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KUALA LUMPUR CITY OF TOMORROW: INTEGRATION OF GEOSPATIAL URBAN CLIMATIC INFORMATION IN CITY PLANNING

Nurul Amirah ISA
Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
nurulamirahisa@salam.uitm.edu.my

Siti Aekbal SALLEH
Applied Remote Sensing and Geospatial Research Group, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
aekbal@salam.uitm.edu.my

Wan Mohd Naim WAN MOHD
Centre of Studies for Surveying Science and Geomatics, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
wmn@salam.uitm.edu.my

Andy CHAN
Faculty of Engineering, University of Nottingham, Semenyih, Selangor, Malaysia
andy.chan@nottingham.edu.my

Abstract
Urbanization brings many benefits. However, due to rapid and uncontrollable urbanization, the urban environment has been dramatically degraded. As a developing country, Malaysia is facing urbanization processes throughout the country and most of the population have migrated to dwell in the cities. Malaysia has envisions designing smart, liveable and comfortable cities, there is a great need to maintain the sustainability of the cities to ensure that the quality of life of urban dwellers is preserved, especially in terms of the environment. This paper reviews the concept of urban climatic mapping and its potential implementation in a Malaysian urban environment. The key elements and parameters of the urban climatic mapping are also discussed. Since being introduced 40 years ago, urban climatic maps have attracted worldwide interest. It is time for Malaysia to have its own urban climatic maps to assist the decision makers to make an informed decision on the development and its impacts to the urban climate conditions in particular.. It is the responsibility of mapmakers to share lessons and experiences with city planners and policy-makers to bring new planning environments that include climate as one of the important aspects to be considered.
Keywords: urban climate, urban climatic map, urban planning, remote sensing, GIS

1. INTRODUCTION

Climate change is affecting most parts of the world and it has lately become a serious issue of concern. Major changes in temperature, precipitation, or wind patterns, among the other effects that occur over several decades and longer, are referred to as climate change (EPA, 2014). In recent decades, changes in the climate have caused impacts on natural and human systems on every continent and across the oceans (IPCC, 2014). In the IPCC report, it was found that there have been increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global sea levels during the 20th century, as shown by the observed data (IPCC, 2007). Since the slight increase in the global temperature has already caused significant changes in the environment, the impending impacts of much higher projected temperature increases in the future may be very distressing (Tangang et al., 2012). Climate change is related to the Urban Heat Island (UHI) phenomenon. UHI is the condition where the temperature in the urban area is higher than the sub-urban and surrounding areas (Hashim, Ahmad, & Abdullah, 2007). The phenomenon has been documented as one of the impacts resulting from urban development (McCarthy, Best & Betts, 2010). It refers to an urban area which has a warmer temperature than that in its outskirts (Buyadi, Mohd, & Misni, 2014). The changes of land use triggered by human activities degrade the natural environment and lead to the formation of UHI (Amanollahi et al., 2016; Hashim et al., 2007; Ibrahim & Samah, 2011; McCarthy, Best & Betts, 2010; Shahruddin et al., 2014). These changes, including the reduction of green spaces, the increment of built-up areas and others, contribute to the increase of the urban surface temperature (Buyadi et al., 2014; Elsayed, 2012; Raghavan, Mandla, & Franco, 2015; Salleh et al., 2013). The condition of the urban climate is believed to be affected by the UHI phenomenon, which plays a role in altering other meteorological phenomena in and around urban areas, including the development of clouds and fog, the frequency of lightning strikes, the development of thunderstorms and changes in precipitation rates (Elsayed, 2012). These alterations are responsible for negative effects on the condition of the urban climate. Due to this relationship, it is crucial to combat the impacts of UHI in order to ensure that the urban climate is protected from harmful disasters that may have direct impacts on urban dwellers. Therefore, many studies suggest that climatic factors should be included for consideration in urban planning decision-making (Acero et al., 2015; Ibrahim, Samah, & Fauzi, 2014; Ren et al., 2013; Ren et al., 2012; Reuter, 2011; Webb, 2016; Elinbaum, 2014; Popescu, 2017).

In Malaysia, urban planning has long been practised, yet many urban developments have failed to avoid the effects of UHI, although they have been anticipated in many cases (Elsayed, 2012; Ibrahim et al., 2014). A solution for developing the climate change resilience of urban nations is taking a long time to

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formulate. In the early years after the independence of Malaysia, environmental problems were considered less important than the development priorities (Elsayed, 2012). Many early development projects in Malaysia gave little or no consideration to environmental aspects (Elsayed, 2012; Ibrahim et al., 2014). As a consequence, many urban areas in Malaysia were affected and turned into heat islands. The negative impacts of urbanization may well worsen if no mitigation measures are taken, as Malaysia is projected to have an increased urbanization rate in the near future (Yuen & Kong, 2009). As an attempt to inject urban climatic information into urban planning, the gap between the field of meteorology and urban planning must be closed. Climatic information is seldom considered in the urban planning process due to the difficulty of presenting the information in ways that suit planners and policy-makers (Mattsson & Lindqvist, 1989). Meteorological data sets as well as climatological information complicate the efforts to integrate urban climate information into urban planning decision-making processes. The fields of meteorology and climatology can provide information about the climate condition to urban planning practitioners, but unfortunately the meteorology datasets are very complicated and do not offer conclusive information about the state of our urban climate. Therefore, it is hard for urban planners or policy-makers to understand and implement this information in practice during planning processes. This is due to the lack of necessary tools and expertise to assess the issues critically (Ibrahim et al., 2014).

