Impact of Rooftop Garden and Shading Effect Towards Human Thermal Comfort

Muhammad Irfan Shathiran[1], Muhammad Syahir Osman[1], Jasasikin Ab. Sani[2]

ABSTRACT

Human thermal comfort is an indicator for satisfaction of human towards the thermal factor in the environment. This topic may be a subjective matter due to the different characteristics of human to reach a certain level for obtaining the same satisfaction of thermal comfort. Factors that are looked into through this study are surface temperature, and solar radiation. Data collected through these factors, are then further supported by photographical observations, which are done simultaneously with questionnaires to relate and display the environment condition with the human thermal comfort. Questionnaires are distributed in order to gauge the statistics of several groups of people to compare between their characteristics and their level of thermal comfort. Site chosen for rooftop garden was the 'Secret Garden' 1 Utama and to contrast it is the plain rooftop of Lot10 and the rooftop parking of Sungei Wang Plaza, Kuala Lumpur. As for urban square, the research was conducted at Standard Charted KL Park. Our results came up with a conclusion that areas that are covered with dense green canopies like rooftop gardens and large vegetation are crucial to provide high level of thermal comfort towards human beings.

Keywords: Garden, Rooftop Garden, Thermal Comfort, Urban, Urban Square, Urban Park

INTRODUCTION

Thermal comfort is the effects of differences in air temperature, surface temperature, humidity, wind speed, and solar radiation. Several studies were conducted in several humidity percentages that show only a few people visit urban squares when the thermal index is high, and only visits them when the thermal index is close to their comfort level. **(Tzu-Ping Lin et al., 2010)** Therefore, thermal comfort of outdoors is influenced by climatic factors and the human usage of urban spaces/squares is affected by it as well.

The built environment usually affects the outdoors thermal comfort in urban squares and also on the rooftop garden, e.g., building wall surface temperature, ground surface temperature and shading provided by trees and vegetation. Sunlight, when is exposed directly on a surface, produces heat, which sustains for quite a period of time. This sustained heat affects the thermal comfort; as humans demands a suitable surrounding temperature in order to feel comfortable.

[1] 3rdyear Landscape Architecture Students, Dept. of Landscape Architecture, KAED, IIUM
[1]Assistant Professor, Dept. of Landscape Architecture, KAED, IIUM

The change of climate condition provides challenges to researchers in order to improve the health quality of people. Cities that have experienced extreme heat effect (EHE) in the 21st century have resulted deaths due to disease from EHE. In a similar case in North America, Harlan (2011) stated that extreme heat is the most common cause of death among all weather-related disasters.
Mahmoud (2011) stated that climatologists are more concerned with the causality of the urban climate, while designers are more interested in the effects of environmental forces on buildings and their impacts on thermal comfort of their users. No studies investigated the assessment of thermal comfort in urban square under the shelter of green shade and rooftop garden in the KL. This study aims to compare and evaluate the effectiveness of green shade and rooftop garden towards the human thermal comfort.

BACKGROUND

Thermal Comfort

According to Brown (2010), in many hot and humid countries tend to be less regulated and less thermally comfortable especially at the outdoor environment. However, improvements can be made when several proper factors are included and applied towards the stated issue. Human thermal comfort can be improved once the design of urbanization undergoes an appropriate interventions that provides a cooling effect **Setaih et al., (2013).** He also stated "*there are six factors to human thermal comfort that should be considered in a design"* These factors are wind speed, radiant temperature, air temperature, relative humidity, clothing isolation and activity level.

Shading Effects

Stathopoulos, T. et al. (2004) said, a wide range of parameters, including wind speed, air temperature, solar radiation, air quality, etc., may affect urban climate. Having vegetation surrounding the issued area can control these ranges of parameters. Vegetation, as in green shade, may reduce temperature if the urban area is hot, filter solar radiation and improve air quality.

As time passes by, global temperature increases gradually. **Carpenter, S. (2008)** states that the temperature is now 3 degrees Celsius higher compared to 30 years ago on average. The radiation from the sun can cause air in large urban areas to build up higher than surrounding rural areas, an effect that is particularly evident at night. All of this is noticeable worldwide, in the news, newspapers and even with our own eyes. Melting of earth caps and other issues. The effect global warming is climate change and distorts the sustainability of the environment. This affects the level of comfort of human beings.

