cover situations of field sites.

Recently, Stewart and Oke (Stewart & Oke, 2012) developed the LCZs classification by addressing the issues of communication and method in heat island studies. The system contains 17 standard classes at the local scale (102 to 104 m) and aims to enable reliability and climatologically related on categorizations of rural and urban field locations for observations of temperature at height of the standard screen (1–2 m above ground) is show in Figure 2.6. Each class of the system is distinctive in its arrangement of cover (prior fraction), surface construction (tree/building height and layout), metabolism (anthropogenic heat flux), and fabric (thermal admittance, albedo). Each LCZ should reveal a typical air temperature system at screen height when compared with the same atmosphere and surface release circumstances. LCZs are separately named and ordered by one (or more) unique surface land, which for the majority of classes is land cover or the spacing/height of buildings and trees. The surface properties of all zones are non-specific and measurable based on place or time is indicated at Table 2.1.

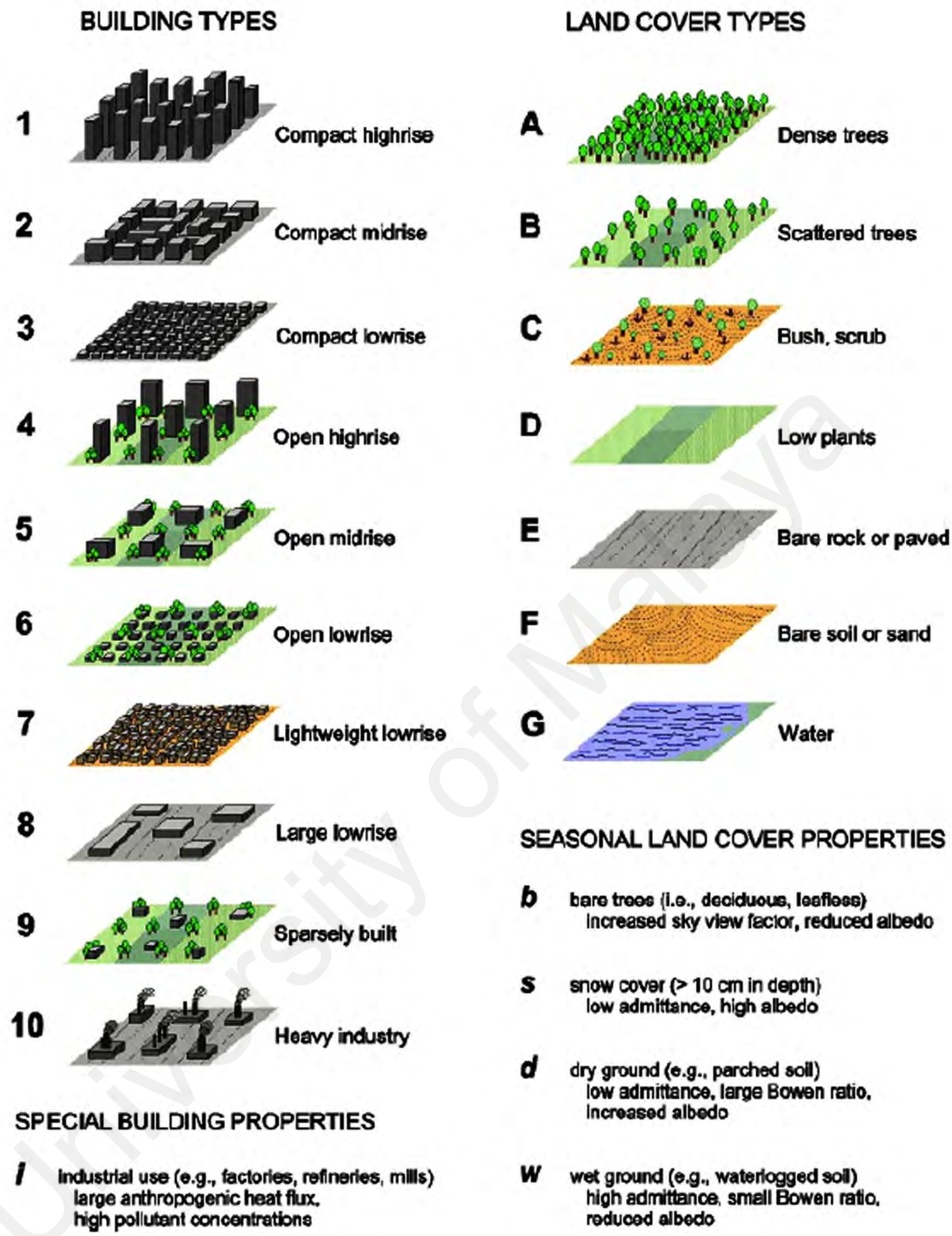


Figure 2.6: The 'local climate zone' (LCZ) classification scheme and its 17 standard classes. Source: Stewart and Oke 2012

Table 2.1: Surface values of local climate zones Source: Stewart and Oke, 2012

TABLE 3. Values of geometric and surface cover properties for local climate zones. All properties are unitless except height of roughness elements (m).

Local climate zone (LCZ)	Sky view factor[a]	Aspect ratio[b]	Building surface fraction[c]	Impervious surface fraction[d]	Pervious surface fraction[e]	Height of roughness elements[f]	Terrain roughness class[g]
LCZ 1 *Compact high-rise*	0.2–0.4	> 2	40–60	40–60	< 10	> 25	8
LCZ 2 *Compact midrise*	0.3–0.6	0.75–2	40–70	30–50	< 20	10–25	6–7
LCZ 3 *Compact low-rise*	0.2–0.6	0.75–1.5	40–70	20–50	< 30	3–10	6
LCZ 4 *Open high-rise*	0.5–0.7	0.75–1.25	20–40	30–40	30–40	>25	7–8
LCZ 5 *Open midrise*	0.5–0.8	0.3–0.75	20–40	30–50	20–40	10–25	5–6
LCZ 6 *Open low-rise*	0.6–0.9	0.3–0.75	20–40	20–50	30–60	3–10	5–6
LCZ 7 *Lightweight low-rise*	0.2–0.5	1–2	60–90	< 20	<30	2–4	4–5
LCZ 8 *Large low-rise*	>0.7	0.1–0.3	30–50	40–50	<20	3–10	5
LCZ 9 *Sparsely built*	> 0.8	0.1–0.25	10–20	< 20	60–80	3–10	5–6
LCZ 10 *Heavy industry*	0.6–0.9	0.2–0.5	20–30	20–40	40–50	5–15	5–6
LCZ A *Dense trees*	<0.4	>1	<10	<10	>90	3–30	8
LCZ B *Scattered trees*	0.5–0.8	0.25–0.75	<10	<10	>90	3–15	5–6
LCZ C *Bush, scrub*	0.7–0.9	0.25–1.0	<10	<10	>90	<2	4–5
LCZ D *Low plants*	>0.9	<0.1	<10	<10	>90	<1	3–4
LCZ E *Bare rock or paved*	>0.9	<0.1	<10	>90	<10	<0.25	1–2
LCZ F *Bare soil or sand*	>0.9	<0.1	<10	<10	>90	< 0.25	1–2
LCZ G *Water*	>0.9	<0.1	<10	<10	>90	–	1

[a] Ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemisphere

[b] Mean height-to-width ratio of street canyons (LCZs 1–7), building spacing (LCZs 8–10), and tree spacing (LCZs A–G)

[c] Ratio of building plan area to total plan area (%)

[d] Ratio of impervious plan area (paved, rock) to total plan area (%)

[e] Ratio of pervious plan area (bare soil, vegetation, water) to total plan area (%)

[f] Geometric average of building heights (LCZs 1–10) and tree/plant heights (LCZs A–F) (m)

[g] Davenport et al.'s (2000) classification of effective terrain roughness (z_0) for city and country landscapes. See Table 5 for class descriptions

Stewart and Oke proposed some set of recommendations and guidelines for LCZs usage. Therefore, the system is resulting theoretically from structural separation of the urban-rural landscape into local-scale units. The thing that is not revealed was climatological data to assist that separation (Stewart & Oke, 2012).

2.5 Urban Heat Island (UHI)

2.5.1 Definition

The Urban Heat Island (UHI) can be defined as the environment, microclimate, or area of warmer air that forms in and over built-up spaces due to the paved or solid surfaces, similar to standing structures, and buildings generating or gathering and releasing heat (Dictionary of Landscape Architecture and Construction, (Christensen, 2005). It also defined as a ground of high air temperatures in an urban environment and is caused by the buildings and structures' heat absorbed (Dictionary of Environment and Conservation, (Allaby & Park, 2013). According to Emmanuel, the UHI definition is developed as best abstract as a ground of standing warm air, which is surrounding the heavily urban cities (Emmanuel, 2005).

Interest in the climates of urban centers was first investigated approximately 200 years ago when (Oke, 1982), first documented cities appearing warmer than the neighboring rural areas (Emmanuel, 2005; Landsberg, 1981; Roth, 2007; Shahidan, 2011). He conducted a comparative study of the temperature in London and the rural area surrounding of Kew Gardens and concluded that the urban was warmer. The Gordon Manley (1958) proposed the UHI effect term. According to Landsberg (1981), a UHI effect is the most noticeable climatic indicator of urbanization that can be seen in every city.

The UHI can be seen throughout the day or night but they are most strong at night, it means during a few hours after sunset, in the presence of light winds under clear skies as indicated in Figure 2.7 (Emmanuel, 2005; Santamouris et al., 2001; Shahidan, 2011). In big cities, the boundary between urban and rural areas exhibits steep temperature curves (Shahidan, 2011). Several 'plateaus' might be characterized by a weak gradient of rising temperatures such as in valleys and city center.

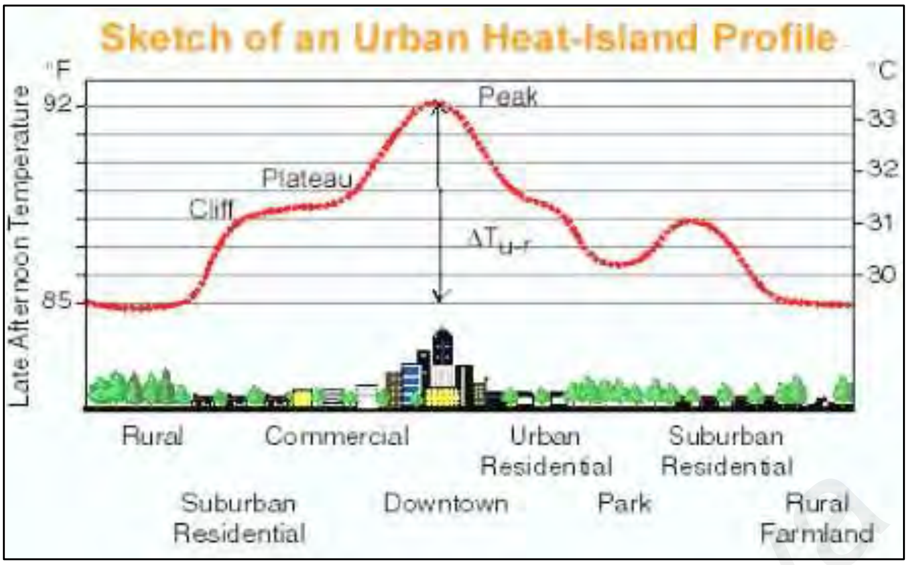


Figure 2.7: Generalized cross-section of typical UHI
Source: Roth, 2007; Shahidan, 2011

Nevertheless, it must be made clear the different characteristics and the local climatic situations strongly determine the time ranges and patterns of the UHI effect, which is restricted to each city (Davies, Steadman, & Oreszczyn, 2008; Roth, 2007; Santamouris et al., 2001; Shahidan, 2011; Taha, 1997). The UHI's intensity is commonly ascertained by the urban region's thermal balance (Shahidan, 2011). This thermal balance can sometimes affect the temperature with a difference of up to 10^{o}C (Santamouris, 2013; Yagüe, Zurita, & Martinez, 1991). UHI max or UHI intensity Turban- rural explains the maximum difference condition in the rural background temperature and the urban peak temperature (Shahidan, 2011; Roth, 2007; Velazquez-Lozada et al., 2006; Bonacquisiti et al., 2006; Wong & Yu 2005; Santamouris, 2001; Tso, 1996; Karaca et al., 1995; Yague et al., 1991; Oke, 1982).

2.5.2 Main UHI Effects

It is important to note various UHI categories to understand the UHI phenomenon entirely based on their height and location in the urban environment (Shahidan, 2011). Oke proposed two common types of UHIs that are simplified by Roth (Roth, 2007), as

Surface Temperature UHI and air temperature UHI that are definite based on their height and location in the urban environment (Oke, 1995) as indicated at Table 2.2.

Table 2.2: Simple classification scheme of UHI types. Source: Oke, 1995 and Roth, 2002

UHI type	Location
Air Temperature UHI:	
Urban canopy layer heat island	Found in the air layer beneath roof-level
Urban boundary layer	Found in the air layer above roof-level; can be
	Affected downwind with the urban plume
Surface temperature UHI:	Found at the urban horizontal surfaces; such as
	Ground surface ,roof tops, vegetation and bare
	Ground .Normally this depends on the definition of
	surface{True3-D (Complete);Bird's-eye2-
	D (air craft, satellite);Ground Road}

2.5.2.1 UHI Impacts on Air Temperature

According to Oke (1995), there are two categories for UHI air temperature as recognized in the urban environment system of the urban energy balance. These categories in two distinct layer such as urban canopy layer (UCL) and urban boundary layer (UBL) (Shahidan, 2011). UCL is the level that most life occurs and it starts from ground level to the mean height of the roof (Shahidan, 2011). UBL is the general atmospheric system, which stretches for kilometers above the surface of the earth (Shahidan, 2011). Accordingly, the majority of climatic effects are mainly felt in the UCL level (Emmanuel, 2005). Thus, the focus of most of the air temperature UHI researches should be to explore UCL features to understand the entire phenomenon that is implemented in air temperature of various cities as indicated in Figure 2.8.

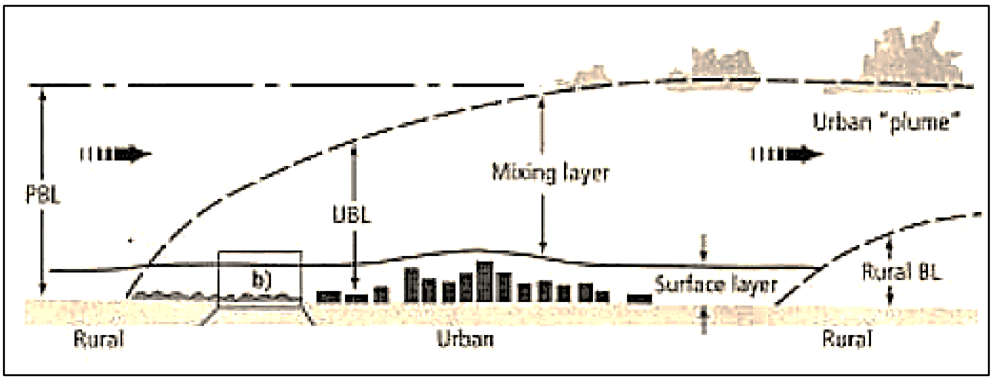


Figure 2.8: The vertical structure of the urban atmosphere over an urban region at the scale of the whole city. Source: Roth, 2002

The UHI air temperature is warmer than temperatures in rural areas environment (Shahidan, 2011) and its intensity varies during the day and night (Gartland, 2012; Wong & Yu, 2005). The lowest air temperature of urban-rural change occurs in the morning but it is increasing throughout the day because of the heating up of urban surfaces, which cause to warm air so this variation depends on the urban surface area that heats the air (Shahidan, 2011). The UHI intensity is higher at night due to the urban surfaces that constantly transfer heat after sunset and slow down the degree of night-time cooling (Shahidan, 2011).

2.5.2.2 UHI Impacts on Surface Temperature

The second category is the UHI surface temperature that is difference to UHI air temperature. UHI surface temperature is most observable throughout the day with the maximum temperature in urbanized spaces in large buildings and paved surfaces and it has a minimum temperature during the night (Shahidan, 2011). The UHI surface temperature is variances after solar noon (Emmanuel, 2005; Outcalt, 1972; Pease, Lewis, & Outcalt, 1976; Shahidan, 2011). During the day hours, urban surfaces contain walls, pavements, roofs, etc. are heated by the sun to around 27°C and 50°C temperatures hotter than the air (Gartland, 2012; Voogt & Oke, 2003). Air temperature at the lowest level of the urban atmosphere is altered (Shahidan, 2011). It further determines the buildings internal climates (Shahidan, 2011). Also, energy exchanges will influence the city dwellers comfort level (Johansson & Emmanuel, 2006; Voogt & Oke, 2003). Moisture content, surface albedo, and land cover or land use conditions are the parameters that measure the magnitude of surface temperature (Shahidan, 2011; Xian, 2008). Thus, the surface temperature is the key factor in the study of urban climatology.

Some strategies can moderate the UHI impact and decrease the temperature in tropical urban environments. One of these strategies is the use of more vegetation as a common characteristic of the Kampung due to its preservation can cause temperature decrecment (Emmanuel, 2005; Santamouris et al., 2001; Shashua-Bar & Hoffman, 2000; Solecki et al., 2005). According to Akbari, the most summer heat islands are generated due to higher solar radiation absorptions of urban surfaces and the lack of vegetation (Akbari, Pomerantz, & Taha, 2001). Consequently, to restore or inverse this tendency, vegetative cover and high-albedo surfaces should be combined into urban planning (Akbari, Pomerantz, & Taha, 2001; Hamada & Ohta, 2010; Shashua-Bar & Hoffman, 2000; Solecki et al., 2005; Wong et al., 2007; Wong & Yu, 2005). Taha has mentioned that geometric research and field studies show that vegetation cover and rising albedo can be efficient in decreasing surface and air temperatures nearby the ground (Taha, 1997).

2.5.2.3 UHI in Temperate Climates

In the West, several UHI studies have been conducted in temperate climates by researchers from European, America, and Asia Pacific and Mediterranean regions. In London, according to (Lyall, 1977), the nocturnal UHI was averaged 2.5^{o}C for over June to July; it is somehow similar to daily limits that measures by Chandler (3.1^{o}C) in 1960. Besides, (Eliasson, 1996) found out a UHI magnitude of 5^{o}C with the night-time nocturnal UHI intensity was up to 0.5^{o}C in Gothenburg, Sweden. In Essen, Germany, the UHI was between 3 and 4^{o}C for day and night, respectively (Swaid & Hoffman, 1990). However, (Shahidan, 2011) conducted study in Stolberg, Germany and found out high extra temperature is approximately 6 °C at night. This difference is because of intensely built-up town center that blocks the airflow to break through into the urban area.

Yague conducted a study in Spain in which the findings show that the UHI intensity was around 2.23°C in September, while in April the lowest UHI intensity was 1.72°C. This agrees with other studies in Canada and the U.S (Yagüe et al., 1991). According to Taha in 1997 investigation, the local climate features is based on the influence of UHI and urban climates. He proposed for particular North America urban areas positions in the heating and cooling degree days from 1941-1970 (Taha, 1997). In compare to rural surrounding, urban areas have more cooling degree-days but fewer heating degree-days. Therefore, increasing of the cooling degree-days has a remarkable impact on the buildings' energy consumption to be cool (Shahidan, 2011). Taha also proposed a list of factors that may had impact on this phenomenon, such as evapotranspiration from vegetation, surface albedo, and anthropogenic heating from stationary and transportation sources. The findings of his study also revealed that vegetation and surface albedo cover have the significant influence on UHI and heating problems. Increased albedo surface as well as low vegetation cover increase heat so the air temperature is raised so the percentage of cooling degree-days in urban environment is much higher than in rural environment.

Moreover, Santamouris carried out at study to evaluate the UHI features in a hot Mediterranean climate and the ambient temperature distribution in the city of Athens (Santamouris, Argiriou, & Papanikolaou, 1996). The findings of study showed that the Athens central areas recorded higher temperatures for winter and summer periods during the daytime. The UHI daily intensity in summer for the central area reached up to 10K and in rural areas, it was between 6K and 2K, although this was 2°C to 3°C in urban green areas lower than the central station, and 2°C and 5°C during the night- time (Shahidan, 2011). They concluded that cooling degree hours in the city area are approximately 350% greater than in suburban areas. Additionally, the UHI max in the Athens is about 16°C with a mean value of 12°C in central areas. In summary, the UHI intensity of central Athens shows a lower value around 6.1K and the park show almost fewer cooling degree around 40% hours than nearby urban locations (Shahidan, 2011).

Measuring surface UHIs in Asian temperate climates were carried out by using Terra/Modis Thermal remote sensing satellite images (Tran et al., 2006). Tran Hung study showed the use of thermal remote sensor that assessing surface UHIs in the eight selected Asian mega cities in both temperate and tropical climate regions: Tokyo, Beijing, Shanghai, Seoul, Pyongyang, Bangkok, Manila and Ho Chi Minh City (Tran et al., 2006). These cities undergoing important UHIs surface temperature in both magnitude (up to 12°C) and extent (up to 8067 km2) in summer 2001 because of land cover, and the urban surface properties in terms of built-up density and vegetation cover (Tran et al., 2006).

2.5.2.4 UHI in Tropical Climates

As an extension to UHI in Asian cities mentioned in Section 2.5.2.3, extra evaluation of surface UHIs in hot and humid climates was carried out by Tran in 2006 by using Terra/Modis Thermal remote sensing satellite images (Tran et al., 2006). There are also some studies conducted in tropical climate zones such as Bangkok, Ho Chi Minh, and Manila City, which have had UHIs intense surface temperature in the range of 5-8°C in the hot season of 2001-2002. This is because of land cover and the urban surface properties (Shahidan, 2011). For instance, Ho Chi Minh, and Bangkok City represented a relationship between UHIs and surface properties that demonstrate the importance of vegetation in the partitioning of latent and sensible heat fluxes in a tropical environment (Shahidan, 2011).

Nieuwolt conducted a study (Nieuwolt, 1966) in Singapore urban south, which was one of the first tropical urban microclimatic studies (Tso, 1996; Emmanuel, 2005; Shahidan, 2011; Wong & Yu, 2005). Comparing the air temperatures of city and relative humidity at nine different points with the single meteorological station located at Paya Lebar airport showed that the city area was considerably drier and warmer up to 3.5°C than the airport. The particular climate conditions indicate lowest humidity and highest temperatures found in narrow streets because of lack of evapotranspiration and higher absorption of solar radiation in urban areas (Shahidan, 2011).

Table 2.3: Recent Tropical UHI studies.
Source: Emmanuel, 2005; Shahidan, 2011

Author	Location	Parameters	Findings
(Tso, 1996)	Kuala Lumpur and Singapore	Air temperature	There is a difference in city-rural temperature because of the more solar radiation absorption and to evapotranspiration reduction in the city. The maximum temperature was in 13:00 to 14:00 h. Moreover, the urbanization pattern and cities location is probable to increase in environment air.
(Nichol, 1996)	Singapore	Remotely sensed surface temperature	Air temperatures of urban area can be replaced by horizontal surface temperatures because of high solar azimuth. Hot and humid cities do not have a single UHI but a collection of small UHIs, which is divided by cooler areas
(Jauregui, 1997)	Mexio City	Air temperature	The growing UHI effect result to warming trend that regularly experiment on clear nights during the dry seasons. The UHI intensity evaluation in a tropical area are more based on the land use features of the rural and suburban control.

Table 2.3: continued

Author	Location	Parameters	Findings
(Jauregui & Romales, 1996)	Mexico City	Convective precipitation	In wet season, rain falls regularly over the city (>20mm/hr.).
(Jauregui, 1997)	Mexico City	Air temperature	A nocturnal UHI (75%) was more frequent than a day-time UHI (25%). Daytime UHI is affected by differences in evaporative cooling in the wet season.
Oke et al. (1999)	Mexico City	Net radiation, sensible and latent heat fluxes	The heat storage in buildings is so large that convective heating is rigorously concealed in the city with massive stone walled buildings during daytime. Thus, the heat release at night is equal to or larger than the net radiation.
Emmanuel (2003)	Colombo	Air temperature and relative humidity	Thermal comfort patterns (THI) are considerably related to hard land cover changes mostly in suburban area.
Wong and Yu (2005)	Singapore	Air temperature and relative humidity	The temperatures of air in various land uses are relatively based on the greenery density. However, less green areas always have a higher temperature so that big green environments have positive influence on mitigating UHI effect.
Velazquez et al. (2006)	Puerto Rico	Air temperature and numerical UHI simulation	The differences between urban and rural temperature is because of urban sprawl. Furthermore, the thermal inertia is the crucial factor that influence on the local urban climate.

Table 2.3: continued

Author	Location	Parameters	Findings
Shahidan (2010;2011)	Putrajaya	Computer simulation, field measurement, remote sensing satellite imagery, and surveys programs	UHI happening because of built-up areas, vegetation loss, and lower albedo ground surface materials that results increasing hot spots in the new urban environment. The high density trees provide better cooling effect on urban microclimate. The cooling optimum performance refers to evapotranspiration process and high quality of shading in the hottest point of day. The cooling influence is larger with more quantities of group planting.
Tran et al. (2006)	Bangkok, Manila and Ho Chi Minh City	Satellite data and remotely sensed surface temperature	In dry season, the tropical cities undergoing intense surface UHIs based on heavily built-up regions in Centre of City. The night time UHI magnitude was lower than day time because of surface cooling rates and moisture availability. The UHIs diurnal variations is different from city to city depending on rural surroundings, topography, and geographical situations of the cities to the sea.

According to Table 2.3, in temperate climates, UHI anatomy is similar to tropical ones (Oke, 1982), which can be identified by various characteristics that refer to the microclimate (Emmanuel, 2005; Shahidan, 2011). In the following, four urban microclimate characteristics of the city climate are discussed.

(i) At night, the urban UHI is related to urban vegetation cover that Sham (1973) found out in Kuala Lumpur, Niewolt (1966) found out in Singapore, and Kawashima (1994) in Tokyo (Shahidan, 2011).

(ii) UHIs of night and daytime are two different circumstances. The urban center UHI happens at night although the daytime records a mixture of heat islands and cool spots. The temperature differences magnitude drops while the background climate turn into hotter (Shahidan, 2011).

(iii) In urban surfaces, any changes of lower albedo materials are strongly associated with higher temperature intensity in the day and at nighttime. Heat storage from ground and wall surfaces have a tendency to be spread at night and make a higher nocturnal UHI in urban areas (Shahidan, 2011).

(iv) Extensive vegetation cover utilization in street canyons where it represented minimal difference from cooling through building shade regarding thermal comfort comparison (Nichol, 1996; Shahidan, 2011). Thus, larger and broad numbers of canopy covered is needed to give the full benefit of thermal comfort in urban areas (Shahidan, 2011).

There are some differences between climatic parameters, which are influenced by several reasons related to the UHI max as indicated in Figure 2.11. Each climate is recognized by the simultaneous effect variable such as precipitation, humidity, temperature, solar radiation and wind speed as follow (Table 2.4).

Table 2.4: Comparative analysis of the influence of UHI based on urban climatic parameters for temperate and tropical climates. Source: (Shahidan, 2011)

Variables	Their Effect	Possible Reasons from urban areas in temperate and tropical regions
Temperature	Increase in daily min. temperature: some change in max. temperature Max UHI: In temperate climates During the summer In tropical climates - During the dry and hot season	Substituting natural green area by hard materials (concrete and asphalt), utilized in urban centers decreases the potential to decrease the ambient temperature via plant transpiration and evaporation. Cities more concern about sensible heat and less concern into latent heat (lack of vegetative cover). Limit of shade cover.
Humidity	Increase in nighttime values but decrease in daytime humidity. Max UHI: In tropical climates, critical/low humidity during dry season, and medium humidity level during wet season. In temperate climates, it causes low humidity level during summer season, and high/medium humidity level during winter season.	During the day, smaller vapor input is created because of the vegetation reduction and therefore caused smaller transpiration rates in the urban center in compare to the larger rural evapotranspiration. At night, there is a humid weather in the urban area because of weak evaporation while the moisture content of the lower layers of rural air are dwindling by dewfall. Large numbers of water-proof surface materials due to the lack of evaporation. Lack of water availability and water bodies.
Precipitation	In temperate climates, lesser increases in winter (5-8 percent) although higher increases in summer (up to 21 percent). In tropical climates, the increase is based on air pollution than heat emission.	Released by animal metabolism or the burning of fuels from either stationary or mobile sources. Emission from the greenhouse and aerosols gases influence on the radiative transfer and perform as condensation nuclei so heat wasted and water vapored from combustion in urban atmosphere.

Table 2.4: continued

Variables	Their Effect	Possible Reasons from urban areas in temperate and tropical regions
Wind	Increases the number of calm periods and reduces (20 %) wind speeds. The influence is greater on weaker winds (Emmanuel, 2005).	Rapid development of difficult factors, for example, buildings that perform as bluff bodies because of their inflexibility, impermeability, and sharp edges features that affected the velocity and air movement. Urban topography is changed.
Solar radiation	The values of radiation are not changed; the values of apparent are high because of the reflected radiation control by heat dome (Emmanuel, 2005). In tropical climates, it happens over the year and in temperate climates, it is during summer season due to long hour exposure in daytime.	Proposing new surface materials with a larger range of emissivity and albedo values in compare to vegetation. Radiation and canyon surfaces reduce the effective system albedo due to the multiple reflection of short-wave radiation of the canyon surfaces. The reduction of long-wave radiation loss in the street canyon because of the complicated exchange between buildings and the screening of the skyline.

2.6 Qualities of an Urban Space with High Frequency of Use

Urban Quality is the overall key term for the understanding of how the relationship between spaces and people works (Architects & Gehl, 2004). When urban quality is low, the number of visits and activities to urban open space will also subsequently be less (Architects & Gehl, 2004). Carr in 1992 said it is important to look at the quality of life in urban open spaces in pursuit of a balanced vision for where people want to move and live. three broad dimensions namely: needs, rights and meaning of a good public spaces was proposed (Carr, 1992). Researchers learned that good public space is responsive to user needs, easily accessible and are meaningful to the community (Carr, 1992; Architects & Gehl, 2004).

2.6.1 Duration and Time of Using Urban Spaces

A person who uses urban spaces and takes time is another important factor that can be considered as a sign of success in urban areas. According to (Tibbalds, 2012), a place that people wants to spend their time there, should comprise "a rich, vibrant, mixed-use environment that does not die at night or at weekends and is visually stimulating and attractive to residents and visitors alike" (Jan Gehl, 1996).

2.6.2 Users' Needs in Open Spaces

According to (Carr, 1992), a good urban open space should fulfill user requirements that known as "those amenities and experiences that people seek in enjoying public open spaces". Relaxation, comfort, active, and passive engagement, and discovery are considered such as enjoyment. User needs in urban open spaces are defined as the experience of amenities that are needed for the public to enjoy the spaces. This is what Danish urban designer Jan refer to as 'life between buildings' (Gehl, 1987). It is also what sociologist calls the 'the third place', an area that accommodates the regular, informal and happily foreseen gatherings of citizens beyond the home and work, which needs providing a rudimental level of function and support in public spaces (Oldenburg, 1989). They are a prerequisite for having an enjoyable experience and a basis for design criteria for which an urban open space can be measured.

Several researchers have developed their own criteria for what a good public space should be. Many of the criteria are developed on the basis of how people perceive urban open spaces (Bentley, 1985; Lynch, 1960; Southworth, 2005). Ilewelyn came up with his own criteria which he used to measure urban quality (Ilewelyn, 2010). Lynch in 1960 makes use of the term legibility, which is a mental 'reading' or 'assessment' of the paths, nodes, edges, landmarks, and districts. Similarly, Bentley in 1985 later propose that the design of urban spaces affect the choices people can make, at many levels but seeming to elaborate further on Lynch's work (Bentley et al,. 1985). All of which are can be measured physically from the built environment. Southworth (2005) proposes that the quality of the pedestrian environment has a mental and physical effect on people; his six criteria are presented from a physical design perspective. In congruence, Urban Design Compendium (Carmona, 2010) adopts an approach that focuses on creating a better pedestrian environment. The similarity amongst is that directly associated with physical elements in public spaces; however, all three developed criteria fall short of assessing the impact, whether significant or not, of the people's physical comfort in urban open spaces.

On the other hand, define their criteria for urban quality as an abstract concept related to human perception without which they argue, public spaces will remain empty (Gehl, 1987; Gehl & Gemzoe, 1996; Shaftoe, 2008, 2012). One of the major criteria they look into is the comfort of people in urban outdoor public spaces. Their earlier works gave way to other researchers looking into life in the outdoor environment and the need to provide a thermally comfortable environment for the public in urban open spaces. Although their research is focused in the western world with temperate, arid and cold climates, such research work is important to establish the life in urban open spaces in tropical climates with heavy rains, overhead sun, radiant heat and the effect of UHI.

2.6.3 Comfort and Microclimate

One of the user requirement is comfort that should be considered in open spaces. It is a crucial factor that other needs depends on them (Carr, 1992). According to (Whyte, 1980) "the most popular plazas tend to have more seating than the less well-used ones". Another interesting point in open spaces is that if there is no place to sit, and then people are not able to find a place to sit "Sitting should be physically comfortable. It is more important to be socially comfortable," It means individuals or groups of users are able to choose the sitting areas in shadows or under the sun. In the use of open space, considered having shelter or access to the sun is a significant factor (Bosselmann, Flores, & O'Hare, 1983), while linked the activities level with the microclimate of the space (Gehl, 1996). Jan believes that social and optional activities are done only when the external conditions are good enough for strolling and stopping. Hence, the following parts are discussing the thermal aspect of human comfort and how its effect on their experience of urban outdoor space. Hence, the following sections discuss the thermal aspect of human comfort and its impact on the outdoor experience in urban environment.

2.7 Thermal Comfort Evaluation in Urban Open Space

Although the microclimatic conditions could significantly influence thermal comfort and the usage of urban open spaces, most of the time, it is clear that the physiological sensation is still considered a necessary but not sufficient factor. Discrepancy between the subjective thermal sensation and objective calculation has been seen as a common situation, people's comfort level in the urban open spaces responding to microclimate could not be explained by physiological parameters all the time. It has been seen that the thermal comfort evaluation in urban open space would not only be contributed by physiological sensation, but also require other psychological factors such as expectation and satisfaction (Höppe, 2002).

2.8 Comfort and the Importance of Outdoor Life

There is strong public interest in the quality of urban open spaces and it is acknowledged that they can contribute to the quality of life within cities, or contrarily enhance isolation and social exclusion (Balgoh & Takacs, 2011; Takano, Nakamura, & Watanabe, 2002). Balgoh and Takacs are characterized by high green-coverage rate with ecological and environmental importance (Balgoh & Takacs, 2011; Takano et al., 2002). These spaces significantly improve the urban climate, reduce the UHI effect by their ecological-balancer function, and reduce environmental damages.

In recent years, increasing attention has been paid to research regarding the evaluation of urban open spaces and their components as well as their effect on the environment. These relate to the physical (i.e. microclimate, thermal, visual, and acoustic comfort, urban morphology, etc.) as well as the social environment. Concerning their social significance, urban open spaces assist urban residents in incorporating a healthy lifestyle on a daily basis (Balgoh & Takacs, 2011; Madanipour, 2013; Takano et al., 2002). With regards to their physical significance, they create visual meaning and ambiance of the area, enriching the built-up character of the cities (Balgoh & Takacs, 2011; Takano et al., 2002). Therefore, to increase use of urban open spaces for the city, the conditions of the physical environment imposed on urban residents using these spaces; have to be likewise measured (Boumaraf & Tacherift, 2012). Recent research in hot and humid regions like Malaysia has shown that the microclimate of outdoor urban open spaces is vital to the way people use these spaces and the activities that are carried out (Boumaraf & Tacherift, 2006; Boumaraf & Tacherift, 2012). This is because the thermal, and by implication, comfort conditions affect the urban residents' behavior and usage of outdoor spaces (Boumaraf & Tacherift, 2006; Boumaraf & Tacherift, 2012). Responses to the microclimate may be unconscious, but they often result in different uses of open space in different climatic conditions (Boumaraf & Tacherift, 2012). Thus, understanding the richness of microclimatic characteristics in urban open spaces, and the comfort implications for the people using those opens up new possibilities for the development of urban spaces.

2.8.1 The Biological Need for Thermal Comfort

The human body regularly scatters heat to maintain an ideal internal temperature around 37°C, which is appropriate for organs of the body mainly for the brain. If the internal temperature of body falls below 30°C or increases above 41°C, death would be accrued. Accordingly, the procedure of the body capability to control its thermal environment requirements is complicated. In human body, the thermal comfort is an essential factor, which is occurred once the temperature of body is in narrow ranges, the strength of body regulation is minimized, and the skin moisture is low. After ASHRAE (formerly known as the American Society of Heating, Refrigeration and Air-Conditioning Engineers), combinations of relative humidity, air temperature, air motion and mean radiant temperatures are considered as thermal comfort (Reddy et al., 1997). The thermal comfort can only be preserved once produced metabolism's heat is equal to the heat loss from the body. The limitations of thermal comfort are not complete, and it is different due to the amount of clothing worn, culture, health, time of year and most importantly physical activity.

2.8.2 Environmental Factor Influencing Thermal Comfort

Human body heat balance and the environmental situations that allow the balance should find out to obtain thermal comfort. In following, these environmental situations are described as:

(a) Air temperature (°C): The body heat is lost to the air by convection. The body tends to gain heat from the environment when the air temperature is above 37°C. The comfort range for the majority of people is from 20°C in winter to 25°C in summer (Lechner, 2014).

(b) Air velocity (feet/minute): Air movement influence on the rare of heat-loss through evaporation and convection. The comfortable range is from approximately 95 to approximately 130 feet/minute (fpm) (Lechner, 2014).

(c) Relative Humidity: It is a ratio of atmospheric moisture present amount in relation to the presented amount when the air is saturated. Relative humidity is a function of temperature and content moisture because the latter amount is reliant on temperature

(Gagge, Fobelets, & Berglund, 1986). Thus, relative humidity, itself, does not directly show the real amount of atmospheric moisture present. The comfortable range of RH is above 20% all year, below 80% in winter and below 60% in the summer.

(d) Mean radiant temperature (Tmrt): It is the uniform surface temperature of an unreal black inclusion that human exchanges the same heat by radiation in the real situation (Handbook, 2009). The Tmrt of an environment is the measure of the combined influence of surfaces temperatures through that environment. The bigger surface area and its surround have more influence on the temperature of the surface.

(e) Physical Activity (Tme): Metabolism is the motor of the human body, and the amount of its released energy is dependent on the amount of muscular activity. For maintaining thermal comfort, physical activity plays an important role for example; the amount of heat that generated by an active person is approximately six times more than a heat that generated by a resting person. An activity level of a resting person is 0.8 Tme, and it is 1 Tme for sitting person while this amount is 8 Tme for a jogging person (Handbook, 2009).

(f) Clothing (CLO): It is a thermal resistance that decreases the heat of the body loss and keeps the body from cold. It is categorized based on its protection value. In general, a high CLO value is 1.5 that indicate a heavy coat while a 0 CLO value specifies a nude person (Handbook, 2009).

(G) Activity: Activity level influences energy production in human body and can considerably affect the comfort level. Activity level is expressed by mets: each met is the metabolic rate of a seated relaxed adult and equals 58 W/m2 (Clark and Edholm 1985). Different types of activities with the relevant metabolic rates are shown in Table 2.5. Some activities such as hard physical work or sport may produce conditions that cause thermal discomfort. For example, an outdoor thermal condition that is comfortable for activity such as walking can be uncomfortable for running. This is due to the surplus of energy added to the energy budget of the body. Therefore, one may take action such as removing some clothing. Another option is providing appropriate design for running paths, which allows suitable thermal conditions for running.

Table 2.5: Metabolic rates of different activities. Source: ISO7730, 2005

Activity	W/m²	Met
Reclining	46	0.8
Seated, relaxed	58	1.0
Sedentary activity (Office, dwelling school, laboratory)	70	1.2
Standing, light activity (shopping, laboratory, light industry)	93	1.6
Standing, medium activity (shop assistant, domestic work, machine work)	116	2.0
Walk on level:		
2 km/h	110	1.9
3 km/h	140	2.4
4 km/h	165	2.8
5 km/h	200	3.4

2.8.2.1 Effect of Urban Design on Outdoor Thermal Comfort

The urban design variation can change the microclimatic situations and in consequence influence on the outdoor thermal comfort. The climate negative aspects can be decreased by a proper urban design and increase the outdoor spaces usage. Many studies have been carried out on the influence of urban design on microclimatic parameters such as solar radiation, relative humidity, air temperature, wind speed, and mean radiant temperature in urban areas (Ahmed, 2003; Coronel & Alvarez, 2001; Ng & Cheng, 2012; Wong et al., 2007), but they do not deal with the effect of urban design on outdoor thermal comfort in urban areas directly. This lack of researches related to urban design and outdoor thermal comfort might be because of the following three reasons. First, urban designers do not have an assessment tool (outdoor thermal comfort index) to assess their design strategies. Although PET is used as thermal indices in some researches, it is considered as temperature degree and not directly related to human thermal sensation. Second is that conducting complete field measurements is complicated because of enormous number of urban variables and processes in urban areas. The last reason is the inadequate interdisciplinary research between urban design and human biometeorology that limit theoretical knowledge.

Recently, the findings of research reveal that the study of urban design influence on outdoor thermal comfort that are usually built on the PET and mainly focus on the urban streets. Ali-Toudert conducted several researches on the influence of aspect orientation and ratio of urban street canyon on outdoor thermal comfort in hot and dry climate (Ali & Mayer, 2006). The findings revealed that spatial distribution of PET at street level strongly depends on aspect ratio and street orientation. Johansson carried out a study on the effect of urban geometry on outdoor thermal comfort by linking very deep and a shallow street canyon in Fez, 30 Morocco (Johansson & Emmanuel, 2006). PET assessed the outdoor thermal comfort and the findings indicate, in summer, the deep canyon is comfortable while the shallow canyon is very uncomfortable. However, the shallow canyon is more comfortable as solar access during winter.

Johansson and Emmanuel conducted a study about the impact of urban design on outdoor thermal comfort in Colombo, Sri Lanka (Johansson & Emmanuel, 2006). The findings showed that the PET value indicated the importance of shading for the improvement of daytime comfort. The conclusion revealed that a compact urban form (high H/W ratios) offer more comfortable situations than a dispersed urban form. This result is in agreement with Ahmad's study that says that semi-enclosed spaces limit air movement but make shade. Sometimes, it is comfortable throughout the hottest period of the day in Dhaka, Bangladesh (Ahmed, 2003). This result is inconsistent to the common belief in the tropical zones, where the most important design strategy is to make air movement available.

Ali-Toudert carried out a study to investigate the thermal comfort in an east–west oriented street canyon in hot summer conditions in Freiburg, Germany. The findings revealed that the street orientation and geometry is crucial factor in the daily dynamics of canyon facet irradiances and impacts on the heat gained by a pedestrian (Ali & Mayer, 2007). The thermal stress was mostly attributable to solar exposure. In cloudless summer, a body absorbs 74% of heat in the form of long-wave irradiance and 26% as short-wave irradiance. Surrounding surfaces and shading the pedestrian are strategies in moderating heat stress in summer under hot conditions. Emmanuel (Ali & Mayer, 2007) used ENVI-met software to simulate the influence of various urban design choices on outdoor thermal comfort in terms of PET. The findings showed that high albedo gives the lowest air temperature at street level during daytime, even though the reduction is approximately 1°C. The increase of H/W ratio from 1 to 3 causes to a PET decrease about 10°C. They also concluded that better air temperature mitigation strategies may not necessarily results to better thermal comfort. Although shadow enhancement by increasing the (height/width) H/W ratio significantly reduces PET, and therefore improved outdoor thermal comfort.

Yang conduct a study in two high-rise residential quarters in Shanghai to explore the thermal comfort effects of urban design strategies in a sub-tropical climate in high-rise urban environments (Yang, Lau, & Qian, 2011). This research was carried out in two residential quarters rather than streets. The findings revealed that an increase of 0.4 in the ground surface albedo cause the thermal comfort reduction. For example, an increase of 5–7°C in PET throughout the day cause a minimal decrease of less than 1°C at night. Therefore, thermal comfort is improved with increasing greenery cover during the entire period under assessment. 15°C reduction in daytime by adding a dense tree cover and it goes up to 20°C by adding the tree cover over the hard pavement with an albedo of 0.2. On the other hand, they conducted a simulation study (Herrmann & Matzarakis, 2012) to measure the effect of orientation on radiation fluxes and the height-to-width ratio in a typical urban canyon in Freiburg, Germany. The findings of their study showed that changes of these parameters by typical urban structures could lead to mean radiant temperature variation over 30°C that can have agreed to three levels of thermal stress.