Due to this, studies on urban climatic information for urban planning purposes were triggered. Various efforts from various disciplines and fields have tried to close the gaps between meteorology and urban planning. In various countries, the climatic information might have different representation and purposes that suits the municipality's objectives and visions. Among various endeavours, this study focused on a concept called Urban Climatic Map (UC-Map). The UC-Map was introduced about 40 years ago by German researchers (Acero et al., 2015; Burghard et al., 2010; Cavan, Lindley, & Smith, 2015; Katzschner & Burghardt, 2015; Ren, Ng, & Katzschner, 2010). The UC-Map is a climatic information and evaluation tool that helps planners to understand climatic–environmental conditions and variations to create a better design (Ren et al., 2012). This approach simplifies the efforts of urban planners and policy-makers to understand the urban climate by translating the climatological and meteorological data sets into specific zones which represent the condition of the urban climate using common terms such as "warming areas", "cooling areas", etc. However, none of these researchers has focused on the Malaysian urban climate. This is because, in the 1960s, there was less development in Malaysian cities, where the negative impacts of climate change were trivial at that time. Therefore, the focus is mostly on today's developed countries such as German, United Kingdom and Japan which were rapidly developing in the 1960s.

Modelling the urban climate condition requires scrutiny of the mechanism of the urban climate, such as the parameters which have a significant impact on the urban climate and their contribution to the climatic conditions (Hebbert, 2014; Ho, Ren, & Ng, 2015; Ibrahim et al., 2014; Ng, 2012; Takebayashi & Oku, 2014). Previous studies have conducted detailed analyses on the behaviour of the climate in order to understand the factors that affect the urban climate condition and how these factors contribute to changes of urban temperatures. Regrettably, in Malaysia, studies regarding the urban climate are still few in number. Although some progress has been indicated, the knowledge gap remains large (Tangang et al., 2012). There is limited knowledge on future variability associated with regional phenomena of Malaysia and its neighbouring countries (as shown in Figure 1) such as the monsoon seasons, El Nino–Southern Oscillation (ENSO), Indian Ocean Dipole (IOD) and Madden–Julian Oscillation, or extreme events such as floods and droughts (Tangang et al., 2012). Therefore, detailed studies and analyses on this area of knowledge has become very important. Thus, this paper intends to review the importance of urban climatic mapping and its implementation for the Malaysian urban planning environment.

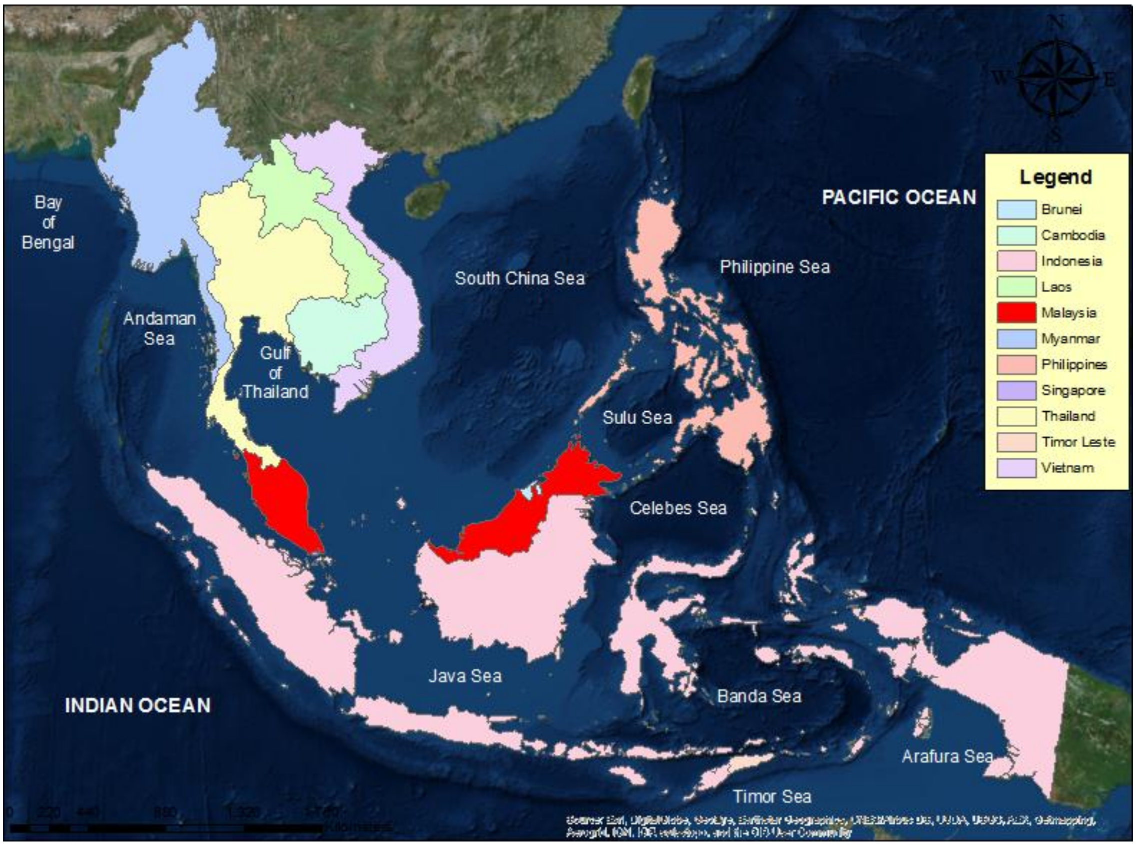

FIGURE 1 - THE LOCATION OF MALAYSIA: THE PENINSULAR IS SURROUNDED BY THAILAND IN THE NORTH, SINGAPORE IN THE SOUTH AND INDONESIA (SUMATRA ISLAND) AS THE FORTRESS FROM THE INDIAN OCEAN. THE EASTERN PART OF THE PENINSULAR IS EXPOSED TO THE SOUTH CHINA SEA.
Source: Authors