Referring to a statement by **Carpenter, S. (2008),** green shade has high chances of reducing surface temperature as much as 10 degrees Celsius when covered by dense vegetation. The vegetation covering most part of the exposed areas of sun radiation will prevent it from directly reaching the surface to build up heat, therefore, will help reduce temperature at the area it covers.

Mahmoud, A.H.A (2011) stated, "*comfortable and healthy microclimate conditions are necessary for any type of environments. People are exposed to varying types of stress in the urban environment. The most influential one is the microclimatic conditions, which vary significantly from rural areas*." This is to say that the

condition of microclimate influences the comfort of humans especially when humans are outdoors. Humans are exposed to many elements and the sun is the most obvious element that is affecting human comfort because of the heat and radiation it produces. Thus, green shades are one of the key factors that can be applied to provide comfort to humans, as well as to sustain the environment the best possible way.

In order to judge the effectiveness of green shade and its relation to users, many studies have been made to prove that dense vegetation provides a cooling effect on what it covers. Trees and vegetation plays a very important role in enhancing the quality of air in urban environments. **Matsuoka and Kaplan, (2008)** had investigated people's requirements in urban landscape. They proved that people tend to request connection with nature, aesthetic experience, entertainment and play, green colors in terms of green areas of trees. **Ng, E. (2009)** cites that the use of plants as a strategy to overcome the UHI and to improve the microclimate has been widely emphasized. Highlighting the hot and humid climate, the best benefit that can be used from vegetation are from its shading aspect to reduce intense solar radiation as the overheating is mainly due to the heat storage by the sun exposed surface. **Mahmoud, A.H.A (2011) once** again said that the effect of street vegetation and urban parks on climatic conditions in hot arid environment received substantial attention in the last two decades, which is one of the indicators of a successful green shade in urban square. Vegetation in urban square has potential of providing "cool-spots", where it can help control thermal conditions. Figure 1 shows the condition of site with the effects of green shade. It makes users of the urban square to feel more comfortable by providing good shade and shelter from the sun.

Figure 1

Impact Of Rooftop Garden

There are many types and categories that can be related with garden such as botanical garden, edible garden, and flower garden. Landscape architects, which can be assumed as professionals, are designing gardens or open spaces by applying principles of design and horticulture aspects in order to make spaces look interesting and benefit to users.

There are many terms and definition that are defined by many specialists about rooftop garden. According to **Prof. Sharon Hall (2001)** rooftop garden can be defined as man-made green spaces on the very top level of industrial, commercial, and residential structures. Meanwhile, according to **R&S Landscaping (2003),** rooftop garden contained a green space on top of man-made structure. It provides a variety way of public and private benefits to the environments and surroundings.

The United States Environmental Protection Agency (EPA) also defined rooftop garden as a vegetative layer grown on a rooftop which give shades surfaces and removes heat from air. EPA stated that the vegetative rooftop surface cooler than the

ambient air. There are 3 major types of rooftop garden – extensive green roof, semi-intensive green roof, and intensive green roof. These 3 types of rooftop garden have different characteristics and roles, which may be various, impact to the surroundings. Figure 2 shows that the types of rooftop garden along with illustration.