These related literatures revealed that the ratio or H/W ratio and street orientation are the most important parameters that affecting PET to design urban streets. The materials of the greenery and ground surfaces were 32 also found to influence on PET. Shading can be considered as a key strategy in improving outdoor thermal comfort in summer. The review of literatures has shown that few of researchers use PET as the thermal comfort index to measure human thermal comfort in outdoor urban spaces. It is because of precise interpret the meaning of one PET value for the thermal comfort of people is difficult (Ali & Mayer, 2006). In addition, in various climate regions, one PET value has different thermal sensation indications for people. For instance, a PET of 26°C corresponds to "neutral" for people in tropical climate (Lin, Matzarakis, & Hwang, 2010) but it corresponds to "slightly warm" for people in mild climate (Matzarakis & Mayer, 1996). Another limitation of the researches is that they conducted only few points in the study areas and consider these points as a representative of the entire area. It means that there is no study points the dimensional microclimatic variances across the whole area such as center and edges. Therefore, there is more study needed to explore the effect of dimensional microclimatic variances on outdoor thermal comfort. Moreover, most of studies used qualitative method to assess effect of urban design on outdoor thermal comfort and there is lacking quantitative assessment in this area.

2.8.2.2 Topography

Air temperature, solar radiation, and wind are influenced by the slope, altitude and exposure of the site in which higher altitudes have higher temperature differences (Clark & Edholm, 1985). The ground overnight become cool quickly because of heat loss by cool air drains down to the bottom and radiation to sky. Otherwise, solar radiation intensity during the day is significant because of the moderately short distance at such altitude that it has to pass through the earth's atmosphere. When solar radiation falls on slopes in different directions, the heating effect of it will be different since this difference in solar radiation is higher on a sloping surface in compare to horizontal. Topography also affects wind. High sites are exposed to stronger and more wind while basins are safe from wind.

2.8.2.3 Ground Cover

The environmental conditions are greater when it is close to the ground since the solar radiation increases the ground temperature during daytime. On the other hand, this temperature decreases next to ground level at night because of outgoing radiation and evaporation. Therefore, in moderating extreme temperatures, the cover of ground plays an important role.

Urban areas and artificial surfaces have a tendency to reduce humidity and increase temperature. Those surfaces radiate, store, and reflect heat to air layers that are surrounding them. Natural cover of ground such as grass assists to moderate extreme temperature (Allan, 1980). Thus, in hot climate areas, paved surfaces are not so beneficial and it should be used rarely in outdoor spaces. Using natural cover such as grass in the urban area impact not only on the thermal area, but also noise levels and air quality. It reduces the temperature of air by direct shading and control of solar heat gain via evapotranspiration (Dimoudi & Nikolopoulou, 2003).

Generally, all materials thermally can be defined by their albedo (Cunningham, Cooper, Gorham, & Hepworth, 1998). The object albedo is the ratio of the diffusively, which is reflected radiation to the incident electromagnetic radiation. It is also closely related to the material color. Dark and rough color surfaces have a tendency to absorb more solar radiation and be warmer than light and smooth color surfaces. On the other hand, using cold materials is another advantage in hot climate to reduce air temperature because of heat transferring and modifying the urban heat island effect.

2.8.2.4 Densities and Building Fabric

Constructions provide shade for surrounding outdoor areas while the urban fabric is compact to decrease the heat gain from solar radiation. The street canyon aspect ratio H/W is important as geometric variable that show the urban fabric density. A regular canyon commonly have an aspect ratio H/W=1, and a deep canyon has an aspect ratio H/W=2 or more (Vardoulakis, Fisher, Pericleous, & Gonzalez-Flesca, 2003). Besides urban density, paved surfaces and buildings also store radiate, heat, and reflect solar radiation that increase air temperature in the urban area of hot climate regions. Thus, recognizing the balance between the shading of building fabric and the effect of urban fabric density on air temperature is very important to minimize the paved areas, and increase vegetation.

2.8.3 Differences between Outdoor and Indoor Thermal Comfort

According to Potter and de Dear (2003), the outdoors thermal sensation is different from indoors and they assumed that indoor thermal comfort standards are not appropriate for outdoor areas (Vardoulakis et al., 2003). Between outdoor and indoor thermal comfort three aspects of differences are available such as: thermos physiological, psychological, and heat balance difference (Peter Höppe, 2002). This psychological aspect is based on expectation. People are able to bear a larger variation in climatic conditions in the outdoors areas than the indoors. According to Emmanuel (2005) the outdoors provided possibilities for appropriate social places and adaptive behavior (Emmanuel, 2005). Spagnolo (2003) proposed that the range of acceptable temperature in outdoor context should be wider than the indoor context because of various expectation (Spagnolo & De Dear, 2003). On the other hand, people can tolerate warmer-than-usual climate in the urban parks, beach, or street canyons (Höppe & Seidl, 1991; Nikolopoulou, Baker, & Steemers, 2001). The thermos physiological aspect refers to differences in clothing, exposure times, and activity levels (Emmanuel, 2005). For example, in warm situations, people have a tendency to do lighter activities, to wear less clothing, and be in environmental situations longer in the indoors than outdoors. Indoor climate exposure usually last in the range of hours while outdoor climate exposures last in the ranges of minutes. Heat balance difference is the last aspect, which is considered between two. While steady-state situations are applicable in the indoors, they are rarely applicable in urban outdoor areas (Emmanuel, 2005). Thermal steady-state under no circumstances achieved even if people spend some hours in outdoor area in real life conditions (Höppe, 2002). Therefore, steady comfort model is not accurate evaluation under outdoor situations. Since indoor thermal comfort is different from outdoor thermal comfort, so only a heat balance thermal comfort index is not able to forecast the outdoor thermal comfort.

2.8.4 Outdoor Thermal Comfort

People's outdoor thermal comfort is influenced by the thermal environment, while its use is dependent on their observation of outdoor thermal environments (Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Hwang, Lin, & Matzarakis, 2011; Lin, 2009; Nikolopoulou et al., 2001; Thorsson, Lindqvist, & Lindqvist, 2004). Besides, outdoor thermal spaces are considerably influenced by the design of built environment (Hussin, Hamid, Zain, & Rahman, 2010; Hwang & Lin, 2007; Wong et al., 2007). Shading is able to prevent direct solar radiation, many studies investigate shading effects on the outdoor thermal environments (Hussin et al., 2010).

Research in the last decade has focused on determining the comfort levels in the internal environment leading to an unintentional lack of focus on thermal comfort in urban outdoor environments especially in light of the increasing UHI effect in urban areas. Conventional comfort theory, focused mainly on the internal environment, depends on a model of steady-state where the produced heat is equal to lost heat in the area to maintain the temperature of core body at 37°C, therefore the environmental situations that offer thermal satisfaction, based on the subjects activity and their CLO level that decreases in a narrow band (Nikolopoulou et al., 2001). Although the models present a similar scenario for the outdoor environment, they often neglect external influences such as the surface materials and presence of vegetative covers.

The complexity of the external built environment depends on variability, spatially and temporally, and the variety of peoples' activities. In contrast, to realize the comfort indoor, there are also some attempts to figure out the outside comfort conditions. Furthermore, studies on grasping outdoor thermal comfort conditions were largely restricted to temperate areas (Makaremi et al., 2012; Nikolopoulou & Lykoudis, 2007). Accordingly, there is a considerable lack of research on the importance of human thermal comfort and material of outdoor thermal situations to enhance urban quality in hot and humid climates (Lin, 2009; Makaremi et al., 2012). Therefore, more research on human comfort situations in outdoor environments in tropical climates related to the certain climate and ground surface conditions as well as the human parameters and the particular subjective responses is needed. In hot and humid climates, the radiant temperature is the crucial factor in human comfort (Lewis, Nicholas, Scales, & Woollum, 1971; Plumley, 1977). One of the main human discomforts in the tropical climate depends on the radiation regime (Emmanuel, 2005) for example, the high level of solar radiation during the year, which is become worse during dry and hot seasons while a UHI is maximum. Therefore, in the urban spaces, the radiant temperature is different regarding urban canyon geometry, shading, the seasons and vegetation availability. The variation is mainly because of the amount of global radiation, which is received from the ground surface and the variances for radiation by the person. Consequently, lack and presence of these factors cause a UHI effect that causes extreme variation in the human thermal comfort of tropical climates.

2.8.4.1 The Comfort Zone

Thermal comfort comes from careful balance of air movement, humidity, temperature and mean radiant temperature. Clothing and physical activity are secondary factors that should be considered when designing for thermal comfort. These combinations of air temperature and relative humidity are plotted on the psychrometric chart, which is defined as comfort zone. Comfort zone is an area on the psychrometric chart that defines the circumstances that most people would be comfortable. As the psychrometric chart relates only relative humidity and temperature, the other two factors of MRT and air velocity are fixed. The air velocity is assumed modest and the MRT is assumed to be close to the temperature of the surrounding air. The comfort zone is not fixed and varies based on time of the year, culture, health, physical activity and amount of clothing (Lechner, 2014).

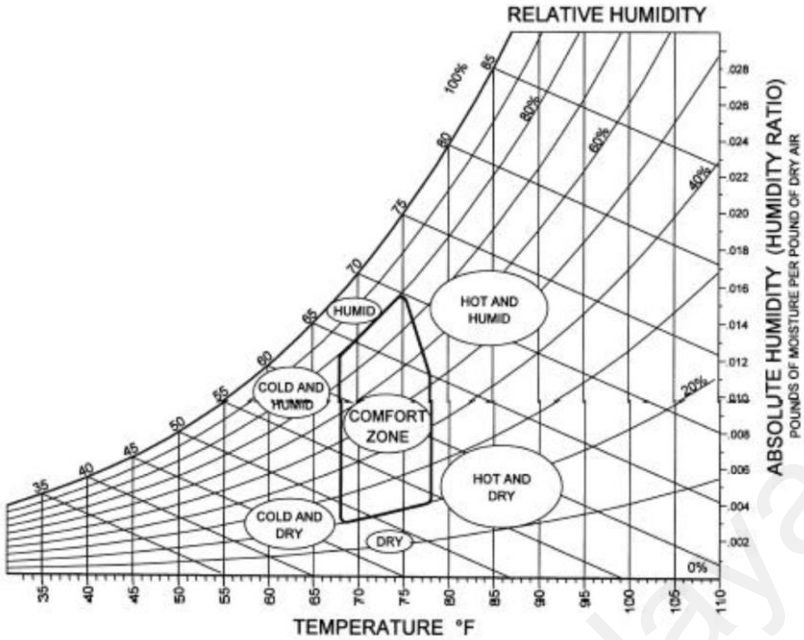


Figure 2.9: Psychrometric chart shows the comfort zone
Source: Poonam, 2005

The comfort zone contains the factors that influence on thermal comfort. Air movements up to a certain point can reduce high temperatures, which is not enough and should be enhanced by other strategies. The comfort zone can adjust it where one factor transformed to restore thermal comfort, which is achieved with a few adjustments in the thermal situations. The comfort zone borders are not fixed and change with personal preferences, climate, place, people, and culture as shown in Figure 2.9.

2.8.4.2 Heat Balance Model of Thermal Comfort

The conventional thermal comfort theory is based on the balance between the human body and its surroundings so the internal body temperature is approximately 37°C. This balance is maintained through a constant exchange of heat the human body and its surroundings, which is occurred by convection, conduction, evaporation, and radiation. These physical procedures are affected by environmental components such as wind speed, solar radiation, air temperature, humidity and personal factors such as clothing (Park, Hagishima, Tanimoto, & Narita, 2012).

ASHRAE and ISO7730 are considered as a model of comfort throughout the worldwide. These proposals are related to the human body heat balanced model and derive from general climate-chamber tests in mid-latitude climate areas. However, they are not used for constructions that are naturally built for outdoor spaces (ASHRAE, 2004; Standard, 2005).

In 1970, Fanger developed Predictive Mean Vote (PMV) as a steady-state model that shows the heat balance between the human body heat dissipation and heat production (Fanger, 1970). Thermal comfort expresses the PMV through a calculation of mean radiant temperature, air temperature, activity level humidity; relative air velocity, and clothing. This model is often used to highlight the influence of adaptation in outdoor areas although it is designed for indoor, buildings. Based on the steady-state heat-balance theory, the body of human is a passive receiver of thermal stimuli (Brager & De Dear, 1998) and Predictive Mean Vote does not have proper version to consider. Therefore, more research have been carried out to expand the applicability of the original PMV (Van Hoof, 2008). For instance, Fanger and Toftum proposed (Fanger & Toftum, 2002)an expectancy factor "e" to the PMV to clarify the assessment of thermal sensation in non-air-conditioned boiling in hot weathers. On the other hand, Yao (Yao, Li, & Liu, 2009) have proposed factors such as climate, culture, and behavioral adaptations and social psychological to enhance the PMV model. The PMV was associated with the actual thermal sensation vote of the visitors of urban public areas in the outdoor locations of temperate climates. The findings revealed that only physiological approach that is related to heat balanced models as PMV, cannot characterize thermal comfort conditions effectively (Nikolopoulou et al., 2001) and other psychological and socio-cultural parameters come to be important gradually (Knez & Thorsson, 2006; Thorsson, Honjo, Lindberg, Eliasson, & Lim, 2004). As a result, the PMV model is not applicable for outdoors areas.

Another thermal index is PET (Mayer & Höppe, 1987), which provide the thermal evaluation of a certain situation. PET is related to Munich Energy-balance Model for Individuals (MEMI) 1 (Höppe, 1984)is defined as the air temperature while the heat budget of the human body is balanced in an indoor area with the same skin and core temperature like as below the complex outdoor area. For example, the PET value may be more than 20 K higher than the air temperature with direct solar irradiation in hot summer days and it is reach up to 15 K lower on a windy day in winter.

2.9 Conclusion

This chapter reported a description about urbanization in global scale and in Malaysia as well. It also explained how urban villages appeared in the modern urbanised areas such as Kuala Lumpur City. Theoretically, the review of the related researches presented in this chapter demonstrates that vegetation and ground materials could be changed and affect the urban microclimate areas. They potentially modify the UHI influence by decreasing air temperature, decreasing building energy utilization, and affecting human thermal comfort. These strategies contain an arrangement of a higher percentage of vegetative cover and other material with higher albedo values to classify physical properties, for example; types of surface, color material, and structure that could increase the cooling effect in urban environments. The entire influence of both changes will provide better shading quality, radiation filtration, and promote important growths in the evapotranspiration. The important modification to the microclimatic situations increases the 'oasis effect' in cities that results in better energy savings and better outdoor thermal comfort. Therefore, more evaluation and measures will be needed to prove the effect towards the urban spaces, especially in the tropics climates. Chapter 3 presents the methodology that has been used in this study.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This section consists of the research design of the study, data collection, and data analysis approach to determine functional spaces of the selected urban villages towards the environmental values of the contexts to achieve higher levels of life quality. The study explores the circumstances of enhancing ambient, outdoor thermal comfort, functionality of spaces and the microclimatic conditions. The collected data were employed for a validation of the study using multiple sources of evidence. The multiple sources of evidence are expected to enhance the research into evidence-based results of the thermal comfort in urban spaces achieving a greener and smarter urban future.

In this chapter, geographical attribution, and climate of KL city identified in section 3.2, and then the criteria for site selection have been explained in section 3.3, followed by the method of research in section 3.4. Next, the model evaluation, microclimate variables and equipment, and research design and framework for three different Kampung (Kampung Sungai Penchala, Kampung Baru, and Kampung Melayu Kepong) explained in sections 3.7 to 3.9. Finally, section 3.10 concluded the methodology chapter.

3.2 Identifying Kuala Lumpur (KL) City

Kuala Lumpur, officially the Federal Territory of Kuala Lumpur, or generally known as KL, is the national capital of Malaysia besides its largest city in the country. The only city in Malaysia has an area of an approximately 94-square-mile area (about 243 km^2), with a population of 1.73 million by 2016, managed by the KL city hall. It is among the fastest growing metropolitan regions in the country, in terms of population and economy.

Figure 3.1 shows the diversity of natural environment and societies in urban characteristics of KL. Between 1860 and 1950, the city has encountered a rapid change toward urbanization. The KL city is portrayed as the best example of a city that proposes the best of its social inheritance and combination with contemporary housings. It is similarly called the blend of traditions and advancement and a cosmopolitan getaways with unique multi-social heritage, nourishment, articulations, and outline (Bunnell, Barter, & Morshidi, 2002).

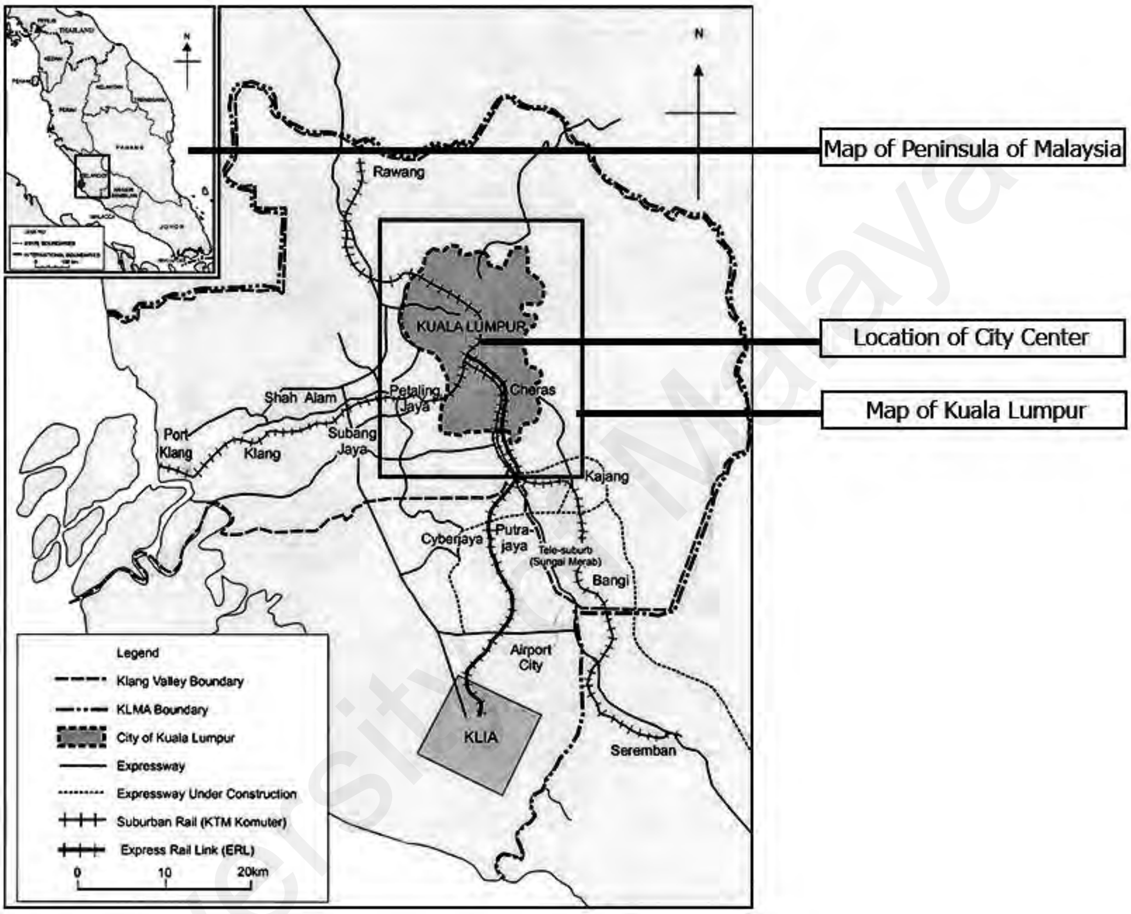


Figure 3.1: Map of the development of the Kuala Lumpur Metropolitan Area. Source: Bunnel, Barter & Morshidi, 2002

3.2.1 Geographical Attributes of Kuala Lumpur

Malaysia, as a tropical country, is located close to the equator in Southeast Asia. The region is divided geographically into two different regions, the peninsula Malaysia and eastern Malaysia, which are separated by the South China Sea. The nation lies in the vicinity of 1° and 7° north area and stretches out from longitude of 100°– 119° east, with hot and sticky climatic conditions and substantial tropical rains (Bakar, 2002). As a tropical nation, Malaysia always encounters high temperatures, relative moistness, variable breeze conditions, extended periods of time of sunshine with overwhelming precipitation, and cloudy overcast cover as the year progressed. The day by day, air temperature shifts from a low of 24°C up to 38°C, while from the recorded least temperature is for the most part at night. Malaysia has high level of humidity in which it has varied from 70% to 90% in different months of the year. Overall, the mean day-by-day mugginess can be as low as 42% to as high as 94% (Dahlan, Jones, Alexander, Salleh, and Dixon, 2008; Makaremi et.al. 2012). These ecological highlights portray the tropical atmosphere of Malaysia.

3.2.2 Climate of Kuala Lumpur

Malaysia always encounters high temperatures and humidity consistently however; this tropical climate is changing over the years. The highest temperature has been recorded was 32-33°C during February and March and it has never exceeded 38.5°C, while the coolest temperature was 31°C in December. The lowest temperature was 23 to 24°C, and have never fallen below 14.4°C (Elsayed, 2012). High rainfall in the KL city was from October to March. It is hard to find a place that the rainfall is lower than 2,000 millimeters per year. The annual rainfall was 2,600 mm (100 in), in minimum, and exceeds 131 millimeters (5.2 in) per month (Nik, Ahmad, Ibrahim, Samo, & Muzathik, 2011).

3.3 Criteria for Selection of Case Study Areas

Selected urban villages in this study are all chosen in KL city. Some different aspects affected on selecting these urban villages in this research. These aspects are as follow.

- Identification and descriptive of environmental surrounding nearby to the urban villages consist of the type of building (traditional or modern) and the natural elements like being nearby a lake.
- Geographical attributes in terms of the location of urban villages in KL city.

- Monitoring the amount of vegetation coverage in terms of low-rate, medium-rate, and high-rate coverage of trees in urban villages of KL.
- Considering population density in terms of high, medium, and low density.

This study has chosen the potential spaces in urban villages in terms of having shaded and unshaded places and has considered the above-mentioned aspects to evaluate the level of thermal comfort in outdoor environment.

3.3.1 Case Study Areas

There are some urban spaces in KL that resembles the same characteristics of traditional rural spaces, called urban villages. The traditional rural spaces are located around the cities, while, the urban villages are placed amongst buildings and streets. The urban villages exist in KL, which can influence the urban environment and human thermal comfort with its specific characteristics. In this research three urban villages have been selected among all existed options, based on equal conditions, e.g. pattern of vegetation, construction and surface materials and the level of shaded or unshaded, SVF and surrounding coverage, to study and measure the influence of each urban village on the environment of their location.

3.3.2 Selected Case Studies and Environments

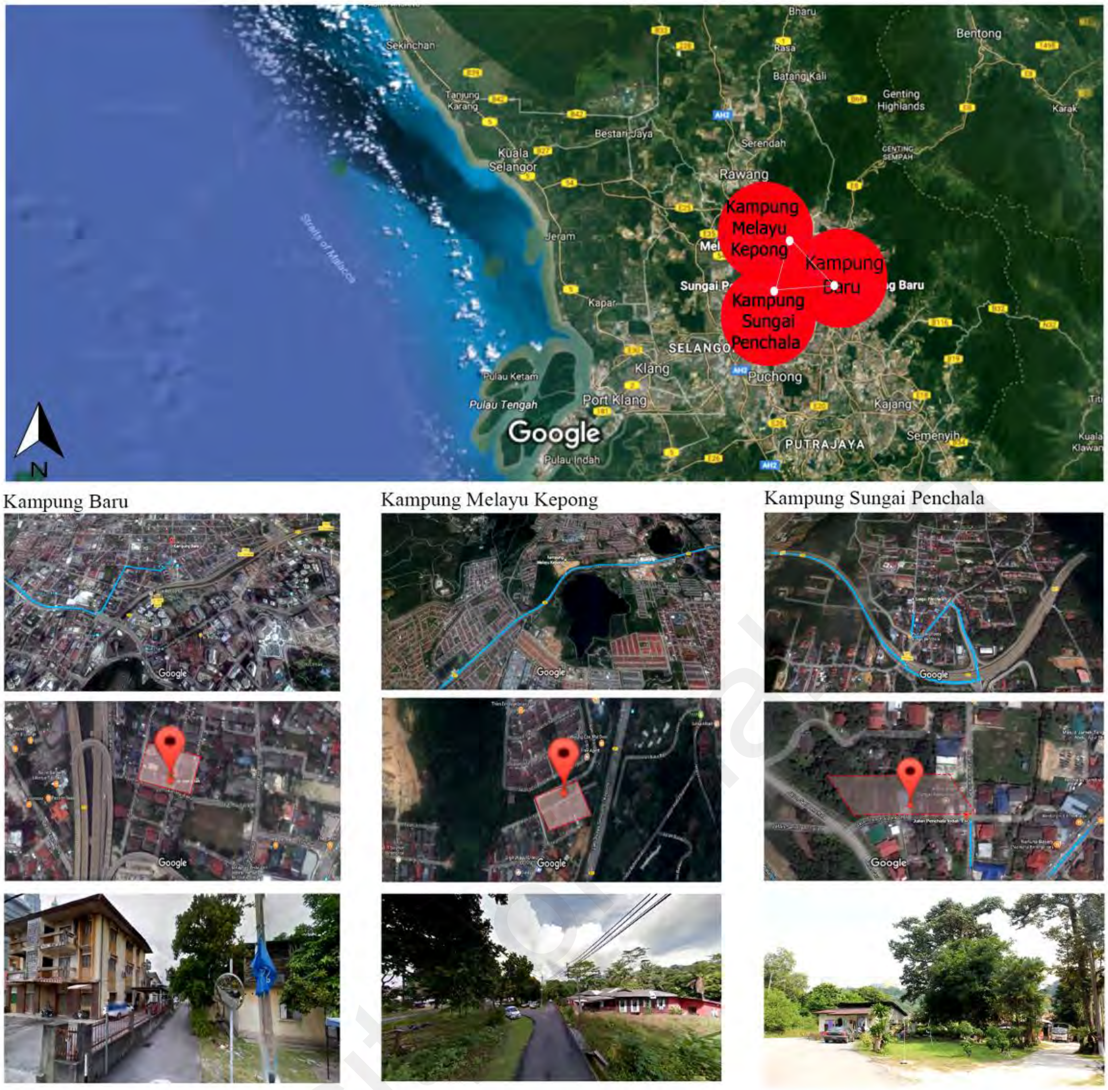
Three different locations have been selected as urban spaces among all urban villages in KL, taking into account the geographical location and environmental conditions, with regard to the priority of the person in outdoor relaxation, including vegetation, density, volume, and preserved or an unpreserved area. This enabled examination of the effects of physical elements and thermal comfort, and the use of outdoor spaces. Additionally, different space enabled exploration of how design affects the use of space through the creation of different microclimates. Hence, three sites were carefully selected in KL and were conducted for two days and extensive data was collected for the analysis. The results for both days will be discussed separately. The urban spaces or Kampungs named as follows; Kampung Sungai Penchala, Kampung Melayu Kepong, Kampung Baru that shows in Figure 3.3 (Google Earth, 2017).

The selected sites for the study area are (i) Kampung Baru or "Kampung Bharu," which is located in the center of KL. Its geographical coordinate is 3° 9′ 47″ north, 101° 42′ 22″ east, (ii) Kampung Melayu (Kepong) is situated in KL. Its geographical coordinates are 3° 13' 46" North, 101° 38' 34" East, (iii) Kampung Sungai Penchala is a small Malay village in KL as displayed in Figure 3.2 which is next to Taman Tun Dr. Ismail (Bunnell et al., 2002). Its geographical coordinates are 3° 9′ 48.88″ North, 101° 36′ 54.33″ East. The study areas were selected because of their strategic locations (located amid the federal territory of Malaysia), and their design (in terms of traditional or new materials such as timber or concrete, and their outdoor design of greeneries).

Thermal comfort condition of outdoor spaces was estimated based upon a simultaneous measurement of major climatic parameters (objective measurement) in urban villages in KL. The field investigations of this study were conducted in Kampung Sungai Penchala, Kampung Melayu Kepong, and Kampung Baru, as presented in Figure 3.2.

Uraban village 1:Kampung Sungai Penchala Uraban village 2: Kampung Melayu Kepong Urban village 3:Kampung Baru

Figure 3.2: Perspective views of the three sites of this study
Source: Author



No	Name of urban villages	Geographical Description	Existed vegetation	Density (High,Medium,Low)	Other elements	Image
1	Kampung Baru	Kampung Baru or "Kampung Bharu" is a Malay enclave located in the heart of Kuala -Lumpur, Malaysia with Longitude of 101.71222 and latitude of 3.16495	Vegetation coverage in low-rate	High density	It surrounded by high rise and modern building at the city-center	
2	Kampung Melayu Kepong	Kampung Melayu (Kepong) geographically coordinates with longitude of 101.6388 East and latitude of 3.22898 North is situated in Kuala Lumpur.	Vegetation coverage In high-rate	Low density	There is a metropolitan lake near by this kampung	
3	Kampung Sungai Penchala	Kampung Sungai Penchala is a small Malay village in the Segambut constituency, which located in northwestern Kuala Lumpur, Malaysia with longitude of 101.62275 and the latitude of 3.16247.	Vegetation coverage in medium -rate	Medium density	This kampung Most surrounded with tradition houses	

Figure 3.3: Environmental analysis of three study areas with criteria of selection Source: Author & Google Earth

(a) SITE A: Kampung Sungai Penchala

Kampung Sungai Penchala is a small Malay village as traditional village, which is gazzated in the Malaya reserved area. It is located in northwest of KL with a longitude of 101.62275 and the latitude of 3.16247 in the Segambut constituency which display in Figure 3.5 (Google, 2018). This village has developed rapidly in the past 10 years, and traditional houses have been replaced with new buildings. Kampung Sungai Penchala is one of the most developed Kampungs in KL. Figure 3.4 illustrates two perspective view of Kampung Sungai Penchala. The first field measurements have been carried on in this place.

Figure 3.4: Two perspective views of Kampung Sungai Penchala
Source: Author

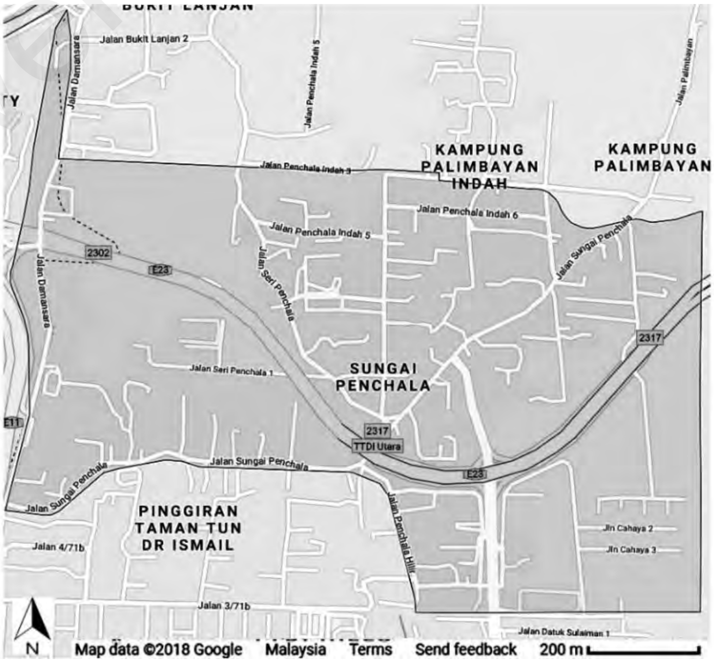


Figure 3.5: Map of the case study area of Kampung Sungai Penchala
Source: Author & Google map

(b) SITE B: Kampung Melayu Kepong

Kampung Melayu Kepong geographically with longitude of 101.6388 east and latitude of 3.22898 north is located in KL as displayed in Figure 3.7 (Google, 2018). Two perspective views of Kampung Melayu Kepong show in Figure 3.6. This kampung is a traditional village, which is not gazzated and it is part of the Malaya reservation area (MRAs), which was created under the Land Enactment in 1987 and the Malay Reservation Enactment in 1913.

Figure 3.6: Two perspective views of Kampung Melayu Kepong
Source: Author

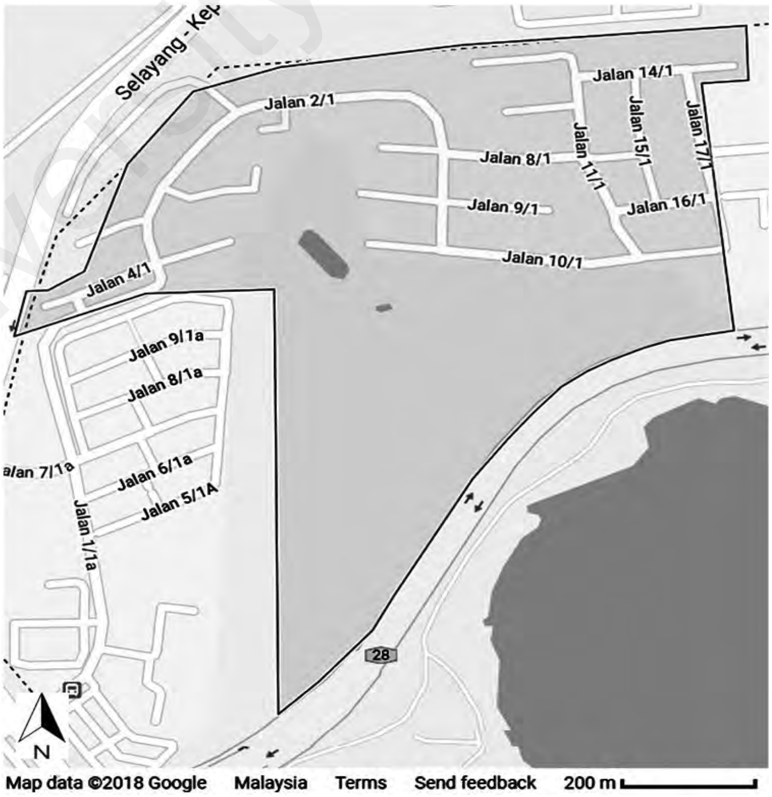


Figure 3.7: Map of the case study area of Kampung Melayu Kepong
Source: Author & Google map

(c) SITE C: Kampung Baru

Kampung Baru is a preserved area in the Malaya reserved area, which is shown the perspective view of the villages in Figure 3.8, is known as a Malay agricultural settlement that allows the Malay people to maintain their village lifestyle in the heart of KL city, (Colonial British Administrators, 1900) with the latitude of 3.16495 and a longitude of 101.71222 as illustrated in Figure 3.9 (Google, 2018). It is a kind of village with the most populated settlement areas with Malay and Javanese population. Kampung Baru has not been developed and modernized so much. It is a political symbol of Malay culture. This village is under tradition village's type, which is gazzated.

Figure 3.8: Two perspective views of Kampung Baru
Source: Author

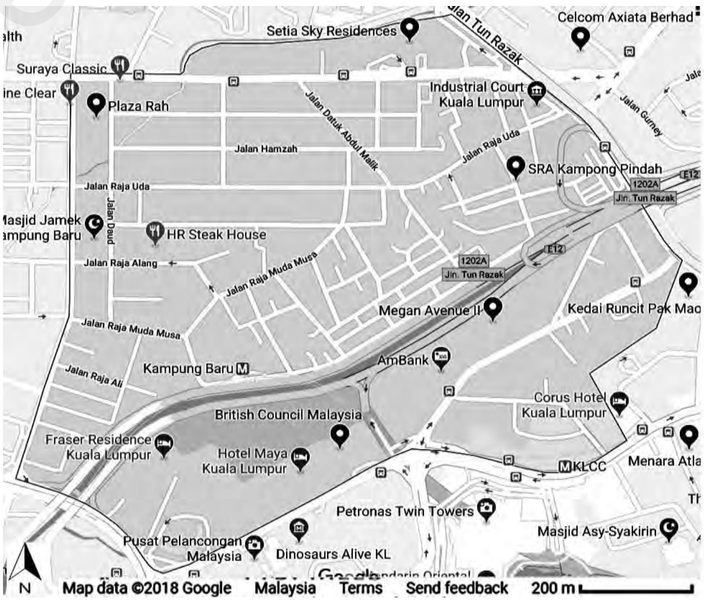


Figure 3.9: Map of the case study area of Kampung Baru
Source: Author & Google map

3.4 Research Design and Framework

The research framework of this study, shown in Figure 3.10, consists of three phases: field observation; field measurement; and the statistical model. Field observations provide accurate information about open spaces of the city according to the surface conditions, shadow levels, and sky vision effects through shooting. Besides, field observation helps to improve research for evaluation of the thermal comfort at open spaces in urban villages. Then Field measurement started after the observation from the site. Therefore, run the data for analysis through Rayman and ENVI-met simulation.

These collected data were entered into Rayman (Matzarakis et al., 2007) at the next step to assess the PET based on the SVF that taken by fish eye lens from the center points of each study areas and microclimate variables. Then with simulating the urban villages the ENVI-met evaluate the thermal performance characteristics of each study areas were analyzed according to the location, orientation, dimensions and albedo of wall enclosures, and presence of greeneries and those parameters that measured for this research. In this study, the outdoor thermal comfort of the points is compared and discussed. Then, the collected data must be classified and analyzed by Rayman and statistical analysis to present and discuss the results. Thermal comfort and thermal discomfort are able to determine by evaluating the microclimatic parameters through weather equipment to show the most influential factor of thermal comfort in outdoor urban areas. Therefore, the urban village project of micro cultural simulation is used to simulate environmental factors and microclimate parameters for evaluating the comfort of outdoor heat in three types of urban villages with different characteristics.

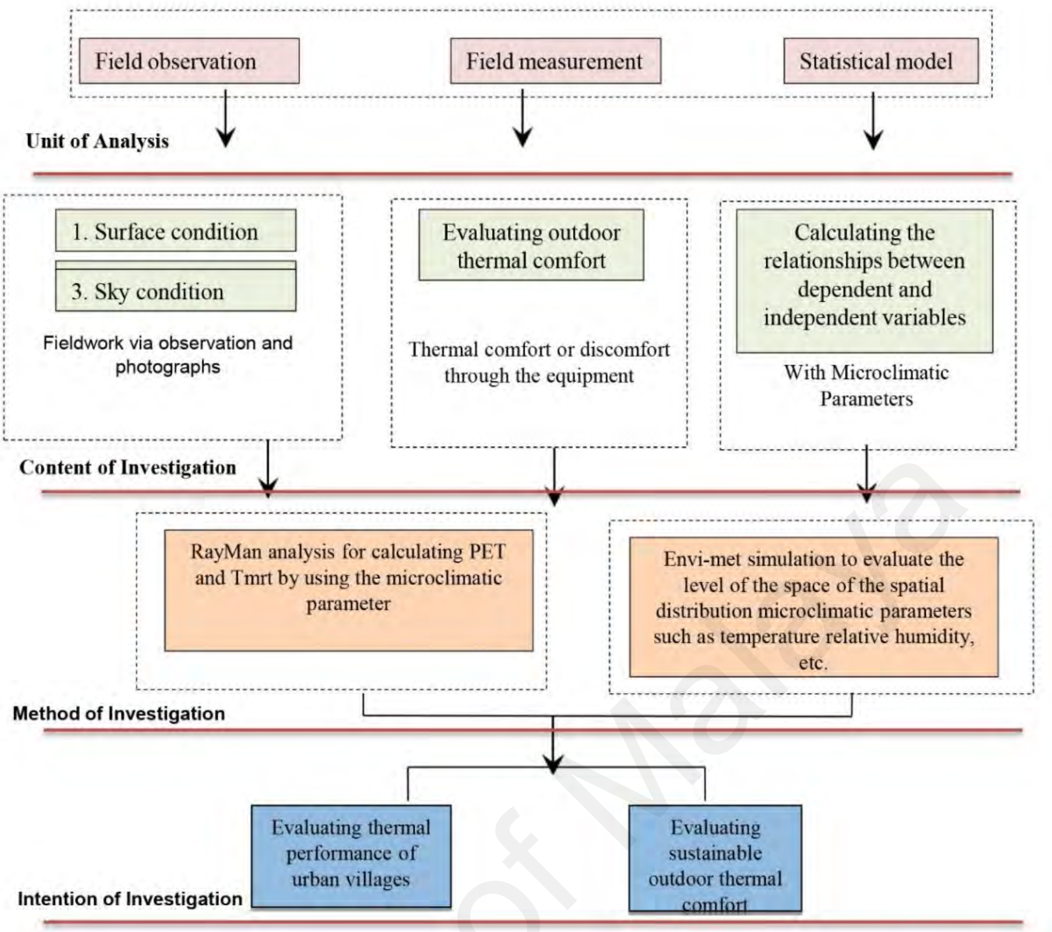


Figure 3.10: Research framework of this study
Source: Author

3.4.1 Physiological Approach of Outdoor Thermal Comfort

In this section, the main argument is that how the microclimatic conditions of the urban spaces determine their comfort conditions and influence the usage of urban outdoor spaces. In addition, the assessment of outdoor thermal comfort would be quite an essential issue to evaluate the quality of urban open public spaces. This physiological approach focuses on the context of outdoor thermal comfort and its relationship with activities and the usage of urban open spaces. The outdoor microclimate in the open spaces of the city is influenced simultaneously by the local climate condition and the urban design, which determines the quality of the open spaces for pedestrian and activities. Previous researches in the field of urban climatology have shown that different urban morphologies would form different microclimate in terms of changing wind condition and providing shade (Blocken & Carmeliet, 2004; Golany, 1996; Johansson & Emmanuel, 2006); building skins and colors would affect the ambient thermal environment as well due to the absorbability and reflection of solar radiation. Therefore, an appropriate urban design would be necessary to provide an attractive open space with relatively comfortable microclimate, and promoting the attendance of pedestrian and activities occur, accordingly.

The microclimatic conditions are complex combinations of several meteorological parameters including the air temperature, wind velocity, humidity, and radiation, which have large spatial and temporal variations (Thorsson, Honjo, Lindberg, Eliasson, & Lim, 2007). Outdoor thermal comfort, which defined as *'that condition of mind which expresses satisfaction with the thermal environment'* (Fountain, Arens, Xu, Bauman, & Oguru, 1999), is developed to characterize these microclimatic conditions, and predict the human comfort resulted from the thermal environment (Fanger, 1970). There're six typical parameters which have been initially examined by Fanger (1970), including air temperature (*Ta*), vapor pressure air velocity (*vw*), solar and thermal radiation, metabolic heat (*M*), clothing insulation (*cl*). Thermal comfort models range from one-dimensional, simple, steady-state simulations to complex transient, finite element codes with thousands of nodes (Jones, 2002). Most of the well-validated models refer to the heat balance models (Fanger, 1970; Gagge, Stolwijk, & Hardy, 1967), which views the person as a passive recipient, and assumes the effects of a given environment would be mediated exclusively by the physics of heat-mass exchanges between body and environment (Brager & De Dear, 1998). These models are developed from indoor steady-state laboratory studies (Givoni et al., 2003; Höppe, 2002; Huizenga, Hui, & Arens, 2001), and would not always be appropriate for outdoor condition, since the human body may not reach equilibrium due to the time of exposure.

The PMV (Fanger, 1970) is one of the widely used indices, used to predict the mean thermal response of a large population under a certain climate condition. It is usually measured on a seven-point integral scale from -3 to +3 (-3 = cold, -2 = cool, -1 = slightly cool, 0 = neutral, +1 = slightly warm, +2 = warm, +3 = hot), and could be interpreted by the corresponding Predicted Percentage Dissatisfied Index (PPD), which represents the percentage of thermally dissatisfied people at each PMV value. Another well-known steady-state model is the Munich Energy-balance Model for Individuals (MEMI) (Höppe, 1984; Höppe, 1994), which is the calculative basis of the physiological equivalent temperature (PET). The MEMI model is based on the energy-balance equation of human body as well and some of the parameters of the Gagge two-node model (Gagge, Stolwijk, & Nishi, 1972; Höppe, 1999). It is defined as a physiological equivalent temperature of any given place, equal to the air temperature of a typical indoor setting assuming constant clothing level of 0.9 and metabolic heat production of 80 W/m2, where the same heat balance of human body with skin and core temperature has been reached (Höppe, 1999). Both indoor and outdoor conditions could be assessed. For outdoor scenarios, PET has been officially used by the German Meteorological Service and widely applied by researcher in various climate conditions (Katzschner, Bosch, & Röttgen, 2006; Lin, 2009; Matzarakis, Mayer, & Iziomon, 1999; Ng & Cheng, 2012; Thorsson, Lindberg, Eliasson, & Holmer, 2007), as it could simplify the complex outdoor scenarios, translating into an easily comprehensible and comparable temperature value.