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1. URBAN CLIMATIC MAPPING: HISTORY OF DEVELOPMENTS

Urban climatic mapping is not new and, in fact, it was introduced in the 1960s by German researchers (Burghard et al., 2010; Chen & Ng, 2011; Ren et al., 2010). The first German researcher to propose a climate-mapping system for planning purposes was Professor Kar Knoch, but the very first study conducted was led by Dr. Baumuller in Stuttgart, Germany, to mitigate air pollution (Ren et al., 2010), so the earliest implementation of climatic information in Germany was to address the air pollution problems of this city. This study was later refined by other German researchers (Brundl, 1988; Katzschner, 1988; Oke, 1988). Urban climate studies in urban planning practices have a long tradition in Stuttgart, which is regarded as the best model for other cities in the world in bringing together urban climatology science and city policy (Reuter, 2011; Webb, 2016). Since then, in the 1980s, many European cities have constructed their own urban climate map studies and similar projects, with the same objectives of integrating urban climate information in urban planning practice (Ren et al., 2012). About 15 countries have already formulated their own urban climatic maps, led by German researchers such as Katzschner, Baumuller, Matzarakis and others (Ren et al., 2010). The concept was then explored by Japanese researchers in the late 1990s (Ren et al., 2010). Unlike the German studies, most of the urban climatic studies in Japan aimed to reduce the UHI effects due to the urban morphology and geometry of Japanese cities (Matsuo & Tanaka, 2014; Shimoda & Narumi, 1998; Tanaka et al., 2009; Yoda, 2009). The difference in the urban morphology of Japan as compared to Germany led to modifications and advances in urban climatic mapping studies. The Japanese studies include more detailed parameters such as thermal sensations and artificial waste heat (Akasaka, 1991; Shimoda & Narumi, 1998). Therefore, understanding the relationship between land cover patterns and UHI is crucial to design effective measures in mitigating UHI effects (Zhou, Huang, & Cadenasso, 2011). Serious consideration has been given to UHI issues, as the Cabinet Office and Japanese government ministries have been promoting measures for monitoring heat island phenomena based on the Outline of the Policy Framework to Reduce Urban Heat Island Effects, which was formulated in March 2004 (Yoda, 2009).

Early urban climate studies only focused on high latitude climate countries which experience cold and dry weather. None of these studies have analysed the urban climate of lower latitude climate countries, which experience hot and humid weather, especially in the tropical regions. It is found that the total number of sub-tropical urban climate studies is still small, accounting for less than 20% of all urban climate studies (Tangang et al., 2012). This is very depressing, given the explosive development of cities in the developing countries are located in tropical and sub-tropical regions (Roth, 2007). The quality of the urban climate condition within tropical and sub-tropical regions is very alarming. Many of these countries have ignored climate parameters as essential elements to be considered during the design and planning phase, which is probably due to the lesser intensity of climate change and lower level of awareness.

TABLE 1 THE CHRONOLOGY OF URBAN CLIMATIC MAP STUDIES (MODIFIED FROM (REN ET AL., 2010))

Year	Country
1960s	Germany
1970s	Germany
1980s	Norway Sweden Germany
1990s	Japan Poland Sweden Germany Israel Austria Switzerland
2000s	Japan Switzerland Germany New Zealand Israel United Kingdom China Greece Poland Portugal Brazil Hong Kong France Holland
2010 - 2016	Germany Taiwan Hong Kong South Korea Japan Portugal France Thailand Vietnam Sri Lanka Singapore

Source: Authors

Hence, given the need to combat urban climate change effects within cities, some other countries in the tropical regions such as Singapore, Thailand and Vietnam have also initiated efforts to conduct detailed analyses on the urban climate in order to formulate their own urban climatic maps for urban planning guidelines (Hien et al., 2011; Jittawikul, Saito, & Ishihara, 2004; Ndetto & Matzarakis, 2013; Storch et al., 2009). The Global Cool Cities Alliance (GCCA) was launched in 2009 as a global alliance to raise

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awareness on the importance of reducing heat production. The alliance encourages worldwide participation to construct advanced policies and actions to cool cities around the world (Salleh et al., 2013). Malaysia, as a developing country in the tropical region is also considering joining the global alliance in battling the effects of UHI. Therefore, this study attempts to fit in within this alliance to contribute to the knowledge and studies on the urban climate by producing Malaysia's very own urban climatic map for urban planning purposes.