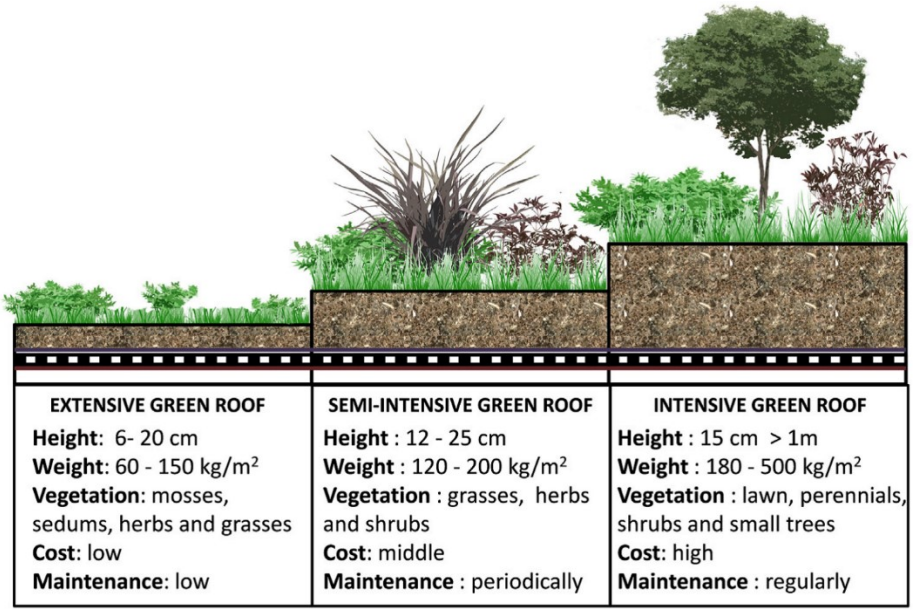

Figure 2: Illustration of the types of rooftop garden ***Sources:*** *Internet sources*

The presence of rooftop garden in the area of urban context may give environmental effect, which benefits the surroundings. Rooftop garden can reduce energy usage and can save energy that is needed to cool or heat the building. The vegetation from the rooftop garden reduces the roof surface temperature and atmospheric air temperature. Hence, the demand of cooling energy reduces. According to **Wong et al. (2003)** the impact of plant shading may reduce the temperature of the building and it is surrounding. It also helps to reduce the energy consumption by 25%.

Rooftop garden may solve the problem of air pollution and greenhouse gas emissions. As the temperature arise, green roofs are playing their role by slowing down the formation of ground-level ozone by lowering the air temperature. The surface of the plant can remove certain pollutants from the air. Besides that, a rooftop garden can remove gaseous pollutants such as nitrogen oxide (NO_x), sulfur dioxide (SO_x), carbon monoxide (CO), and ground level of ozone (O_3). Trees and growing medium like common garden soil also can store carbon. According to **Climate Protection Partnership Division**, (2004), because of the size of the plants that are not too big and the growing medium is slightly thin, rooftop gardens tend to not able to store big amount of carbon as trees in the forest.

Malaysia's climate is categorized as equatorial, always being hot and humid all year long. Malaysia essentially has a tropical weather, but it does not get too hot. Unfortunately, it is contrast with the situation in urban area like Kuala Lumpur. The lack of green space and the spreading of concrete forest is one of the main reasons why the urban area experiences the hot climate and may lead to urban heat island (UHI).

The presence of rooftop garden in urban context may include some environmental effects, which can benefit the surroundings. Rooftop garden or green roof can reduce and conserve precious energy that is needed to cool the building. The vegetation from the rooftop garden can reduce the roof surface temperature and atmospheric air temperature. So, the demand of cooling energy is becomes lesser. According to **Wong et al. (2003)** the impact of plant shading may reduce the temperature of the building and it is surrounding. It also helps in reducing the energy consumption by 25%. Due to the tropical weather of Malaysia which experience hot and humid throughout the year, the effectiveness of rooftop garden can be seen in terms of reducing the surface runoff and enhance the storm water management. The results from rooftop garden and conventional roof are compared. Amazingly, rooftop garden can reduce surface runoff and managed storm water 50% better than the conventional roof. This happens because the presence of plants may able to slow down the water run off while the soil absorbs the water into the ground. The rest of the water runoff will flow into the drainage system. Indirectly, this method will assist urban area like Kuala Lumpur from experiencing a major flash flood during heavy rain **(Sabariah et al., 2008).** Other than its vegetation, the depth of the soil and planting selection are also can be a supportive factor to prevent the surface of the building from receiving the direct sunlight. Based on the results of the experiment, the presence of vegetation on the roof give a better indoor environment especially to spaces below the landscape. Both of these factors will increase the ability to stabilize and keep a comfortable temperature in buildings that contribute to energy savings. Rooftop garden may solve the problem of air pollution and greenhouse gas emissions. As the temperature arise, green roofs play their role by slowing the formation of ground-level ozone by lowering the air temperature. The surface of the plant can remove certain pollutants from the air. Besides that, a rooftop garden can remove gaseous pollutants such as nitrogen oxide (NOx), sulfur dioxide (SOx), carbon monoxide (CO), and ground level of ozone (O3). Trees and growing medium like common garden soil also can store carbon. Because of the size of the plants that are not too big and the growing medium is slightly thin, rooftop garden tend to not able to store big amount of carbon as trees in the forest **(Climate Protection Partnership Division, 2004)** There are also methods which can gain some ecological benefit to the environment from the rooftop garden, which is the ability to increase biodiversity value by the preservation of natural habitat for several species like birds, insects, and the other small plants **(Getter and Rowe, 2006).** Due to the loss of green space in urban area, many of species also lose their natural habitats and at the same time affect their livability. The presence of rooftop garden may provide them a new place to live with basic habitat component such as protection from weather and predators, food, water and space **(Canero and Redondo, 2010).**