In accordance with the guideline 3787 of the German Association of Engineers (VDI, 1998), in which documented the methodology and parameters involved in the PET model, a PC software "Rayman" for calculating PET and other indices has been developed (Matzarakis, Rutz, & Mayer, 2007). In practices, PET values could be computed using Rayman, with certain parameters including air temperature, vapor pressure, air relative humidity, wind velocity, cloud cover, global radiation, mean radiation temperature, clothing and activity and other date and location information, et al. Among all the factors influencing the human activities and usage of urban open spaces, outdoor thermal comfort is a main and important one, since the amount and intensity of outdoor activities are highly related with the level of discomfort perceived by people when they are directly exposed to the ambient environment of the outdoor places (Givoni et al., 2003; Nikolopoulou et al., 2001). On the contrary with indoor conditions, inhabitants in outdoor spaces would experience a more dynamic environmental situation (Höppe, 2002)in terms of variations of air temperature, solar radiation, humidity, wind speed and direction and other characteristics like clothes and level of activity et al. People's thermal sensation would directly impact their decisions of behaviors in the open spaces, stay or leave, sit or walk for longer or shorter, attend frequently or never. Thus, outdoor thermal comfort acts a vital role to affect the outdoor activities of people and usage of urban spaces, thereby determining the vitality of the urban area, which happens to be the essential goal in the field of urban planning and design.

3.4.2 Evaluating Outdoor Thermal Comfort

In the thermal comfort evaluation from the energy fluxes between the atmosphere and the body, versatile thermal indices is improved such as effective temperature (ET), predicted mean vote (PMV) (Fanger, 1970; Hwang et al., 2011; Makaremi et al., 2012), and standard effective temperature (SET) for internal use (Gagge et al., 1986; Lin et al., 2010; Makaremi et al., 2012) and OUT_SET (Pickup & de Dear, 2000; Spagnolo & De Dear, 2003) and physiologically equivalent temperature (PET) (Höppe, 1999; Makaremi et al., 2012) for external use, which the process of estimating the PET shows in Figure 3.11. Recent studies identify PET as the most suitable choice for assessing the thermal comfort conditions of an outdoor environment (Höppe, 1999; Makaremi et al., 2012). This is due to the consideration of the interrelation between the human body's energy balance and short- and long- wave radiation (Lin et al., 2010).

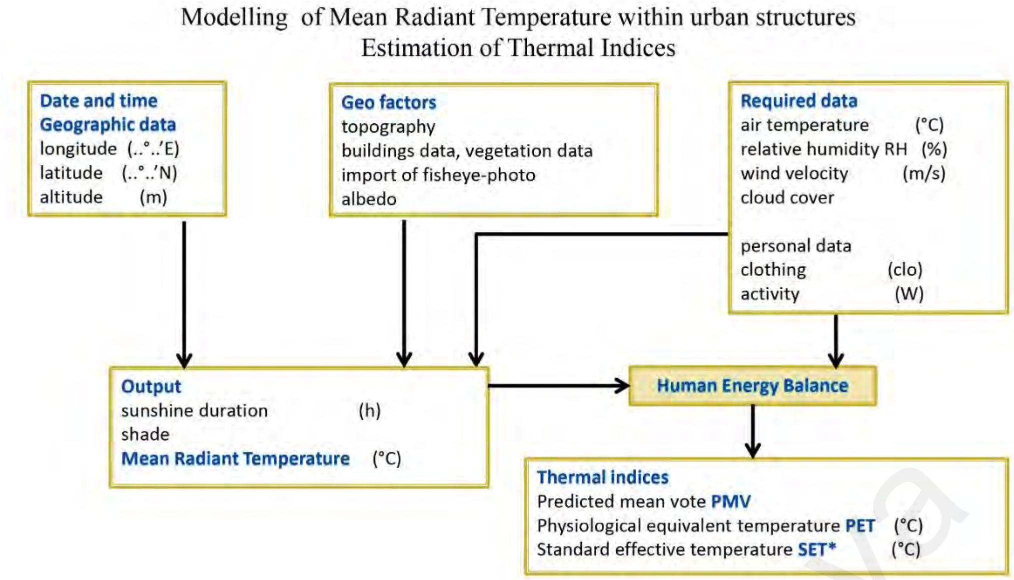


Figure 3.11: Rayman analysis procedure
Source: Höppe, 1999; Makaremi et al., 2012

PET is the physiological equivalent temperature at any spaces such as indoors or outdoors. It is same as the air temperature in a usual indoor space (v ¼ 0.1 m/s, water vapor pressure ¼ 12 hPa and Tmrt ¼ Ta). The human bodies' heat balance is maintained with the skin and core temperatures same as those under the situations that being measured (Makaremi et al., 2012). This way PET enables a layperson to compare the integral effects of complex thermal conditions outside of the experience indoors (Höppe, 1999). In the current study, PET is used as key thermal comfort index since it has been used in various research of outdoor thermal comfort (Oliveira & Andrade, 2007; Thorsson, Lindberg, et al., 2007). PET is also involved in setting standard 3787 of the German Association of Engineers (VDI) (1998). Additionally, the PET's thermal comfort standards are changed and implemented the operation for various climate areas (Lin & Matzarakis, 2008; Matzarakis & Mayer, 1996). On the other hand, PET can be evaluated by the Rayman Model, which is used in urban built-up spaces and can predict thermal comfort in outdoor spaces (Gulyás, Unger, & Matzarakis, 2006; Matzarakis et al., 2007).

Ali-Toudert and Mayer (2006; 2007) used ENVI-met model to simulate modifications in the microclimate in Ghardaia, Algeria. The findings showed that the PET's spatial distribution at the street is strongly based on the urban streets' H/W ratio (Makaremi et al., 2012). Emmanuel & Johansson (2006) carried out field study during spring at five locations in Colombo, Sri Lanka. They used Rayman Model to assess Tmrt and PET and results showed that deep street canyons enhance the outdoor thermal comfort of pedestrians (Lin et al., 2010). Lin et al. (2010) carried out several field studies in hot and humid tropical regions such as at a university campus in central Taiwan. They used the Rayman Model to predict long-term thermal comfort by using meteorological data throughout a 10-year period of time. Lin also conducted a field study of the PET's thermal comfort range in Taiwan in 2008. This was also used as the standard to determine the comfort ability of whether a thermal environment (Lin et al., 2010). Although there is some field studies have conducted on outdoor human comfort in hot and humid regions, this is still widely uninvestigated (Makaremi et al., 2012). Therefore, a filed study to measure individuals' thermal comfort (subjective assessment) and to assesse major climatic parameters (objective measurement) seems necessary to measure thermal comfort conditions in the outdoor environment of tropical climates (Makaremi et al., 2012).

Lin et al. (2010) proposed that Tmrt, human clothing, Ta, v, relative humidity (RH), and activity in the model (Hwang et al., 2010) could evaluate the PET. The Tmrt as the key factor in hot condition while calculating PET also could be evaluated through cloud cover (Cd), global radiation (Gr), fisheye photographs, the Bowen ratio of ground surface albedo, and the Linke turbidity (Hwang et al., 2010). The sky view factor (SVF) also can be assessed by the Rayman Model like PET and Tmrt, which is the ratio of free sky spaces to the whole fisheye view at some location (Hwang et al., 2010).

3.5 Method of Research

The research procedure is partitioned into three stages that portray the stream of the whole study. For this subprogram, quantitative approach is used by the successive informative plan of the data, which the after effects of the quantitative investigation will be trailed by information with subsequent interpretation.

Scientific researchers and literature are essential wellsprings of perusing materials. Furthermore, books, sites, articles of daily papers, national and global seminars and conferences, and additionally applicable flyers are the auxiliary wellsprings of perusing materials. Observational examinations completed by different specialists have been additionally investigated in this research in order to reinforce the comprehension of the current improvements.

3.5.1 Data Collection

In this study, the method of data collection was through thermal load meter multifunction data logger of the microclimatic analysis (outdoor) in two different days. The measurement was taken place on August 2016 based on (Aflaki et al., 2017; Elsayed, 2012; Lai, Guo, Hou, Lin, & Chen, 2014; Qaid, Lamit, Ossen, & Shahminan, 2016; Yusuf, Pradhan, & Idrees, 2014) since the weather in the period from June to August as the “hot season”, the field measurement collected in 6 different days (9, 10, 12, 13, 16, and 17) for sampling of field measurements; moreover, each village needed two days of data collection which hereafter in this thesis called day 1, and day 2.

In every study area, two devices were utilized to measure the parameters of the microclimatic atmosphere (temperature, relative humidity, wind speed, wind direction) in every experimental day. The followings are a short description of these devices: a) Thermal load meter multifunction data logger, which is for microclimatic analysis, b) Weather Station.

This measurement equipment was located in three types of urban villages under various environmental conditions with a wide range of air temperature, wind conditions, solar radiation, and humidity. Figure 3.12 to Figure 3.14, shows the location of the weather stations in unshaded and shaded area for Kampung Sungai Penchala, Kampung Melayu Kepong, and Kampung Baru respectively. As it can be seen in following figures, all shaded area locations placed at the left side of figure numbered with “a”, while all the right side photos representing the unshaded areas numbered with “b”.

a. Shaded area b. Unshaded area

Figure 3.12: Weather stations located in Kampung Sungai Penchala
Source: Author

a. Shaded area b. Unshaded area

Figure 3.13: Weather stations located in Kampung Melayu Kepong
Source: Author

a. Shaded area b. Unshaded area

Figure 3.14: Weather stations located in Kampung Baru
Source: Author

The monitored climatic variables such as wind direction and speed, air temperature and humidity, and solar radiation are based on ISO 7726 (ISO, 1998). The measurement procedure was done at two periods of each day of observation for 5 hours (typically from 11:00am to 16:00 pm local time). Figure 3.15 shows two HOBO onset weather stations that were used in this research, which operated with a three-cup anemometer S-WCA-M003 (at approximately 1.9 m height), and two Copper gray-colored globe thermometers S-TMA-M002 (for measuring globe temperatures), also air temperature and humidity probes S-THB-M002 at 1.1 m, and a silicon pyrometer S-LIB-M003 at 1.6 m. Data from all sensors were recorded every 30 minutes and registered at the logger (H21-001).

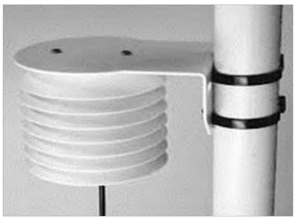
wind speed/Gust & Direction S-WCA-M003	S-THB-M002 Temperature /RH Smart Sensor	Silicon Pyranometer Smart Sensor (S-LIB-M003)
		
It is not suitable for use in the following locations: • on tall buildings • in the wake of wind turbines or other locations with turbulence • in locations with icing combined with high winds	A Temperature/RH Smart Sensor designed for use with HOBO H21 Weather Stations. The Smart sensor has a plug-in modular connector that allows it to be easily added to HOBO Weather Stations.	The Silicon Pyranometer smart sensor is designed to work with the HOBO® Weather Station logger. The smart sensor has a plug-in modular connector that allows it to be added easily to a HOBO Weather Station.
Measurement Range : 0 to 44 m/s (0 to 99 mph)	**Measurement Range:** Temperature: -40°C to +75°C Relative Humidity: 0 to 100%	**Measurement Range:** 0 to 1280 W/m
Accuracy: ± 0.5 m/s (± 1.1 mph) ± 3% 17 to 30 m/s (38 to 67 mph) ± 4% 30 to 44 m/s (67 to 99 mph)	**Accuracy**: Temp: 0.2°C over 0° to 50°C: RH: +/- 2.5% from 10% to 90% RH (typical), to a maximum of +/- 3.5%.	**Accuracy:** Typically within ± 10 W/m2 or ± 5%, whichever is greater in sunlight; Additional temperature induced error ± 0.38 W/m2/°C from +25°C (0.21 W/m2/°F from +77°F)

Figure 3.15: Davis Vantage Pro2 Weather Station variables (air temperature and humidity, wind speed and direction and solar radiation)
Source: ISO, 1998

3.5.2 Microclimatic Equipment

The data collection method used in this study was thermal load meter multifunction data logger, weather station for micro calibration analysis of the environmental parameters. The environmental monitoring concentrates on calculating the four classical thermal parameters such as wind speed (V); relative humidity (RH); air temperature (Ta); solar radiation (S) and globe temperature (Tg), which are known for their effects on the thermal sensation. Moreover, simultaneously, the following measurements were taken using two more devices for surface temperature and thermal image by: a) FLUKE has built the 59 MAX infrared thermometer determine the temperature distribution of various surfaces and design with stand a 1 meter drop. , b) FLIR Systems' is type of camera to demonstrate the thermal image as show in Figure 3.16, were collected in three different types of urban villages in different environmental conditions in two different days.

Figure 3.16: Descriptions of the equipment used in this study
Source: Author

A set of manageable instruments used to assist monitoring of the situations (Nikolopoulou & Lykoudis, 2006) (Nikolopoulou & Steemers, 2003). A comprehensible similar probe was used to measure air humidity and temperature covered with a radiation screen to achieve perfect measurement of outdoor air temperature and solar radiation. To measure wind speed with a Squirrel 1001 gauge and a compact solid-state transmitter at the weather station, a low wind power meter was used.

3.5.3 Field Measurements

This study illustrates the current status of the functional spaces embodied in urban villages and envisages their future directions. During the quantitative phase of the research, the study attempts to identify the correlation level values as independent variables, and the quality of the living environments as dependent variable of the study. Likewise, field measurements and parametric simulations (Rayman Model software) were conducted. Parametric simulations for analyzing the thermal/energy effects of the environmental values of the functional spaces of kampungs were conducted in the selected urban villages in KL.

3.5.4 Rayman Model Analysis

In the current study, the PET was used as a suitable thermal indicator in order to explore the thermal performance of the chosen outdoor spaces. The Rayman Model is used to evaluate PET (Matzarakis et al., 2007). This model is used in urban built-up areas studies to anticipate thermal comfort in outdoor spaces (Jusuf et al., 2006; Muhaisen & Gadi, 2006). PET can also evaluate relative humidity, Tmrt, temperature, wind speed, human activity, and clothing in the model with ease. The Rayman Model is also used to calculate the ratio of free sky spaces to the whole fisheye view at some location that is known as the SVF. Therefore, PET agrees with thermal comfort range values, which is between 22°C and 34°C, whereas a relatively wider "acceptable range" is for neutral, slightly cool, and slightly warm Table 3.1.

Table 3.1: Thermal Perceptions Classification (TPC) for Temperate Region and (sub) Tropical Region. Source: a) (Lin & Matzarakis, 2008), b) (Matzarakis & Mayer, 1996)

Thermal perception	TPC (sub) tropical Region [a] (°C PET)	TPC for temperate Region [b] (°C PET)	Sensation of human
Very cold	<14	<4	
Cold	14-18	4-8	Much too cool
Cool	18-22	8-13	Too cool
Slightly cool	22-26	13-18	Comfortably cool
Neutral	26-30	18-23	comfortable
Slightly warm	30-34	23-29	Comfortably warm
Warm	34-38	29-35	Too warm
Hot	38-42	35-41	Much too warm
Very hot	<42	<41	

3.5.5 Estimating Sky View Factors of a Person with Fish Eye Lens Photographs

The sky view factor (SVF or ψs) is a dimensionless parameter with values between zero and one. It represents the fraction of visible sky on a hemisphere, which lays centered over the analyzed location (Oke 1981). Different sky view factors mean different radiation budgets and accordingly different energy budgets: On a point with a SVF of 1 (the complete sky is visible) under clear sky conditions neither reflected short-wave radiation, nor additional long-wave radiation is received.

In this research, SVF was calculated using. As shown in Figure 3.17, in radiation exchange studies, fish-eye lens photographs is utilized to show the hemispheric radiating area in the urban situation. Watson and Johnson (1988) proposed fish-eye lens technique in New South Wales, Australia. The fish-eye lens photographs assist urban designers to evaluate radiating levels that influence human thermal comfort. This technique shows a view factor of person in a radiating field. A person's view-factor can be defined as the radiant flux fraction that strikes a person from a certain surface to that which would be received from the whole situation radiating consistently (Chalfoun, 2014).

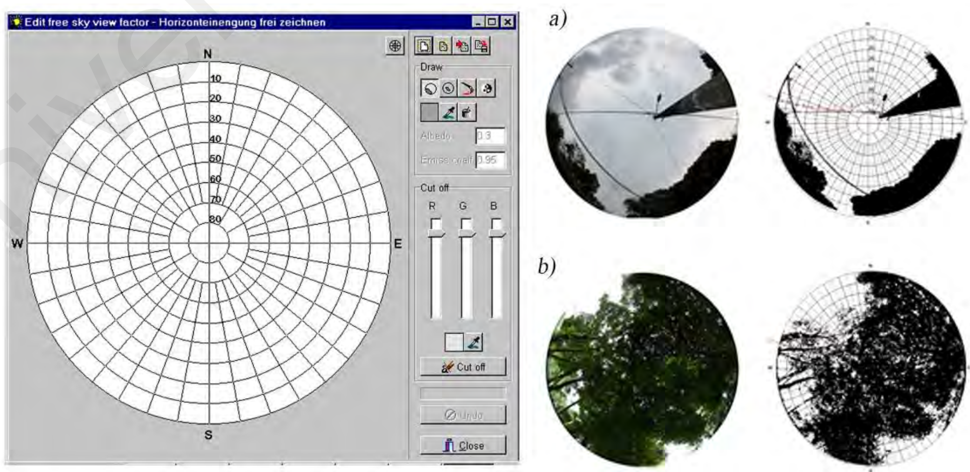


Figure 3.17: Process of getting sky view factor through Rayman
Source: Matzarakis 2010

Fish-eye lens photographing is a simple technique that shows which view factors should be assessed for a person at positions nearby building geometry. It is very complex and contains multiple radiating surfaces. This technique covered a polar graph with a specific part of a person's view factors (Chalfoun, 2014).

3.5.5.1 Sky View Factor of KSP

The visibility of the sky in two selected areas taken with fish-eye lens technique photo, with its polar diagram are illustrated in Figure 3.18. Comparison of the fieldwork through the weather stations was taken under the two different SVF with a number of 0.720 for the unshaded area, and 0.144 for the shaded area.

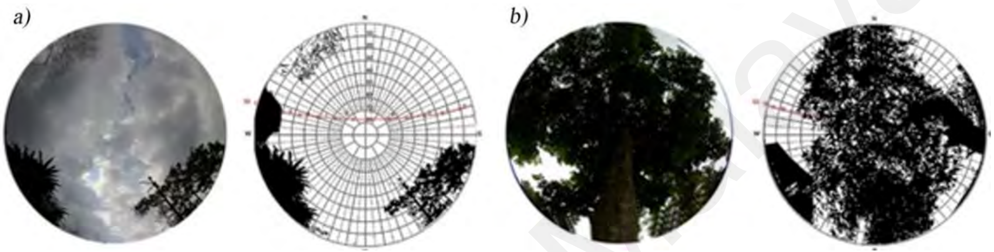


Figure 3.18: Sky view factor and polar diagram: a) Sky view factor: 0.720 b) Sky view factor: 0.144
Source: Author

3.5.5.2 Sky View Factor of KB

In Kampung Baru, the comparison of field measurement was via weatherstation under two different levels of SVF with a number of 0.598 for the unshaded area and 0.14 for the shaded area, as shown in Figure 3.19. The photos were taken with fish-eye technique as decribed previously, carried on with its polar diagram.

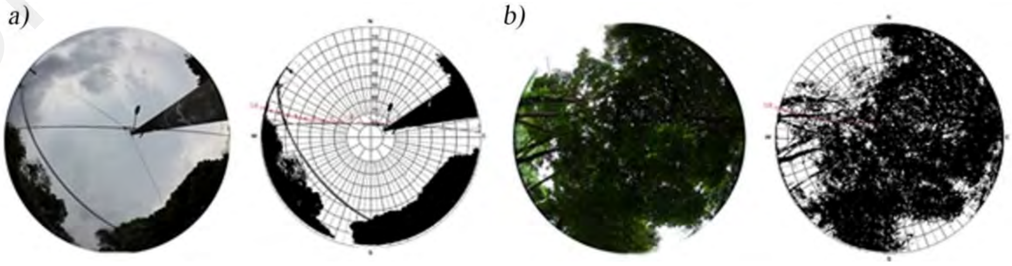


Figure 3.19: Sky view factor and polar diagram: a) Sky view factor: 0.598 b) Sky view factor: 0.14
Source: Author

3.5.5.3 Sky View Factor of KMK

As it can be seen in Figure 3.20, the sky view factor in Kampung Melayu Kepong, for unshaded (a), and shaded (b) area has been taken, used the fish-eye lens technique for two different sky view factor (SVF) in the selected areas with a number of 0.598 for the unshaded area and 0.14 for the shaded area respectively as indicated in the following figure.

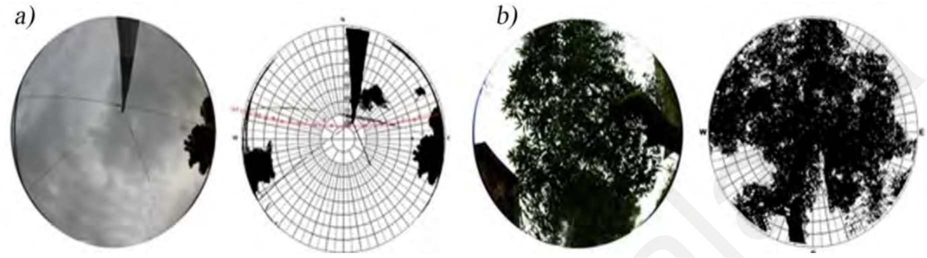


Figure 3.20: Sky view factor and polar diagram: a) Sky view factor: 0.598 b) Sky view factor: 0.14
Source: Author

3.5.6 ENVI-met Simulation

A climatic modeling software innovation named ENVI-met (Bruse & Team, 2012), which is enhanced by Michael Bruse (Huttner & Bruse, 2009) form the Bochum University, Germany (Bruse, 1999; Ozkeresteci, Crewe, Brazel, & Bruse, 2003) is adopted and used in this study to improve our understanding of the urban environment and make the high accuracy of the results. Moreover, this software can suggest a method for having a better environment in future. Some ENVI-met fundamental design features as a simulation program include the following:

(a) It simulates the entire coupled climate system such as thermodynamics, fluid mechanics, and pollutant dispersion.

(b) It uses state of the art computational techniques and offered high-resolution model determining single buildings.

(c) It is a simulation of surface-vegetation-atmosphere procedures contains photosynthesis rate, and friendly user interface and output/input data handling.

(d) Easy to use interface and input/output data handling (Ozkeresteci et al., 2003).

This modeling program has four user interfaces. It edits input of prepared digital maps of the domain outline. Therefore, anyone has to produce data herself/himself in ENVI-met's own cartographic format or has to produce standard data from other geographic knowledge systems. It can be relatively complicated and complex depends on the environmental domain. The feature of high-resolution of the program allows the user to see the details in smaller scales (0.5 m) or to be coarser in lower scales for example, 10 meters in a neighborhood.

The ENVI-met modeling program employs its own configuration editor for the climatic information plus the soils, plants, and sources databases and its own graphic interface to plot the outline of the environment. Consequently, all cartographic data should be collected first on a digital map and next redrawn in own graphics editor of ENVI-met for the modeling language. This information (buildings, soils, plants, surface materials) are applied as generic forms for the first stage, so a comparative matching to the closest similarities are chosen as for plant, soil and building features.

The outputs will be fundamental 3D information on surface, soils, atmosphere, and fluxes. Whilst the first phase of the model was to accurately model the context, second phase included changing certain variables to composition such as width, wind direction, plantation, surface character, etc. Figure 3.21 shows how this process is implemented in this modeling study. This editing process is crucial in the practical level and must be undertaken by any user of the ENVI-met model.

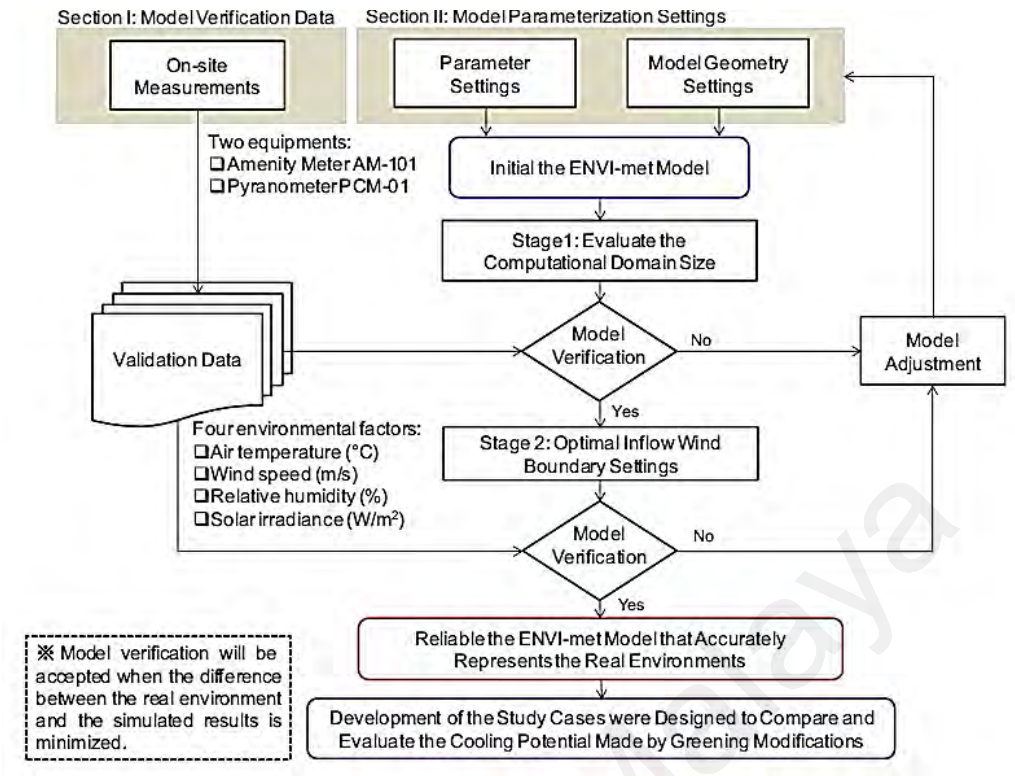


Figure 3.21: Process of achieving a valid ENVI-met model for the outdoor environment, Source: Manat, 2013

The configuration editor is the second interface where data from the temporal input, humidity, soil types, and temperature are inputted. Modeling the area is the third interface while extra parameters are presented. Then, the modeling procedure is started. The output results can be visualized and interpreted in Leonardo (Bruse & Team, 2012) the example of output simulation result it shown in Figure 3.22. Since the modeling program configuration is public, it is possible to edit the collected data in other programs.

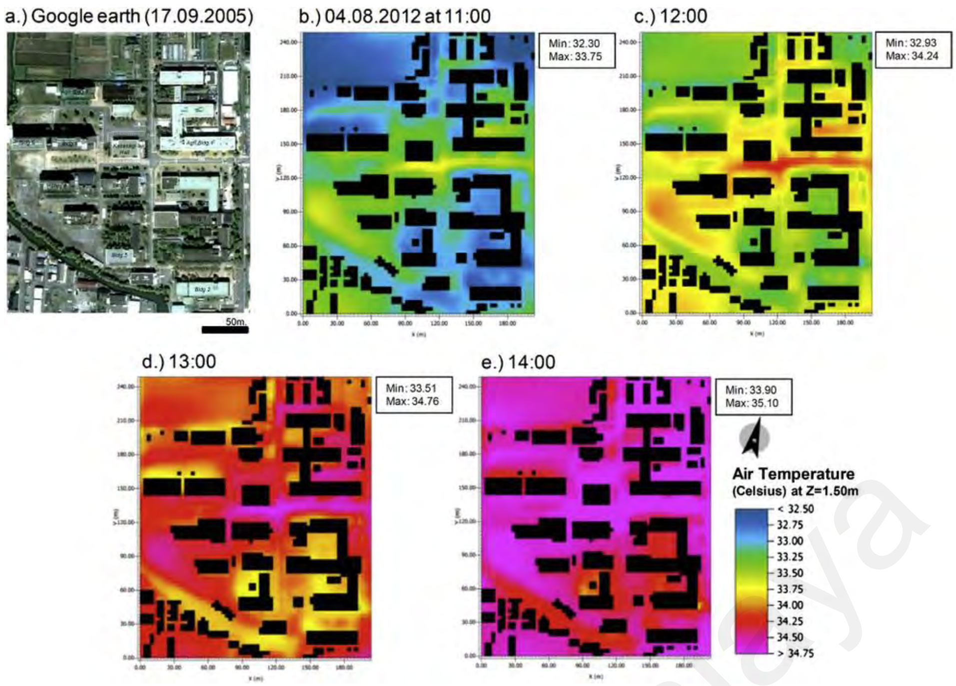


Figure 3.22: Mixed-landscape scenario drawn in ENVI-met
Source: Manat, 2013

3.6 Microclimate Simulation

In this study, the ENVI-met 4.0 standard versions were used in the simulation of urban villages in KL. ENVI-met model simulates the outdoor thermal comfort based on the layout of field measurement and Google Earth pro software. It models the layout of three study areas based on resolution (grid sizes), urban geometry, sun orientation, soil, geographical location vegetation, materials of the construction as it can be seen in Figure 3.23. In this study, the measurement for all kampung has been done for 36 hours, which is six hours per day in every kampung. In another word, every kampung measured for two different days, which in this thesis called day 1 and day 2, and each day of six hours of measurement for 3 different kampungs. The height of the device installed at site was 1.5 meter from the ground surface. The field measurements were conducted in August 2016; however, after all measurements were taken during the specified period, only one day was chosen for each kampung (which was the first day of data collection) for simulation and validation.

The date of measurements has chosen according to the weather condition (rainy or clear sky), and solar radiation between 11:00 am to 16:00 pm. The weather station measured the microclimate variables such as relative humidity, air temperature, wind direction, wind speed, and solar radiation to evaluate the outdoor environment of the selected case study areas.

3.7 Input Modeling of ENVI-met

In the current study, three study areas were modeled by ENVI-met in their actual conditions. The base model of the three-study area (kampungs) are shown in Figure 3.24, 3.25 and 3.26 (Google, 2018). The input data such as building properties, initial temperature, wind speed, and general model setting were also summarized for each kampung. The simulation details and the database, which use for simulation, are listed in the configuration files in Table 3.2, 3.3 and 3.4. The simulations of Kampung Sungai Penchala, Kampung Baru, and Kampung Melayu Kepong were initiated using the obtained data from recorded weather history of Sultan Abdul Aziz Shah-Subang (Sultan Abdul Aziz Shah-Subang, https://www.wunderground.com, Weather History for WMSA - August, 2016), the nearest weatherstation to these study areas.

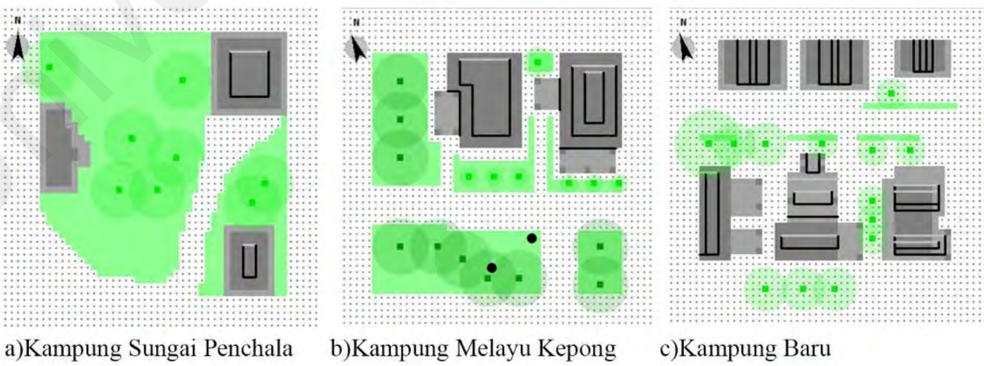


Figure 3.23: Model simulation for Kampung Sungai Penchala (a), Kampung Melayu Kepong (b), and Kamung Baru (c)
Source: Author

3.8 Model Evaluation

In this research, after evaluating the metrological variable through the devices, and taking into account the analysis of the collected data, it is necessary to create a high level of accuracy by evaluating R-squared. R2, or in another word known as the coefficient of determination is a statistical measure of how close the data are to the fitted regression line. In this study, R-squared used to validate one of the most important variable measured in this research, which is the temperature. Since temperature is one of the most important and effective environmental parameters to evaluate the performance of thermal comfort in selected kampung as case study areas, the fittnes of the data obtain from field measurement has evaluated with coefficient of determination line (De & Mukherjee, 2017; Qaid, Lamit, Ossen, and Shahminan, 2016; Rosso et al., 2018). However, for a perfect correlation, the coefficient of determination R-squared index of agreement (d) and Nash-Sutcliffe coefficient of efficiency (E) values should be close to 1 (Willmott, 1982; Willmott et al., 1985).

3.8.1 Site Representation of Study Areas: 2D ENVI-met Map, Google Satellite Image, and Surrounding Views

(a) Kampung Sungai Penchala

Figure 3.24: The detailed representation of the studied urban village in 2D view and perspectives, Source: Author & Google map

Table 3.2: ENVI-met parameters as specified in the configuration file ENVI-met simulations input parameters. Source: Author

<u>KAMPUNG SUNGAI PENCAHALA</u>

LOCATION	Kuala Lumpur, Malaysia (latitude 3.16247 N and longitude 101.62275 E)	
SIMULATION DAY	9th August 2016	
SIMULATION DURATION	12 h, from 6:00am to 6:00 pm	
GRID SIZE	50 x 50 x 25	
<u>SOIL DATA</u>		
INITIAL TEMPERATURE, UPPER LAYER (0-20 CM)	[˚C]	50
INITIAL TEMPERATURE, MIDDLE LAYER (20-50 CM)	[˚C]	60
INITIAL TEMPERATURE, DEEP LAYER (>50 CM)	[˚C]	60
RELATIVE HUMIDITY, UPPER LAYER (0-20 CM)	[%]	88
RELATIVE HUMIDITY, MIDDLE LAYER (20-50 CM)	[%]	90
RELATIVE HUMIDITY, DEEP LAYER (>50 CM)	[%]	93

TABLE 3.2: continued

BUILDING DATA		
INSIDE TEMPERATURE	[˚C]	20
HEAT TRANSMISSION COEFFICIENT OF WALLS	[W/m² K]	1.7
HEAT TRANSMISSION COEFFICIENT OF ROOFS	[W/m² K]	2.2
ALBEDO WALLS		0.36
ALBEDO ROOFS		0.4
METEOROLOGICAL DATA		
WIND SPEED, 10 M ABOVE GROUND	[m/s]	0.4
WIND DIRECTION (0:N, 90:E, 180:S, 270:W)	[deg]	67.15
ROUGHNESS LENGTH	[m]	0.01
INITIAL ATMOSPHERIC TEMPERATURE	[˚C]	29
ABSOLUTE HUMIDITY AT 2500 M	[g/kg]	7
RELATIVE HUMIDITY AT 2 M	[%]	70
CLOUD COVER		0
PHYSIOLOGICAL DATA		
WALKING SPEED	[m/s]	0
MECHANICAL FACTOR	[met]	0
HEAT TRANSFER RESISTANCE CLOTHS	[clo]	0.6

(b) Kampung Melayu Kepong

Figure 3.25: The detailed representation of the studied urban village in 2D view and perspectives, Source: Author & Google map

Table 3.3: ENVI-met parameters as specified in the configuration file ENVI-met simulations input parameters. Source: Author

KAMPUNG MELAYU KEPONG		
LOCATION	Kuala Lumpur, Malaysia (latitude 3.228898 N and longitude 101.6388 E)	
SIMULATION DAY	12th August 2016	
SIMULATION DURATION	12 h, from 6:00am to 18:00 pm	
GRID SIZE	50 x 50 x 25	
SOIL DATA		
INITIAL TEMPERATURE, UPPER LAYER (0-20 CM)	[˚C]	50
INITIAL TEMPERATURE, MIDDLE LAYER (20-50 CM)	[˚C]	60
INITIAL TEMPERATURE, DEEP LAYER (>50 CM)	[˚C]	60
RELATIVE HUMIDITY, UPPER LAYER (0-20 CM)	[%]	88
RELATIVE HUMIDITY, MIDDLE LAYER (20-50 CM)	[%]	90
RELATIVE HUMIDITY, DEEP LAYER (>50 CM)	[%]	93
BUILDING DATA		
INSIDE TEMPERATURE	[˚C]	20
HEAT TRANSMISSION COEFFICIENT OF WALLS	[W/m² K]	1.7
HEAT TRANSMISSION COEFFICIENT OF ROOFS	[W/m² K]	2.2
ALBEDO WALLS		0.36
ALBEDO ROOFS		0.4
METEOROLOGICAL DATA		
WIND SPEED, 10 M ABOVE GROUND	[m/s]	0.9
WIND DIRECTION (0:N, 90:E, 180:S, 270:W)	[deg]	157.5
ROUGHNESS LENGTH	[m]	0.01
INITIAL ATMOSPHERIC TEMPERATURE	[˚C]	28.5
ABSOLUTE HUMIDITY AT 2500 M	[g/kg]	7
RELATIVE HUMIDITY AT 2 M	[%]	70
CLOUD COVER		0
PHYSIOLOGICAL DATA		
WALKING SPEED	[m/s]	0
MECHANICAL FACTOR	[met]	0
HEAT TRANSFER RESISTANCE CLOTHS	[clo]	0.6

(c) Kampung Baru

Figure 3.26: The detailed representation of the studied urban village in 2D view and perspectives. Source: Author & Google map

Table 3.4: ENVI-met parameters as specified in the configuration file ENVI-met simulations input parameters. Source: Author

KAMPUNG BARU		
LOCATION	Kuala Lumpur, Malaysia (latitude 3.16495 N and longitude 101.71222 E)	
SIMULATION DAY	16th August 2016	
SIMULATION DURATION	12 h, from 6:00 am to 18:00 pm	
GRID SIZE	50 x 50 x 25	
SOIL DATA		
INITIAL TEMPERATURE, UPPER LAYER (0-20 CM)	[˚C]	50
INITIAL TEMPERATURE, MIDDLE LAYER (20-50 CM)	[˚C]	60
INITIAL TEMPERATURE, DEEP LAYER (>50 CM)	[˚C]	60
RELATIVE HUMIDITY, UPPER LAYER (0-20 CM)	[%]	88
RELATIVE HUMIDITY, MIDDLE LAYER (20-50 CM)	[%]	90
RELATIVE HUMIDITY, DEEP LAYER (>50 CM)	[%]	93
BUILDING DATA		
INSIDE TEMPERATURE	[˚C]	20
HEAT TRANSMISSION COEFFICIENT OF WALLS	[W/m² K]	1.7

TABLE 3.4: continued

HEAT TRANSMISSION COEFFICIENT OF ROOFS	[W/m² K]	2.2
ALBEDO WALLS		0.36
ALBEDO ROOFS		0.4
METEOROLOGICAL DATA		
WIND SPEED, 10 M ABOVE GROUND	[m/s]	0.6
WIND DIRECTION (0:N, 90:E, 180:S, 270:W)	[deg]	90
ROUGHNESS LENGTH	[m]	0.01
INITIAL ATMOSPHERIC TEMPERATURE	[˚C]	29.5
ABSOLUTE HUMIDITY AT 2500 M	[g/kg]	7
RELATIVE HUMIDITY AT 2 M	[%]	78
CLOUD COVER		0
PHYSIOLOGICAL DATA		
WALKING SPEED	[m/s]	0
MECHANICAL FACTOR	[met]	0
HEAT TRANSFER RESISTANCE CLOTHS	[clo]	0.6

3.9 Conclusion

This chapter looks into the microclimate of outdoor thermal comfort in three different urban villages in Kuala Lumpur (KL) namely Kampung Sungai Penchala, Kampung Melayu Kepong, and Kampung Baru. A preliminary observation of the selected areas has been conducted to perform the field measurements. Then, the attention was drawn to identifying the geographical attributes and climate of KL. In fact, this study considers the geographical attributes, microclimatic weather, the amount of vegetation, level of density, and surrounding environment of the selected urban villages in KL.

This study is a field measurement work on outdoor thermal comfort by utilizing the weather stations to measure the weather in urban villages in KL. After collecting data using weather equipment, microclimatic variables including air temperature, relative humidity, solar radiation, wind speed and wind direction were studied. In addition, this research evaluated meteorological variables, which are influential on the level of thermal comfort. The evaluation of outdoor thermal comfort has been carried out by using Rayman Model and ENVI-met simulation. More details about experimental results and related analysis are reported in Chapter 4.

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

This chapter is the analysis of data collection and visualization of the surrounding area weather stations during the field measurement. It provides reports on the outcomes of data collection from weather stations and field measurement. These reports are developed based on implementing and measuring of temperature of materials and the ground surface, as well as capturing the sky view factor using fish-eye lens device and its calculation through Rayman analysis. These reports are helpful for better understanding of the environment in the selected case study areas.

Section 4.1 introduces the case study areas environmentally and reports the criteria and conditions that are used in this research. Three different experimental sites, the number of days and the field measurements are described in this section. Section 4.2 reports the collected data from two weather stations, surface thermometer, and fish-eye lens devices. In section 4.3 the analysis of the collected data from the devices are reported. At the end, a conclusion of this chapter is provided in Section 4.5.

4.2 Field Measurement Data and Analysis

The following results presented in this section were taken from 11:00 am to 16:00 pm. The microclimatic data were sampled and stored every 10 minutes and observation was taken hourly during the 6 days in the outdoor spaces of urban villages at two different spaces with various aspects. The measurement taken through the fluke thermometer of thermal data and Flir camera for digital image form each surface material was conducted surrounding each device. The data is recorded every 30 minutes during the specified time of field measurement.

4.3 Kampung Sungai Penchala (KSP)

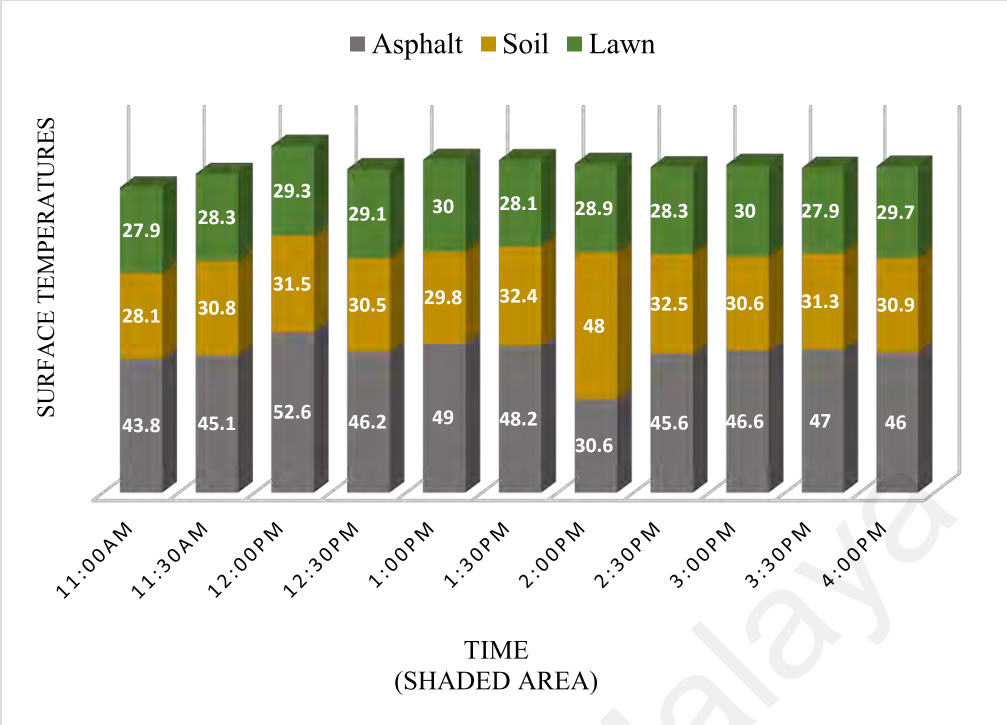
4.3.2 Surface Temperature and Thermal Images in KSP, Day 1

Figure 4.1 and 4.2 shows the surface temperature of the surrounding area of both weather stations and the thermal image of the area. The materials considered in this experiment, located in the shaded area, and unshaded area, were lawn, asphalt, and soil (earth material). The data collection in terms of temperature measurement had carried out from 11:00 am to 16:00 pm at every 30 minutes.