2. URBAN CLIMATIC MAPPING: CONCEPT AND SYSTEM

The urban climatic map can be used as a mechanism that helps planners to understand climatic–environmental conditions and variations and thus to create a better design (Ren et al., 2012), as well as its meteorological responses. Although there are other terms referring to the same maps, such as UC-Map (Ban et al., 2009; Burghard et al., 2010; Ibrahim et al., 2014; Ng, 2012; Ng et al., 2009; Ren et al., 2013; Ren, Ng, & Katzschner, 2009; Ren et al., 2010; Ren et al., 2012), Climate Atlas (Reuter, 2011; Yoda, 2009) and Urban Environment Climate Maps (Matsuo & Tanaka, 2014; Tanaka et al., 2009) and Urban Climate Zones (Alcoforado et al., 2009; Alcoforado & Matzarakis, 2010), they all consist of the same information that can be used to represent urban climatic conditions. The urban climatic map consists of two main components: the urban climatic analysis map and the urban climatic recommendation map (Ren et al., 2010). The Urban Climatic Analysis map or UC-AnMap presents the urban climatic characteristics of different regions and uses the analysis and evaluation of their urban climatic factors and their effects on thermal conditions and their dynamic potential as the basis. This map also maps out the wind information layer in order to make the information more complete (Acero et al., 2015; Baumuller et al., 2009; Burghard et al., 2010; Eum et al., 2013; Houet & Pigeon, 2011; Mora, 2010; Ng et al., 2009; Ng et al., 2012; Ren et al., 2013; Ren et al., 2012; Tanaka et al., 2009). On the other hand, the Urban Climatic Recommendation map or UC-ReMap shows the spatial evaluation of the current climatic conditions and characteristics and identifies problematic areas or areas which are sensitive climatically that need attention in strategic planning and improvements (Acero et al., 2015; Baumuller et al., 2009; Burghard et al., 2010; Eum et al., 2013; Houet & Pigeon, 2011; Mora, 2010; Ng et al., 2009; Ng et al., 2012; Ren et al., 2013; Ren et al., 2012; Tanaka et al., 2009).

The UC-AnMap provides a platform for climatic information and evaluation by synthesizing, summarizing and evaluating the scientific understanding based on the input climatic parameters and land data under annual or specific seasonal scenarios (Ren et al., 2010). Two main aspects are considered in the production of the UC-AnMap, named the thermal load aspect and dynamic potential aspect. The considerations made on these two aspects are intended to balance the negative and positive impacts of urban climatic parameters into a display. The urban climate of the city can be characterized with a balanced consideration of “negative” thermal load effects due to building bulks and building layouts and “positive” dynamic and mitigating effects (Ng et al., 2008). Thermal load describes the temperature of the urban area resulting from analysis of various parameters such as the building volume, the topography and the availability of green space. In the thermal load aspect map, the stored or emitted heat intensity of particular localities of urban areas is measured (Ng et al., 2012; Ren et al., 2010). The dynamic potential aspect describes the roughness of the ground, which influences the air ventilation and air exchange of the areas (Ng et al., 2012; Ren et al., 2010). An Urban Climatic Recommendation map (UC-ReMap) provides planning recommendations based on the evaluation of a number of planning parameters, including building volume, building heights, ground coverage of buildings, greenery coverage, air paths, and breezeways (Ng et al., 2012). Recommendations can be made based on the climatopes resulting from the UC-AnMap analyses. The resulting urban climatic map will identify areas which are more in need of attention and improvements from an air ventilation perspective, e.g. highlighting locations that have poor wind circulation or are sensitive to wind variation, and where important breezeways and open spaces should be protected or preserved (Ng, 2009). Problematic areas can be identified, and the map can also show the classifications of the areas along with the information required by urban planners to understand the climatic conditions of specific regions.

Although most of the studies use the same concept and structure of the Urban Climatic Map regardless of their distinct climates, the parameters and indicators that are suitable for each country may differ due to the regional climatic behaviour, urban morphology, geography, and other factors that influence the variability of the urban climate. For example, cities which are situated near the coast, unlike inland cities, may have to consider sea breezes as one of the parameters to include in the analysis. Figure 2 shows the main structure of the Urban Climatic Map which consists of several input layers that make up the two main components mentioned earlier: the UC-AnMap and the UC-ReMap.

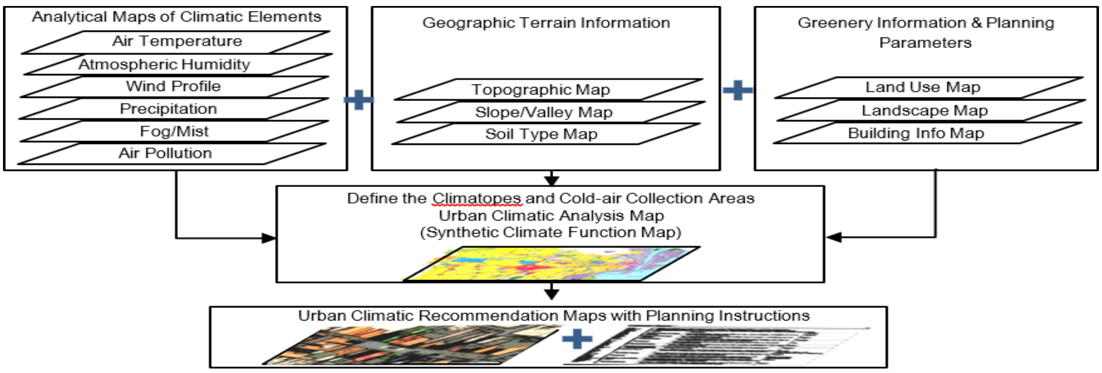

FIGURE 2 - THE URBAN CLIMATIC MAP STRUCTURE
Source: Ren et al (2010)

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The main purpose of the urban climatic map is to bridge the gap between urban climatic studies and urban planning studies. The concept of urban climatic mapping emerged from the need to "inject" climatic parameters into urban planning and guidelines so that urban developments can be sustainable and resilient to the impact of climate change. In order to implement the climatic parameters into the urban planning processes, consideration of how the information should be analysed, displayed and presented is the most critical issue (Ibrahim et al., 2014; Ren et al., 2010). This is to ensure that information that is crucial to the urban planners can be understood easily in well-presented maps.