METHODOLOGY

To determine the impact of shade and rooftop garden towards human thermal comfort, this study was conducted at several locations with rooftop gardens and an urban square, with different shading levels. . The study was conducted in 5 stages, which are (1) Research Proposal & Literature Review, (2) Development of Methods for Data Collecting, (3) On-Site Study, which is the primary data collection, (4) Findings of Data & Analysis, and (5) Conclusion & Design Recommendations.

Literature Review

This stage is where most secondary data is obtained, for example the definitions of the topic related to green corridor and thermal comfort. This stage describes almost everything that is needed to aid the research study including the benefits of green corridor and the issues of thermal comfort. All materials include previous research papers, journals, articles and Internet sources.

Development of Methods for Data Collection

This is the next stage where methods for collecting data are developed. A few methods were prepared to collect data such as questionnaires, use of equipment, and photographic observations. Details of questionnaires, equipment used will be further discussed later in this chapter.

On-Site Study (Data Collection)

Data collections were done by distributing 30 questionnaires randomly to pedestrians who are mingling around site. A pilot study had been carried out before the real observation and interview process. Surface temperature and solar radiation were recorded between 12pm to 4pm at 3 different spots on site. Photographic observations were done by taking photos of potential areas, which shows the obvious effects of green shade towards urban thermal comfort. Figure 2 shows the site at urban square. Figure 3 shows the site on a rooftop garden research.

Figure 3: Photo of Green Shade Covering Urban Square

Figure 4: Views on several rooftop gardens

Data Analysis

All questionnaire data are analyzed by using Microsoft Excel. The test analyzes all the data based on their variables and relationship between each other before concluding the results. Primary data such as solar radiation and surface temperature, which were recorded on site, are put into graphs to compare the differences of the elements researched.

Conclusion and Recommendations

Conclusions of the research were rendered from the results of data analysis. This should assist in recognizing the effects of green shade and rooftop garden towards urban thermal comfort. Recommendations are proposed to improve the situation