Recorded temperature reports in shaded area for different materials are as follow. The highest recorded temperature in shaded area measured for asphalt material. The highest temperature measured for asphalt was 52.6°C at 12:00 pm, compare to its lowest temperature with 30.6°C at 14:00 pm, while it measured ranged between 43.8°C to 49°C for the rest of the time. In terms of lawn material, the highest temperature recorded at 13:00 pm, and 15:00 pm with 30°C, whereas the lowest measurement was taken at 11:00 am, and 15:30 pm with 27.9°C. The soil (earth material) reached to its maximum temperature at 14:00 pm with 48°C, and the minimum of 28.1°C measured at 11:00 am.

With regard to the unshaded area, the results reported in terms of material temperature measurement as follow. Again, the asphalt hit the highest temperature recorded with 54.5°C at 12:00 pm and dropped to its lowest temperature at 11:00 am with 45.4°C. Another material measured was soil (earth material), and it showed its maximum temperature at 12:00 pm, and minimum temperature at 11:00 am with 48.4°C, and 30.3°C respectively. With regard to the measured temperature for lawn material, the results indicated that the coolest temperature recorded at 11:00 am with 28°C, and the warmest temperature with 32.6°C at 14:00 pm.

The result from shaded and unshaded area shows that the asphalt with 52.6°C, and the lawn with 27.9°C, were the warmest and the coolest material temperature respectively.



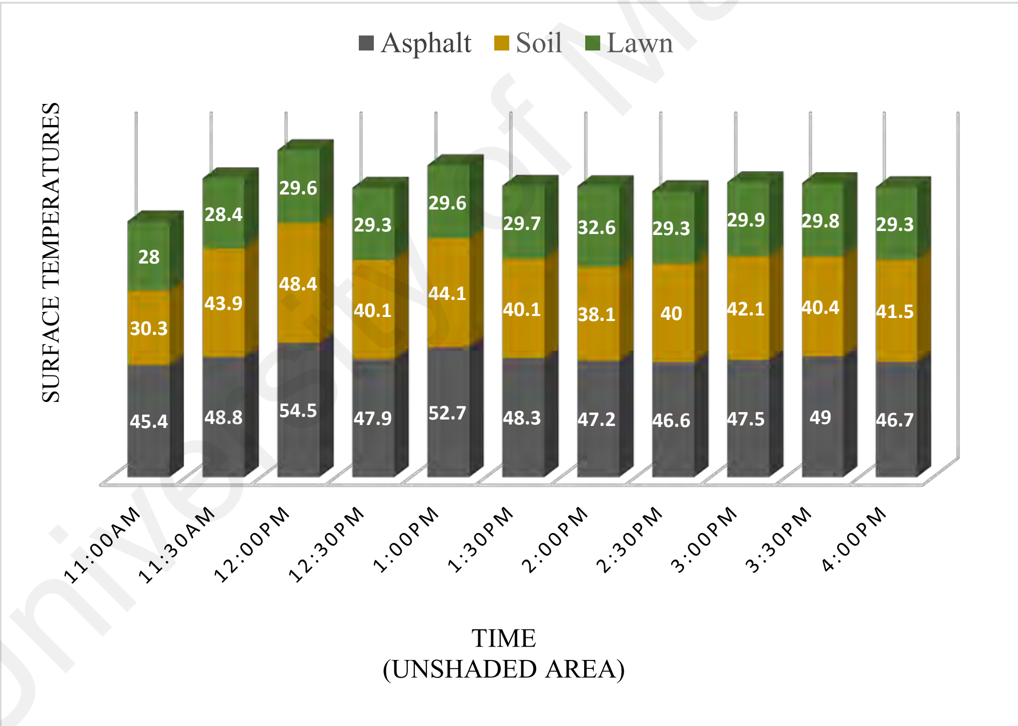


Figure 4.1: Surface temperature with fluke thermometer from 11:00 am to 16:00 pm. Source: Author

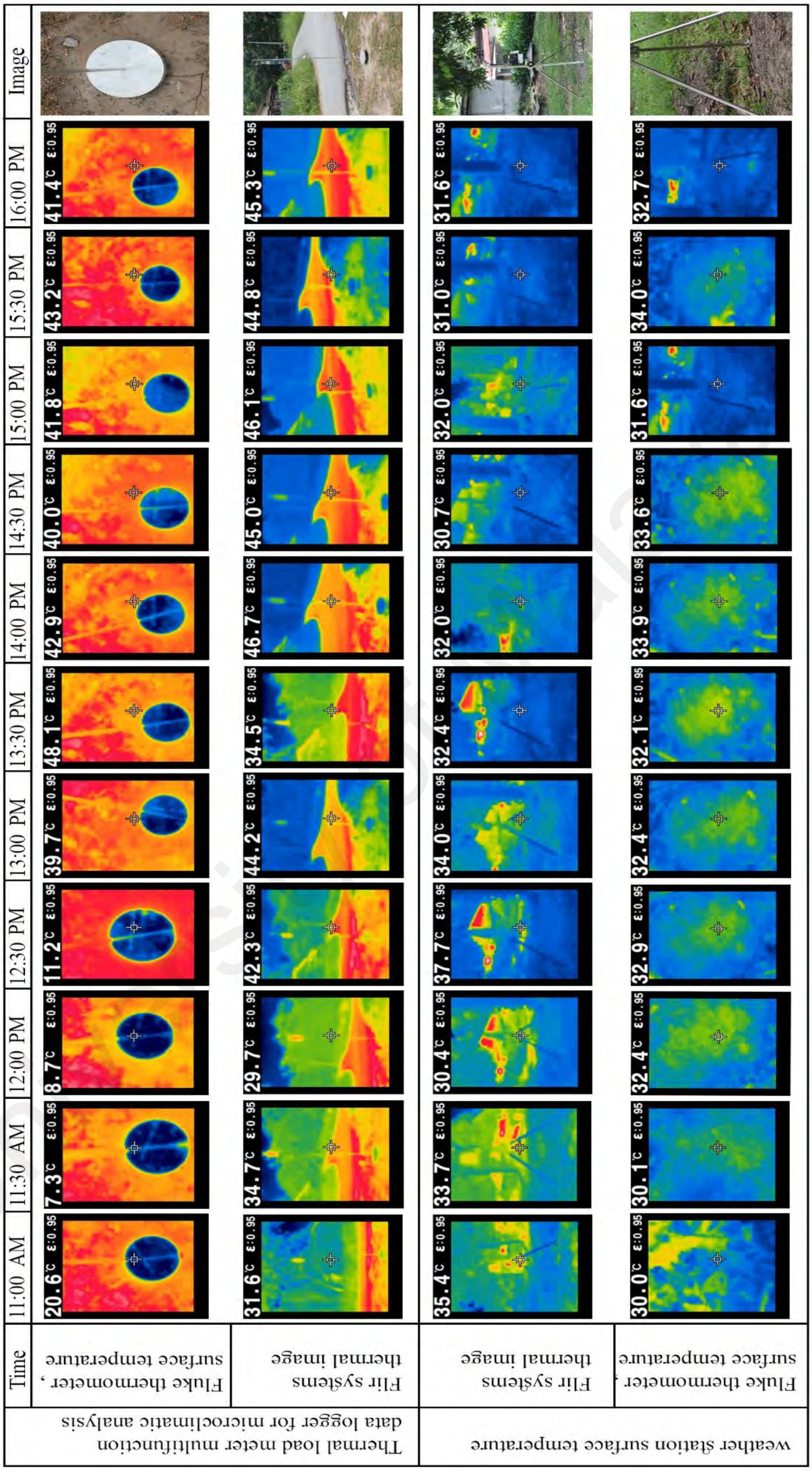


Figure 4.2: Graphs showing the thermal images from 11:00 am to 16:00 pm with surface temperature taken with Flir camera
Source: Author

4.3.3 Weather Station Report at KSP, Day 1 (shaded area)

As it is shown in Figure 4.3, data collection was conducted from 11:00 am to 16:00 pm, and the temperature, relative humidity, visibility of the sky, wind direction, and velocity were measured at the time. This experiment was carried out under the tree, which is considered as a shaded region. As shown in Figure 1.1 in appendices, the sky was generally cloudy throughout the day, except at noon that it was almost sunny. The wind speed was constant throughout the day and recorded as 0.4m/s all the time and blew from the northeast direction of the region. At the beginning of the experimental study, the temperature was 31.6ºC at 11:00 am in the morning, with a minimum temperature, while the last temperature recorded was 32.8ºC at 16:00 pm. Moreover, the maximum temperature recorded in this space was 33.1ºC at 15:00 pm. According to the moisture content, the results shows that the relative humidity of the measured daytime with the recorded value of 61% at 11:00 am and 16:00 pm, and 57% from 13:00 pm to 14:00pm. The relative humidity measured at 12:00 pm, and 15:00 pm with 2% different was 58%, and 60% respectively. The average temperature and relative humidity were 32.53ºC, and 59% respectively. Overall, the human sensation ranged as slightly warm (ranged 30ºC to 34ºC); moreover, some obstacles such as trees, houses, cars, and greeneries were blocking the wind blow, resulting in the warmer temperature in this space.

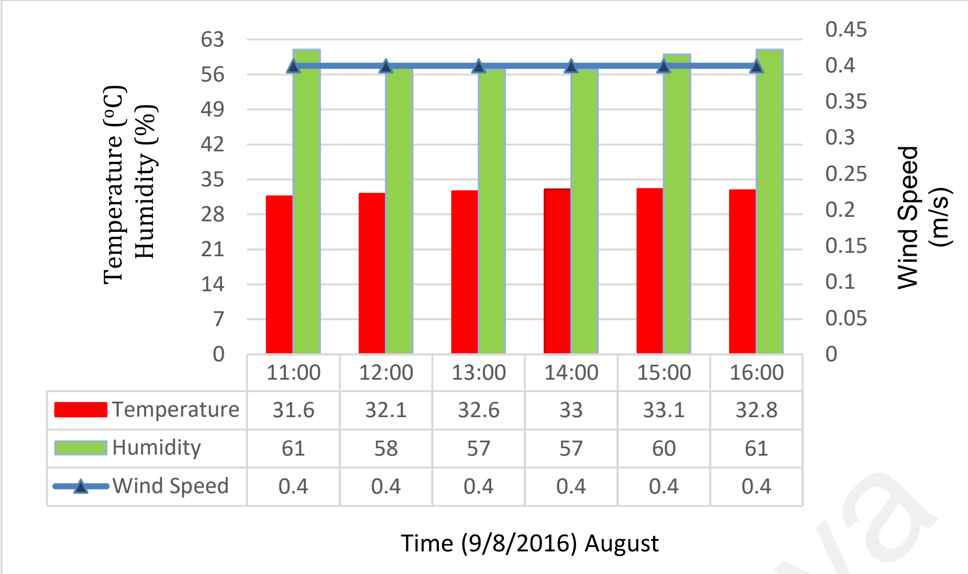


Figure 4.3: Weather station reported data for day1, shaded area in Kampung Sungai Penchala, Source: Author

4.3.4 Weather Station Report at KSP, Day 1 (unshaded area)

In the unshaded area, time, and other variables are shown in Figure 4.4. In the beginning of the experimental study, the temperature was recorded 35°C at 11:00 am, whereas the last measurement at 16:00 pm shows very slight increment in temperature with 36.3°C. In addition, the maximum and minimum temperature recorded were 37.3 °C at 15:00 pm, and 34.3°C respectively. In terms of humidity, the results show that the measured relative humidity initially was 49.1% at 11:00 in the morning and rise marginally to 49.5% at 16:00 in the afternoon. The maximum relative humidity recorded was 55.2% at 15:00 pm, while the minimum percentage was 42.8% at noon. The average temperature and relative humidity obtained were 35.71°C, and 49.7% respectively. The wind blew this space from northeast with an average speed of 1.095m/s. The maximum wind speed measured was 1.82m/s at 14:00 pm, in contrast to a minimum record where the wind speed recorded was 0.51m/s at noon. All in all, the human sensation ranged as warm (ranged 34 °C to 38 °C) in this space due to the lack of shade.

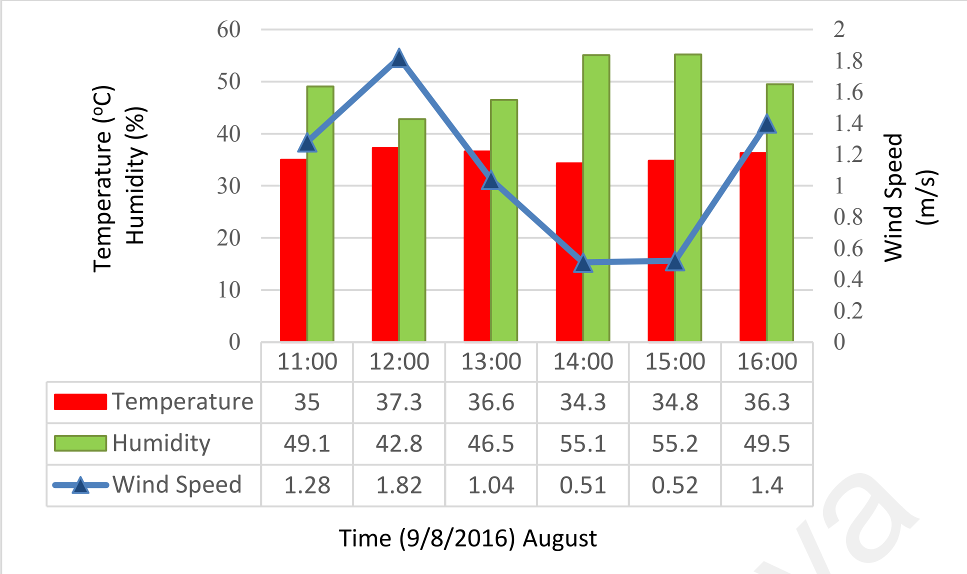


Figure 4.4: Weather station reported data for day1, unshaded area in Kampung Sungai Penchala, Source: Author

4.3.5 Surface Temperature and Thermal Images in KSP, Day 2

Figures 4.6 and 4.7 show the surface temperature of the surrounding areas of both weather stations and the thermal image of the areas. The materials considered in this experiment, located in the shaded area, and unshaded area, were lawn, asphalt, and soil (earth material). The data collection in terms of temperature measurement had carried out from 11:00 am to 16:00 pm at every 30 minutes.

Recorded temperature reports in shaded area for different materials in Kampung Sungai Penchala, day 2, are as follow. As it can be seen from the results, the highest recorded temperature in shaded area measured for asphalt material as same as the day 1. The highest temperature measured for asphalt was 43.9°C at 14:00 pm, compare to its lowest temperature with 37.8°C at 11:00 am, while it measured ranged between 39.7°C to 43.1°C for the rest of the time. In terms of lawn material, the highest temperature recorded at 16:00 pm with 29.7°C, whereas the lowest measurement was taken at 12:30 am with 26.8°C; moreover, for the rest of the time, it measured between 27°C and 29.1°C. The soil (earth material) reached to its maximum temperature at 14:00 pm with 31.8°C, and the minimum of 28.6°C measured at 12:30 pm; furthermore, the temperature measured for the rest of the hours ranged between 29°C to 31.7°C.

Regarding the unshaded area, the results reported in terms of material temperature measurement as follow. Regarding the measured temperature for lawn material, the results show that the coolest temperature recorded at 11:30 am with 29.5°C, and the warmest temperature with 35.4°C at 12:00 pm. Once again, the asphalt hit the highest temperature recorded with 44.9°C at 14:30 pm and dropped to its lowest temperature at 11:00 am with 39.7°C. Another material measured was soil (earth material), and it showed its maximum temperature at 14:30 pm, and minimum temperature at 13:00 pm with 39.8°C, and 34.1°C respectively.

Altogether, the result from shaded and unshaded area shows that the asphalt with 44.9°C, and the lawn with 26.8°C, were the warmest and the coolest material temperature respectively.

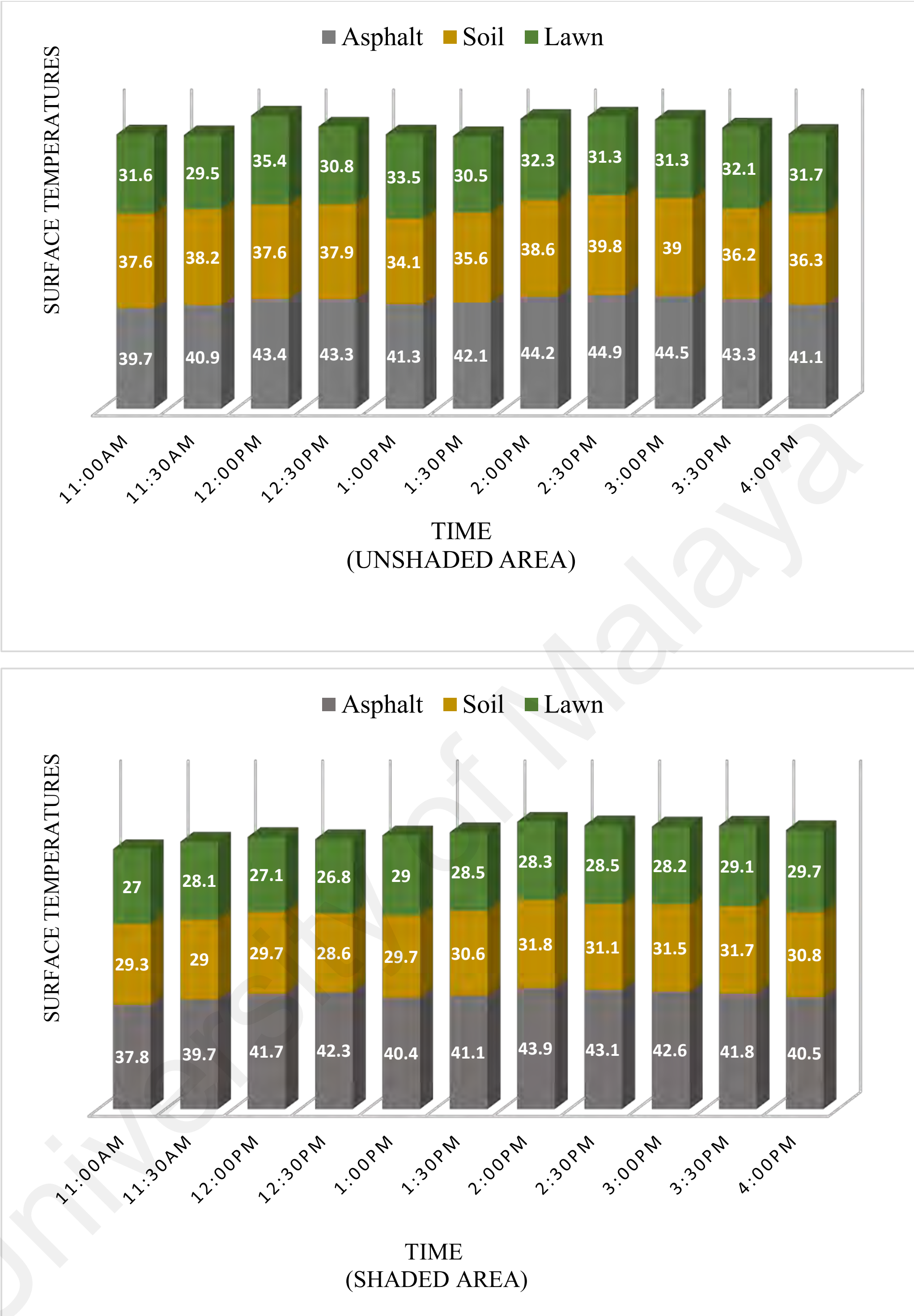


Figure 4.5: Surface temperature with fluke thermometer from 11:00 am to 16:00 pm, Source: Author

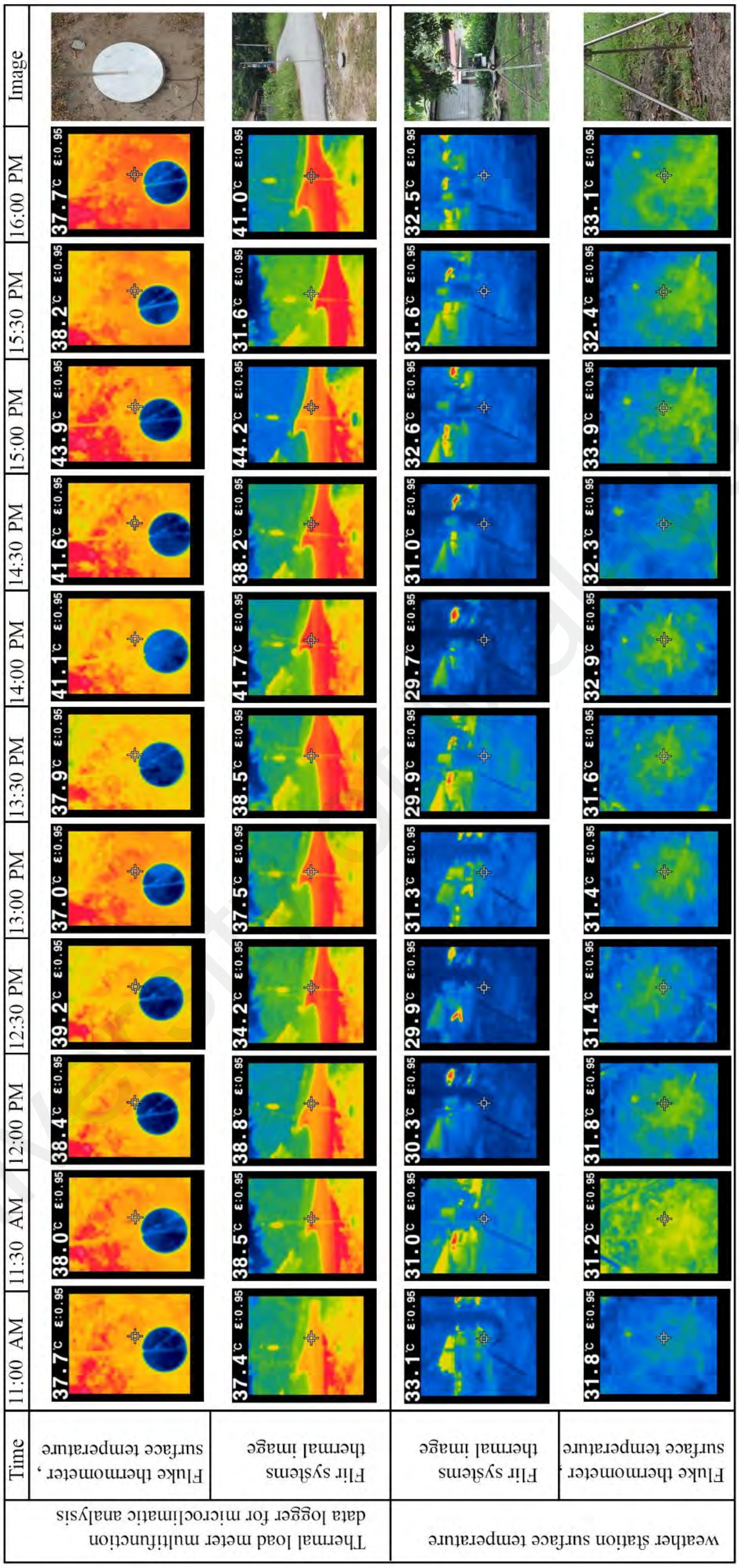


Figure 4.6: Graphs showing the thermal images from 11:00 am to 16:00 pm with surface temperature taken with Flir camera
Source: Author

4.3.6 Weather Station Report at KSP, Day 2 (shaded area)

Figure 4.8, indicated that initially the temperature was recorded 26.2ºC at 11:00 am, which was the minimum temperature; whereas, the measurement from 15:00 pm to 16:00 pm shows that the temperature went up to 31.1ºC, which can be pointed out as the maximum temperature throughout the day. In terms of humidity, the result shows that the measured relative humidity in the very early stage was 78% at 11:00 am in the morning and dropped steeply to 65% at 16:00 in the afternoon. The maximum relative humidity recorded was 78% at 11:00 am, while it is bottomed out with 55% at noon. The average temperature and relative humidity obtained were 29.13ºC, and 67.33% respectively. Wind blew to this space from northeast with average speed of 0.2m/s. The maximum wind speed measured was 0.4m/s, in contrast to a minimum record where the wind speed was 0m/s from 11:00 am to 13:00 pm. All in all, the human sensation ranged as neutral (ranged 26ºC to 30ºC) in this space, in addition, although the greeneries and houses were blocked the wind blow, also it is cleared that the wind speed was negligence, the comfort level has been achieved for inhabitants due to the sky condition and trees' coverage.

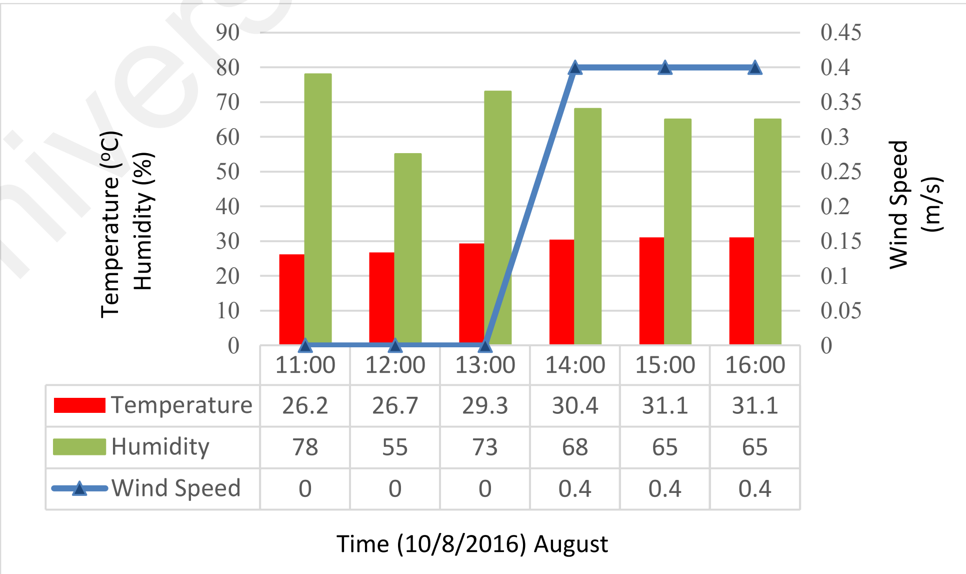


Figure 4.7: Weather station reported data for day2, shaded area in Kampung Sungai Penchala, Source: Author

4.3.7 Weather Station Report at KSP, Day 2 (unshaded area)

As it is clear in Figure 4.9, the data collection was started at 11:00 am until 16:00 pm in the afternoon, and temperature, relative humidity, sky view factor, wind direction, and speed has been considered in measurement throughout the day. Although the test has been done under the tree, which is considered as shaded area, generally the sky was cloudy throughout the day as it shown in Figure 1.2 in appendices. The wind speed was recorded initially at 11:00 am as 1.23m/s, while it is dropped to 0.58m/s in the afternoon at 16:00 pm, moreover wind blew from northeast. The temperature measurement begins at 11:00 am was 34°C, whereas the last measurement shows the temperature slightly decreased to 33.6°C at 16:00 pm. In addition, the maximum, and minimum temperature recorded in this space were 36.7°C at 15:00 pm and 33 °C at 13:00 pm respectively. In terms of humidity, the results indicated that the measured relative humidity shows very slightly changes throughout the day with recorded percentage of 57.3% in the morning at 11:00 am and 58.6% at 16:00 pm; however, the maximum humidity was at 13:00 pm with 60.7% compared to the minimum percentage of 18.4% at 15:00 pm. The average temperature and relative humidity were 34.43°C, and 55.71% respectively. It can be concluded that with regard to the cloudy sky and the lack of shade in this space; the human sensation ranged as slightly warm (ranged 30 °C to 34°C).

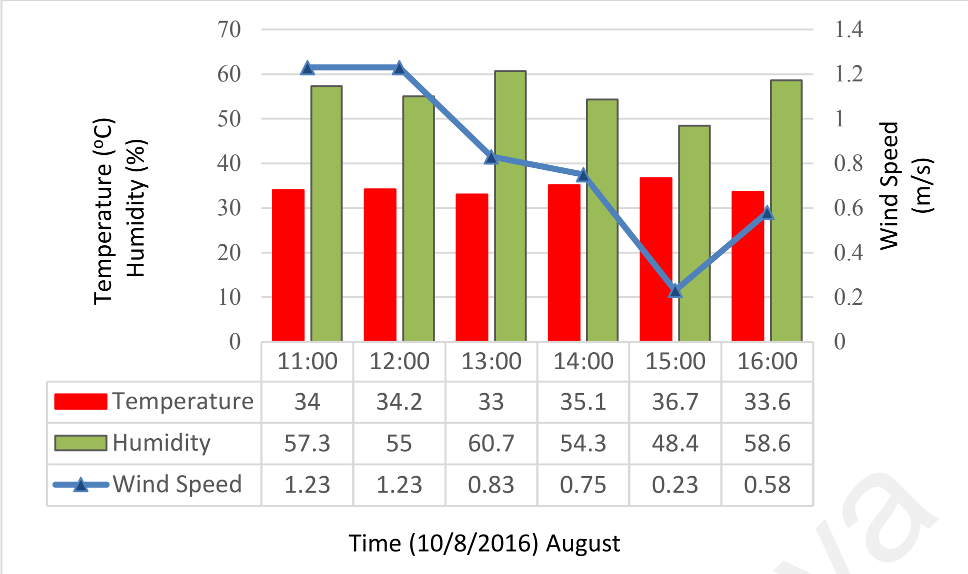


Figure 4.8: Weather station reported data for day2, unshaded area in Kampung Sungai Penchala, Source: Author

4.4 Kampung Melayu Kepong (KMK)

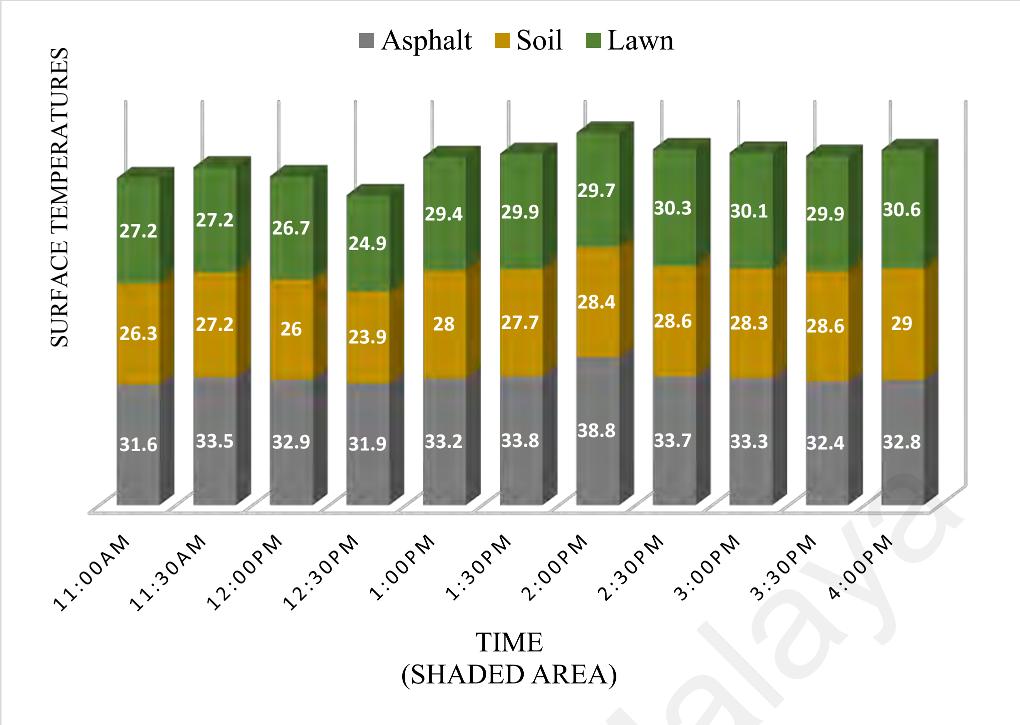
4.4.2 Surface Temperature and Thermal Images in KMK, Day 1

Figure 4.11 and 4.12 shows the surface temperature of surrounding area of both weather stations and the thermal image of the area. The materials considered in this experiment, located in the shaded area, and unshaded area, were lawn, asphalt, and soil (earth material). The data collection in terms of temperature measurement had carried out from 11:00 am to 16:00 pm at every 30 minutes.

Recorded temperature reports in shaded area for different materials are as follow. The highest recorded temperature in shaded area measured for asphalt material. The highest temperature measured for asphalt was 38.8°C at 14:00 pm, compare to its lowest temperature with 31.6°C at 11:00 am, while it measured ranged between 31.9°C to 33.8°C for the rest of the time. In terms of lawn material, the highest temperature recorded at 16:00 pm, with 30.6°C, whereas the lowest measurement was taken at 12:30 pm, and with 24.9°C. The soil (earth material) reached to its maximum temperature at 16:00 pm with 29°C, and the minimum of 23.9°C measured at 12:30 pm.

Refer to the unshaded area, the results reported in terms of material temperature measurement as follow. Again, the asphalt hit the highest temperature recorded with 51.2°C at 13:00 pm and dropped to its lowest temperature at 11:00 am with 35.5°C. With regard to the measured temperature for lawn material, the results indicated that the coolest temperature recorded at 15:30 pm with 29.7°C, and the warmest temperature with 40.2°C at 13:00 pm. Another material measured was soil (earth material), and it showed its maximum temperature at 14:00 pm, and minimum temperature at 11:30 am with 39.2°C, and 30.3°C respectively.

In brief, the result from shaded and unshaded area shows that the asphalt with 51.2°C, and the soil with 23.9°C, were the warmest and the coolest material temperature respectively.



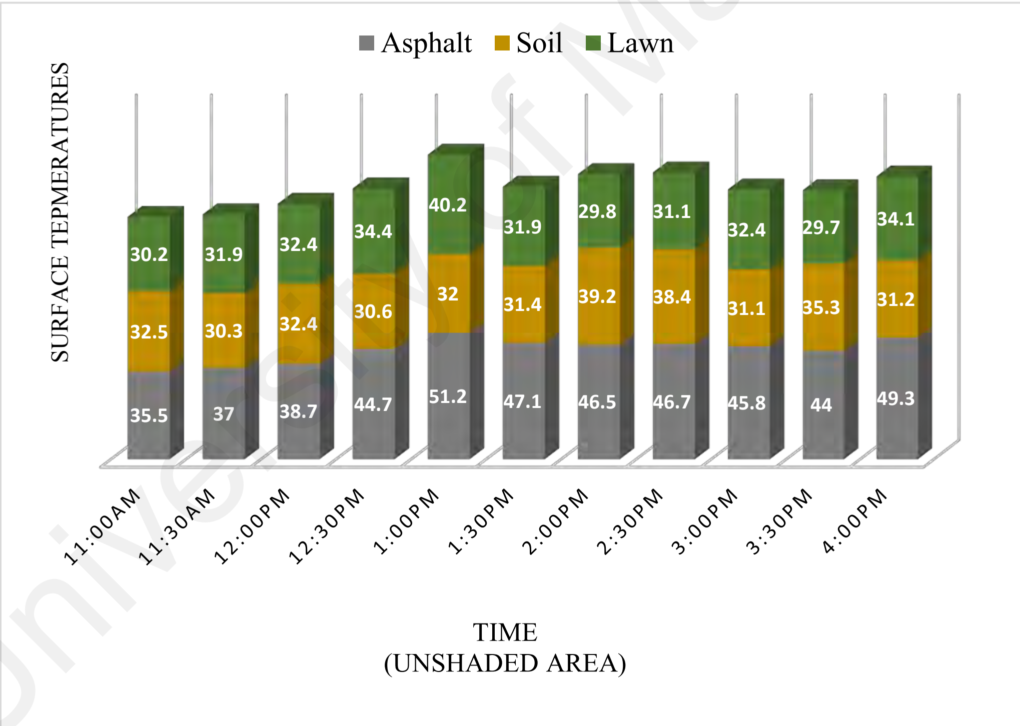


Figure 4.9: Surface temperature with fluke thermometer from 11:00 am to 16:00 pm, Source: Author

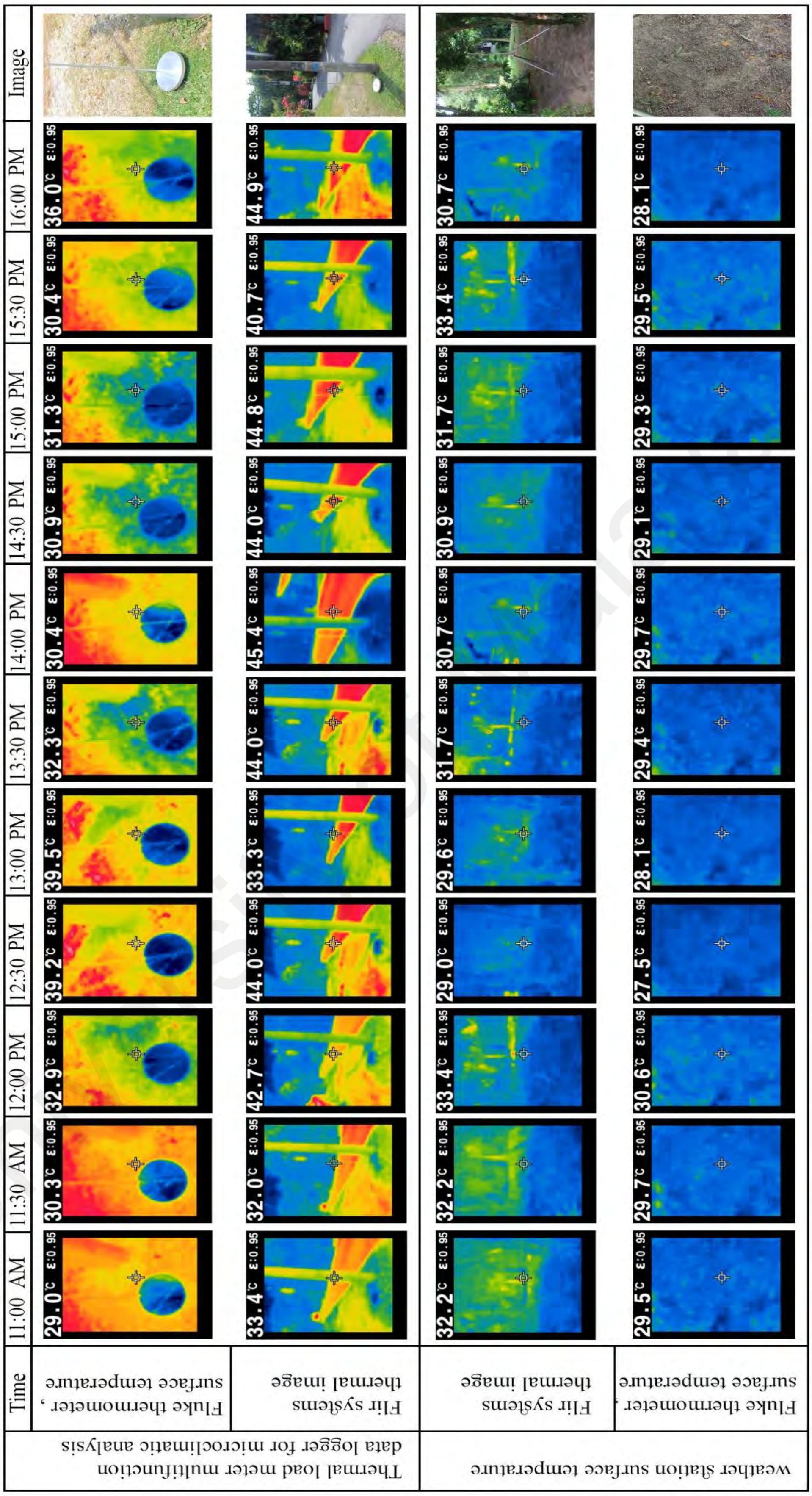


Figure 4.10: Graphs showing the thermal images from 11:00 am to 16:00 pm with surface temperature taken with Flir camera
Source: Author

4.4.3 Weather Station Report at KMK, Day 1 (shaded area)

As it can be seen in Figure 4.13, the data collected from 11:00 am until 16:00 pm in the afternoon, and temperature, relative humidity, sky view factor, wind direction, and speed has been considered in measurement throughout the day. Generally, this space was fully shaded and covered with trees as it shown in Figure 4.16. The temperature measurement begins at 11:00 am was 27.8°C, whereas the last measurement shows the temperature slightly increased to 32°C at 16:00 pm. In addition, the maximum, and minimum temperature recorded in this space were 32°C at 16:00 pm, and 27.8°C at 11:00 am respectively. The wind speed was recorded initially at 11:00 am as 0m/s, while it rose to 0.9m/s in the afternoon at 16:00 pm and blew from south-east with an average speed recorded of 0.5m/s during the day. In terms of humidity, the results indicated that the measured relative humidity shows some changes throughout the day with recorded percentage of 77% in the morning at 11:00 am and 58% at 16:00 pm, which represented the maximum and minimum temperature measurements throughout the day respectively. The average temperature and relative humidity were 30.15°C, and 66.83% respectively. As a result, with regard to the temperature outcomes the space, the level of comfort can be considered as neutral (ranged 26°C to 30°C) that is the fruit of the shaded condition.

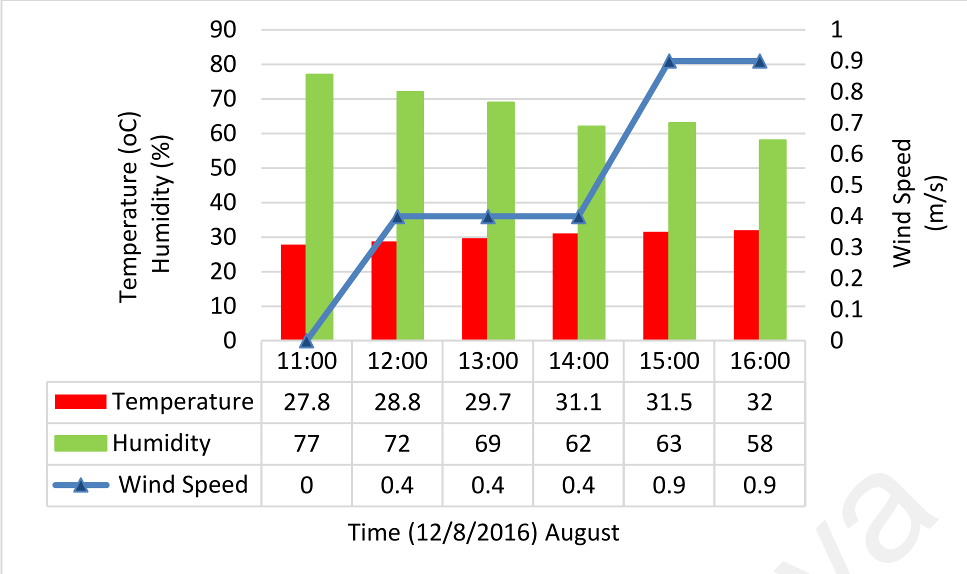


Figure 4.11: Weather station reported data for day1, shaded area in Kampung Melayu Kepong, Source: Author

4.4.4 Weather Station Report at KMK, Day 1 (unshaded area)

Figure 4.14 indicated that initially the temperature of 30.4°C was recorded at 11:00 am, which was the minimum temperature as well; whereas, the measurement at 16:00 pm shows that the temperature rose to 31.1°C, which can be pointed out as the maximum temperature throughout the day. In terms of humidity, the result shows that the measured relative humidity in the very early stage was 66.4% at 11:00 am in the morning, and fell to 40.9% at 16:00 pm in the afternoon, which were considered as the maximum and minimum relative humidity recorded throughout the day respectively with an average of 54.26%. The average temperature obtained was 33.51°C. The wind blew to this space from south-east with an average speed of 1.17m/s. The maximum wind speed measured was 1.43m/s, in contrast to a minimum record where the wind speed was 0.55m/s at 16:00 pm, and 13:00 pm correspondingly. Altogether, as it is shown in Figure 1.3 in appendices, there was a fluctuation in terms of sky condition as it was cloudy at 11:00 am, and it changed to mostly cloudy at noon; while in just an hour changed to shiny between 12:00 at noon, and 13:00 pm; meanwhile it remained steady until 14:00 pm and then changed to cloudy until the next hour, and finally the sunny sky observed at the end of the experiment at 16:00 pm. Last but not least, with regard to the measured temperature, the sensation was at a slightly warm range (ranged 30°C to 34°C).