3. IMPLEMENTATION IN MALAYSIAN URBAN PLANNING PRACTICE (POTENTIAL)

The implementation of urban climatic mapping has been widely introduced around the world with the intention of assisting urban planners to make wise decisions during the planning processes. Urban climatic mapping is very relevant in urban planning as it uses the urban climate indicators to determine the appropriateness of future developments in the specific urban climate condition (Ibrahim et al., 2014). Many studies have indicated that urban climatic information is an important aspect for urban planning guidelines to ensure that environmental aspects within urban areas can be sustained or improved. However, the implementation of the theory into the urban planning practice seems to be lacking, especially in the developing countries of tropical regions such as Malaysia.

In Malaysia, the urban climate condition has always been ignored. By the end of the 1960s there were about 20 laws related to the environment available for urban planning practice but not originally designed specifically to address environmental problems (Elsayed, 2012). However, the lack of environmental consideration in urban planning does not mean that relevant issues are not appreciated, but rather the lack of the necessary tools and expertise to assess the issues critically makes it hard to implement in real practice (Giridharan, 2016). There is local variation in the interest taken by planners in the climate, but it is seldom considered in the planning process due to the difficulty of presenting the information in a meaningful and accessible way (Mattsson & Lindqvist, 1989). Due to current environmental issues such as UHI effects, many studies on urban climate conditions have been conducted. Awareness of the importance of urban climatic information in urban planning practice has also increased lately. Since this study intends to introduce the urban climatic map concept in the Malaysian urban planning environment, the concept needs to be able to suit Malaysia's urban structure planning system. To understand city planning, it is necessary to mention the spatial and landscape planning system, which operates at different scales, levels, and responsibilities (Ren et al., 2010).

In general, Malaysia's urban structure planning system consists of four different plans with different area coverage as shown in Table 1. At the federal level, a five-year plan is produced and is complemented by regional and master plans to guide the development of specific areas. The regional and master plans are written statements showing the development policies and project proposals. These plans are then broken down into structure plans and local plans which are prepared by the local authority. The policies, strategies and general proposals of the structure plans are to be reflected in detailed local plans, which are usually in the form of maps (accompanied by brief written statements) showing the authority's planning decisions on every piece of land (Goh, 1988).

TABLE 2 - THE URBAN STRUCTURE PLANNING SYSTEM IN MALAYSIA

Plans	Area Coverage	Prepared by
5-year plan	Whole country	Federal government
Regional/master plan	Region/state	Regional development authority or state government
Structure plan	Local authority area	Local authority
Local plan	Local authority area	Local authority

Source: Goh (1988)

Previous studies on urban climatic map concepts have established a general framework of how urban climatic maps can fit into the urban planning system. Since the urban structure planning system is hierarchically structured, the proposed urban climatic map and planning recommendations with different scales and themes should be formulated and adopted to meet the different requirements of planning uses (Ren et al., 2010). More importantly, the representation of urban climatic information and recommendations should be easy to understand or they may not be used by the planners, developers and policy-makers (Alcoforado, 2006; Carter et al., 2015; He et al., 2015; Ren et al., 2010)Due to the difficulty of presenting information on local climate variations in a meaningful and accessible way, it is seldom considered by urban planners in the planning process (Mattsson & Lindqvist, 1989).

In urban climatic mapping, the main focuses of the planning recommendations are to reduce the thermal load and improve the urban ventilation, which depends on the urban structures and factors underlying the thermal and wind distribution. Therefore, many researchers suggest that an urban climatic map series should be produced based on the master plans and local plans (He et al., 2015; Hunt & Watkiss, 2011; Katzschner, 1988; Matsuo & Tanaka, 2014; Rannow et al., 2010; Ren et al., 2010; Takebayashi & Oku, 2014). It is found that the urban climatic map is very useful when ranging from the regional scale of 1:100,000 to the urban scale of 1:5000, which provides a holistic and strategic understanding where further microscale studies can be conducted (Burghard et al., 2010). Moreover, the climatic information and planning recommendations can be implemented into actual planning processes such as the municipality/city master plan, zoning plan and land use plan using the urban climatic mapping concept (Ren et al., 2010).

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Based on the previous studies, the urban climatic mapping concept has a great potential and relevance for implementation in Malaysian urban planning practices, since the planning system does not differ much from other countries. Moreover, many urban climate studies conducted in Malaysia recommend that urban climatic information should be considered as an important aspect in urban planning (Buyadi et al., 2014; Elsayed, 2012; Ibrahim et al., 2014; Morris, 2016; Morris et al., 2015; Morris et al., 2016; Oke, 1988; Salleh et al., 2013; Salleh et al., 2013) The implementation of the urban climatic mapping concept in Malaysian master and local plans is expected to be able to solve the shortcomings of the current practices regarding the consideration of urban climate conditions. Urban climatic maps of Malaysian cities should be formulated based on suitable scales and levels of detail of the urban climate information to suit the needs of urban planners within the country's urban structure planning system (Isa et al., 2017).