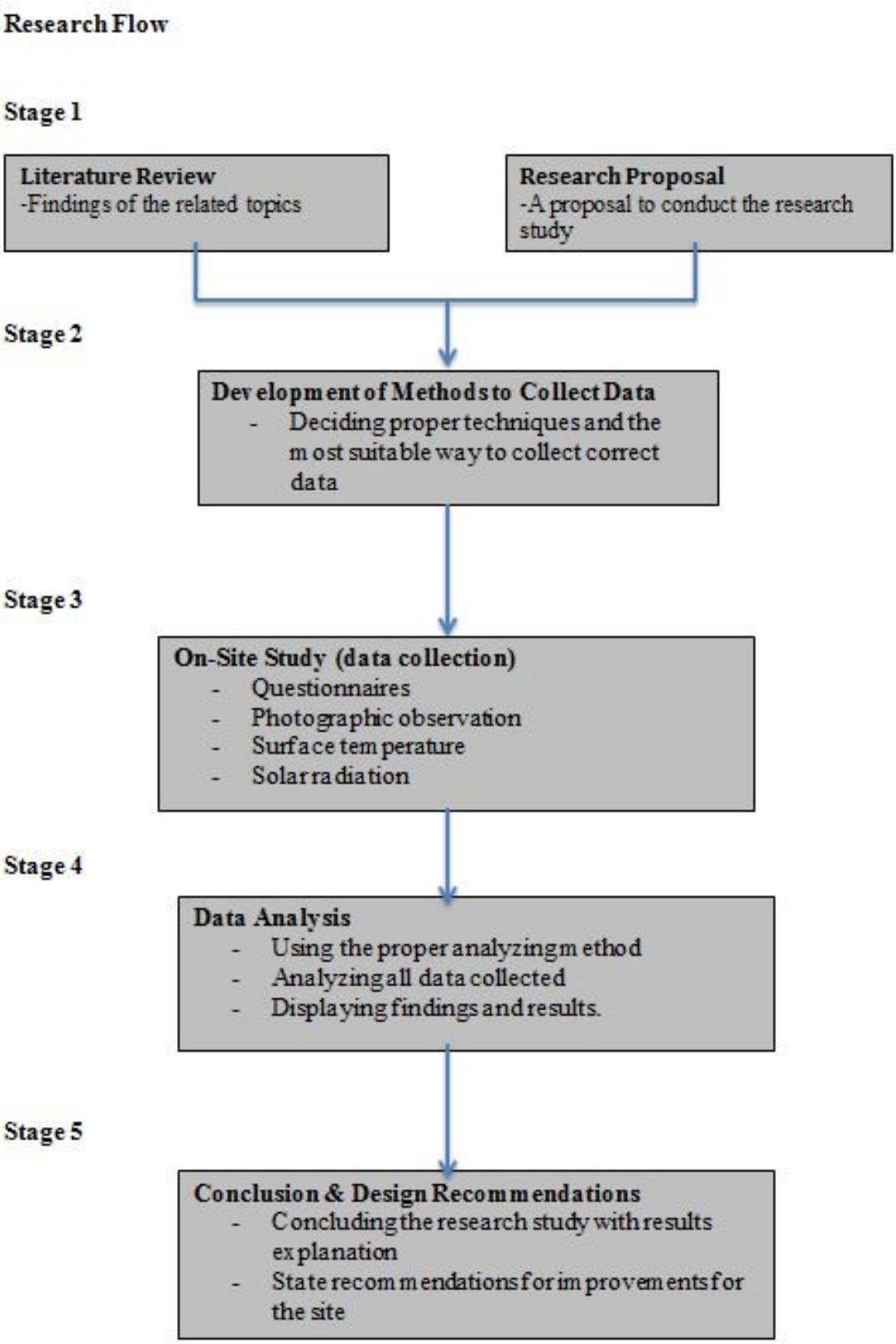

Figure 5: the research flow

DATA ANALYSIS

There were 4 data collection methods, which were done and mentioned previously. Two of quantitative data and two of qualitative data were taken during filed study. Tools were used in order to record quantitative data, which are the solar radiation and surface temperature. Questionnaires and photographs were done for the qualitative data analyzing.

Table 1: Solar radiation

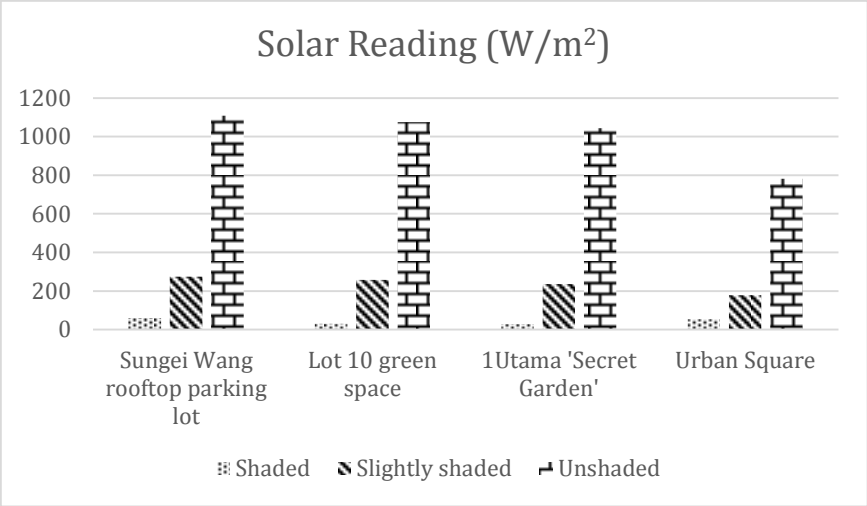

Table 1 shows the readings of solar radiation of all four sites. Three conditions were looked into, which are shaded area, slightly shaded, and non-shaded areas. These conditions show very different results of solar readings. The highest solar reading obviously goes to the non-shaded site condition. This kind of solar radiation in any situation does not provide good thermal comfort towards humans because of the strong sunrays, which will definitely give sunburn to whoever are exposed for too long underneath the sun, without any shade.