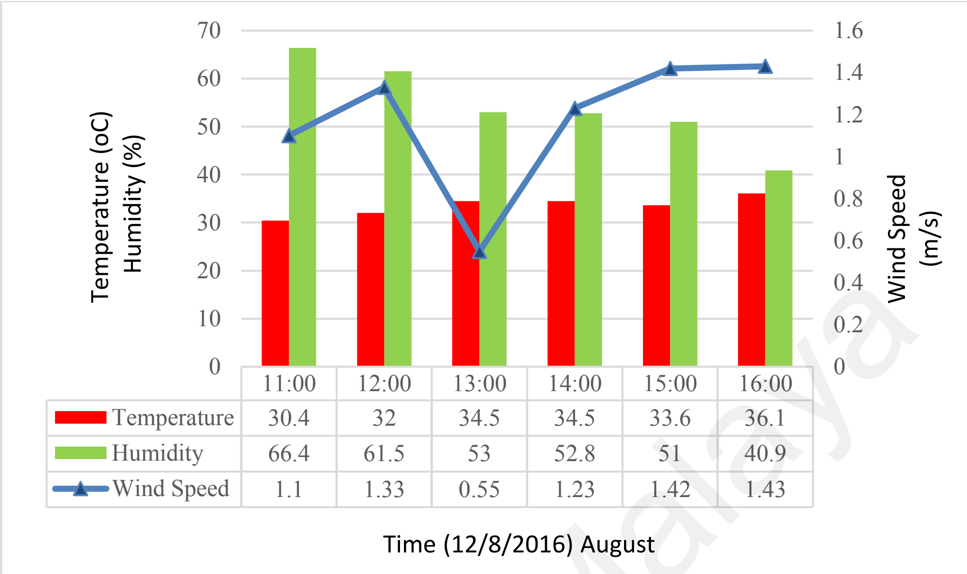


Figure 4.12: Weather station reported data for day1, unshaded area in Kampung Melayu Kepong, Source: Author

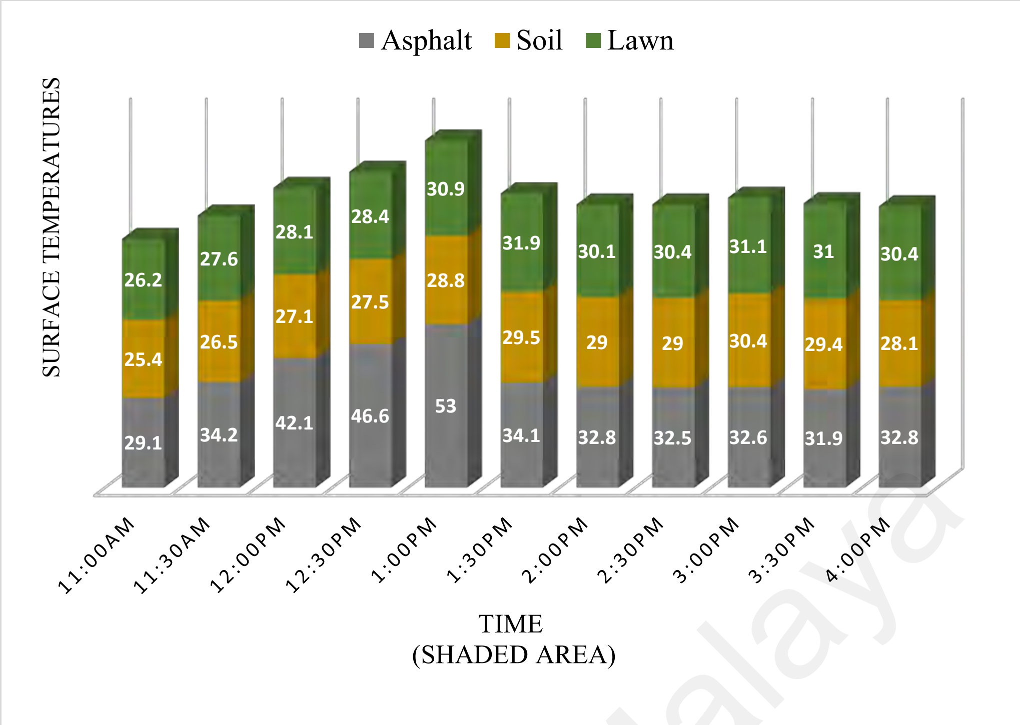
4.4.5 Surface Temperature and Thermal Images in KMK, Day 2

Figure 4.16 and 4.17 shows the surface temperature of surrounding area of both weather stations and the thermal image of the area the materials considered in this experiment, located in the shaded area, and unshaded area, were lawn, asphalt, and soil (earth material). The data collection in terms of temperature measurement had carried out from 11:00 am to 16:00 pm at every 30 minutes.

Recorded temperature reports in shaded area for different materials are as follow. The highest recorded temperature in shaded area measured for asphalt material. The highest temperature measured for asphalt was 53°C at 13:00 pm, compare to its lowest temperature with 29.1°C at 11:00 am, while it measured ranged between 31.9°C to 46.6°C for the rest of the time. The soil (earth material) reached to its maximum temperature at 15:00 pm with 30.4°C, and the minimum of 25.4°C measured at 11:00 am. In terms of lawn material, the highest temperature recorded at 13:30 pm with 31.9ºC, whereas the lowest measurement which was taken at 11:00 am with 26.2ºC.

With regard to the unshaded area, the results reported in terms of material temperature measurement as follow. With regard to the measured temperature for lawn material, the results indicated that the coolest temperature recorded at 11:00 am with 29ºC, and the warmest temperature with 46.6ºC at 16:00 pm. Again, the asphalt hit the highest temperature recorded with 59.4ºC at 14:30 pm and dropped to its lowest temperature at 11:00 am with 33ºC. Another material measured was soil (earth material), and it showed its maximum temperature at 14:00 pm, and minimum temperature at 11:00 am with 45.7ºC, and 32.3ºC respectively.

The result from shaded and unshaded area shows that the asphalt with 59.4ºC, and the soil with 25.4ºC, were the warmest and the coolest material temperature respectively.



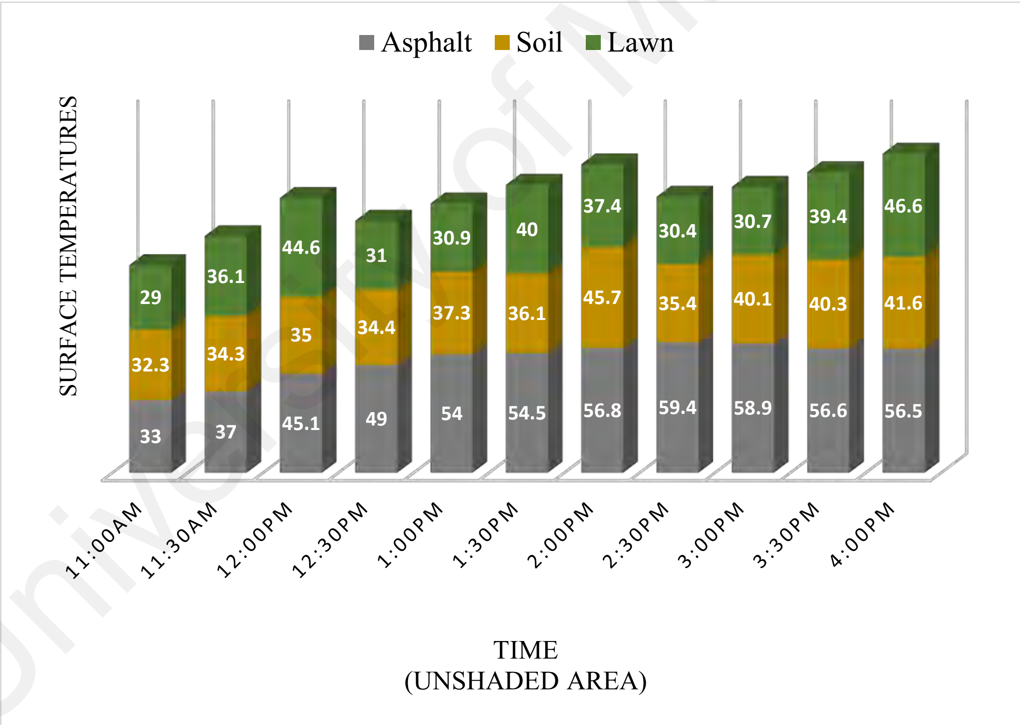


Figure 4.13: Surface temperature with fluke thermometer from 11:00 am to 16:00 pm, Source: Author

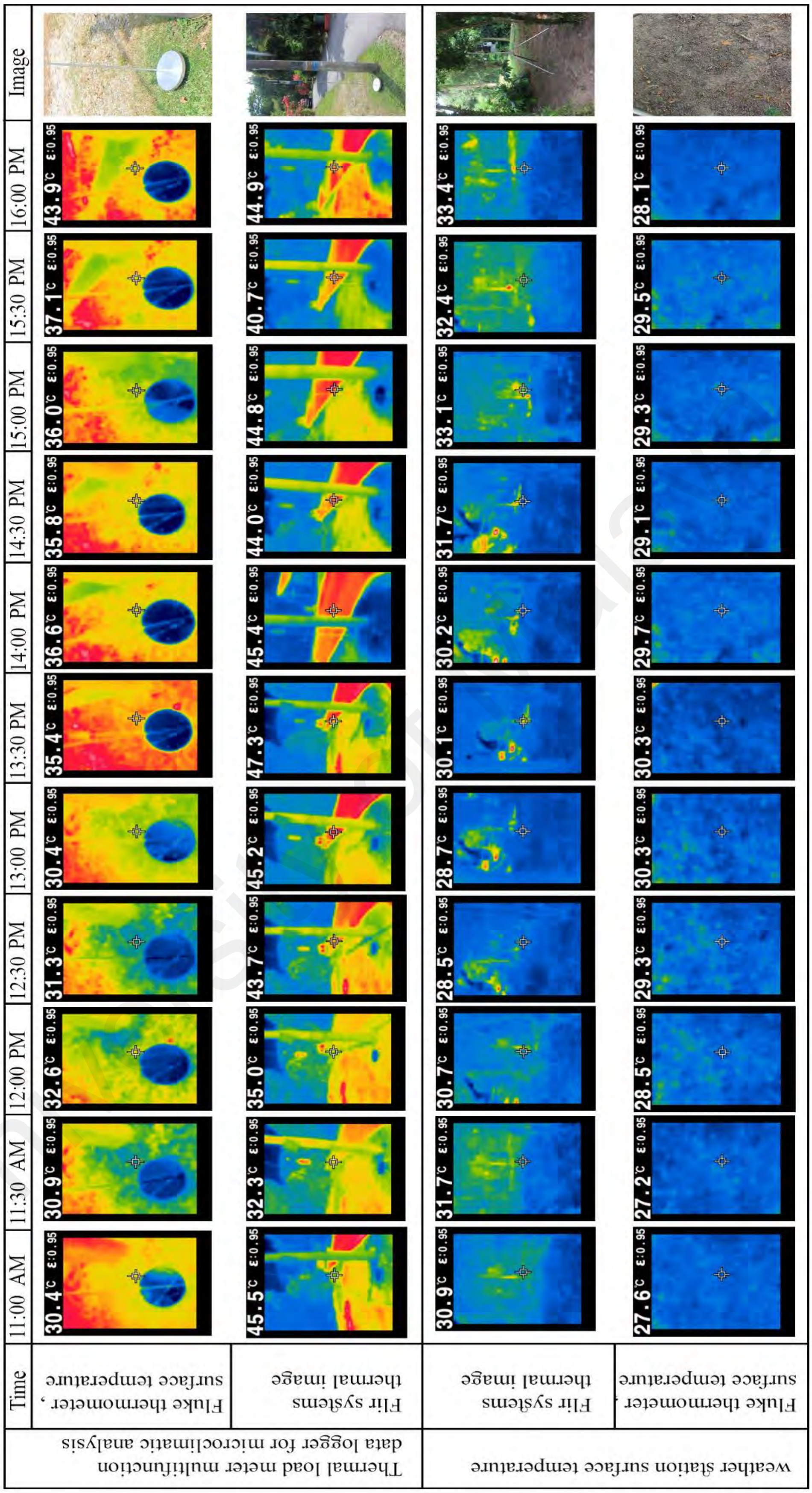
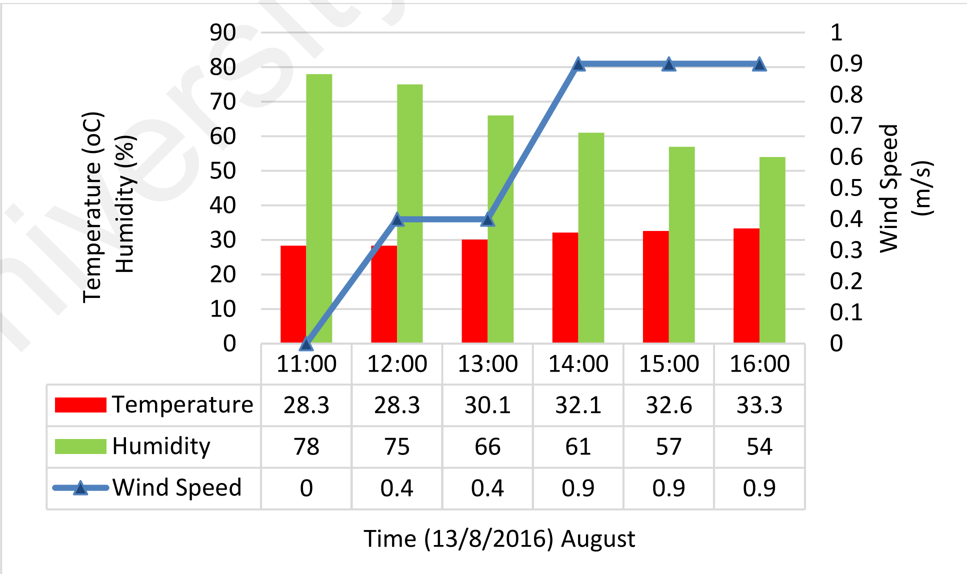


Figure 4.14: Graphs showing the thermal images from 11:00 am to 16:00 pm with surface temperature taken with Flir camera
Source: Author

4.4.6 Weather Station Report at KMK, Day 2 (shaded area)

As it can be seen in Figure 4.18, the outcomes determined that originally at 11:00 am the temperature of 28.3ºC was recorded, which was the minimum temperature until the next hour as well; whereas, the measurement at 16:00 pm shows that the temperature rose gradually every hour to 33.3ºC, which can be identified as the peak temperature throughout the day with the average temperature of 33.51ºC. In terms of humidity, the result shows that the measured relative humidity in the very early stage was 78% at 11:00 in the morning and leveled down to 54% at 16:00 in the afternoon, which were considered as the peak and the least possible relative humidity recorded throughout the day accordingly with an average of 65.16%. The wind blew to this space from south-east with an average speed of 0.58m/s. The maximum wind speed measured was 0.9m/s, in contrast to a minimum record where the wind speed was 0m/s at 16:00 pm, and 11:00 am respectively. As it is shown in Figure 4.20, the space was fully shaded by trees and resulted in neutral range in sensation (ranged between 26ºC to 30ºC).



	11:00	12:00	13:00	14:00	15:00	16:00
Temperature	28.3	28.3	30.1	32.1	32.6	33.3
Humidity	78	75	66	61	57	54
Wind Speed	0	0.4	0.4	0.9	0.9	0.9

Figure 4.15: Weather station reported data for day2, shaded area in Kampung Melayu Kepong, Source: Author

4.4.7 Weather Station Report at KMK, Day 2 (unshaded area)

From Figure 4.19, the result shows that in the beginning of the experiment at 11:00 am the temperature has been measured at 32.2ºC, which was the least measured temperature throughout the day; compared to the measurement at 16:00 pm that shows the temperature increased gradually to 36.2ºC, which can be identified as the maximum temperature throughout the day with the average temperature of 34.65ºC. With regard to the humidity, the result shows that the measured relative humidity initially was 60.8% at 11:00 in the morning and fell down to 43% at 16:00 in the afternoon, which were considered as the peak and the least possible relative humidity recorded throughout the day accordingly with an average humidity measurement of 51.13%. The wind blew to this space from south-east with an average speed of 2.03m/s. The maximum wind speed measured was 3.28m/s, in contrast to a minimum recorded speed of 0.67m/s at 14:00 pm, and 11:00 am respectively. In brief, as it is shown in Figure 1.4 in appendices, the space was unshaded but the sky was cloudy starting from 11:00 am until 12:00 at noon; then it changed to partially cloudy until 13:00 pm then suddenly became sunny for the next hour and between 14:00 pm to 15:00 pm was partially cloudy again; while it ended up to the shiny sky at the end of the experiment at 16:00 pm. The human sensation was in a slightly warm range (ranged between 30ºC to 34ºC).

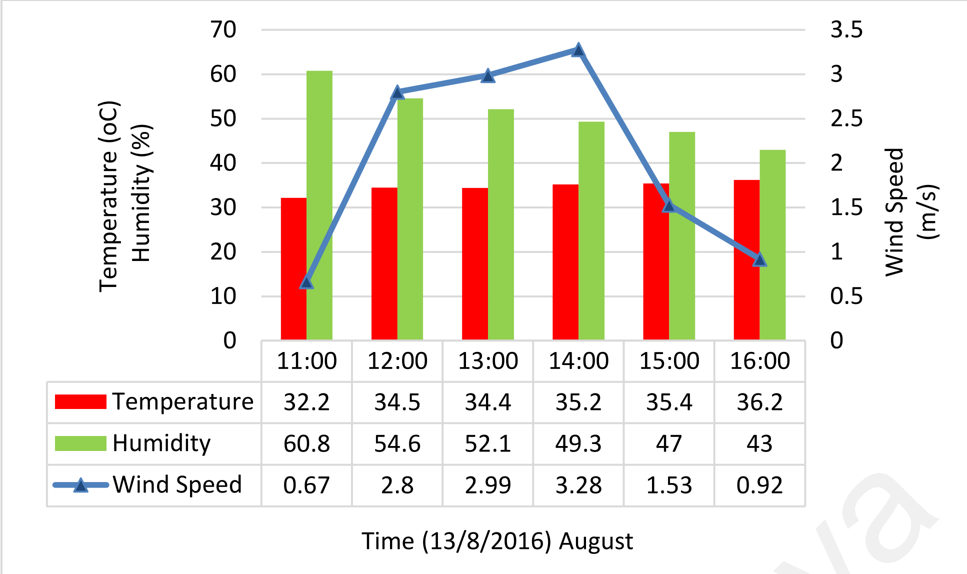


Figure 4.16: Weather station reported data for day2, unshaded area in Kampung Melayu Kepong, Source: Author

4.5 Kampung Baru (KB)

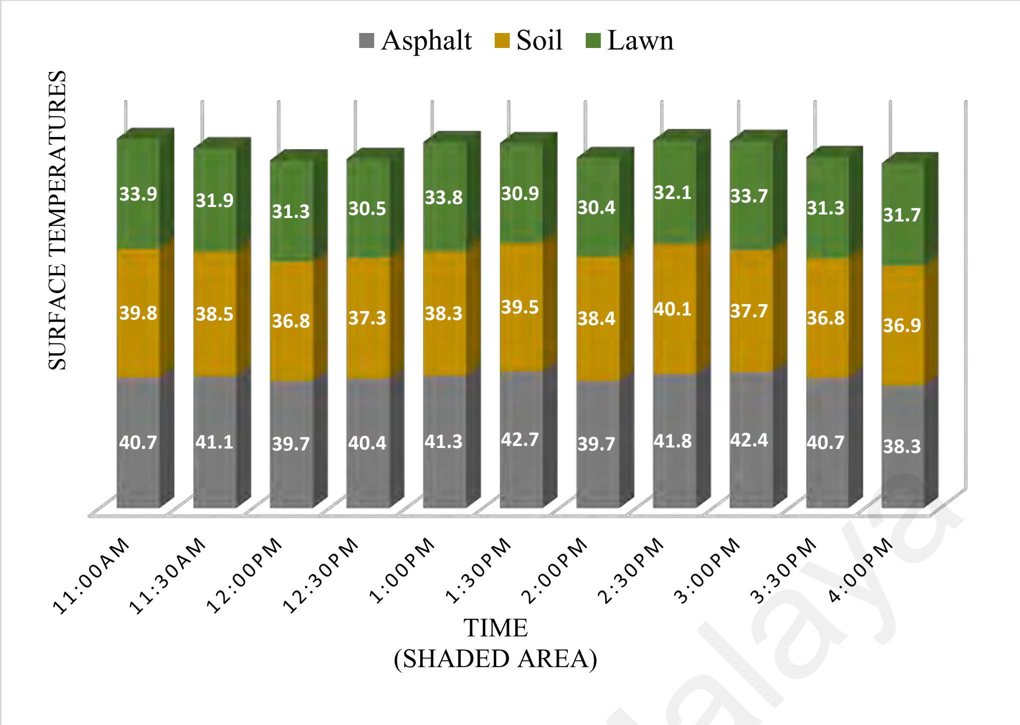
4.5.2 Surface Temperature and Thermal Images in KB, Day 1

Figure 4.21 and 4.22 shows the surface temperature of surrounding area of both weather stations and the thermal image of the area. The materials considered in this experiment, located in the shaded area, and unshaded area, were lawn, asphalt, and soil (earth material). The data collection in terms of temperature measurement had carried out from 11:00 am to 16:00 pm at every 30 minutes.

Recorded temperature reports in shaded area for different materials are as follow. The highest recorded temperature in shaded area measured for asphalt material. The highest temperature measured for asphalt was 42.7°C at 13:30 pm, compare to its lowest temperature with 38.3°C at 16:00 pm, while it measured ranged between 39.7°C to 42.4°C for the rest of the time. In terms of lawn material, the highest temperature recorded at 11:00 am with 33.9°C, whereas the lowest measurement, which was taken at 14:00 pm with 30.4°C. The soil (earth material) reached to its maximum temperature at 14:30 pm with 40.1°C, and the minimum of 36.8°C measured at 15:30 pm, and 12:00 pm.

With regard to the unshaded area, the results reported in terms of material temperature measurement as follow. Again, the asphalt hit the highest temperature recorded with 43.4ºC at 15:00 pm and dropped to its lowest temperature at 16:00 pm with 39.6ºC. Another material measured was soil (earth material), and it showed its maximum temperature from 13:30 pm until 15:00 pm, and minimum temperature at 16:00 pm with 42.3ºC, and 37.6ºC respectively. With regard to the measured temperature for lawn material, the results indicated that the coolest temperature recorded at 14:00 pm with 28.9ºC, and the warmest temperature with 33.7ºC at 15:00 pm.

The result from shaded and unshaded area shows that the asphalt with 43.4ºC, and the lawn with 28.9ºC, were the warmest and the coolest material temperature respectively.



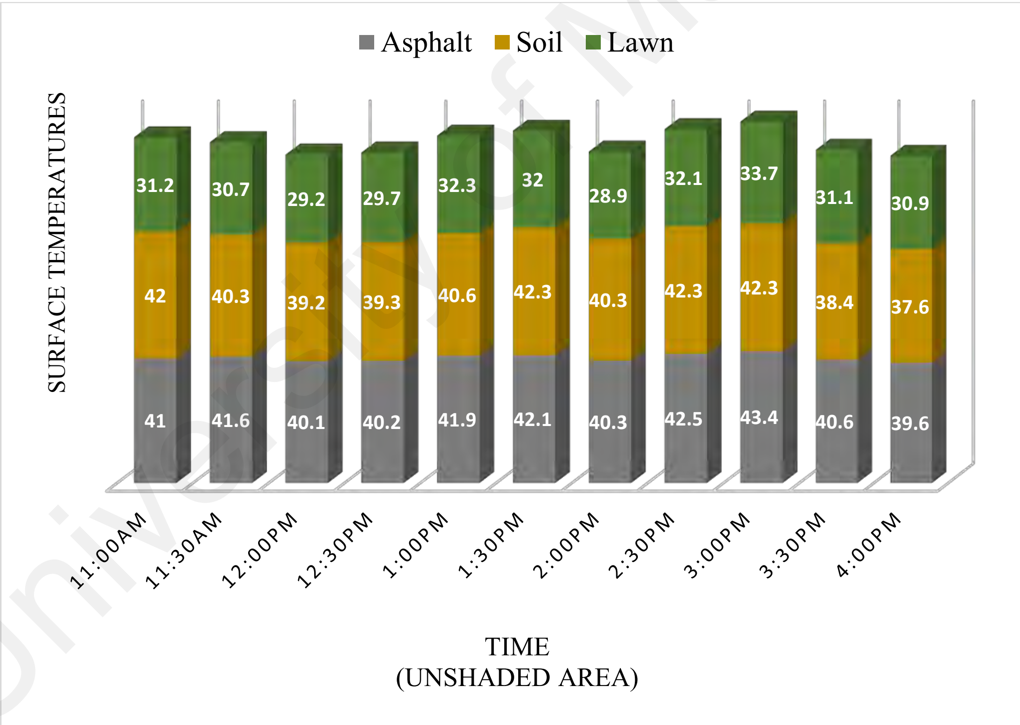


Figure 4.17: Surface temperature with fluke thermometer from 11:00 am to 16:00 pm, Source: Author

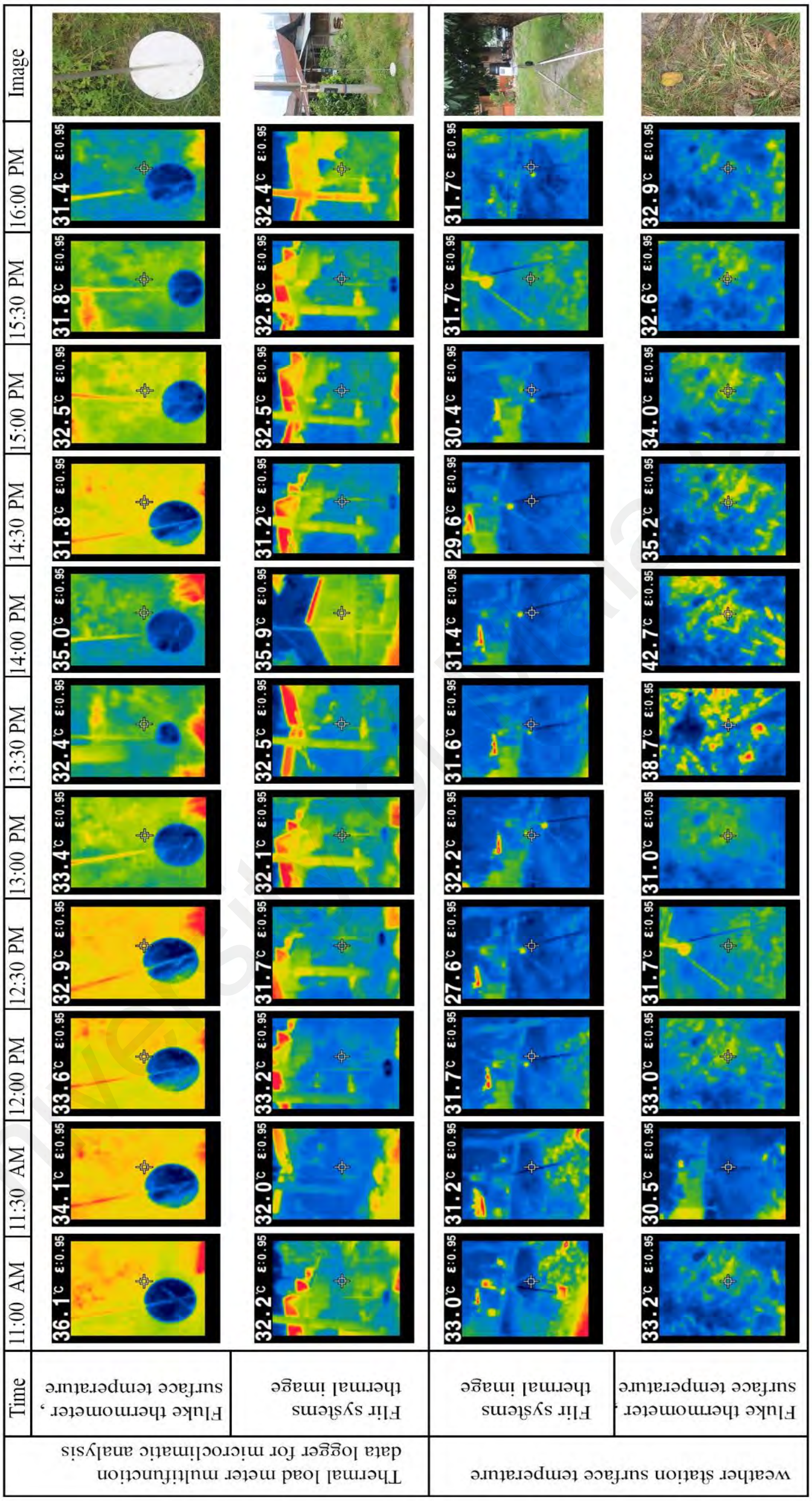


Figure 4.18: Graphs showing the thermal images from 11:00 am to 16:00 pm with surface temperature taken with Flir camera
Source: Author

4.5.3 Weather Station Report at KB, Day 1 (shaded area)

The result shows that in the beginning of the experiment at 11:00 am the temperature of 31.8ºC has been recorded, which was the least measured temperature throughout the day; in contrast to the measurement at 16:00 pm that shows the temperature increased gradually to 34.8ºC, which can be identified as the maximum temperature throughout the day with the average temperature of 33.83ºC. Regarding the relative humidity, the result shows that the measured relative humidity initially was 65% at 11:00 in the morning and fell down to 55% at 16:00 in the afternoon, which were considered as the peak and the least possible relative humidity measured throughout the day accordingly with an average humidity measurement of 57.5%. The wind blew to this space from east with an average speed of 0.4m/s. The wind speed leveled off the whole day with a measured wind speed of 0.4m/s, due to the condition of the area, which was surrounded with traditional house located at the eastern direction, where they blocked the wind blow. Altogether, the results mentioned above can be seen in Figure 4.23. In brief, as it is shown in Figure 1.5 in appendices, the space was shaded and covered by trees; however, the sky was mostly cloudy throughout the day, and the human sensation was in the slightly warm range (ranged between 30ºC to 34ºC).

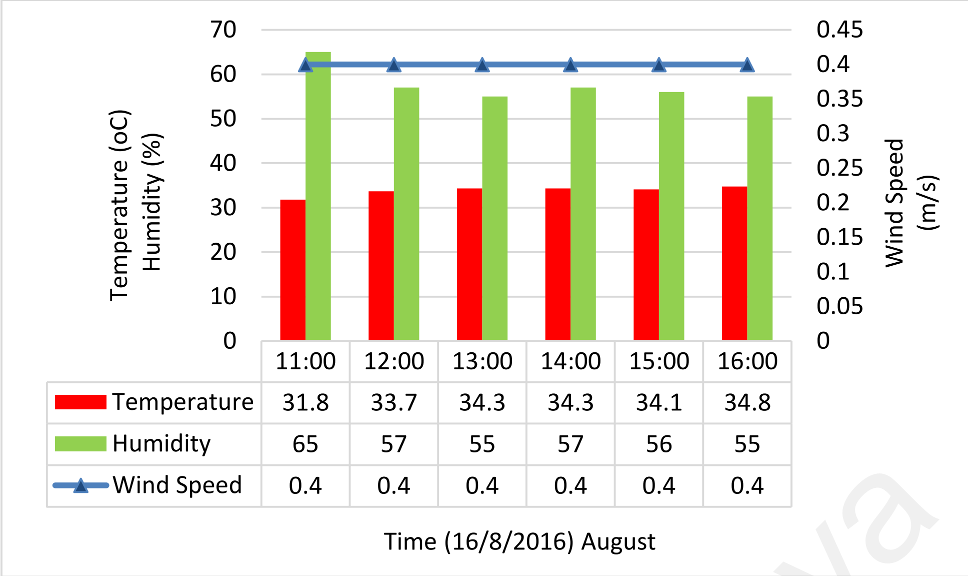


Figure 4.19: Weather station reported data for day1, shaded area in Kampung Baru, Source: Author

4.5.4 Weather Station Report at KB, Day 1 (unshaded area)

In this space, time, and other variables are shown in Figure 4.24. In the beginning of the experimental study, the temperature of 33.8°C was recorded at 11:00 am, whereas with negligible change, the last measurement at 16:00 pm shows very slight decrease in temperature with 33.7°C. In addition, the maximum and minimum temperature recorded were 35.8 °C, and 33.7°C respectively. In terms of humidity, the results show that the measured relative humidity initially was 54.4% at 11:00 in the morning and rose marginally to 58.3% at 16:00 in the afternoon, which can be pointed out as the maximum relative humidity recorded, while the minimum percentage was 50.6% at 15:00 pm. The average temperature and relative humidity obtained were 34.41°C, and 53.8% respectively. The wind blew to this space from east with average speed of 0.85m/s. The maximum wind speed measured was 2.12m/s at 11:00 am, in contrast to a minimum record where the wind speed recorded was 0.26m/s at noon. Overall, with regard to the Figure 4.25, the space was in unshaded area, and the sky view was cloudy, also the human sensation ranged as slightly warm (ranged 30°C to 34°C) in this space due to the lack of shade.

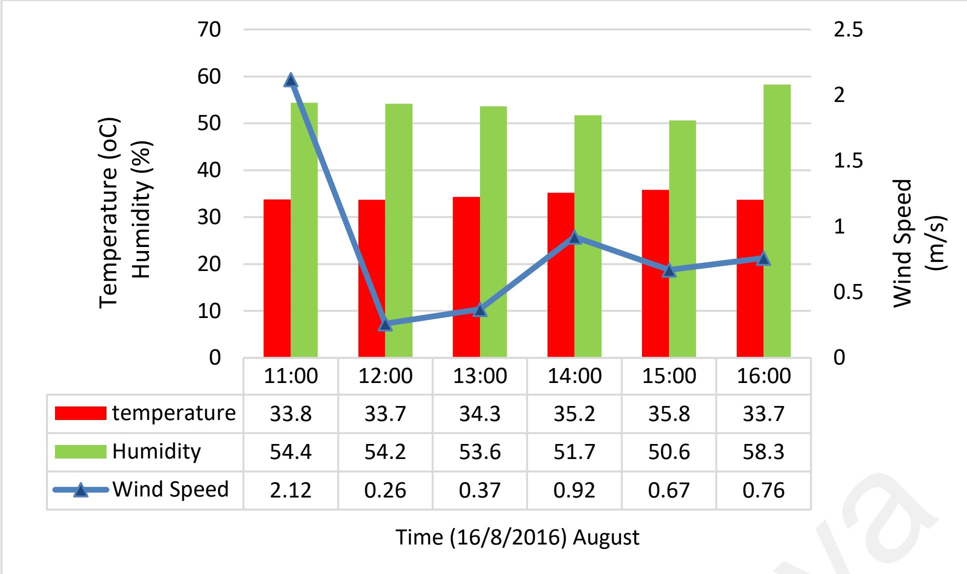


Figure 4.20: Weather station reported data for day1, unshaded area in Kampung Baru, Source: Author

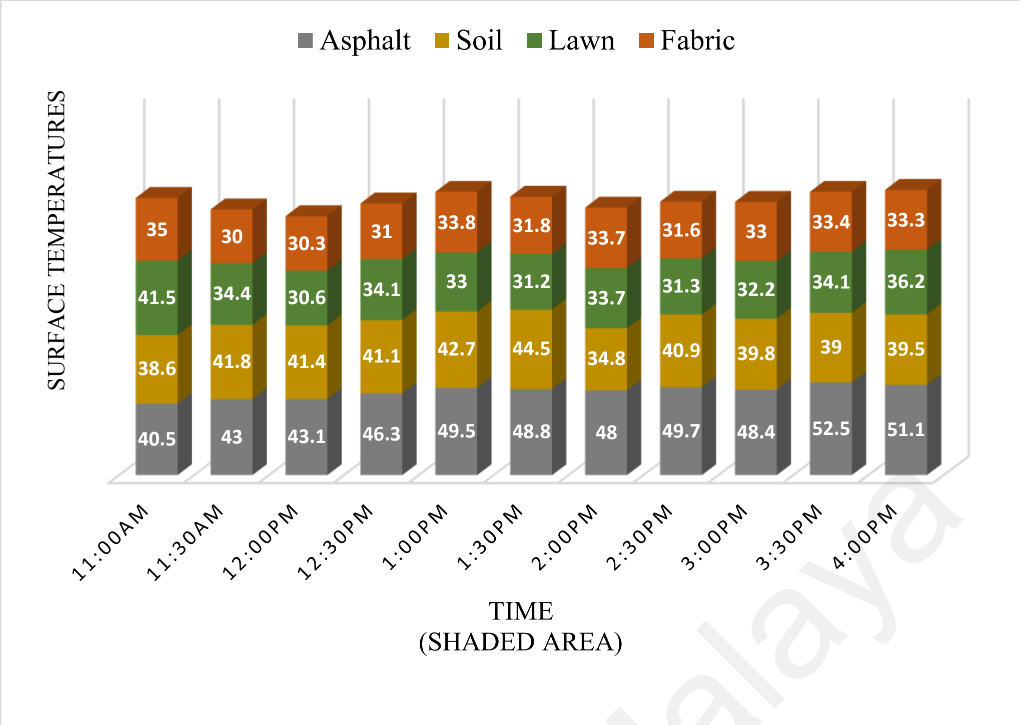
4.5.5 Surface Temperature and Thermal Images in KB, Day 2

Figure 4.26 and 4.27 shows the surface temperature of surrounding area of both weather stations and the thermal image of the area. The materials considered in this experiment, located in the shaded area, and unshaded area, were lawn, asphalt, and soil (earth material). The data collection in terms of temperature measurement had carried out from 11:00 am to 16:00 pm at every 30 minutes.

Recorded temperature reports in shaded area for different materials are as follow. The highest recorded temperature in shaded area measured for asphalt material. The highest temperature measured for asphalt was 52.5°C at 15:30 pm, compare to its lowest temperature with 40.5°C at 11:00 am, while it measured ranged between 43°C to 51.1°C for the rest of the time. The soil (earth material) reached to its maximum temperature at 13:30 pm with 44.5°C, and the minimum of 34.8°C measured at 14:00 pm. In terms of lawn material, the highest temperature recorded at 11:00 am with 41.5°C, whereas the lowest measurement which was taken at 12:00 pm, with 30.6°C.

With regard to the unshaded area, the results reported in terms of material temperature measurement as follow. Regarding the measured temperature for lawn material, the results indicated that the coolest temperature recorded at 12:30 pm with 30.6ºC, and the warmest temperature with 38ºC at 16:00 pm. Once again, the asphalt hit the highest temperature recorded with 53.2ºC at 15:30 pm and dropped to its lowest temperature at 11:00 am with 38.3ºC. Another material measured was soil (earth material), and it showed its maximum temperature at 15:30 pm, and minimum temperature at 15:00 pm with 52.2ºC, and 38.5ºC respectively.

The result from shaded and unshaded area shows that the fabric with 57.6ºC and the lawn with 30.6ºC, were the warmest and the coolest material temperature respectively.



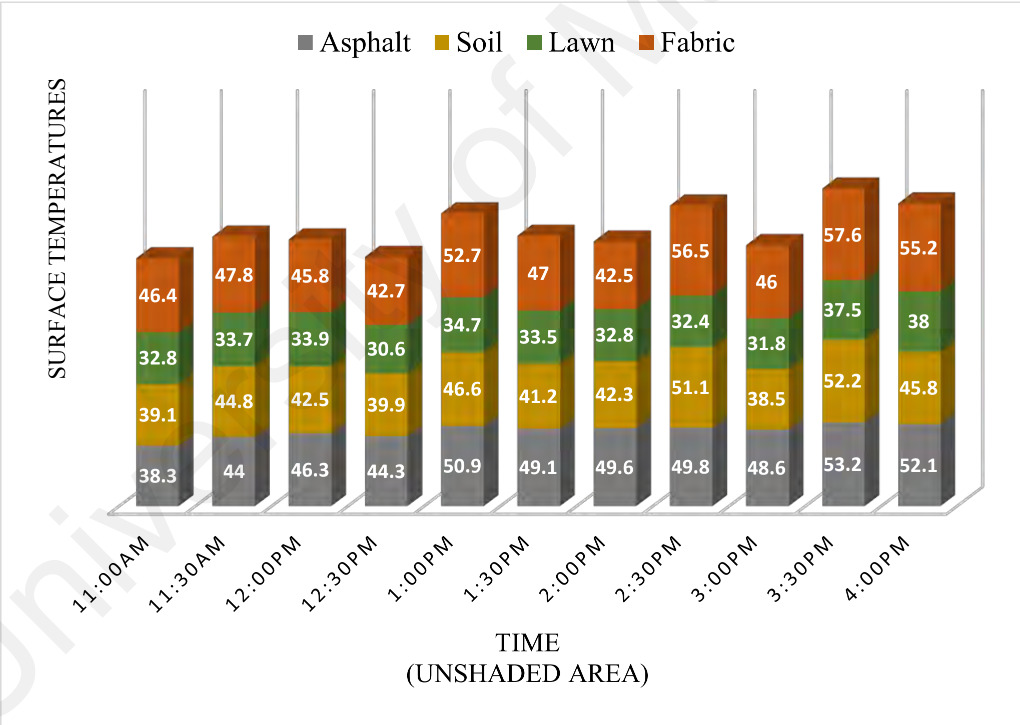


Figure 4.21: Surface temperature with fluke thermometer from 11:00 am to 16:00 pm, Source: Author

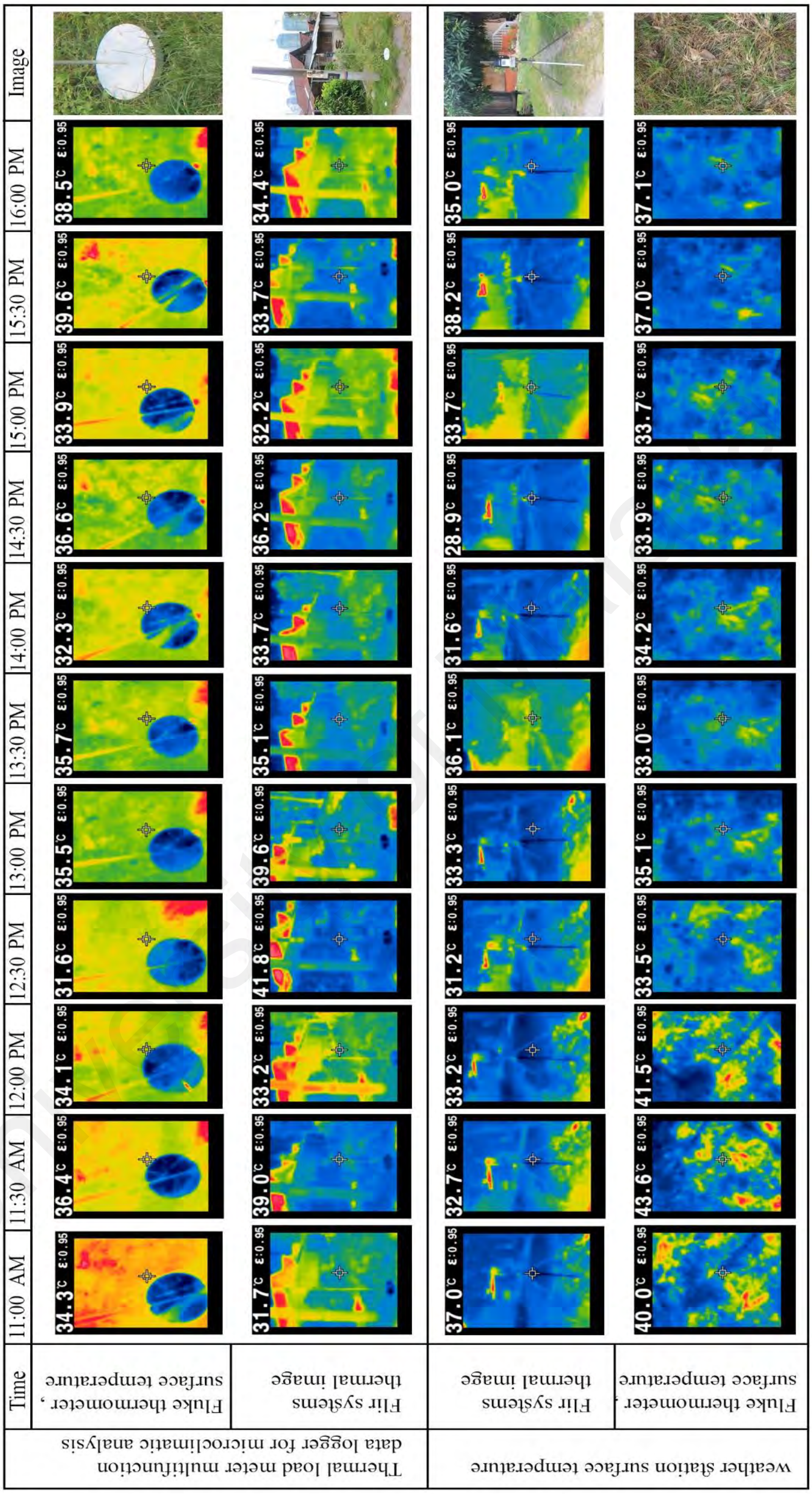


Figure 4.22: Graphs showing the thermal images from 11:00 am to 16:00 pm with surface temperature taken with Flir camera
Source: Author

4.5.6 Weather Station Report at KB, Day 2 (shaded area)

Figure 4.28 shows that the measured temperature originally was 28.8°C at 11:00 am, which was the lowest measured temperature throughout the day in contrast to the measurement at 16:00 pm that shows the temperature increased gradually to 35.6°C, which can be identified as the highest temperature throughout the day with the average temperature of 32.81°C. Regarding the relative humidity, the result shows that the measured relative humidity initially was 58% at 11:00 in the morning and fell down to 52% between 15:00 pm to 16:00 pm in the afternoon, which were considered as the least possible relative humidity measured throughout the day in comparison with the maximum recorded percentage of 60% at noon, with an average humidity measurement of 55.66%. Wind blew to this space from east with an average speed of 0m/s. The wind speed leveled off the whole day with no wind blow measured at all. In brief, as it is shown in Figure 4.30, the space was shaded and covered by trees; however, the sky was cloudy throughout the day, and the human sensation was in the slightly warm range (ranged between 30°C to 34°C).