4. GEOGRAPHICAL INFORMATION SYSTEM (GIS) ANALYSIS PLATFORM AND DATA ACQUISITION

The employment of the GIS technique allows the database to be stored and managed digitally. Hence, exporting maps into different scales and layouts is possible for flexible planning purposes. GIS has always had a special relationship to the academic discipline of geography, as it has to other disciplines that deal with the Earth's surface, including geodesy, landscape architecture, planning and surveying (Longley et al., 2011). Integrated with remotely-sensed data, the studies on urban climate can be enhanced with larger data coverage can be obtained and analysed. Due to the capability of remotely sensors specified for mapping purposes, important information can be extracted. In one study (Scherer et al., 1999), GIS was employed in urban climate studies to produce a series of climate maps documenting the influence of surface properties on temperature, wind fields and ventilation for Basel, Switzerland. Another study by Esparza (2012) employed GIS techniques to evaluate the quality of life within the urban regions. The study employed GIS not only for data preparation and digital processing steps, but also in the production of most of the maps in the study. The use of GIS has become a powerful tool to evaluate the urban thermal environment of a given region because it allows the fast integration and representation of several surface morphological attributes (Srivanit, Hokao, & Iamtrakul, 2014). GIS techniques provide a useful tool in many aspects of research on urban climates (Chapman & Thornes, 2003; Grimmond & Souch, 1994). For example, in understanding current processes both through measurement and modelling, linking a spatially nested georeferenced database to a dynamic sampling strategy provides an objective and versatile way to describe the urban surface (Grimmond & Souch, 1994).

5. GEOGRAPHICAL SETTINGS

It is best to understand the nature of the climate in order to formulate the urban climatic map of a particular area. The variation in climate describes the difference of factors that influence the urban climate condition of a city. It is found that there are variations in the urban climate condition with respect to the latitude (Wienert & Kuttler, 2005). This means that the climate behaves differently in different climate zones and hence is impacted differently based on the geographical setting. In hot climates, the UHI is a negative feature and must be mitigated, while in cold climates the UHI is a positive feature as it contributes to street heating for thermal comfort (Alcoforado, 2006). In hot climates, the solar radiation needs to be reduced and the air ventilation must be maximised to combat the UHI issues. In contrast, in cold climate regions it is necessary to maximise the solar gain and minimise the wind exposure to preserve the heat for thermal comfort at street level. These differences must be taken into account as urban climatic maps are used to develop sustainable cities which offer comfortable living experiences in terms of the climate.

Many early studies on urban climatic mapping evolved within the context of countries with four seasons such as Germany, Japan, Portugal, Sweden and others (Acero et al., 2015; Burghard et al., 2010; Cavan et al., 2015; Eum et al., 2013; He et al., 2015; Houet & Pigeon, 2011; Mora, 2010; Ren et al., 2012; Reuter, 2011; Tanaka et al., 2009; Yoda, 2009). Although detailed analyses on urban climate have already been conducted in these countries, the results cannot be applied to tropical countries such as Malaysia. The geographical setting of tropical countries leads to different climate experiences and the behaviour of the urban climate is not even slightly similar to countries with four seasons except during the summer season. Recently, efforts to map urban climatic information for urban planning purposes in sub-tropical and tropical cities have been widespread. These efforts were triggered by Hong Kong's comprehensive urban climatic studies and analyses (Chen & Ng, 2011; Ho et al., 2015; Lau, Ng, & Ren, 2013; Ng, 2009, 2012; Ng et al., 2009; Ng et al., 2008; Ng et al., 2011; Ren, Ng, & Katzschner, 2007; Ren et al., 2009, 2010). The urban climatic map of Hong Kong was formulated based on the earlier studies by Germany and Japan, although new formulations have been developed to suit the sub-tropical climate of Hong Kong. A few years later, the emergence of urban climate studies in tropical regions is growing quite fast.

Other than the variations caused by different latitudes, the geographical locations of particular countries have different impacts on the urban climate condition. For example, countries such as Taiwan, Vietnam and Singapore have similar tropical climates but have different geographical settings. In Taiwan, most cities are located on the coast in the west. Surrounded by the East China Sea, Philippines Sea and

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South China Sea, these counties benefit from the wind environment. The land and sea breezes are very prominent and can be utilized for their cooling effects in the cities (Ren et al., 2013). This differs from Vietnam, where the most important city, Ho Chi Minh, is located on the mainland. Therefore, this city has a less advantageous wind environment than Taiwan's. Singapore, on the other hand, is a coastal country which is surrounded by Malaysia in the north and many islands owned by Indonesia in the south, which give the prevailing winds a different profile from those of Taiwan and Vietnam. These countries have also initiated efforts to formulate their own urban climatic maps based on their country's characteristics (Katzschner & Burghardt, 2015; Ren et al., 2013; Wong et al., 2015).

Malaysia is a tropical country located very near to the equator with the latitude of 4.2105° N and longitude of 101.9758° E. Malaysia has hot and humid weather throughout the year with little variation in temperature and humidity. The hottest temperatures are in March and the coldest temperatures are in December to January (Elsayed, 2012). Malaysia is the southernmost country in the mainland of the Asian continent. The country is divided into two main regions called Peninsular Malaysia and Sabah and Sarawak. It is surrounded by several countries, straits and seas. The geographical setting of Malaysia leads to a different climatic behaviour from those of previous study locations. For that reason, the factors that affect the urban climatic condition of the cities in Malaysia may also differ from the previous studies. Identification of the climatic factors is crucial in order to model the climatic information in the formulated urban climatic maps. Unfortunately, no detailed studies have been conducted for Malaysian cities to identify the actual factors that affect the urban climatic condition of the urban areas or their magnitude.