For the slightly shaded condition on site, solar radiation reading drops almost more than 60 percent in comparison to the one non-shaded. Considering that there is some vegetation, which filters some of the sunrays from getting through and in contact with the ground or floor surface.

Looking into the data of the shaded condition on all four sites, all of them have a very low solar radiation reading, which proves that vegetation really helps in filtering and most likely to even block the sunrays completely.

In summary, more than 90% of solar radiation is deflected by vegetation. Vegetation provides a very good shade and can benefit humans to avoid the heat from the sun thus; human's thermal comfort may be improved and stabilized.

Table2: Surface temperature reading at 3 different conditions at 4 different site locations

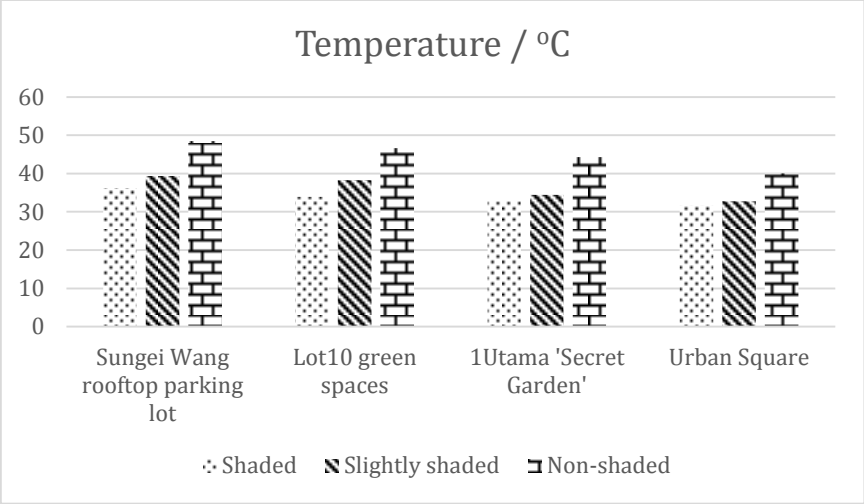

Table 2 shows the reading for surface temperature that has been collected for all four sites. Data collected are categorized based on 3 aspects, which are shaded, slightly shaded and non-shaded. The highest temperature reading for non-shaded is obviously at Sungei Wang rooftop parking lot. Due to the direct sunlight and no filter to the surface area, it increases the surface temperature and may be harmful to people that are exposed directly to sunrays in certain amount of time.

Readings for shaded areas in Lot10 green space, 1Utama 'Secret Garden' and Urban Square differ as the presence of trees and shrubs that are covering the edges of buildings are a lot dense in the urban square. This can be a good cooling agent for the rooftop and ground temperature.

The second aspect is slightly shaded meaning that the presence of trees can be penetrated by the sunrays, but in a lesser amount. Locations that do not have any vegetation is at the Sungei Wang rooftop parking lot had the highest surface temperature reading. The second highest goes to Lot10 green space, which had a slightly less reading compared to Sungei Wang. There were no planted trees in Sungei Wang rooftop but less number of trees in Lot10 green space effects the surface temperature. In relating to thermal comfort, people feel less comfortable when there are minimum shady areas.

Surface that is covered with trees and shrubs are the places with the most shaded areas. Urban Square and 1Utama 'Secret Garden' had the lowest temperature reading. Both of the places still provide high surface temperature reading but the large amount of plants can reduce the surface temperature without any other cooling aid such water mist or water spray.

The temperature reading for 1Utama 'Secret Garden' is higher than Urban Square because of the distance of the rooftop garden is closer to the sun compared to the ground level urban square. In fact, 1Utama 'Secret Garden' can be categorized as intensive rooftop garden, which have a thick layer for growing agent, which is soil. This shows that soil, acts as a heat insulator to the building that can possibly decrease the surface temperature.