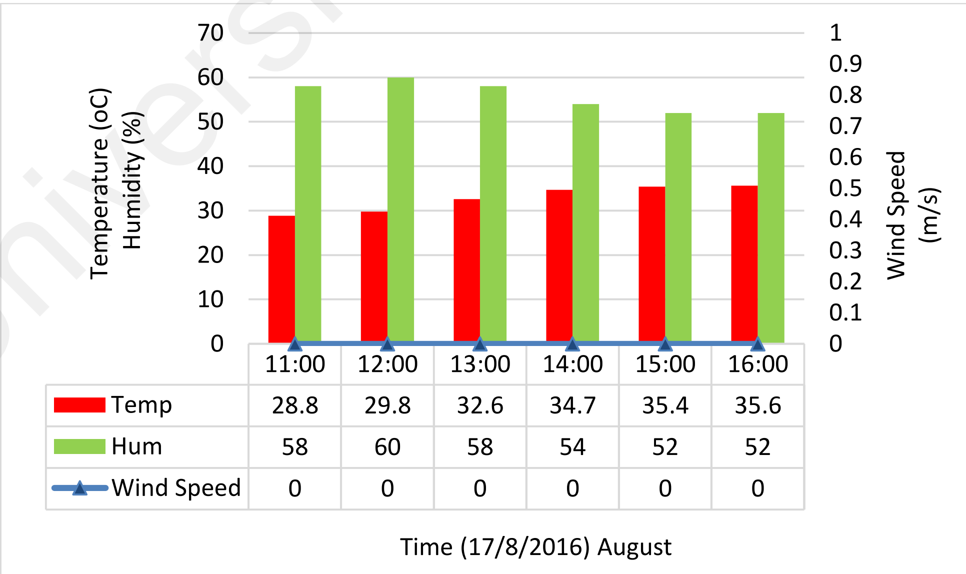


Figure 4.23: Weather station reported data for day2, shaded area in Kampung Baru, Source: Author

4.5.7 Weather Station Report at KB, Day 2 (unshaded area)

As it can be concluded from Figure 4.29, the measured temperature at the very early stage of experiment of 37.6°C was recorded at 11:00 am, in contrast to the measurement at 16:00 pm that shows the temperature increased slightly to 38.9°C, which can be identified as the highest temperature throughout the day, while the minimum temperature measured was 36.2°C, with the average temperature recorded of 37.55°C. Regarding the relative humidity, the result shows that the measured relative humidity initially was 45.9% at 11:00 in the morning and fell down to 42% at 16:00 pm in the afternoon, which were considered as the lowest possible relative humidity measured throughout the day in comparison with the maximum recorded percentage of 50.9% at noon, with average humidity measurement of 46.68%. The wind blew to this space from east with an average speed of 0.77m/s. The minimum wind speed was 0.34m/s at noon, and the maximum recorded as 1.87m/s at 14:00 pm. In brief, as it is shown in Figure 1.6 in appendices, the space was considered as unshaded; however, the sky was mostly cloudy throughout the day, and the human sensation was at the warm range (ranged between 34°C to 38°C).

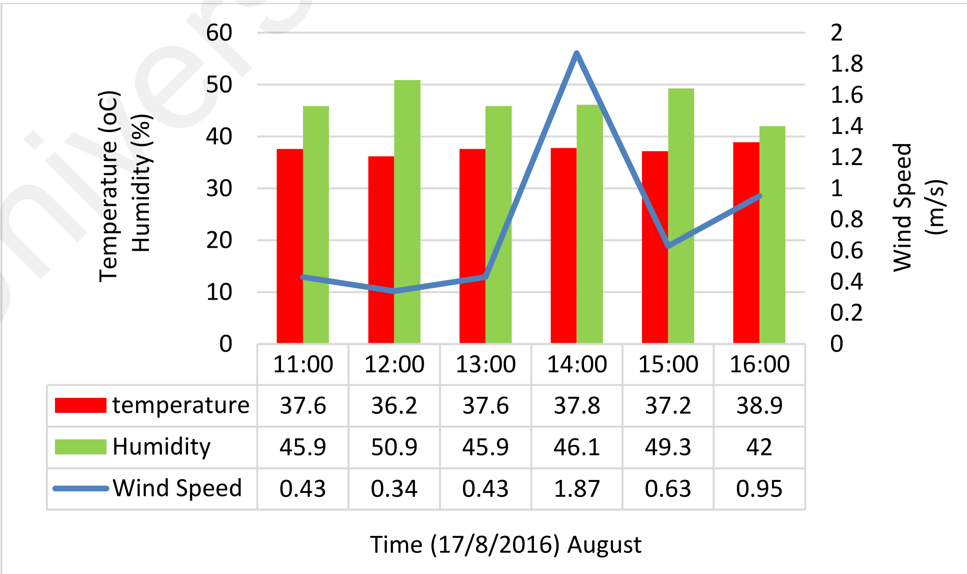


Figure 4.24: Weather station reported data for day2, unshaded area in Kampung Baru, Source: Author

4.6 Conclusion

The field measurement of study areas and the microclimatic condition of the three selected urban villages in Kuala Lumpur were described in this chapter. In each urban village, the inviromental conditions in shaded and unshaded areas on 2 days have been investigated. Moreover, the surface conditions of the surrounding areas were studied. This chapter includes the analysis of the data recorded during the data collection phase to determine the thermal comfort condition of the selected study areas. This study considers only the thermal comfort in the outdoor spaces.

From field measurement data in urban village 1 (Kampung Sungai Penchala), it is recorded that the temperature on day 2 was lower than day 1. This is due to sky condition factor, which was mostly cloudy during the day. Therefore, the level of thermal comfort on day 1 had better condition than day 2. However, according to the results of the experiments in shaded and unshaded spaces by looking at two spaces (shaded and unshaded) on each day, the shaded area has overall cooler temperature than the unshaded area. This is likely to be due to two factors; direct solar radiation and existing vegetation in that space.

The difference between the solar radiation values on both days in urban village 2 (Kampung Melayu Kepong), particularly during the middle of the day was quite noticeable. Solar radiation was much higher from 13:00 pm to 16:00 pm on both days. There was a clear difference in the air temperatures during the day on both day 1 and 2. The most pleasant thermal condition of the day was at the started time of data collection at 11:00 am, in which the weather was colder than the hours approaching the afternoon.

The results of the investigation in Kampung Baru as thethird studied urban village, show that the wind speed in this area was mostly low. The breeze can affect the level of temperature if obstacles do not block it. Day 1 in contrast to day 2 is in better condition of temperature due to more wind and cloudy sky.

In conclusion, this chapter reports the assessment of the thermal comfort condition in hot and humid climate by investigating shaded and unshaded areas in the three urban villages. The relationship between the environmental variables and the level of thermal comfort were examined. The solar radiation intensity together with air temperature appeared as the most important predictor in the level of thermal comfort condition in the study areas. They have an excessive impact on the use of the outdoor spaces in hot and humid climate. Based on the outcome of the experiments, the most pleasant thermal comfort condition among the experimental days in those urban villages was belong to day 1 in Kampung Melayu Kepong and to day 2 in Kampung Sungai Penchala. More outcomes of the experiments and filed measurement using Rayman Model analysis and ENVI-met simulation in the three case study areas are provided in Chapter 5.

CHAPTER 5: FINDINGS AND DISCUSION

5.1 Introduction

This chapter provides a deep discussion on the findings and outcome of the experiments using Rayman Model analysis and ENVI-met simulation in the three case study areas. In addition, a comparative study on the extracted results from ENVI-met simulation and the outcomes of the described experiments in Chapter 4 has been conducted and reported in this chapter. Moreover, after evaluating the metrological variable through the devices and analysis of the collected data, this chapter creates a high-level accuracy by evaluating R-squared, which is known as the coefficient of determination. It is a statistical measure of how close the data are to the fitted regression line.

Section 5.1 gives an introduction about this chapter, and then section 5.2 reports the calculation of PET through the Rayman Model in the selected case study areas. In Section 5.3, the findings of ENVI-met simulation of the field measurement data has been reported. At the end, a conclusion of this chapter is provided in Section 5.4.

5.2 PET Calculation through Rayman Model

In this study, the relationship between the urban form factors and thermal comfort is considered to determine the best condition in terms of thermal comfort within urban villages in KL. Simulation of urban villages (kampungs) is applied to quantify the microclimatic variables, orientation, and the influence of H/W on urban village zone. The energy balance of the human body is utilized to extract thermal indices for describing impacts of the thermal environment on human beings. For this reason, with utilize hourly estimations of the meteorological information to calculate PET and perform the simulation using by Rayman Model with existing data by considering the above factors mentioned as the target to extract the characteristics in different conditions within the urban villages on the level of human thermal comfort.

5.2.1 PET Outcomes in Kampung Sungai Penchala

From PET calculated values as shown in Figure 5.1, the temperature fluctuation has had the most influence on the experimental study throughout the whole each day of data gathering; the highest value of PET was 40.1ºC due to the lack of vegetation coverage recorded on first day and in unshaded area at 11:30 am, which was the hot thermal sensation level based on the grades of thermal sensation of human beings (ASHRAE scale); meanwhile, for second day in shaded area with shaded condition, the coolest temperature has be measured at 11:30 am. It can be concluded that these measurements were the warmest and the coolest points respectively for Kampung Sungai Penchala. It is clear that overlaid with trees, which makes shadow can decrease the environment temperature, which improves the human comfort to its satisfaction level. In general, Figure 5.1 indicated that mostly PET values are between 33ºC to 36ºC, which is called "slightly warm" to "warm" based on the thermal sensation definition (ranged between 30ºC to 38ºC). The most notable part of the figure is between the times in the morning and in the afternoon, which is between 11:00 am to 13:00 pm. Considering different temperature changes in each day shows that unshaded area is mostly warmer than shaded due to sky view factor and the shading of direct radiation occurred from obstacles. As reported from shaded area, the sky view factor was 0.144, which means the area was not faced clearly to the sky, while it measured 0.729 in unshaded area, which was clearly faced to the sky. In another word, the sky view factor is ranged between 0 (when it is purely shaded) to 1 (when it is purely unshaded).

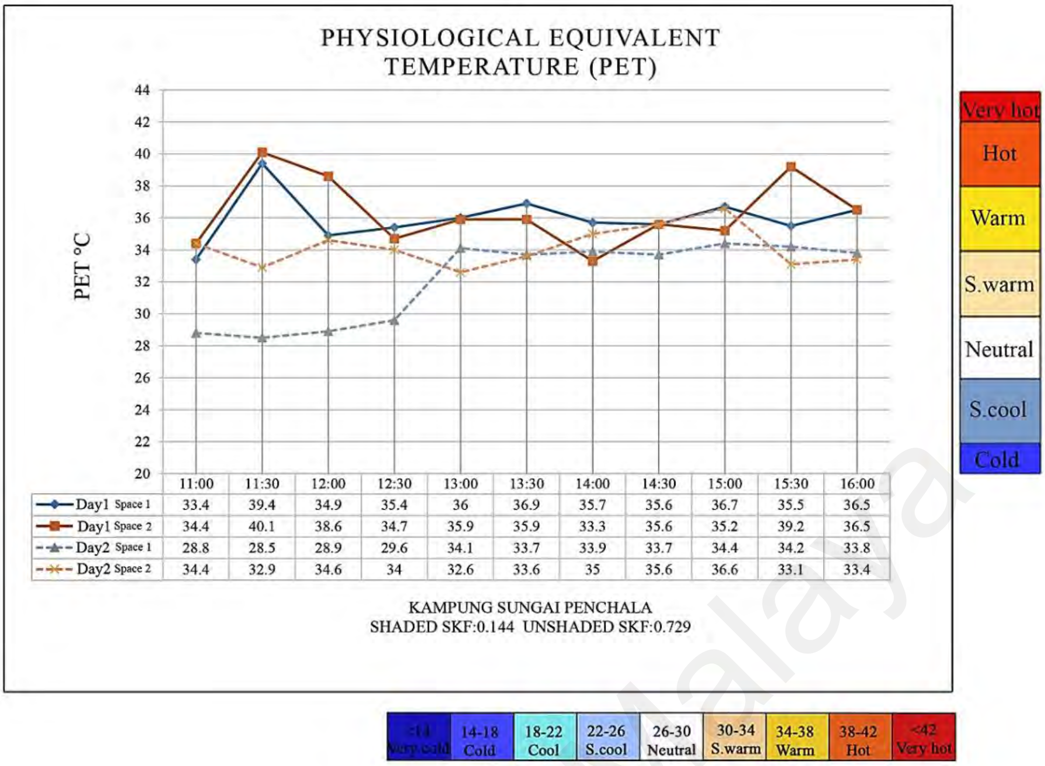
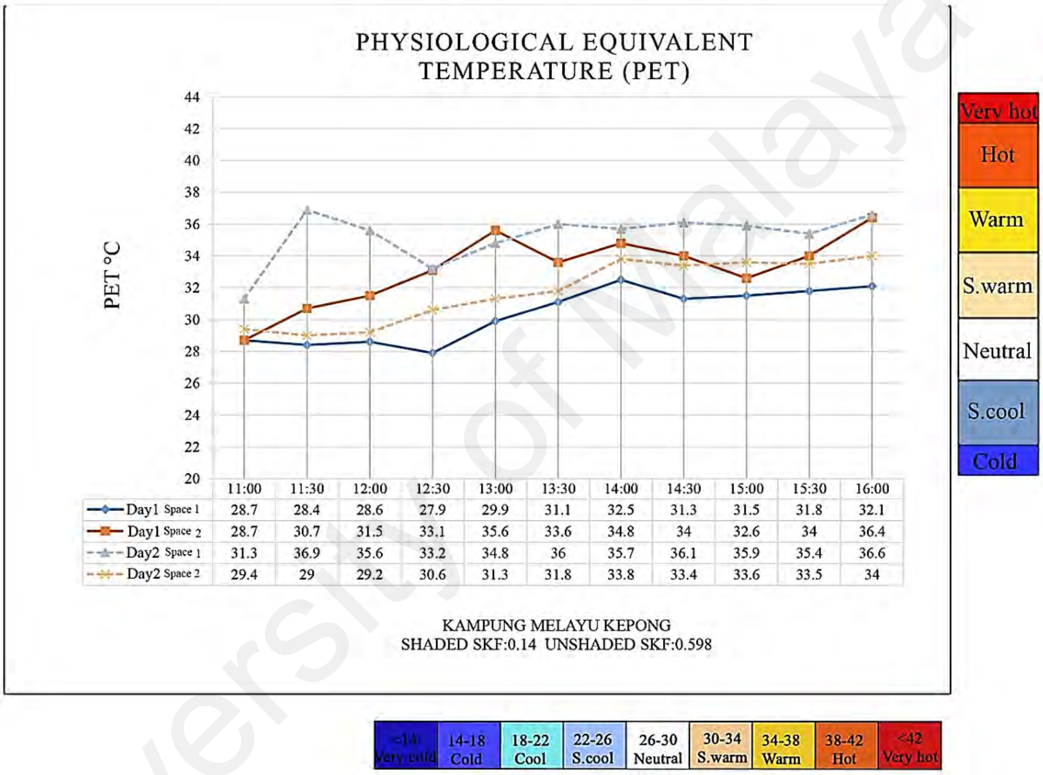


Figure 5.1: Physiologically equivalent temperature (PET) computed by Rayman Model in Kampung Sungai Penchala on 9-10th August 2016, Source: Author

5.2.2 PET Outcomes in Kampung Melayu Kepong

As it can be seen in Figure 5.2, there is a slightly upward trend of PET for both day1, and day 2 started from 11:00 am to 16:00 pm recorded in two different spaces named as shaded, and unshaded in this study. The result shows that on day 1 for shaded and unshaded, the coolest temperature recorded were 27.9°C at 12:30 pm, and 28.7°C at 11:00 am respectively; whereas, the warmest temperature measured was 32.5°C at 14:00 pm, and 36.4°C at 16:00 pm respectively. Furthermore, on day 2 for shaded and unshaded, the results indicated that the temperatures of 31.3°C at 11:00 am and 29°C at 11:30 am were measured as the coolest temperature respectively; meanwhile the warmest temperature recorded were 36.9°C at 11:30 am, 34.4°C at 16:00 pm for shaded and unshaded respectively. It can be concluded that, the maximum temperature recorded was 36.4°C, and the minimum was 27.9°C on day 1 for shaded and unshaded; however, on day 2, shaded and unshaded area had the maximum and minimum temperatures recorded as

36.9°C, and 29°C respectively. In addition, based on Thermal Perceptions Classification (TPC), both day 1 and day 2 can be considered as neutral (ranged between 26°C to30°C) to warm (ranged 34°C to 38°C) (Lin & Matzarakis, 2008). In terms of Sky View Factor (SVF), the results from Rayman illustrated that the shaded and unshaded resulted SVF were 0.140, and 0.598 respectively. In another word, the number that closer to 0 has the less visibility to sky, in contrast the number that closer to 1 has a high visibility to sky.



	11:00	11:30	12:00	12:30	13:00	13:30	14:00	14:30	15:00	15:30	16:00
Day1 Space 1	28.7	28.4	28.6	27.9	29.9	31.1	32.5	31.3	31.5	31.8	32.1
Day1 Space 2	28.7	30.7	31.5	33.1	35.6	33.6	34.8	34	32.6	34	36.4
Day2 Space 1	31.3	36.9	35.6	33.2	34.8	36	35.7	36.1	35.9	35.4	36.6
Day2 Space 2	29.4	29	29.2	30.6	31.3	31.8	33.8	33.4	33.6	33.5	34

Figure 5.2: Physiologically equivalent temperature (PET) computed by Rayman Model in Kampung Melayu Kepong on 12-13th August 2016, Source: Author

5.2.3 PET Outcomes in Kampung Baru

Looking into PET outcomes as it shown in Figure 5.3, it is indicated that on day 1 in shaded and unshaded, the coolest temperature recorded were 33.5°C, and 32°C both at 11:00 am respectively; whereas, the warmest temperature measured was 38.1°C at 13:00 pm, and 35.8°C at 14:30 to 15:00 pm respectively. Furthermore, on day 2 for shaded area and unshaded area, the results indicated that 33.1°C from 11:30 am to 12:30 pm, and 35.1°C at 12:30 pm were measured as the coolest temperature respectively; meanwhile the warmest temperature recorded were 37.5ºC at 16:00 pm, and 41.9ºC at 15:30 pm for shaded area and unshaded area respectively. It can be concluded that, the maximum temperature recorded was 38.1ºC, and the minimum was 32ºC on day 1 for shaded and unshaded area; however, on day 2 in shaded and unshaded area the maximum and minimum temperatures recorded were 41.9ºC, and 33.1ºC respectively. In addition, based on TPC (Lin & Matzarakis, 2008), both day 1 and day 2 can be considered as slightly warm (ranged between 30ºC to34ºC) to hot (ranged 38ºC to 42ºC). In terms of Sky View Factor (SVF), the results from Rayman Model shows that the shaded and unshaded resulted SVF were 0.088 (less vision to sky), and 0.747 (high vision to sky) respectively.

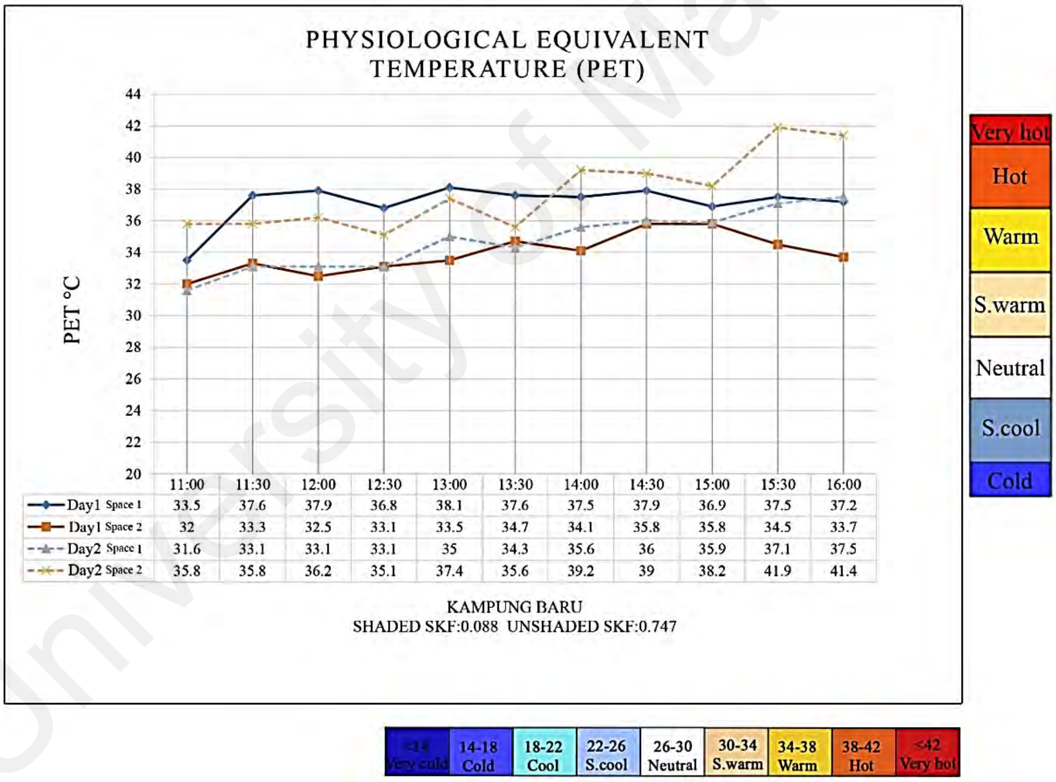


Figure 5.3: Physiologically equivalent temperature (PET) computed by Rayman Model in Kampung Baru on 16-17th August 2016, Source: Author

5.3 ENVI-met Simulation

The measure information from field estimation was contrasted and the outcome created by ENVI-met reenactment (base case), to comprehend the quality and constraints of the level of comfort in outdoor spaces and prove of the accuracy of the field data through the infinite analysis software.While the purpose of evaluating the outdoor thermal comfort through the ENVI-met simulation was providing a high level accuracy, an analysis and a comparison between the ENVI-met simulation and the data from field measurement were carried out .

Based on the microclimatic variables on August 2016 (days 9,10,12,13,16, and 17) for the three study areas, 2500 data records per hour in a 2500 square-meter surface in each area were extracted. Then, the simulation outcomes of the two weather stations' locations in the shaded and unshaded areas were studied and validated using R^2 statistical measure to reach higher accuracy. The most significant vital variable used to validate the execution of models is temperature (Ta^{o}C) (De & Mukherjee, 2017; Peng & Jim, 2013; Qaid, Lamit, Ossen, & Shahminan, 2016; Rosso et al., 2018; W. Yang, Wong, & Li, 2015). Therefore, by studying and validating the compared the temperature data as the most important factor in view of just a single point, this investigation gives a more solid approval of ENVI-met reenactment. In statistics, the coefficient of assurance indicated R^2 or r^2 and articulated "R squared," is the extent of the change in the reliant variable that is unsurprising from the free variable(s). It is a measurement utilized as a part of the setting of factual models whose fundamental design is either the expectation of future results or the testing of theories, based on other related data. It gives a measure of how very much watched results are imitated by the model, in view of the extent of an aggregate variety of results clarified by the model (Glantz, 1990; Steel & Torrie, 1960).

5.3.1 ENVI-met Validation

5.3.1.1 Kampung Melayu Kepong

Figures 5.4.a and Figure 5.5.a shows the comparison between ENVI-met simulation, and field measurement data in different temperatures versus different times for the different shaded and unshaded areas respectively. Shaded location was located nearby the traditional houses and surrounded and covered by trees with a distance of at least five meters from the east and six meters from the north. In contrast, unshaded location was faced to clear sky. The result shows that for both the shaded and unshaded areas, the lowest temperature of 27.8ºC and the highest temperature of 36.1ºC have been recorded. In terms of coefficient of determination, Figure 5.4.b and Figure 5.5.b show that the multiple regression value of 0.94 and 0.74 has been obtained for the shaded and unshaded areas respectively, which indicated that the field measurement data are fitted with good accuracy using the ENVI-met simulation model.

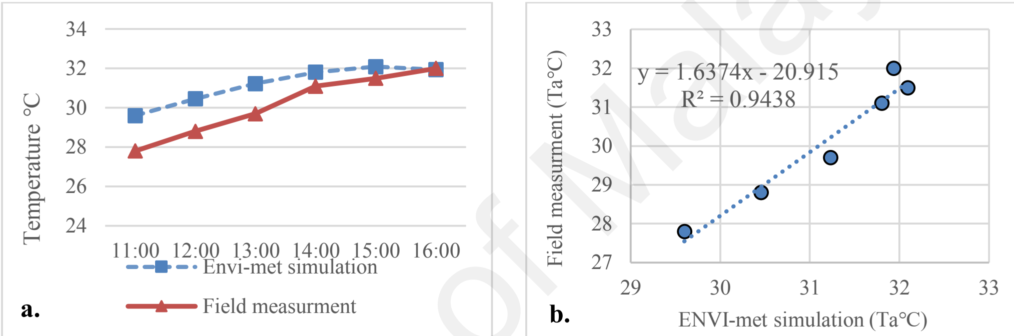


Figure 5.4: Comparison of ENVI-met simulation data with field measurement data at Kampung Melayu Kepong (shaded area), Source: Field study

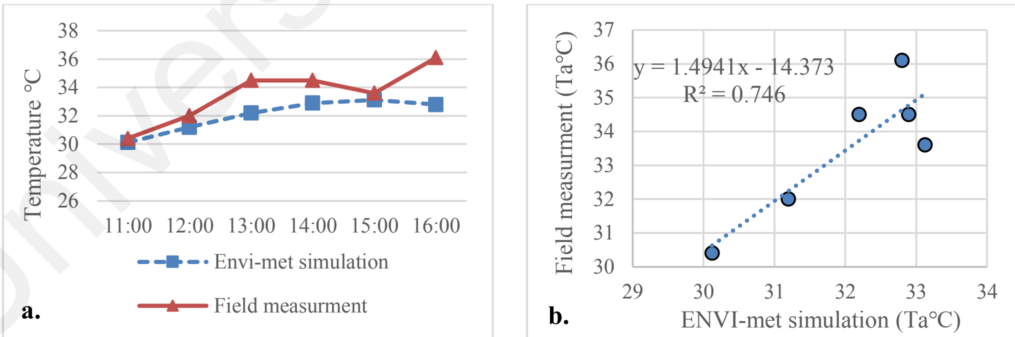


Figure 5.5: Comparison of ENVI-met simulation data with field measurement data at Kampung Melayu Kepong (unshaded area), Source: Field study

5.3.1.2 Kampung Sungai Penchala

Figures 5.6.a and Figure 5.7.a show the comparison between ENVI-met simulation and field measurement data in different temperatures versus different times for the different shaded and unshaded areas respectively. The shaded area was blocked from north-east with mass of trees and blocked from the west with traditional houses; in comparison, the unshaded area was located in an open location without any greeneries coverage nor any houses. The result shows that for the shaded and unshaded areas, the lowest temperature of 31.6°C, and the highest temperature of 37°C have been recorded. In terms of coefficient of determination, Figures 5.6.b and Figure 5.7.b show that the multiple regression value of 0.96, and 0.04 has been obtained for both the shaded and unshaded areas respectively, which indicated that the field measurement data are fitted with good accuracy using the ENVI-met simulation model.

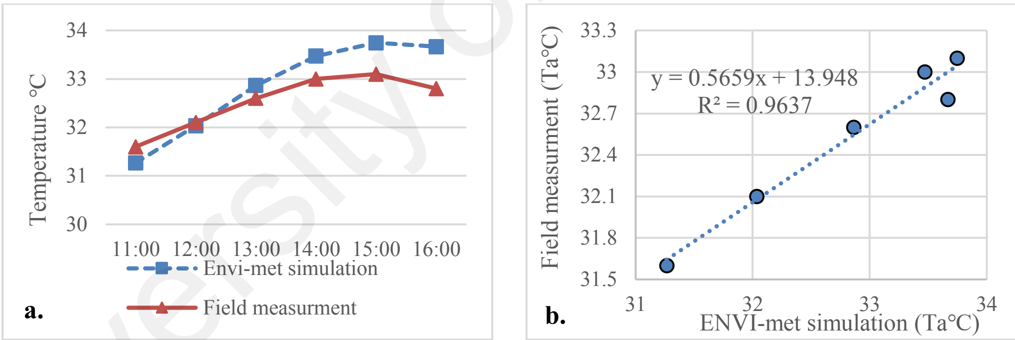


Figure 5.6: Comparison of ENVI-met simulation data with field measurement data at Kampung Sungai Penchala (shaded area), Source: Field study

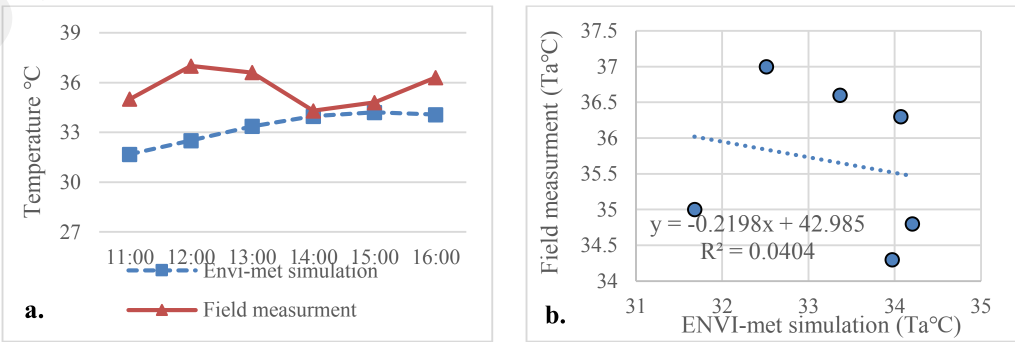


Figure 5.7: Comparison of ENVI-met simulation data with field measurement data at Kampung Sungai Penchala (unshaded area), Source: Field study

5.3.1.3 Kampung Baru

Figures 5.8.a and Figure 5.9.a show the comparison between ENVI-met simulation and field measurement data in different temperatures versus different times for the different shaded and unshaded areas respectively. The shaded area was blocked from north and south with houses and with mass of trees; in addition, the wind direction was from east to west. The result shows that for the shaded and unshaded areas, the lowest temperature of 31.8°C and the highest temperature of 35.8°C have been recorded. In terms of coefficient of determination, Figures 5.8.b and Figure 4.40.b show that the multiple regression value of 0.73, and 0.58 has been obtained for both the shaded and unshaded areas respectively, which indicated that the field measurement data are fitted with good accuracy using the ENVI-met simulation model.

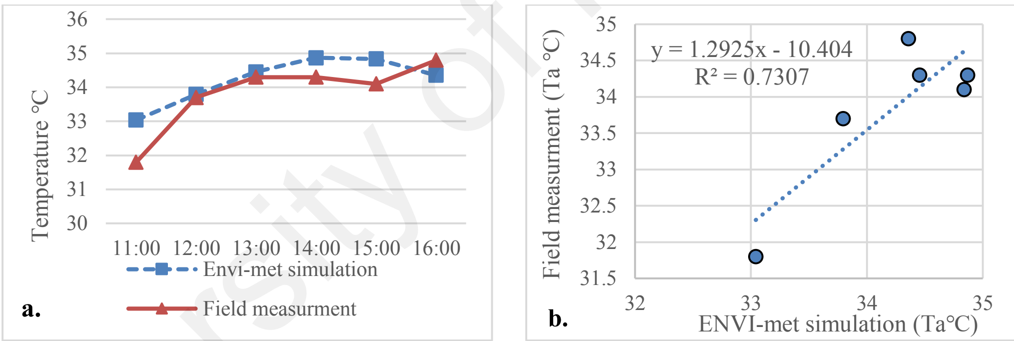


Figure 5.8: Comparison of ENVI-met simulation data with field measurement data at Kampung Baru (shaded area), Source: Field study

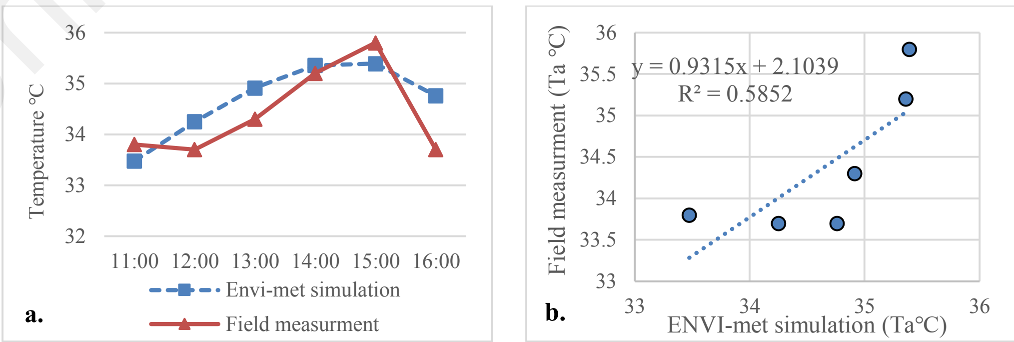


Figure 5.9: Comparison of ENVI-met simulation data with field measurement data at Kampung Baru (unshaded area), Source: Field study

5.3.2 Output Data of the ENVI-met Simulation

5.3.2.1 Kampung Melayu Kepong

The results of comparison between meteorological simulation data and the output of ENVI-met simulation have been analyzed. Variables such as Air Temperature (Ta), Relative Humidity (RH), Air Temerature Change (ATC), Mean radiation Temperature (Tmrt), Wind Speed (WS), and Solar Radiation (Sr), which can affect the level of thermal comfort were used for the ENVI-met simulation. These microclimatic parameters are clearly illustrated in the pattern and color from coolest to hottest temperature in grids of X:50 by Y:50 covering traditional houses and vegetation, from 11:00 am in the morning until 16:00 pm in the afternoon in the urban villages.

Temperature is the most important parameter, which has a significant impact on the level of outdoor thermal comfort. Figure 5.10 shows different temperature measurements in different hours during the first day of the data collection days in a squared surface with dimensions of X: 50 by Y: 50 located in the urban villages. The lighter colors are representing the cooler temperature; likewise, the darker colors are representing the warmer areas. The lowest temperature was measured at 11:00 am and it gradually started to rise up until 16:00 pm. The temperature range was between 30.7^{o}C to 32.3^{o}C. It is clear in each grid that the highest temperature has been localized at the center area, which is shown by the darker colors. The lowest and highest temperature recorded was 31.63^{o}C, and 33.85^{o}C respectively.

Looking at humidity, Figure 5.11 shows the humidity measurement; where the darker the color, the more the humidity in the area. The humidity ranged from 72% to 88%, and the maximum and minimum recorded were 80.33% and 67.61% accordingly.

The simulation results of mean radiation temperature are shown in Figure 5.12; which ranged from 39^{o}C to 63^{o}C, with minimum and maximum of 36.97^{o}C, and 66.52^{o}C respectively. As it is clear, the low temperature areas are around the houses and under the trees where shading can be observed. The temperature fluctuation is the fruit of the sky condition, wind direction, and the time, which pointed out the highest mean radiation temperature measured by 66.52ºC, while the lowest was just 36.97ºC.

Figure 5.13 shows short wave solar radiation distribution at outdoor spaces of the village, where the darker areas are representing the lower radiation intensity while the lighter colors are indicating the higher irradiance. The radiant energy ranged between lower than 89W/m^2 to above 801W/m^2 where the maximum measurement was 930.31W/m^2 and the minimum was 0W/m^2. It goes without saying that those areas located under the shadows were less affected by radiation.

Looking to the air temperature change as shown in Figure 5.14, it is indicated that the air temperature change gradually decreased starting from 11:00 am until 16:00 pm. The maximum measurement at 11:00 am was 1.89K/h, while it declined to -0.10K/h at 16:00 pm.

From the investigation of wind speed from Figure 5.15, it can be observed that the air flow from south-east, which is shown by the darker colors; however, the houses blocked the path of the airflow toward the north (shown with brighter color). The wind speed ranged between below 0.15m/s and above 1.19m/s. Meanwhile, the maximum and minimum measurements recorded were 1.39m/s, and 0.02m/s respectively.