6. URBAN MORPHOLOGY AND URBAN SETTINGS

The urban climate condition is reported to depend on the urban morphology. Urban morphology refers to the arrangements of urban structures (geometry) and the materials that make up the urban features. From the previous studies, it has been found that the urban morphology of different cities will have different impacts on their urban climate. Several studies indicate that the variability of urban characteristics results in different impacts on the urban climatic condition (Alexander, Fealy, & Mills, 2016; Zhao et al., 2011). The factors that determine the extent to which an urban climate differs from the climate of the surrounding area are formed by the characteristics of the built environment and the activities that take place there (Papamanolis, 2015). There has long been debate on the characteristics of the urban morphology. Many studies suggest that the uniqueness of cities should be taken into account to closely depict the actual situations of their urban climate condition in the urban climatic map. Threshold values for urban parameters must also be established in order to be used as guides in formulating our own urban climatic maps.

Above all, the compactness of a city is usually scrutinized. Most of the previous studies agree that compact developments (built-up areas) with many tall buildings will increase the temperature (Isa, Mohd, & Salleh, 2017; Ren et al., 2013; Ren et al., 2007; Srivanit et al., 2014). The composition and configuration of urban morphology features significantly affect the magnitude of the daytime near-surface air temperature and surface temperature (Srivanit & Kazunori, 2011). One important finding was that the microclimate conditions showed a high level of variation between different urban fabric types, but also within individual quadrants across relatively small distances (Stiles et al., 2014). A study conducted in Phoenix, Arizona, agrees that compact development with high concentrations of buildings, structures, and impervious surfaces increases radiative heating and intensifies UHI effects, but the study also indicates that tall buildings play a significant role in reducing urban heat (Middel et al., 2014). Therefore, detailed analyses regarding urban compactness should be conducted specifically for the targeted study area.

Highly populated cities such as Tokyo, Kaohsiung and Hong Kong may be affected differently from less populated cities. This is because the population density is very closely related to the amount of anthropogenic heat produced by cities (Ng et al., 2009; Qiu, 2014; Ren et al., 2013). The impact of anthropogenic heating may be important in urban centres but negligible in residential and commercial areas (Taha, 1997). The anthropogenic heat release can not only degrade the quality of the urban atmosphere, but also increase the air surface temperature of a particular city. Therefore, improving the air ventilation is a must for certain countries. Less compact cities may not really need to be concerned with the population density due to the minor impacts it will have on the urban climate condition.

Other than that, the variation of UHI intensity during day- and night-time differs between cities. In Japan, the discomfort of UHI effects in summer is more significant during the night than in the daytime (Kusaka, Hara, & Takane, 2012). However, in India, the effect is more significant during the daytime, and exceeds the comfort zone threshold value set for India (Amirtham, Horrison, & Rajkumar, 2015). This study also stated that stipulating the built geometry and orientation is the best way to mitigate UHI effects in India. Further studies that use multiple daytime and night-time thermal images for different seasons are encouraged. In addition, comparison studies across metropolitan areas under different climatic conditions are recommended (Srivanit & Kazunori, 2011).

Air ventilation is one of the most important aspects to look into as it can improve the thermal environment of an urban area. Surface roughness, which depends on the urban morphological characteristics, is directly related to air ventilation and urban permeability. This is because the spatial configuration can obstruct the urban wind flow and increase the thermal mass of the urban fabric, which could heat up the local climate zone and thus affect the urban climatology in the summer diurnal range

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(Srivanit & Kazunori, 2011). The alteration of the urban radiative energy balance and the reduction of heat loss by wind-driven turbulence in a city environment are both consequences of the urban surface geometry (Smith & Levermore, 2008). The arrangements of buildings without proper (climate-based) planning may end up blocking the air flows that are crucial as cooling agents within urban areas. Thus, the stagnant heat will increase the air temperature and result in uncomfortable surroundings.

The green cover area has been identified as the most significant urban planning factor affecting the urban thermal environment (Buyadi et al., 2014; Isa, Mohd, & Salleh, 2017; Zhao et al., 2011). Areas of vegetation achieve higher thermal reductions than water surfaces due to a combination of evapotranspiration and shading (Muller, Kuttler, & Barlag, 2014). The cooling rate in densely vegetated areas is fast and can be attributed to evaporation and evapotranspiration (Jonsson, 2004). Vegetation management, particularly increasing the tree canopy, has been considered an effective means to mitigate excess urban heat and to alleviate the thermal discomfort in the summer months for both highly urbanized areas and areas where urbanization is still in progress (Srivanit & Kazunori, 2011). Even though vegetation cover is favoured by most studies, regardless of climate, it must be noted that the cooling rates may be different. The effect of vegetation in a hot and dry climate on the urban climate condition may differ from that in a hot and humid climate (Martilli, 2014). Therefore, it is very important to quantify in detail the effects of green cover on the urban climate.

Malaysian cities own unique urban morphology as compared to the other countries that already have or started the study on urban climatic maps. Most of the countries are situated in higher latitude as compared to Malaysia. Even though there are some studies focused on lower latitude regions such as Singapore, Vietnam and Thailand, the studied cities are located near to the coastal area which gives different climate behaviour especially Kuala Lumpur. Kuala Lumpur is situated in the mainland of the Malaysia peninsular and surrounded by other satellite cities which give different effects of wind flows and urban heating effects. Also, Kuala Lumpur owns various urban morphology and urban settings. Every part of Kuala Lumpur needs to be critically assessed so that the urban climatic map produced will succeed in depicting the city's urban climatic condition.