Questionnaires or surveys were distributed to random people on site to get their perception and experience about their current thermal comfort. It came out as expected where most respondents demands good shade when they are outdoors. They

would look for trees or any other form of shelter to avoid the scorching hot sunlight. In the survey, a question was asked about what type of shelter do they prefer. Either man made shelter or natural shelter like trees. Most respondents chose to look for trees and vegetation as their shelter because of several reasons. They explained that vegetation gives them good cooling effect and filters the sunrays. That information is sufficient enough to make the research more solid.

CONCLUSIONS AND RECOMMENDATIONS

This research paper provides basic knowledge about different locations of shaded areas and evaluates the human thermal comfort theories. Field studies and surveys were conducted in order to obtain the information of thermal comfort towards humans, by referring to the elements of surface temperature and solar radiation. Surveys found out that human's perception on thermal comfort is when they are not directly exposed to the hot sun and when they are surrounded by a cool surrounding temperature simultaneously. Two factors that were taken into account are the surface temperature and solar radiation. These two elements can be related to one another. During the sun is strong and produces a very high reading of solar radiation, surface temperature will rise accordingly and it will only be reduced when the solar radiation is disturbed by other elements. That other element in this study refers to the vegetation that is allocated on site. After this study is conducted, the results obtained were promising. Dense vegetation really proved their benefit by filtering most of solar radiation and reducing the surface temperature on site. This will definitely affect humans and thus increases the percentage of human thermal comfort.

By completing this research, a conclusion can be made on the relation of rooftop garden and the shading effect on urban square. Both of these locations have potential to improve thermal comfort because of the presence of greenery. Furthermore, it can be recommended that to propose an urban square in accordance with the height of a rooftop garden, which means an elevated urban square to reduce temperature and provide more airflow for improved ventilation.

REFERENCES:

Anderson, M. Design Development of a Roof Garden, McCaren Design, Inc., Vandalia Street.

Canero, R. F and Redondo, P. G. (2010). Green roofs as a habitat for birds: a review. Journal of Animal and Veterinary Advances. 9(15), 2041-2052

Che Soh, M. , (2010), Crime and Urbanization : Revisited Malaysian Case, *ASEAN Conference on Environment-Behaviour Studies,* pp. 1-9, Faculty of Administrative Science and Policy Studies, Universiti Teknologi MARA, Shah Alam, 40450, Malaysia

Getter, K. L. and Rowe, R. B. (2006). The role of extensive green roofs in sustainable development. HortScience. 41. Pp 1276-1285.

Handbook on Skyrise Greening in Singapore (2002). From NParks website and CTBP http://www.nparks.gov.sg/cms/.

Hui, S. C. M. and Jiang, J., (2014). Assessment of thermal comfort in transitional spaces, In *Proceedings of the Joint Symposium 2014: Change in Building Services for Future*, 25 Nov 2014 (Tue), Kowloon Shangri-la Hotel, Tsim Sha Tsui East, Kowloon, Hong Kong

Jusuf, S. K. et al. , (2007), The Influence of Land Use on The Urban Heat Island in Singapore, *Habitat International*, pp. 1-11, Department of Building, School of Design and Environment, National University of Singapore, 4 Architecture Drive, Singapore 117566, Singapore.

Lin, T. et al., (2010), Shading Effect on Long-Term Outdoor Thermal Comfort, *Building and Environment,* Vol. 45, pp. 213-221, Department of Leisure Planning, National Formosa University, 64 Wen-hua Road, Huwei, Yunlin 632, Taiwan

Mahmoud, A.H.A. (2011). Analysis of the microclimatic and human comfort conditions in an urban park in hot and arid regions, *Building and Environment,* Vol. 48, pp. 2641-2656, Department of Architecture Engineering, Faculty of Engineering, Cairo University, Giza 12211, Egypt, Department of Architecture Engineering, The British University in Egypt, El-Sherouk City, Egypt

Memon, R. A. et al. , (2009), An Investigation of Urban Heat Island Intensity (UHII) as an Indicator of Urban Heating, *Atmospheric Research*, pp. 1-10, Department of Mechanical Engineering, The University of Hong Kong, Hong Kong, China.