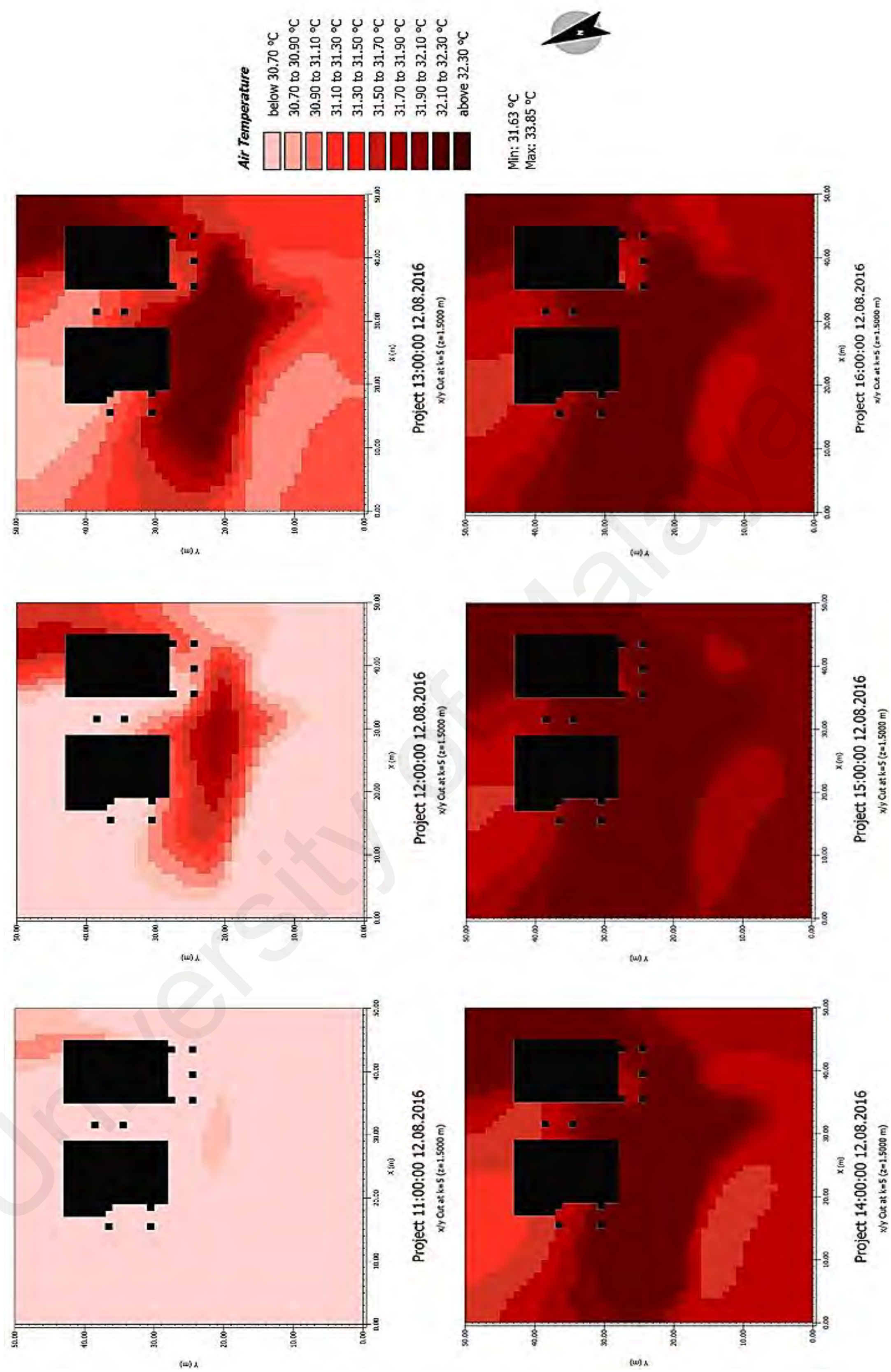


Figure 5.10: Comparison of Air Temperature in different times from 11:00 am to 16:00 pm, Source: Field study

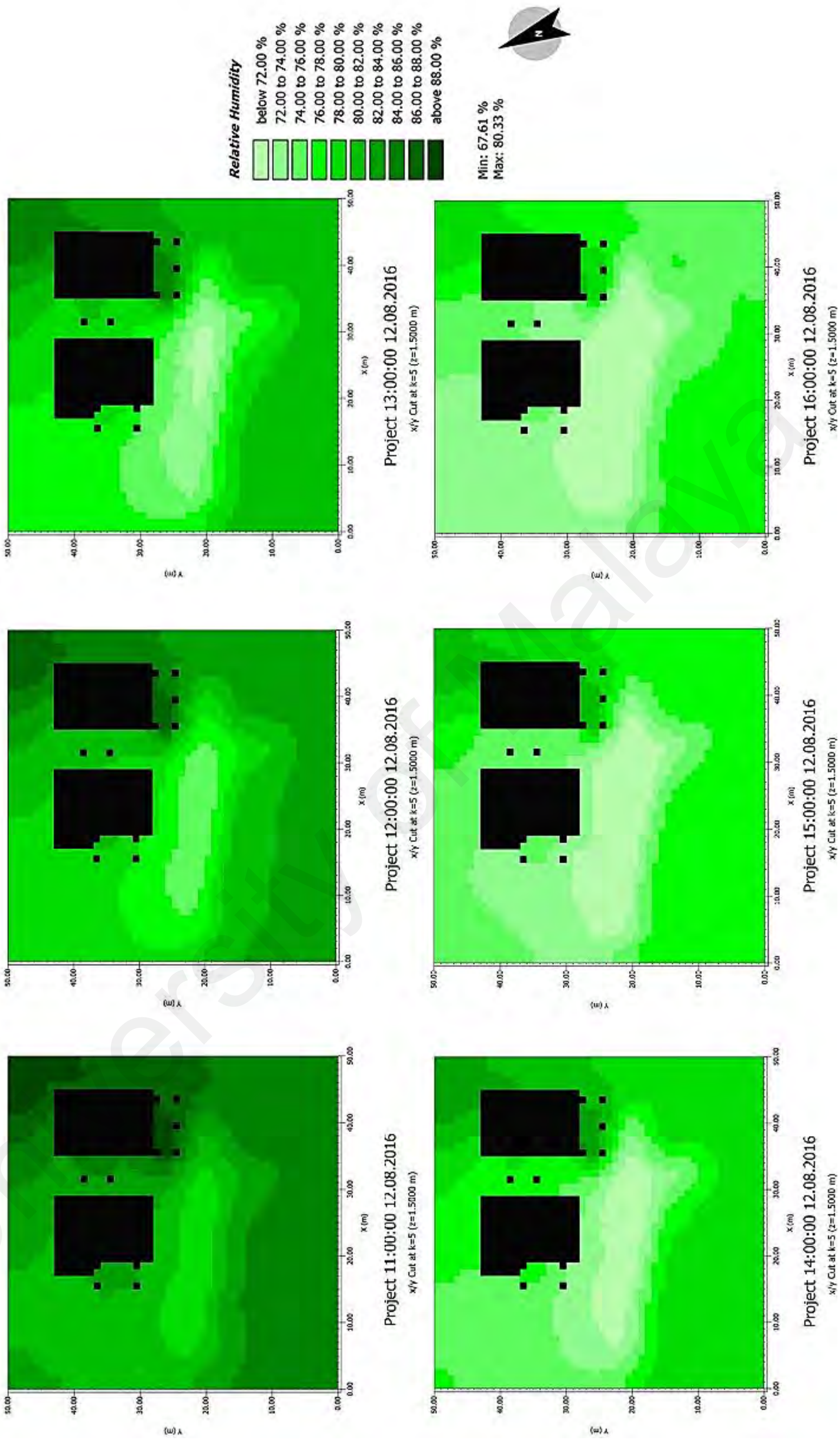


Figure 5.11: Comparison of Relative humidity in different times from 11:00 am to 16:00 pm, Source: Field study

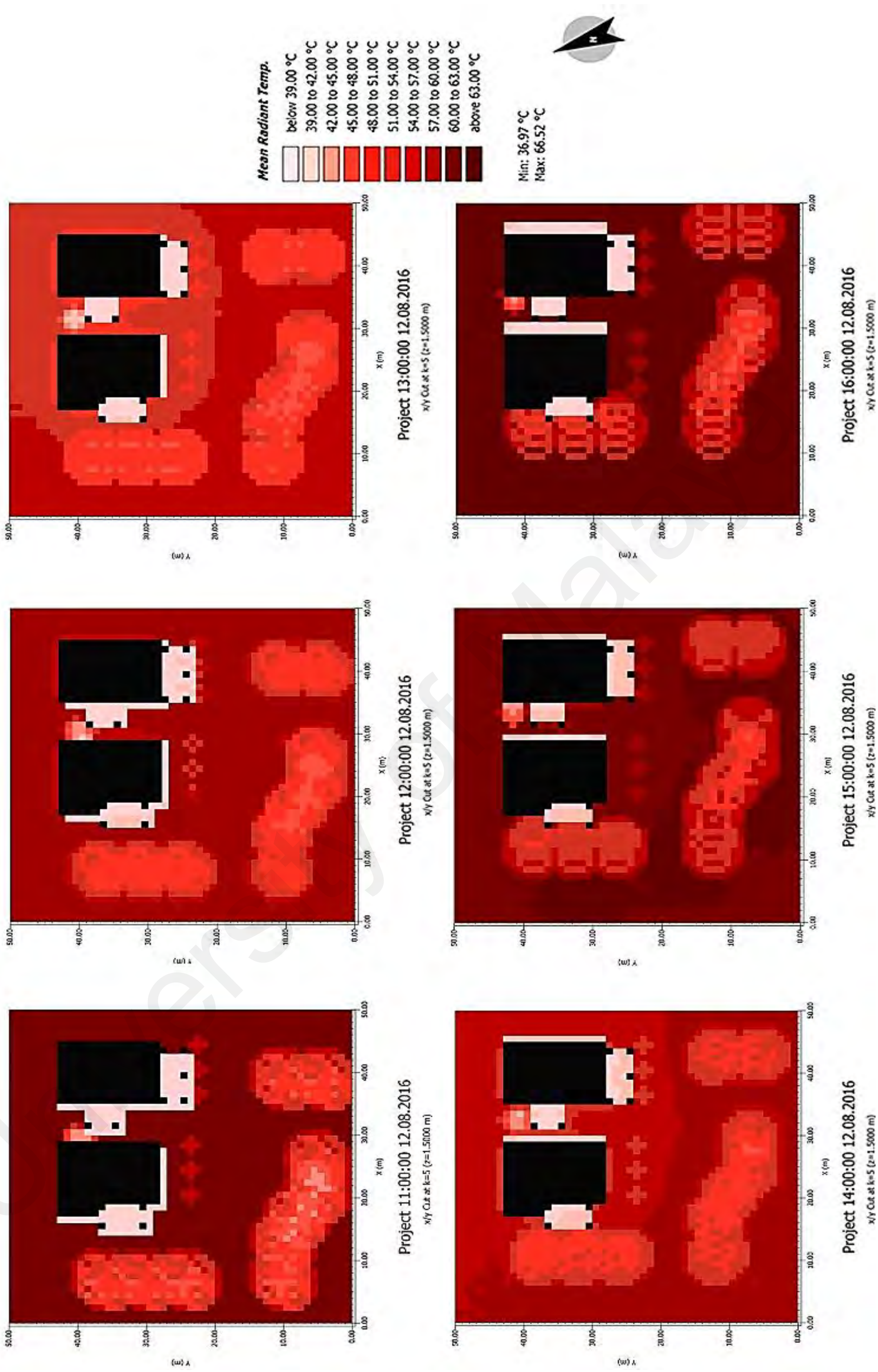


Figure 5.12: Comparison of Mean radiant temperature in different times from 11:00 am to 16:00 pm, Source: Field study

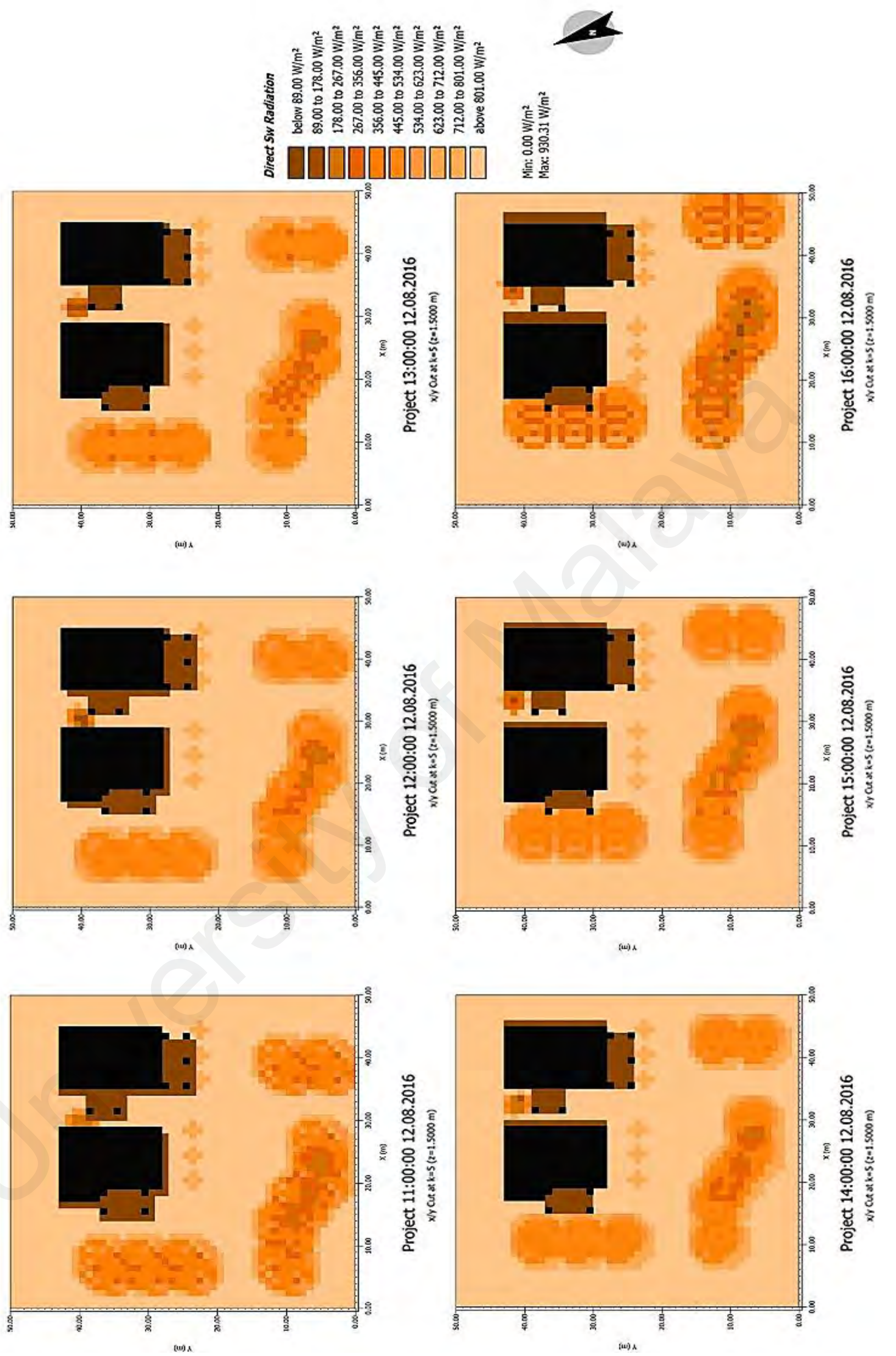


Figure 5.13: Comparison of Solar radiation in different times from 11:00 am to 16:00 pm, Source: Field study

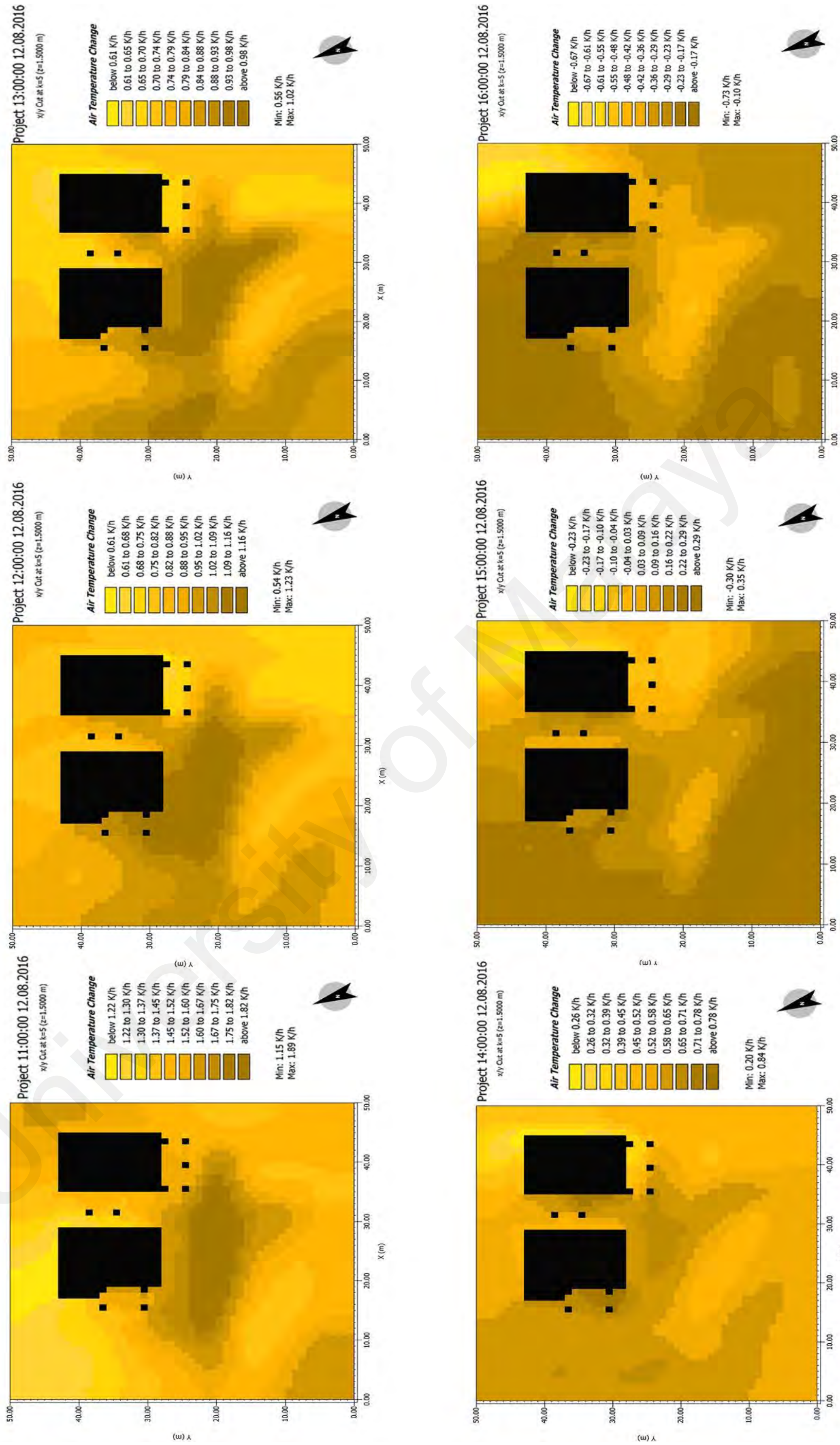


Figure 5.14: Comparison of Air temperature change in different times from 11:00 am to 16:00 pm, Source: Field study

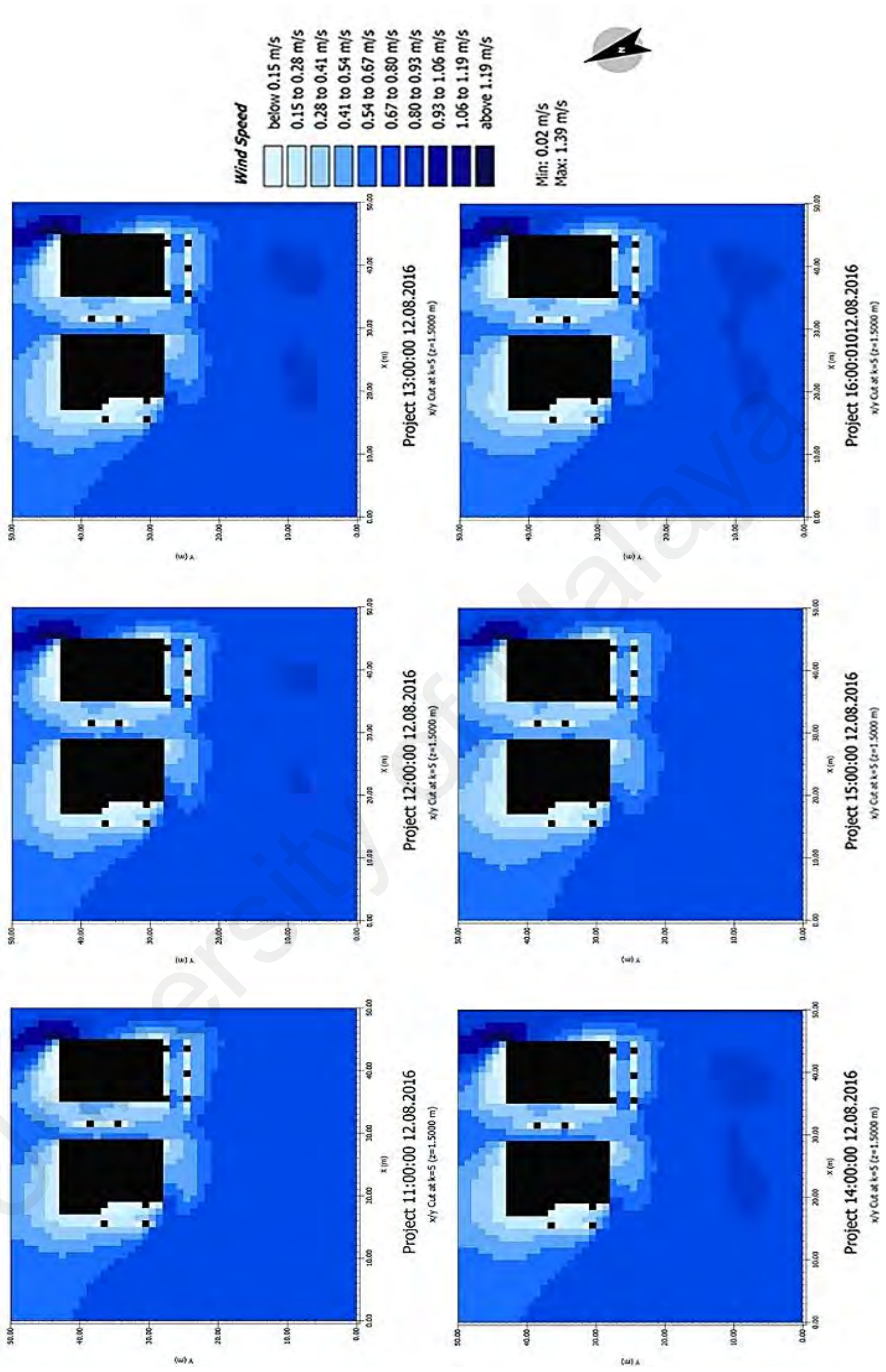


Figure 5.15: Comparison of Wind speed in different times from 11:00 am to 16:00 pm, Source: Field study

5.3.2.2 Kampung Sungai Penchala

Figure 5.16 displays the variation of air temperatures in Kampung Sungai Penchala utilizing the meteorological data for simulation through ENVI-met. From the field temperature measurement, there was an increment in temperature from 11:00 am to 16:00 pm. Air temperatures ranged from below 30.50°C to above 34.50°C. However, the maximum and the minimum temperatures recorded were 35.51°C, and 33.28°C, while the temperature increased gradually during the experiment period.

Figure 5.17 shows the relative humidity variations output from ENVI-met simulation. It is explicitly observed that the highest humidity was 86.36% at 11:00 am, and in contrast the lowest humidity was 71.46% at 16:00 pm. The difference between the lowest and the highest percentage of humidity throughout the day was 14.9%. Moreover, the boundary of relative humidity ranged from less than 77.5%, up to more than 89.50%.

From Figure 5.18, it can be concluded that the mean radiant temperature was influenced by air temperature. The higher mean radiant temperature was recorded when the air temperature was higher. In addition, the humidity percentage and the air temperature have an opposite relationship. The upper and the lower boundaries were below 38°C up to above 54°C, while the maximum measured temperature was 65.16°C, compared to the minimum of 40.85°C. The color intensity represents the different level of temperatures, which is the more the darker the color, the higher the temperature recorded in that space. Since the shaded areas have cooler temperatures, the lighter color is used to differentiate them with the unshaded areas.

Figure 5.19 shows the short wave solar radiation distribution for outdoor spaces, where the darker areas are representing the lower radiation intensity and the lighter areas are representing the higher irradiances. Radiation energy is limited between lower than $96W/m^2$ to above $854W/m^2$, where the maximum measurement was $935.98W/m^2$, and the minimum was 0W/m^2. It goes without saying that those areas located under the shadows have lower radiation.

Looking to the air temperature changes as shown in Figure 5.20, it is indicated that the air temperatures change gradually decreased starting from 11:00 am until 16:00 pm. The maximum measurement at 11:00 am was 2.35K/h, while it declined to -0.01K/h at 16:00 pm. The measurement started from the very early stage of the experiment at 11:00 am and the air temperature change status of the data extracted from the simulation was positive until 14:00 pm and changed to negative afterward until the end of the experiment at 16:00 pm.

Considering wind speed investigation from Figure 5.21, it could be determined that the air blew from north-east, ranged between below 0.07m/s and above 0.55m/s. Meanwhile, the maximum and minimum measurements recorded were 0.61m/s, and 0.01m/s respectively. The darker colors represent the higher wind speed, in contrast with the brighter colors. Since the air blew from the north-east of the space, the gap between those houses located at the eastern side makes the air turbulence to occur at that area, which ended with the temperature decrement shown in darker color.

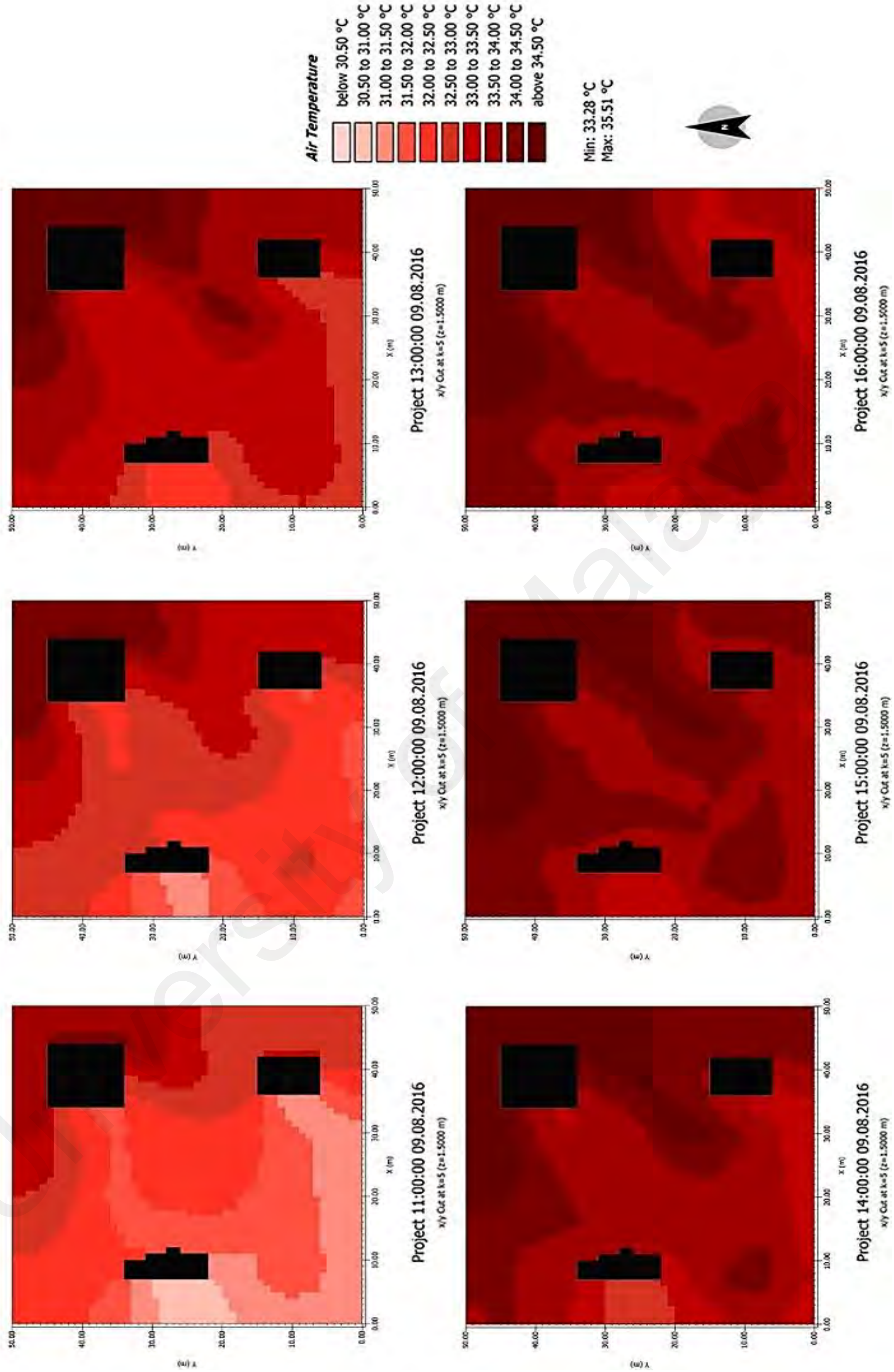


Figure 5.16: Comparison of Air Temperature in different times from 11:00 am to 16:00 pm, Source: Field study

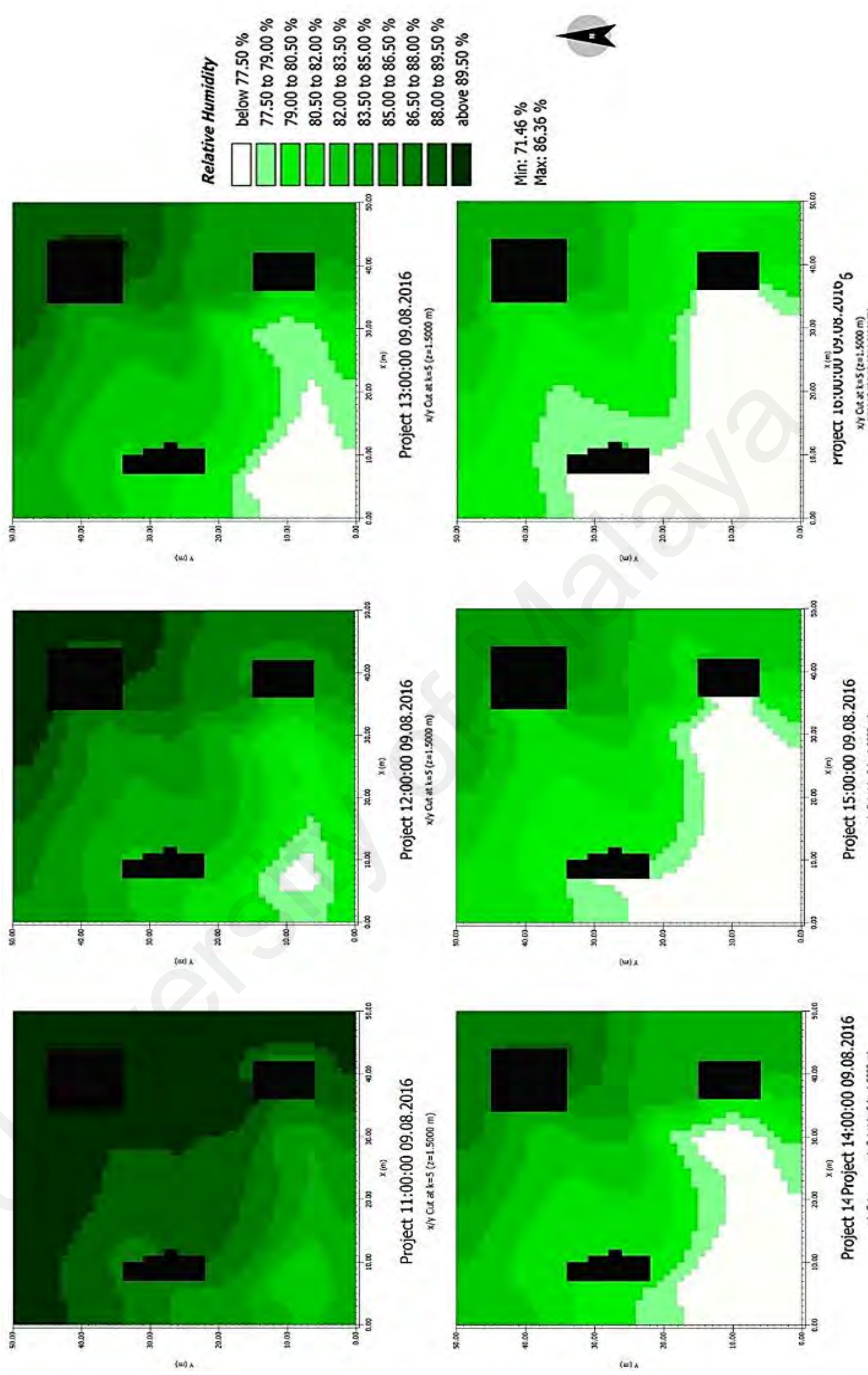


Figure 5.17: Comparison of Relative humidity in different times from 11:00 am to 16:00 pm, Source: Field study

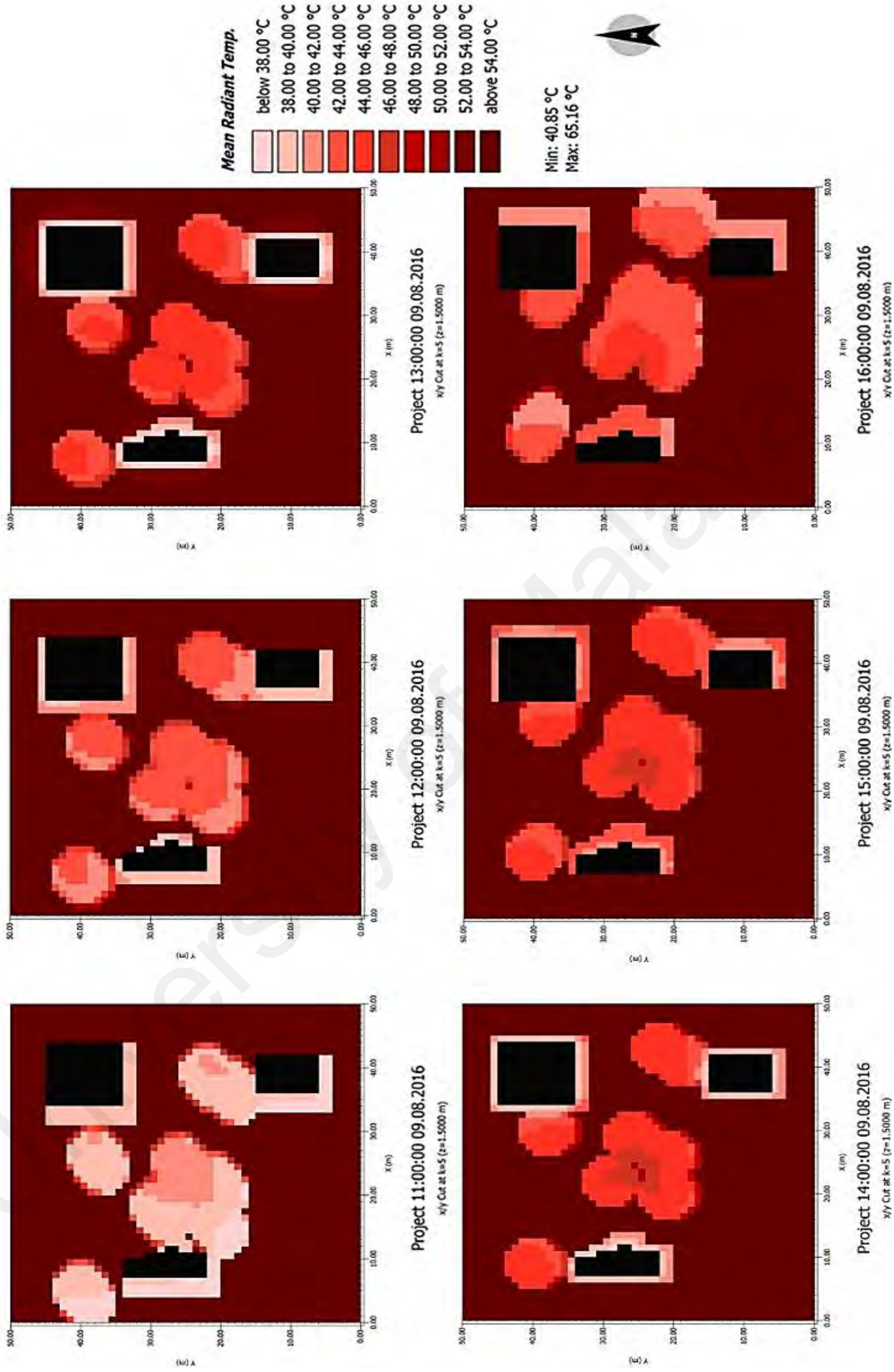


Figure 5.18: Comparison of Mean radiant temperature in different times from 11:00 am to 16:00 pm, Source: Field study

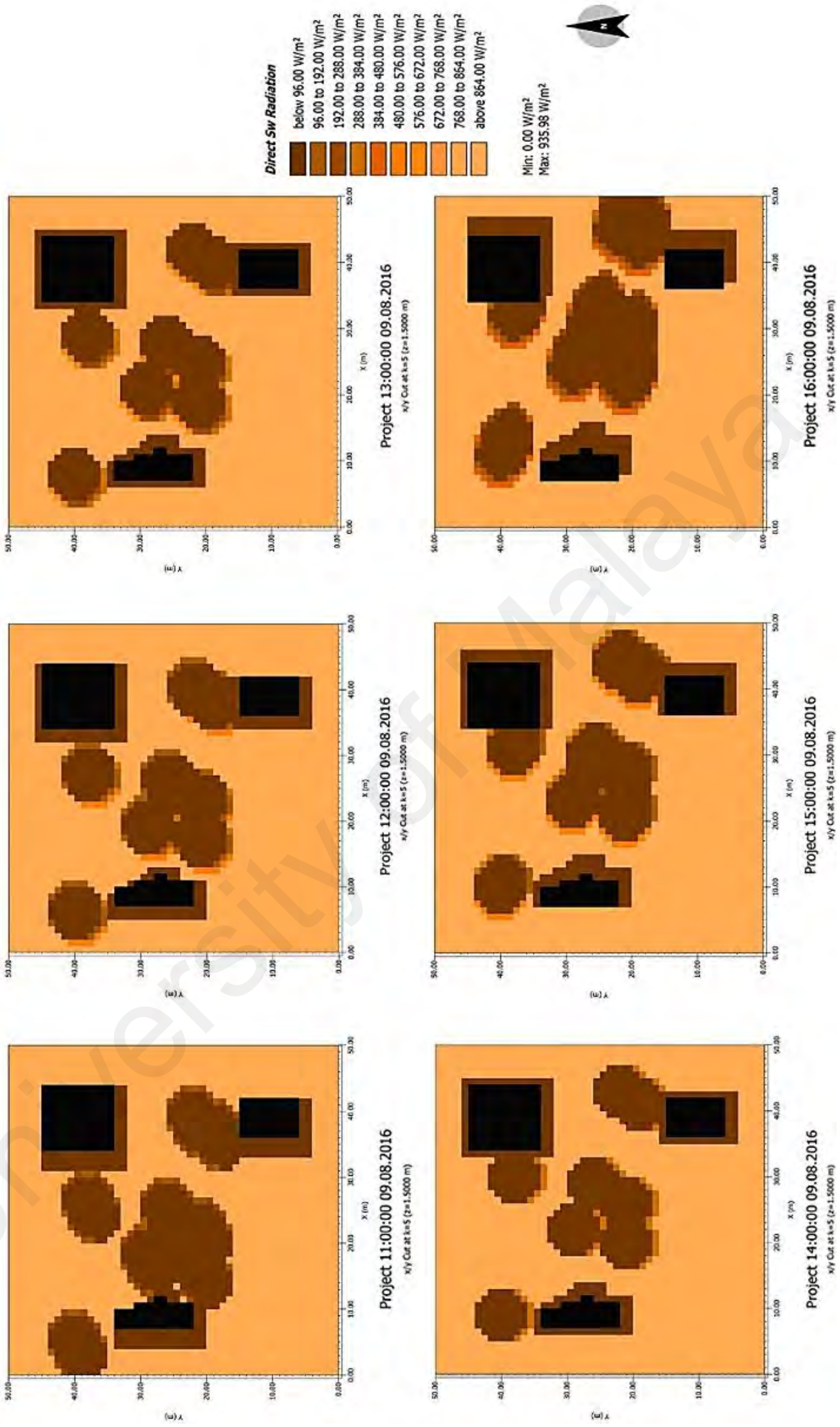


Figure 5.19: Comparison of Solar radiation in different times from 11:00 am to 16:00 pm, Source: Field study

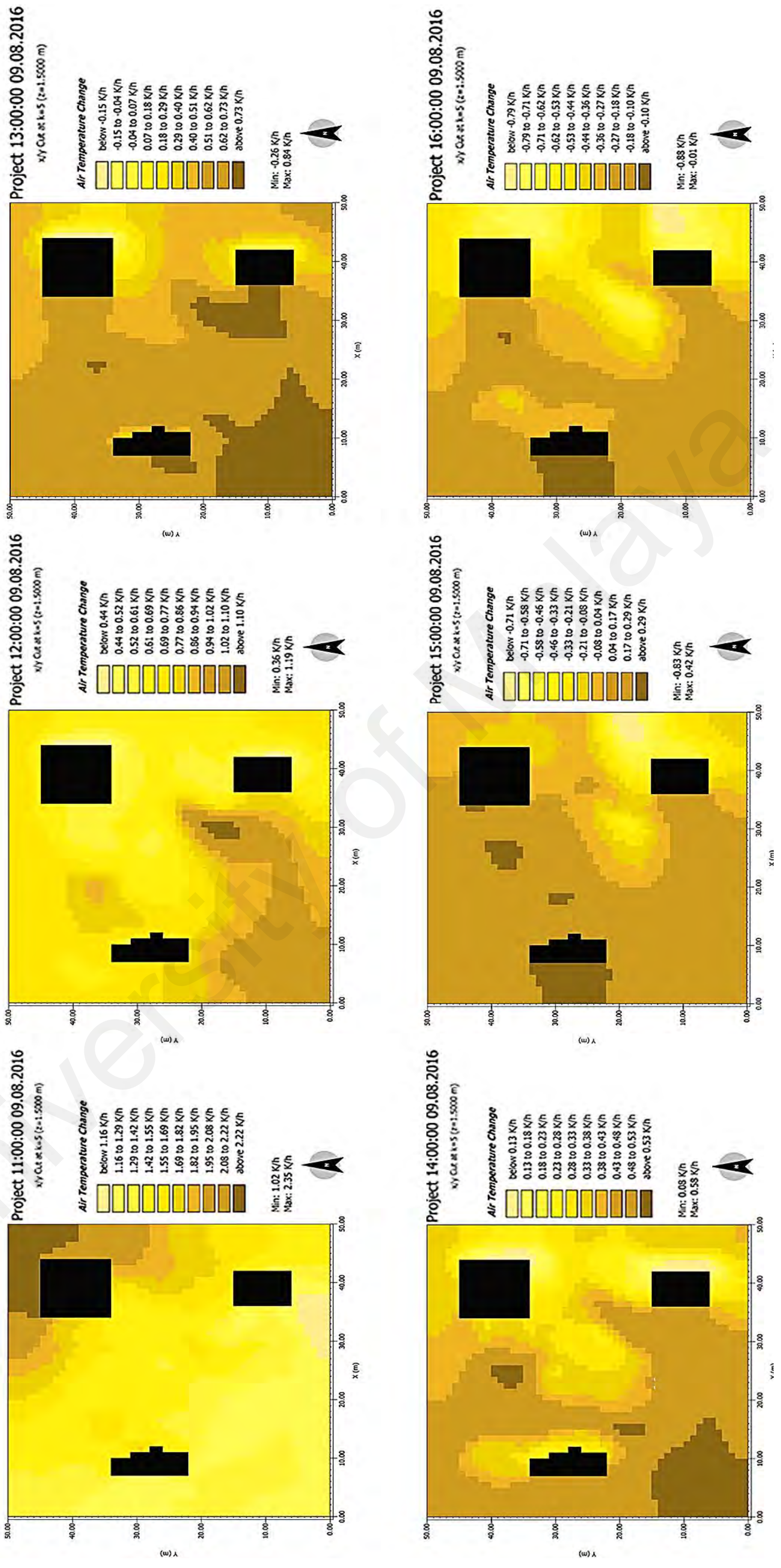


Figure 5.20: Comparison of Air temperature change in different times from 11:00 am to 16:00 pm, Source: Field study

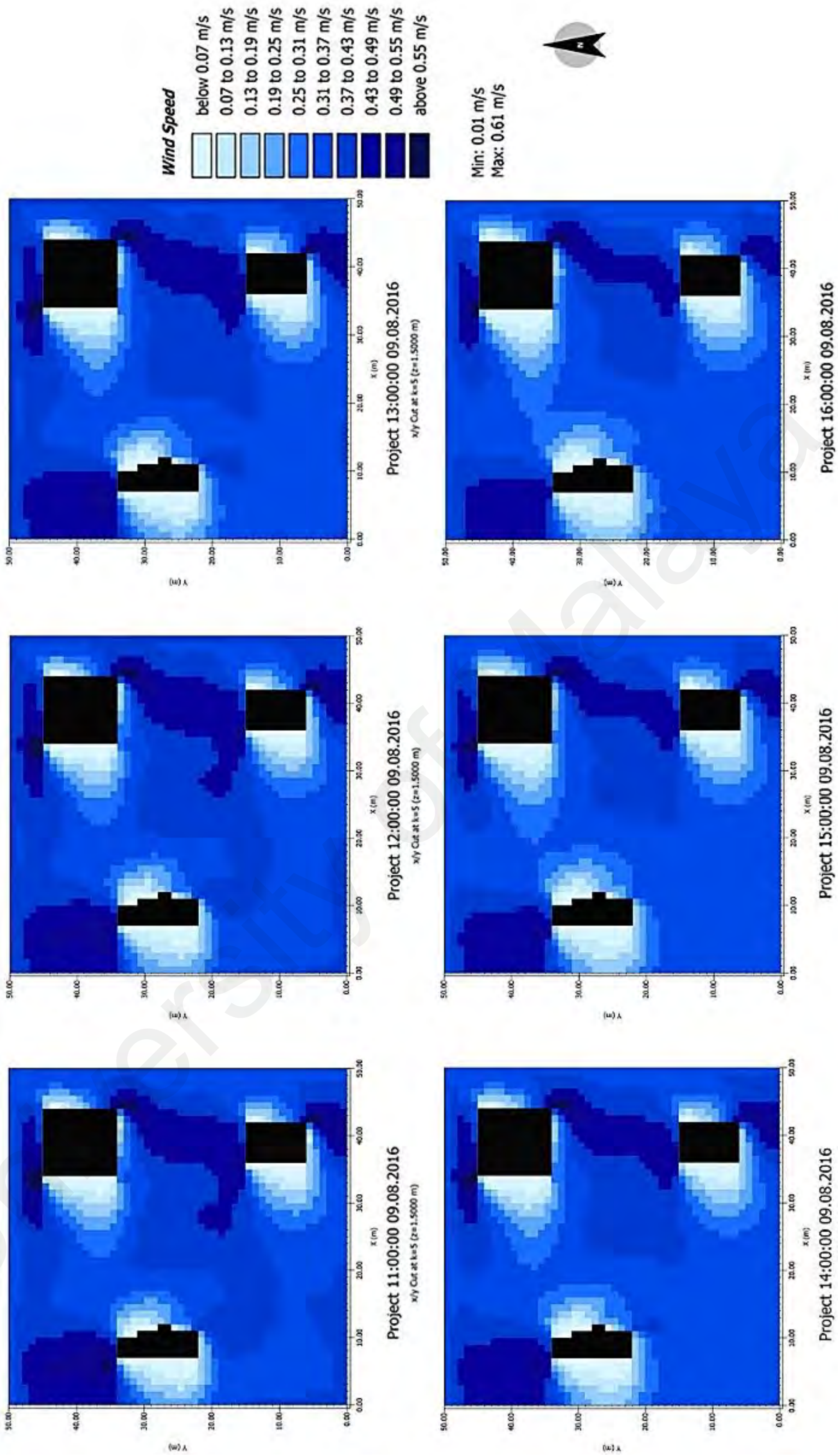


Figure 5.21: Comparison of Wind speed in different times from 11:00 am to 16:00 pm, Source: Field study

5.3.2.3 Kampung Baru

Looking to the Kampung Baru ENVI-met simulation output in Figure 5.22, it shows how temperature has increased from 11:00 am to 16:00 pm. The highest temperature was observed between 13:00 pm to 15:00 pm. The maximum temperature measured was 35.17ºC, and the minimum was 32.08ºC; meanwhile, the air temperature is bounded from below 32.30ºC to above 34.70ºC. As described in the previous section, the color density represents the discrepancy between the different measured temperatures, that is the denser the color, the warmer the area is.

Figure 5.23 shows the relative humidity variation output from ENVI-met simulation. It is observed that the highest humidity was at 11:00 am with 94.42% and the lowest humidity measured at 16:00 pm with 82.05%. The difference between the lowest and the highest percentage of humidity was 12.37%. The relative humidity ranged from less than 85%, and more than 93%.

As can be seen in Figure 5.24, the variation of the mean radiant temperatures is influenced by air temperature. The maximum measured degree was 62.04ºC while the minimum recorded of 33.17 ºC. It shows that air temperature has a direct relationship with mean radiant temperature, and the relative humidity has the opposite relationship with temperature.

Figure 5.25 shows the short wave solar radiation distribution for outdoor spaces of the selected areas. Radiation energy is bounded between lower than 87W/m^2 to above 783W/m^2, where the maximum measurement was 965.73W/m^2 and the minimum was 0W/m^2. It goes without saying that those areas located under the shadows have less direct radiation from sun.