7. LESSONS FOR MALAYSIA AND FUTURE RESEARCH DIRECTIONS

As a developing country in the region, Malaysia is experiencing a fast urbanization rate, especially in the southern parts of the peninsular region (Klang Valley). Many cities are developing to cope with the trend for migration to more urbanized areas. Urbanization brings many benefits. However, rapid and improper urbanization can lead to the formation of UHI within a few decades (Elsayed, 2012; Hashim et al., 2007; Ibrahim & Samah, 2011; Rajagopalan, Lim, & Jamei, 2014; Shahruddin et al., 2014). Previous studies on Malaysian urban climate conditions emphasized the best mitigation of UHI effects, but always offered the knowledge using complicated "language". Thus, this knowledge cannot be used directly by those responsible for urban development due to communication problems between them. Therefore, this study proposes to develop Malaysia's very own urban climatic maps to suit the needs of urban planners and policy-makers. The concept of the urban climatic map is introduced in this study to assist urban planners to make better decisions during urban planning processes in terms of urban climate conditions.

Future studies on Malaysia's urban climate are encouraged to scrutinize and quantify the impacts of our specific urban parameters on the urban climate condition. Most of the previous studies on tropical urban climate mapping and modelling have only focused on coastal urban regions such as Kaohsiung, Hong Kong and Ho Chi Minh. The geographical setting of these urban regions creates different experiences of urban climate conditions as compared to the urban regions of Malaysia and especially the capital city, Kuala Lumpur, which is situated far into the mainland. In addition, the uniqueness of Malaysia's urban morphology should be taken into account. As discussed earlier, the different urban geometry, processes that take place in urban regions, materials and other urban characteristics will have different impacts on urban climatic conditions. Therefore, this study proposes to establish threshold values for the magnitude of the impact of each of the urban parameters that affect the urban climate condition. Figure 3 shows the research opportunities that exist in this research area.

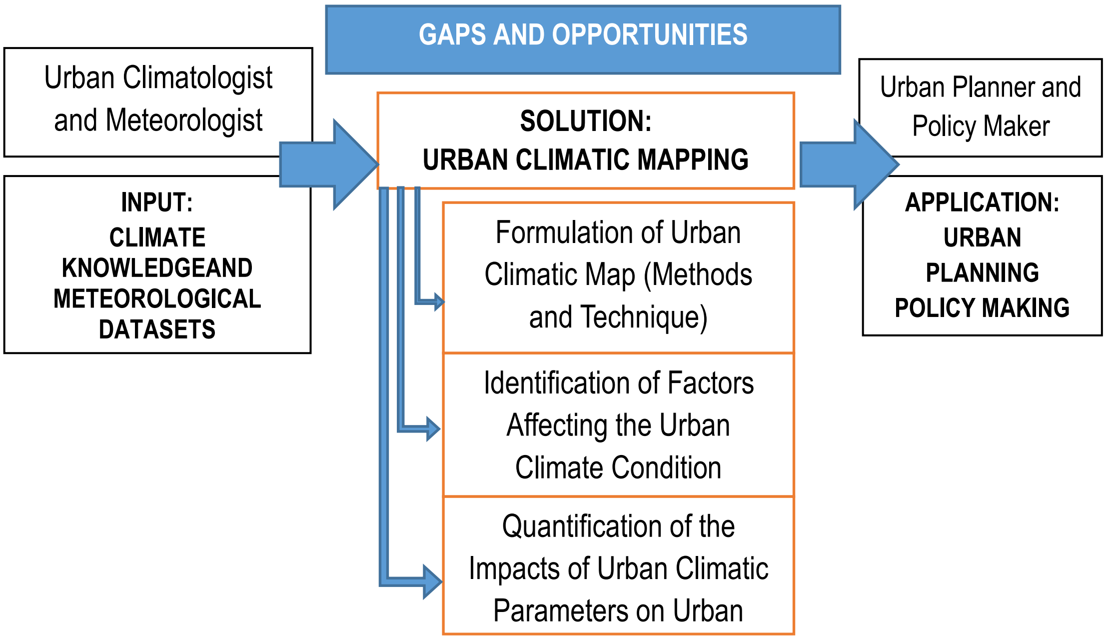

FIGURE 3 - RESEARCH GAPS AND OPPORTUNITIES OF THIS STUDY AREA
Source: Authors

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8. CONCLUSIONS

Climate alteration due rapid urbanization leads to environmental degradation. Previous studies have proven that rapid urbanization with little or no consideration on the urban climate condition often leads to negative consequences such as UHI phenomena, air pollution and flash floods. Therefore, great concerns on the implementation of climatic information into urban planning decision making is started. Various endeavours to address the significant effects of climate alteration are introduced using different techniques, methods and representations that fit the municipality's cases as well as their objectives and visions. As discussed, this study focuses on the UC-Map concept which has the same general ideas as other efforts; to address the urban climatic information for urban planning purposes.

This study identifies the research opportunities, which involve three major aspects: the formulation of urban climatic maps, identification of the urban climatic parameters affecting the urban climate of Malaysia's urban regions, and quantification of the impacts of each urban climatic parameter on the urban climate condition. In order to bridge the gap between the urban climatology and urban planning fields, this study proposes the formulation of our own urban climatic maps to assist urban planners to understand urban climate conditions more easily while making decisions for better urban development. The formulation of urban climatic maps is expected to translate the complicated series of meteorological and climatological datasets into simpler language and a representation of urban climate conditions which can be used directly by urban planners. As such, thorough analyses on urban climate behaviour, the factors affecting the urban climate, and their magnitude should be conducted. This is to ensure that the formulated urban climatic maps will be able to represent clearly the actual condition of the urban climate.

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