Rocha, E. R. R. M. and Ramos, A. R. R. , Network of Urban Parks and Green Corridors in the City of Braga, Portugal, *Advances in Environment, Computational Chemistry and Bioscience,* pp. 205-207, Department of Civil

Engineering, C-TAC Centre for Territory, Environment and Construction University of Minho – Engineering School, Braga, Portugal

Roslina Sapawi (2009). Urban Heat Island Mitigation through Green Roof Technology. Sarjana Pengurusan Persekitaran. Fakulti Kejuruteraan Awam, Universiti Teknologi Malaysia.

Sabariah, Nor Aini, Mas Rahayu, Hartini, Zarina dan Mohd Shukri (2008). Potential of storm water capacity using vegetated roofs in Malaysia. International Conference on Civil Engineering Practice (ICCE08), Hyatt Regency Kuantan Resort, Kuantan, Pahang.

Thompson, J. W., and Sorvig, Kim (2008). Sustainable Landscape Construction: A Guide To Green Building Outdoors. Wasington D. C: Island Press.

Setaih. K. et al., (2013). Assessment of Outdoor Thermal Comfort in Urban Microclimate in Hot Arid Areas, *Proceedings of BS2013: 13th Conference of International Building Performance Simulation Association, Chambéry, France, August 26-28,* School of Architecture, Planning and Landscape, Newcastle University, Newcastle upon Tyne, UK.

Takebayashi H, Moriyama M. (2007) Surface heat budget on green roof and high reflection roof for mitigation of urban heat island. *Building and Environment*, Vol. 42, pp. 2971-2979.

Tzoulas, K. et al. , (2007), Promoting Ecosystem and Human Health in Urban Areas Using Green Infrastructure: A Literature Review, *Landscape and Urban Planning,* Vol. 81, pp. 167-178, The Research Institute for the Built & Human Environment, The University of Salford, Peel Building, Greater Manchester, UK

Weeks, R. J and Jurgens (eds), (2010), Defining Urban Areas, *Remote Sensing of Urban and Suburban Areas,* San Diego, CA, United States of America

Wong, M. S. et al. , (2010), A Simple Method for Designation of Urban Ventilation Corridors and Its Application to Urban Heat Island Analysis, *Building and Environment*, pp. 1-10, Department of Land Surveying and Geo-Informatics, The Hong Kong Polytechnic University, Kowloon, Hong Kong.

Wong, N. H., Cheong, D.K.W., Yan, H., Soh, J., Ong, C.L. & Sia, A., (2003b). The effects of rooftop garden on energy consumption of a commercial building in Singapore. Energy and Building. 35. pp353–364.

Standards

Commission for Architecture and the Built Environment (CABE), (2010), Managing Green Spaces, Seven Ingredients for Success, London: CABE

Online Websites

Sourcable Industry News & Analysis, State Government to Protect Melbourne's River Landscape, [online], available at: <http://sourceable.net/state-government-to-protect-melbournes-river-landscapes/# > [20 February 2015]

Seattle.gov, Seattle Green Factor, [online], available at: <http://www.seattle.gov/dpd/cityplanning/completeprojectslist/greenfactor/whatwhy/> [23 February 2015]

Green Roofs for Healthy Cities, Green Walls Benefits, [online], available at: < http://greenroofs.org/index.php/about/green-wall-benefits> [22 February 2015]

European Federation of Green Roof Associations – EFB, Environmental Advantages, [online], available at: <http://www.efb-greenroof.eu/verband/fachbei/fa01_englisch.html> [21 February 2015]

Green Roofs for Healthy Cities, Green Roof Benefits, [online], available at: <http://greenroofs.org/index.php/about/greenroofbenefits> [21 February 2015]

Rooftop Gardens (2001) 'Project Promotion and Implementation', <http://faculty1.coloradocollege.edu/~shall/ev421/joekurland.html> [Assessed 20 February 2015]

Heat Island Effect (2013) 'Green Roofs, Benefits and Costs', <http://epa.gov/heatisland/mitigation/greenroofs.htm> [Assessed 20 February 2015]

R&S Landscaping (2011) 'What is a Roof Garden?' http://www.rscape.com/what_is_a_roof_garden.html [Assessed 20 February 2015]