Looking to the air temperature changes as shown in Figure 5.26, it is indicated that the maximum measurement was at 11:00 am with 2.54K/h, which gradually decreased to -0.18K/h at 16:00 pm. The measurement started from the very early stage of the experiment at 11:00 am and the air temperature change status of the data extracted from the simulation was positive until 14:00 pm and changed to negative afterward until the end of the experiment at 16:00 pm. Considering wind speed investigation from Figure 5.27, it could be concluded that the air blew from east, ranged between below 0.09m/s and above 0.73m/s. The maximum and minimum measurements recorded were 0.86m/s, and 0.01m/s respectively. The darker color represents the higher wind speed, in contrast with the brighter colors which represent the lower wind speed. Since the air blew from the east direction of the space, the gap between those traditional and renovated houses located at the northern and southern side causing air turbulence to occur at those areas leading to temperature decrement.

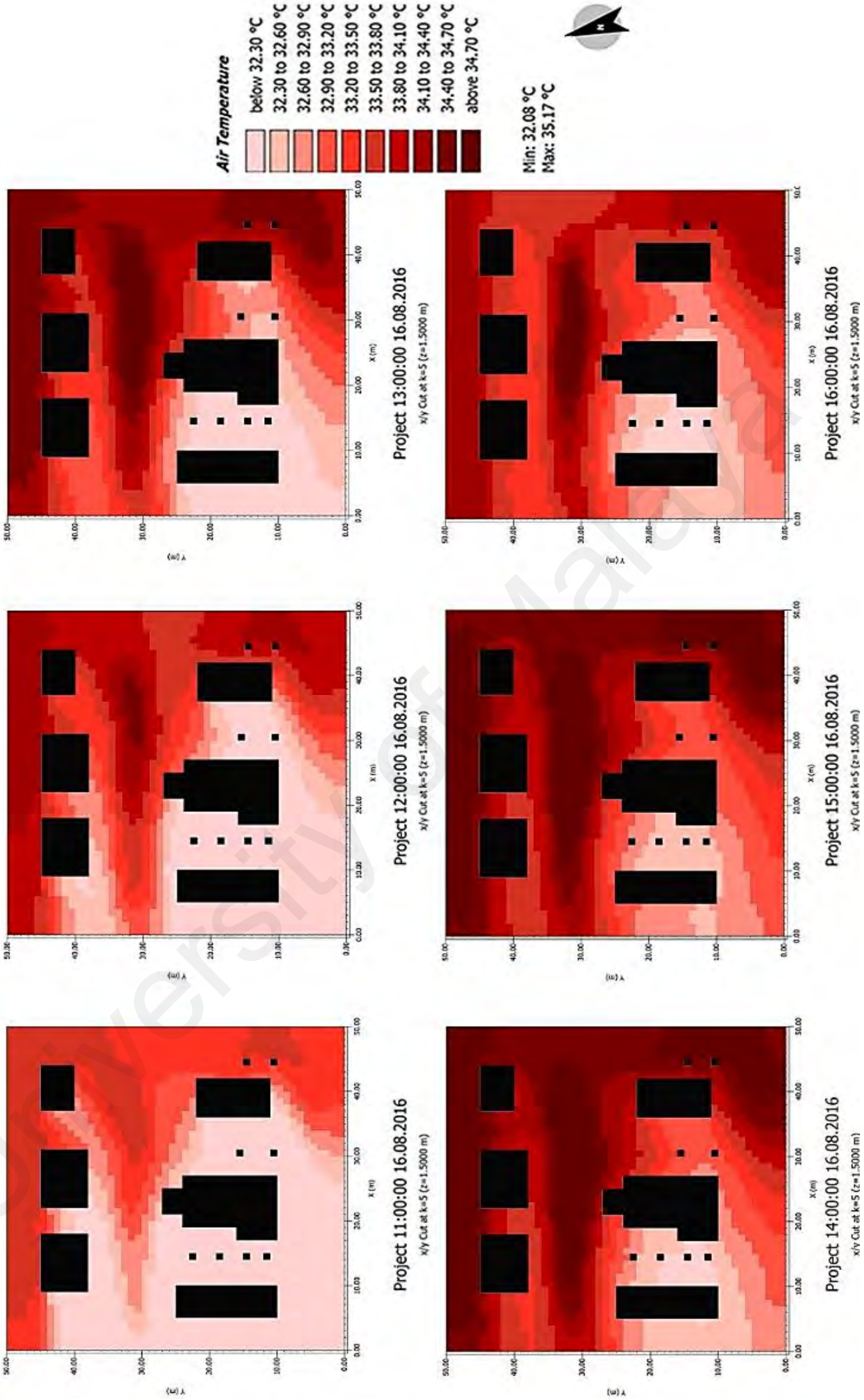


Figure 5.22: Comparison of Air Temperature in different times from 11:00 am to 16:00 pm, Source: Field study

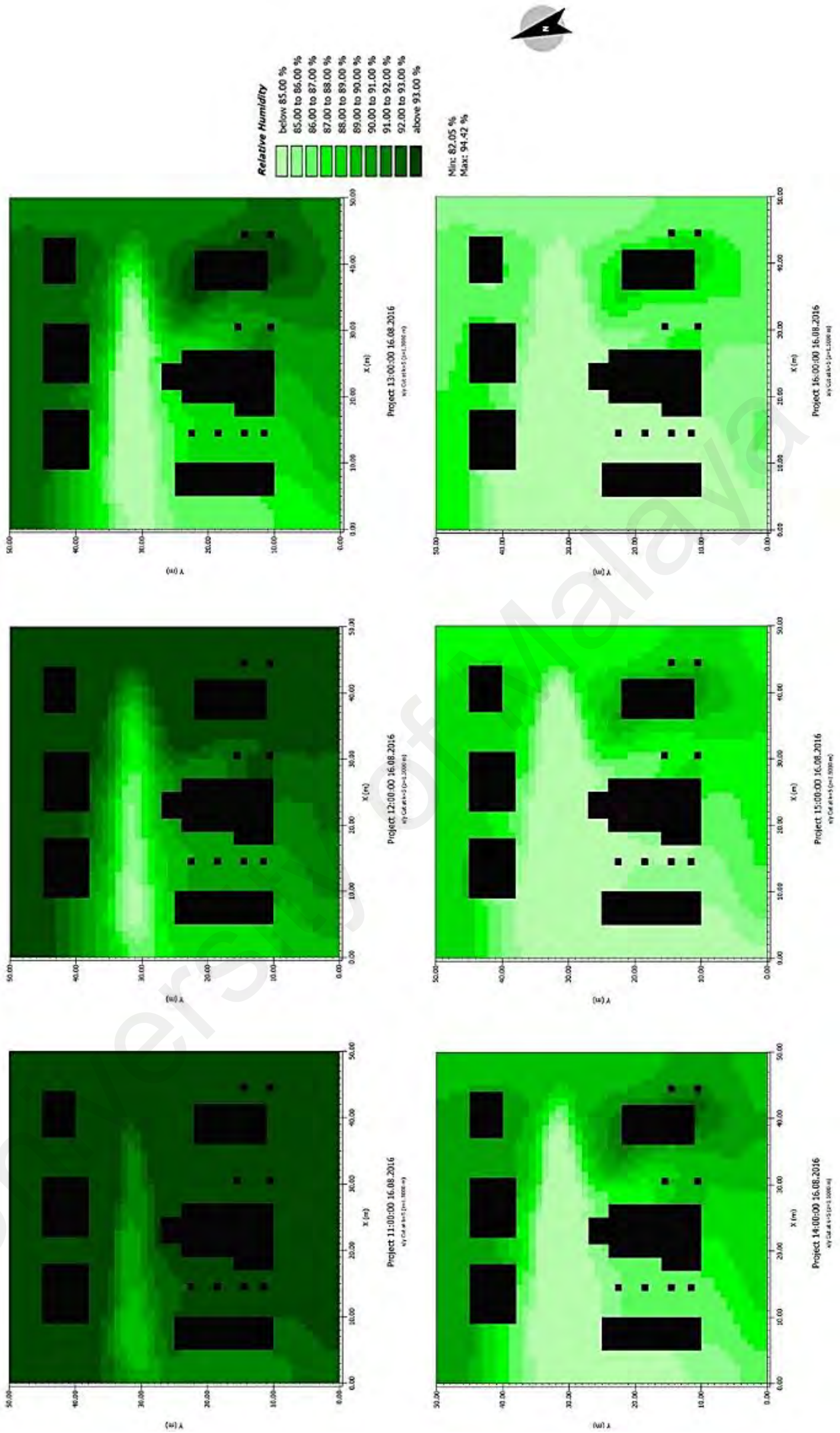


Figure 5.23: Comparison of Relative humidity in different times from 11:00 am to 16:00 pm, Source: Field study

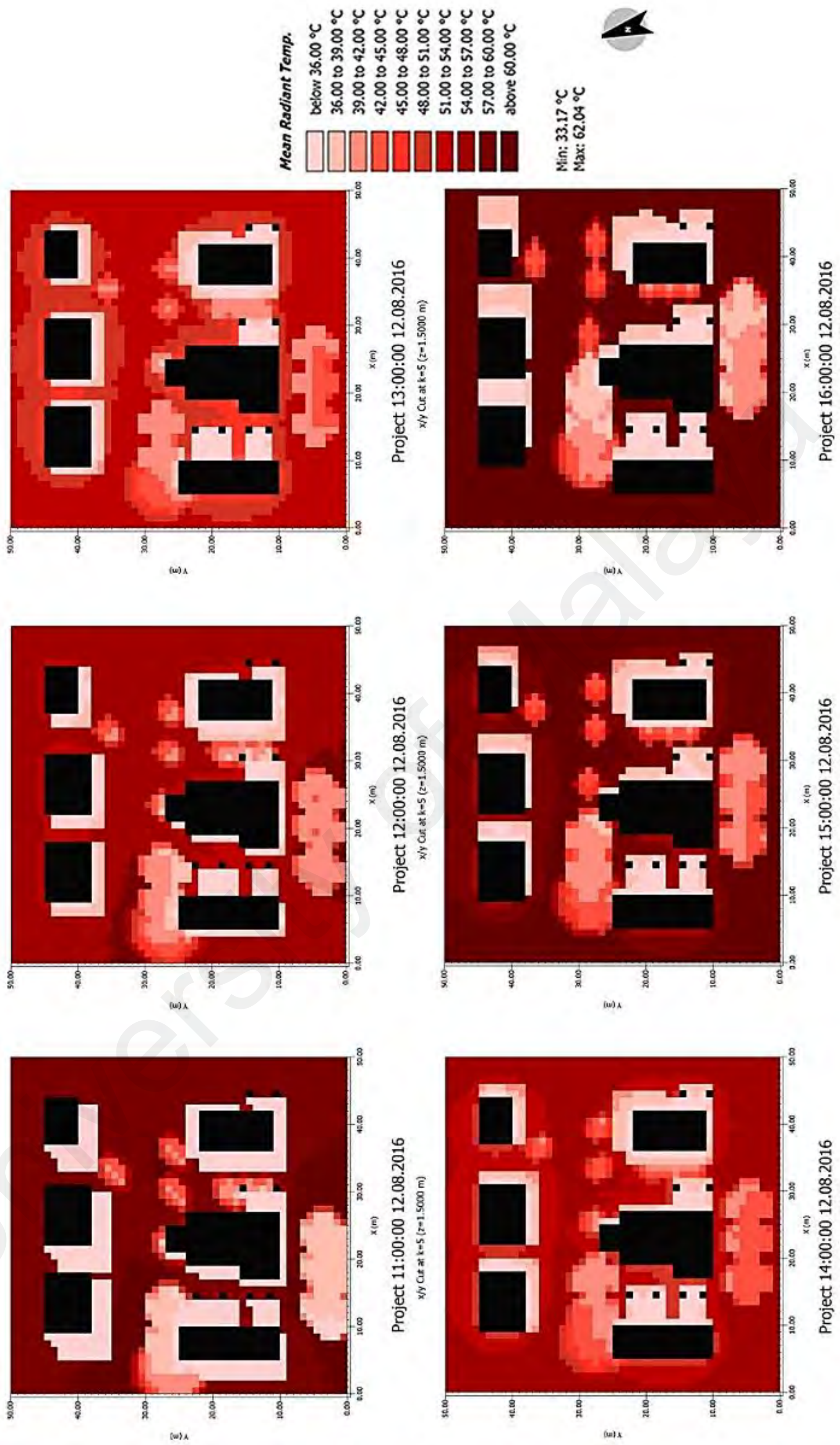


Figure 5.24: Comparison of Mean radiant temperature in different times from 11:00 am to 16:00 pm, Source: Field study

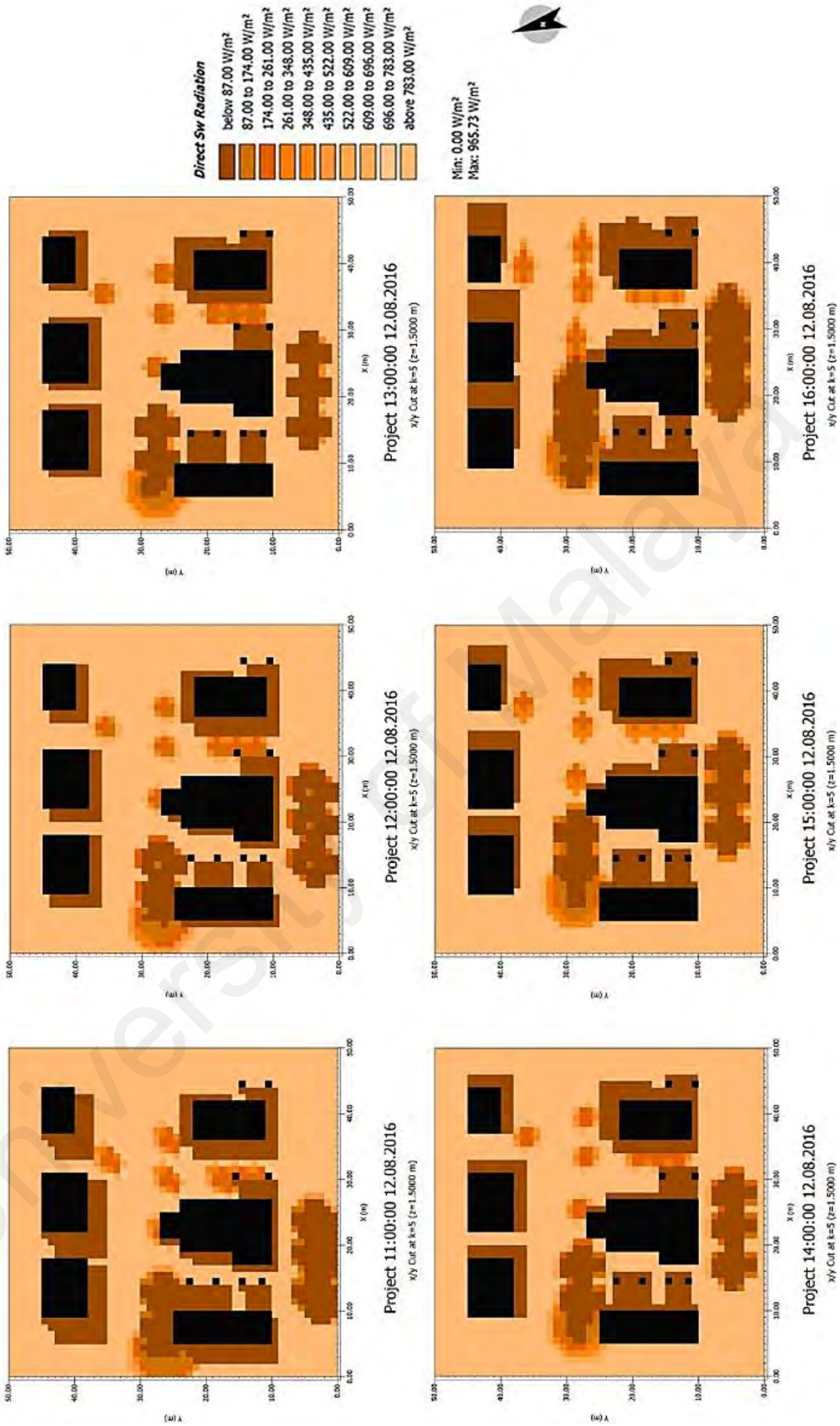


Figure 5.25: Comparison of Solar radiation in different times from 11:00 am to 16:00 pm, Source: Field study

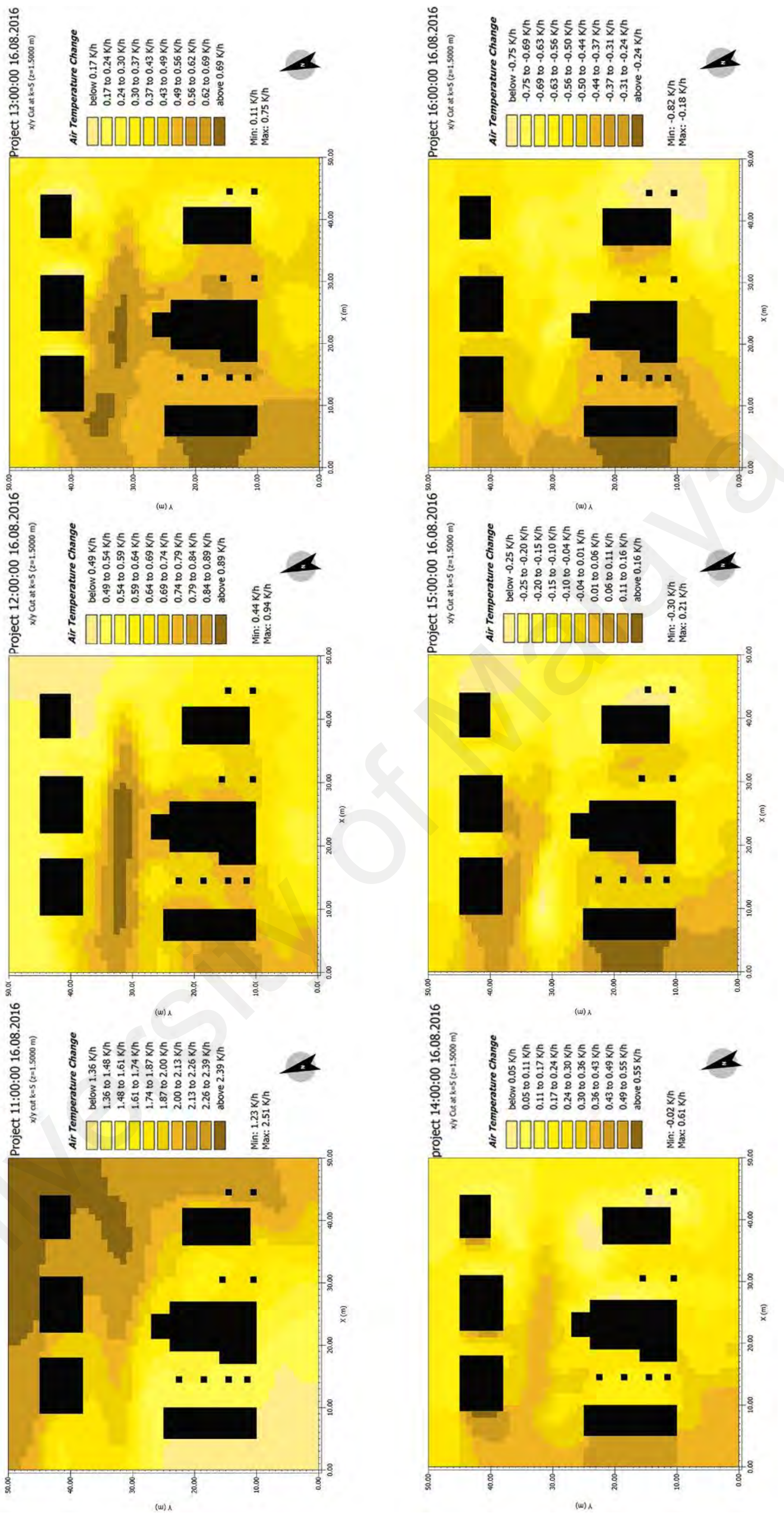


Figure 5.26: Comparison of Air temperature change in different times from 11:00 am to 16:00 pm, Source: Field study

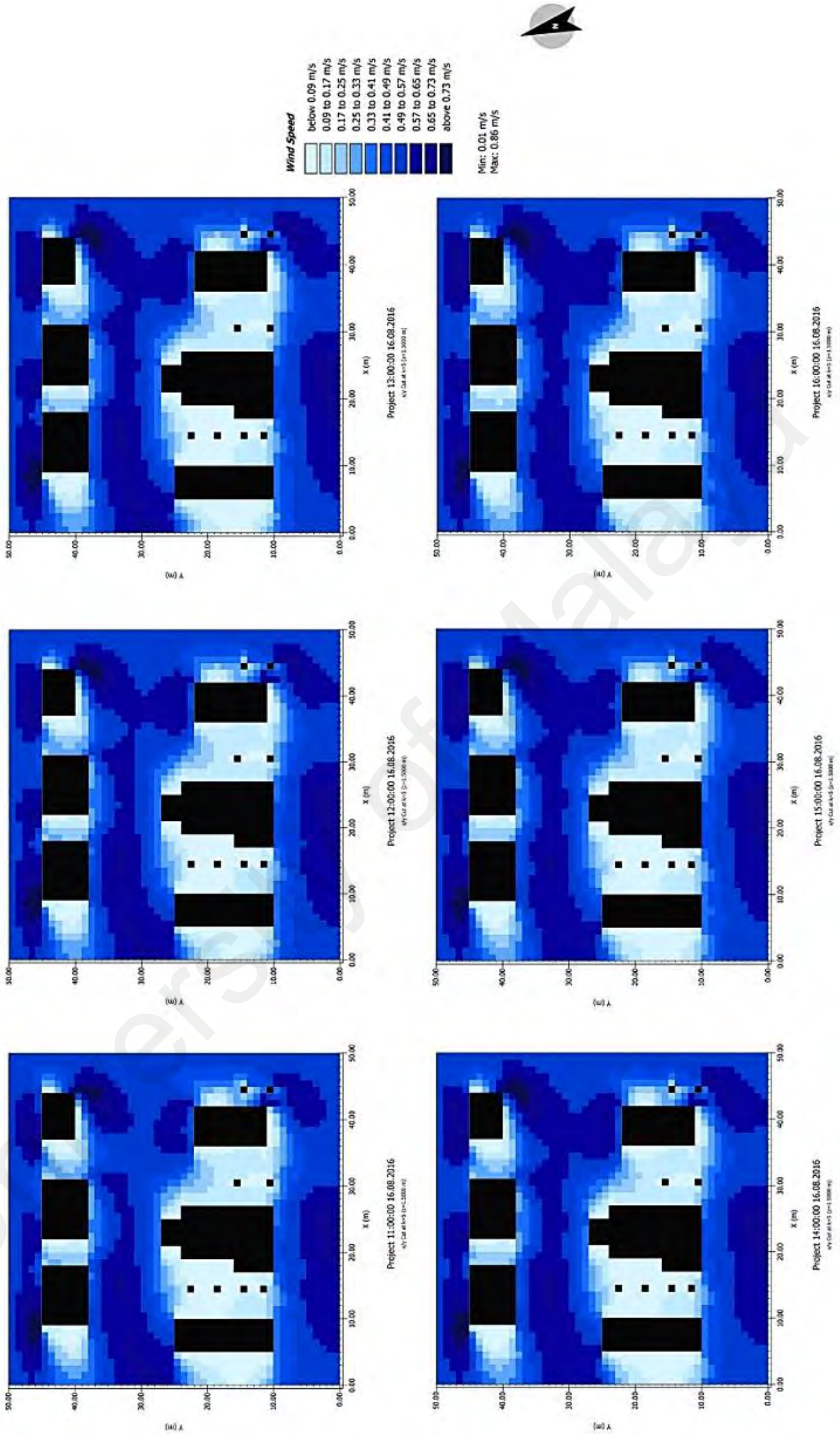


Figure 5.27: Comparison of Wind speed in different times from 11:00 am to 16:00 pm, Source: Field study

5.4 Discussion of Temperature between ENVI-met Simulation and Field Measurements

Figure 5.28 shows the temperatures in field measurement versus the ENVI-met simulation recorded in Kampung Sungai Penchala (KSP), Kampung Baru (KB), and Kampung Melayu Kepong (KMK) from 11:00 in the morning to 16:00 in the afternoon in the shaded area. The straight lines represent the field measurement data while the dashed lines represent the ENVI-met simulation data. Field measurement was measured in Kampung Baru with initial temperature of 31.8 ^{o}C at 11:00 am. Moreover, it is recorded that the warmest space among the others were 34.80^{o}C, and 34.86^{o}C for field, and ENVI-met measurement respectively. However, Kampung Sungai Penchala recorded the second warmest space with 32.8^{o}C, and 33.6^{o}C for field, and ENVI-met measurement accordingly; while its first measurement was 31.6^{o}C in field at 11:00 am. In contrast, the coolest place was Kampung Melayu Kepong, with initial temperature of 27.8^{o}C measured at 11:00 am, while the maximum temperature recorded was 32^{o}C, and 31.9^{o}C for field, and ENVI-met measurement respectively. Mass of greeneries and taller trees in KMK were more than KB, thus more shaded coverage can be seen in KMK which makes it cooler. Moreover, the air flow was blocked in Kampung Baru due to the height and number of buildings.

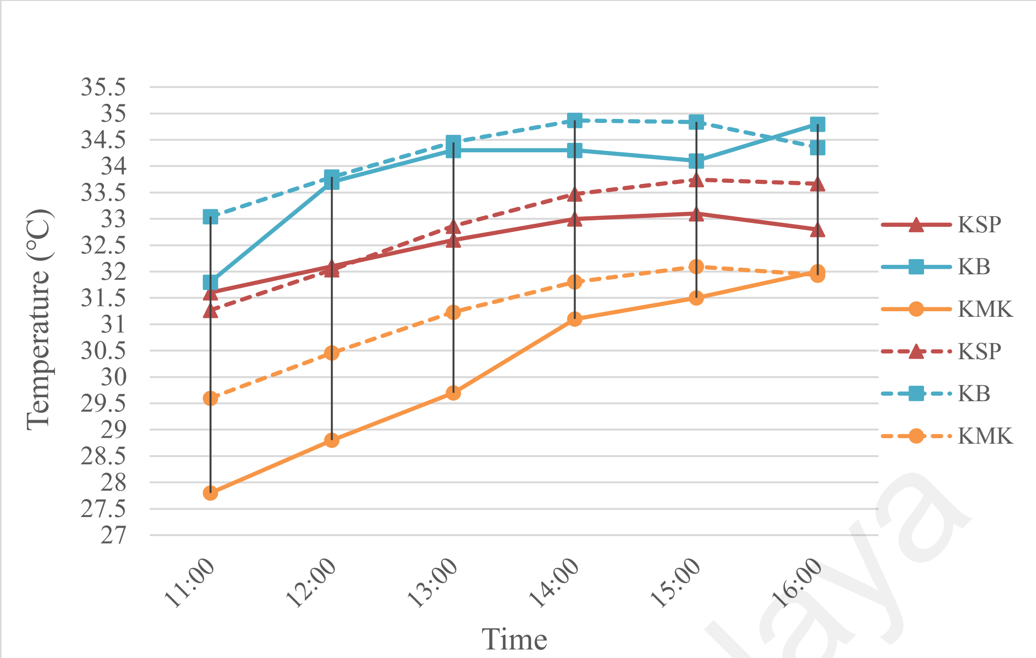


Figure 5.28: Comparison the real data with ENVI-met data of air temperature distribution in shaded area at selected urban villages
Source: Author

Figure 5.29 presents the recorded air temperatures in field measurement versus ENVI-met simulation from 11:00 am to 16:00 pm for unshaded areas in the three different urban villages namely Kampung Sungai Penchala (KSP), Kampung Baru (KB), and Kampung Melayu Kepong (KMK. At a glance, it is visible that there are some fluctuations in temperature measurements due to the instability of sky condition during the dayand, the inconsistency of the field measurement with ENVI-met simulation caused by the nature of simulation that only considers a very typical day in the simulation assumption. The temperature recorded in Kampung Sungai Penchala initially at 11:00 am was 35°C while it increased to 37°C in the next hour. The lowest measurement recorded in this place was 34.3°C at 14:00 pm. Likewise, for Kampung Baru the measured temperature was 35.8°C, and 33.7°C as maximum and minimum respectively, in comparison to KMK which recorded the maximum temperature of 36.1°C, at 16:00 pm and the lowest temperature of 30.4°C at 11:00 in the morning which also was the coolest temperature among other areas.

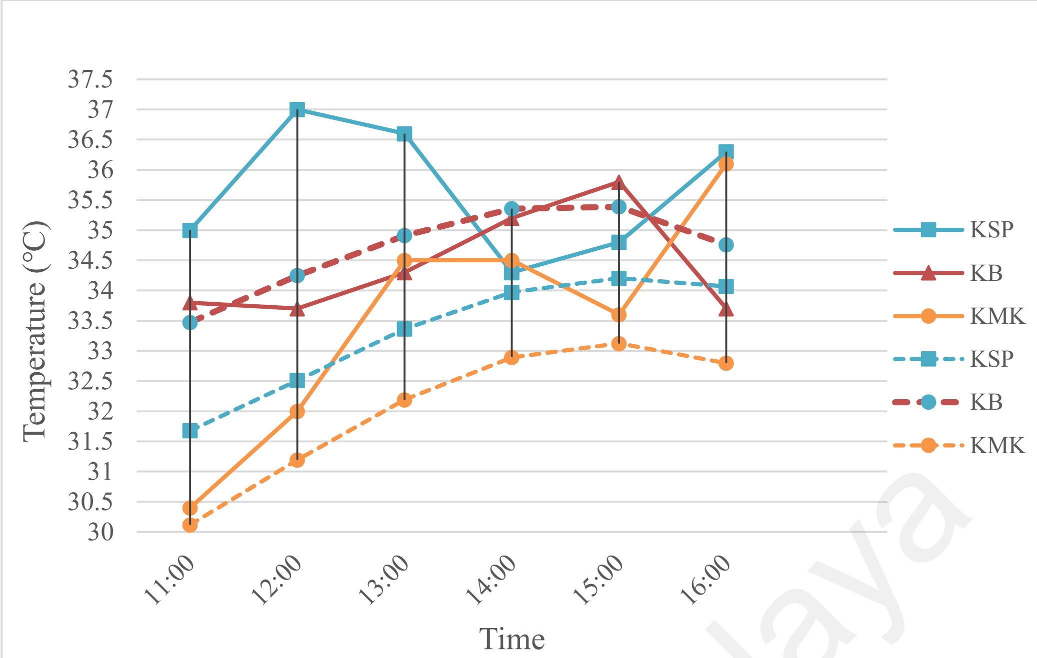


Figure 5.29: Comparison the real data with ENVI-met data of air temperature distribution in unshaded area at selected urban villages
Source: Author

5.5 Conclusion

The results obtained using the Rayman analysis and ENVI-met simulation for evaluating the outdoor thermal comfort has been discussed in this chapter. The overall evaluation of outdoor thermal comfort in the three selected urban villages in Kuala Lumpur via Rayman Model (based on PET index) for both shaded and unshaded areas in each urban village is considered individually. Besides, the simulations of the urban villages by ENVI-met have been derived for evaluating the thermal performance. In order to evaluate the thermal comfort in this study, hourly measured metrological data of hot and humid climate in urban villages were compared with the data extracted from ENVI-met simulation. Likewise, the comparison between hourly measured metrological data in hot-humid temperature and the ENVI-met data is conducted to examine the accuracy of the simulation.

Based on PET outcomes of determining the outdoor conditions in urban villages, it is found out that the shaded area in day 2 PET in Kampung Sungai Penchala has a favorable condition than day 1 in the same area. According to the recorded data, the PET for day 2 was from 28.5ºC to 34.4ºC while the PET for day 1 was from 33.4ºC to 36.9ºC respectively. In contrast, in the unshaded area of day 1, PET is in more heat condition than day 2 in most of the hours. Consequently, the PET in day 2 (range between neutral to warm) of both shaded and unshaded area has a better condition than day 1 (range between warm to hot) in terms of the level of thermal comfort.

In Kampung Melayu Kepong, the results of experiments on day 2 compared to the results of the experiments on day 1; the PET was in a better condition in the shaded area. While in the results of the experiments in the unshaded area on day1 compared to the results of the experiments on day 2, PET was in hotter condition at most of the hours. Nevertheless, the coolest PET has occurred in day1 at the shaded area (ranged neutral to slightly warm) and the hottest PET was in day2 at the shaded area (ranged slightly warm-to-warm).

In Kampung Baru, the outcome of the PET shows that in the shaded area on day 2 has a better condition compared to the outcome of the PET on day2 while PET in day 2 has a higher level of temperature than day1 in the unshaded area. Therefore, as a result of PET analysis, the coolest temperature was in day 1 in the unshaded area (ranged slightly warm to warm), and the hottest temperature was in day 2 in the unshaded area at the most hours (ranged hot to very hot).

Looking into the comparison between the field data and ENVI-met simulation data, similarly, it shows the same results as PET analysis. The findings illustrate that the Kampung Melayu Kepong has the coolest level of temperature in the shaded area (ranged between Neutral to slightly warm). In contrast, the Kampung Baru has the hottest temperatures in the shaded area (ranged between slightly warm-to-warm). Meanwhile, in the unshaded area at most of the hours of the experiments, the Kampung Melayu Kepong has the coolest temperature and Kampung Sungai Penchala has the hottest temperature.

Overall, according to the correlation validation of R-squared, Kampung Melayu Kepong, Kampung Baru, and Kampung Sungai Penchala were demonstrating a acceptable agreement between the predicted values and real data of meteorological stations; except the unshaded area in Kampung Sungai Penchala due to the sky condition, which unexpectedly has been changed. This behaviour is common in the tropical climate of Malaysia.

CHAPTER 6: CONCLUSION

6.1 Introduction

In this chapter, the principle findings regarding the research objectives are condensed and general conclusions considering the findings of the research showed in this thesis are represented. Besides, the strengths and limitations of this thesis are considered and recommendations for further research are presented. This part is separated into introduction, interpretation of finding, the knowledge contribution, the key recommendation, future studies recommendation, and limitation of the study.

6.2 Addressing the Research Questions and Objectives

As already mentioned in the introduction of this thesis, this study attempts to answer the following:

1. What is the thermal comfort condition of the urban spaces in the selected urban villages in Kuala Lumpur (KL)?
2. What is the impact of the embedded physical elements in the studied outdoor spaces of urban villages in KL on their thermal comfort?
3. What is the solution or technical guideline to improve the outdoor thermal comfort of urban villages in KL?

Therefore, the following set of objectives has been developed:

1. To investigate the thermal comfort condition of outdoor spaces in selected urban villages in Kuala Lumpur (KL).
2. To evaluate the impacts of embedded physical elements in the studied outdoor spaces of urban villages on their thermal comfort.
3. To recommend design solutions and technical guidelines for enhancing the outdoor thermal comfort of urban villages in KL.

6.2.1 Thermal Comfort Conditions of the Urban Spaces in Selected Urban Villages

This study investigated thermal comfort condition of the selected urban villages in KL. Thermal comfort condition assessment is conducted through the field observations and field measurements. For the field measurement, this research utilized two equipment called weather station for measuring the weather and surface thermometer for measuring the surface temperature to evaluate the thermal comfort condition. In addition, for the field observations, data were recorded based on the experiments of the weather condition in the surrounding area of the weather station. Comparing recorded data resulted from the experiments with field measurement data provides outcomes that show thermal comfort condition of the selected urban villages. These outcomes are explained further in section 6.3.

6.2.2 Evaluating the Impact of the Physical Elements in the Selected Outdoor Spaces of the Urban Villages

The study presents a purely physiological approach for assessing the conditions of outdoor thermal comfort in hot and humid climate. Thermal comfort is evaluated by measuring the microclimatic parameters such as temperature, relative humidity, solar radiation, wind speed and wind direction to find out PET index to determine the level of comfort in outdoor spaces and to compare that with the Tmrt (mean radiation temperature) of those selected urban villages. This research provides the evidence for the outcomes through the physiological approach by Rayman Model and simulates the outdoor spaces of urban villages by the ENVI-met to expand the existing knowledge and to help in finding a way for having a better environment. This thesis considers the impact of the physical elements using the outcomes of physiological approach in functional spaces in the selected urban areas in order to have more accurate evaluation of thermal comfort conditions.

6.2.3 Recommended Solution to Improve the Outdoor Thermal Comfort of Urban Villages

The design strategy for having a better thermal environment has to take the general standards and address the individual urban frame factors as indicated by the principles recommended in Section 6.5. In terms of radiation, the view of the sky and geometry relationship with the sun is two factors that are driven from attention in any urban design. A design strategy using general standards looks at every urban form factor to provide detailed instructions for enhancing our living conditions in the city. However, the orientation and angel of sun to the spaces are effective on the level of shading in the areas. Therefore, it is important to make barriers to prevent direct sun radiation from sky to the areas that are mostly used by individuals in order to decrease the temperature level. The barriers can be different types of vegetation, shelters for the houses, the arranging design of area, and the h/w of the buildings, which are helpful for making shadow in outdoor areas to achieve a better environment condition. Moreover, the type of construction materials is another factor can be significant for comfort condition in outdoor spaces. Therefore, utilizing the low albedo materials causes temperature decrement.

All in all, the data collected from both Rayman analysis and ENVI-met simulation, and also a comprehensive summary based on the findings are discussed further in section 6.3.

6.3 Interpretation of Findings

In this study, a better understanding of the general thermal environment in outdoor urban villages in KL city has been provided to be utilized in other urban spaces for thermal comfort improvement and UHI minimization. It is summarized as follow.

1. The findings summarized from the PET calculation through the Rayman Model in this field measurement for both shaded and unshaded spaces in two different days are concluded as below.

   i. **Results in Kampung Sungai Penchala** indicated that the highest, and lowest measured temperature for unshaded space day 1 were 40.1°C, and 33.3°C respectively, which was bounded between slightly warm (ranged 30°C to 34°C) to hot (ranged 38°C to 42°C). The maximum, and minimum temperature recorded for day 2 was 36.6°C, and 32.6°C accordingly, where bounded from slightly warm (ranged 30°C to 34°C) to warm (ranged 34°C to 38°C). On the other hand, as it is observed in the shaded space, the higher temperature was 39.4°C, and the lowest was 33.4°C recorded on day 1. It is considered as a slightly warm region (ranged 30°C to 34°C) to a hot region (ranged 38°C to 42°C). The highest and lowest temperatures were taken on the second day as 34.4 °C, and 28.5°C respectively, which was ranged from neutral (ranged 26°C to 30°C) to slightly warm (ranged 30°C to 34°C). It can be concluded that in terms of temperature in the shaded area, day 2 shows lower temperature records than day 1. It can be concluded that in terms of temperature in the shaded area, day 2 has lower temperature than day 1. Also, based on the results, it can be seen that on day 2, most of the records show lower temperature even in the unshaded area

   ii. **Kampung Melayu Kepong results** indicated that the highest, and lowest measured temperature for unshaded space on day 1 were 36.4°C, and 28.7°C respectively, which was bounded between neutral (ranged 26°C to 30°C) to warm (ranged 34°C to 38°C). For day 2, the maximum, and minimum temperature recorded was 34°C, and 29°C respectively, which is bounded from neutral (ranged 26°C to 30°C) to slightly warm (ranged 30°C to 34°C). The highest temperature recorded in the shaded space was 32.5°C, and the lowest was 27.9°C on day 1, which can be considered as neutral (ranged 26°C to 30°C) to slightly warm (ranged 30°C to 34°C). Whereas, on day 2, 36.9°C, and 31.3°C measured as the highest and lowest temperatures which was ranged between slightly warm (ranged 30°C to 34°C) to warm (ranged 34°C to 38°C). It can be concluded that in terms of temperature in the shaded area, day 2 shows the higher temperature than day 1.

iii. **In Kampung Baru according to the results** the highest, and lowest measured temperature for unshaded space on day 1 were 35.8°C, and 32°C respectively, which was bounded between slightly warm (ranged 30°C to 34°C) to warm (ranged 34°C to 38°C). However, the maximum, and minimum temperatures recorded on day 2 were 41.9°C and 35.1°C respectively, which is bounded between warm (ranged 34°C to 38°C) to hot (ranged 38°C to 42°C). On the other hand, the highest and the lowest temperature measured on day 1 were 38.1°C, and 33.5°C respectively, which is bound between slightly warm (ranged 30 °C to 34°C) to warm (ranged 34°C to 38°C). On day 2, the highest and lowest temperature measured as 37.5°C, and 31.6°C, which was ranged between slightly warm (ranged 30°C to 34°C) to warm (ranged 34°C to 38°C). All in all, day 2 shows the lower temperature records than day 1.

2. The results demonstrate the correlation and validation of the ENVI-met simulation analysis modeling of urban villages as follow.

   i. Due to the inadequacy of the layout, particularly the arranging of green spaces in urban villages, which can act positively on the level of shading on different objects, also with the lack of understanding of the most proper use of greenery pattern, there was a barrier created, which reduce the flow of breezes through the spaces. As a result, these kampungs are bounded in the warm level (ranged 34ºC to 38ºC) due to blockage of air blowing through. As a consequence, the discomfort level rises and there is a minimal fluctuation between shaded and the unshaded temperature variation. Likewise, the other factor that should be considered is the suitability of size and vegetation growth in a correct orientation geographically.

ii. With the impression of these results, this research required a few more researches and repeated studies to generalize better understanding on the findings of this study. Vegetation arrangement can be one of the factors, which can affect the level of comfort. This research showed that the mass of vegetation in most of spaces increased the temperature, instead of making comfortable weather condition due the inappropriate layout. However, generally the lack of vegetation and greenery spaces in urban areas can cause the uncomfortable conditions in urban spaces.

iii. Additionally, considering the output data discovered about the necessity of the distance between the specific areas to the surrounding factors such as buildings or houses, the mass of trees, type of materials of construction or ground surface and any other factors can have significant affect the kampungs' thermal weather conditions.

iv. Most of outdoor spaces of these study areas show that approximately 70% of temperature variation were started from a lower temperature at 11:00 am and increased until 16:00 pm except those hours when the sky condition unexpectedly changed, which is common in tropical climate of Malaysia.

6.4 Knowledge Contribution of the Study

This study shows how temperature is the most influential parameter on the human thermal comfort, physical activity, and livability, amongst all other variables such as humidity, solar radiation, mean radiation temperature, air temperature change, wind direction, wind speed, surface structure, and so on. This investigation gives a connection between the hypothetical learning on human thermal comfort observation and the reasonable urban design process. The outcomes add to the urban design or arranging and performance practice to give a level of satisfaction of thermal comfort condition in the spaces in urban villages in KL.

6.5 Recommendation and Suggestion for Future Studies

The following points are recommended for further research on outdoor thermal comfort in tropical countries with hot and humid climate.

i. Since the indoor areas were not investigated in this study, it is recommended to explore the level of thermal comfort for indoor areas for future research.
ii. Evaluate and compare the thermal comfort index in both modern and traditional urban areas, with greater focus on the relationship between the outdoor and indoor spaces in KL.
iii. This experimental study has been done in August so, it is highly recommended to do the same measurements in different time of the year as well, to compare the effect of seasonal climate on experiment outcomes.
iv. This research has been done within Kuala Lumpur area. However, different places might result differently. It is recommended to do similar research for other places throughout Malaysia.

v. The recommended attempts to find out solutions based on heat mitigation strategies, provides possibilities to improve the thermal comfort conditions of outdoor spaces in urban villages of KL for improving the users 'outdoor activities and quality of life.

6.6 Limitation and Needs for Further Research

Ordinarily, in each logical research, there are weaknesses and deficiencies that could have a negative impact on it. In this research, there were a few limitations that, to some extent, constrained creator to discover different approaches to accomplish the objectives. These impediments had likewise some negative consequences for inquiring about the system. A few restrictions are recorded as follow.

i. Due to the lack of time, only three Kampungs have been chosen and investigated in this study.

ii. In this research, only outdoor spaces have been examined, and evaluated; however, the indoor examination is highly recommended for future studies.

iii. Because of some limitations, like the distance between the locations, the experimental study has been done in different days instead of simultaneous data gathering in all areas.

iv. This research has been done only for two different days; however, allocating more time for data collection will results in better understanding of the situation.

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