Microclimate Environmental Model for New Built Environment and Design Complex UiTM Puncak Alam

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Abstract. Microclimate is a smaller area within a general climate zone that has its own unique climate. In a particular area, there can be a myriad of smaller climates within the larger climate zone. ENVI-met is a computer program that enables to stimulate the microclimate of an environment. It is also can be used to estimate the effect of changing climate conditions on the thermal comfort within the area. The aim of this study was to measure the microclimate of an area been received within, by generating the microclimate environmental model using ENVI-met software. This simulation module is used to understand and quantify the interactions between the man-made and natural environment, and the outdoor microclimate in new development. The microclimate area that has been selected is at Built Environment Complex, UiTM Puncak Alam, a new campus area located in a hot and humid tropical climate. The physical elements involved were vegetation, multi-storey buildings, roads, paving areas and open/green areas. The simulation model shows that the highest temperature recorded was 33˚C, which is at 17.00 hours. The relative humidity is below 58% during this peak time with wind speed 1.3 m/s. This high temperature occurs due to the pre-mature tree, which only can provide a minimum shade and make the area become hot and uncomfortable to users.

Keywords: Microclimate, environmental model, ENVI-met, tropical climate, development.

1. Introduction

The microclimatic environmental quantification is conducted to identify the range of neutral thermal environment of the development areas in a hot and humid tropical climate. The study area is located in the new campus development includes the open space and green area. There are two main microclimate evaluations in order to gain the microclimate character of the urban areas. Namely as microclimate ground measurement and microclimate simulation model [1]. This study focused on numerical simulation model of ENVI-Met, supporting with the ground data obtained from the Meteorology Department. Basically, the evaluation methods cover the real-time or continuous monitoring at hourly interval in tropical climatic condition. This is to enables to monitor the surrounding new green space microclimate modification surround the campus layout. The overall microclimate condition around the new campus will influence the comfort level of users especially in outdoor areas. The basic characters of outdoor thermal environment space usually should have covered by natural shades. The shades can be provided by mature trees, small trees, shrubs, and groundcovers [2]. Water elements and natural earth surfaces can provide evaporation process together with transpiration from plants. All these elements usually will be supported by wind flow to comfort the outdoor spaces.
2. Literature review

Urban microclimatic models can be used to evaluate the interactive effects between green space and development areas such as in new campus development. Data related to microclimate components are air temperature, relative humidity, wind, solar radiation, and evapotranspiration. There is a significant microclimate model that can be used for estimating the campus microclimates pattern, such as the ENVI-met model which was developed by M. Bruse from the University of Mainz, Germany in 2004. ENVI-Met is a microclimate model for measuring those microclimate parameters. ENVI-Met is a three-dimensional numerical model that can simulate the surface-plant-air interactions of urban environments with a typical resolution of 0.5-10 m in space from a single building up to a neighbourhood providing 250 grids as a maximum [3]. ENVI-Met is one of the only models of its kind that is actually considered for vegetation in a detailed manner, using single trees to compose, or grasses, paved areas, roads, buildings and so on. Study by [3] also explained the basic data structure of ENVI-met as a simulation program includes; i) simulate the complete coupled climate system; ii) provides a high resolution model resolving single buildings; iii) adequate simulation of surface-vegetation-atmosphere processes; iv) use state of the art computational techniques; and v) easy to use interface and input/output data handling.

The strength of this model is that ENVI-Met has implemented a soil-plant-air sub-model and its plant database, which depends on the plant numerical physiological representation using height, albedo, leaf area density, stomata resistance, leaf surface temperature water content, etc. Simulation result in the previous studies indicated that the location of buildings near or surrounded by different greenery levels has showed different ambient temperatures than those located with less density of the green area [4] [5]. It is scientifically believed that adding more vertical green cover within the built-up area is one effective way to lower the ambient temperature [5]. A similar model was used to predict different scenarios and the results showed that by adding more green cover, the campus environment becomes markedly cooler than it is at present [3].

Some studies on microclimates were also conducted in order to identify the temperature impact of vegetation in the urban environment with respect to the reduction of air temperature. Hence, the microclimatic effect of vegetation underwent ground measurement for verification and computer simulation. These two approaches were conducted on the institutional campus of Saga University, Japan, including an on-site measurement and a numerical simulation model that used ENVI-Met [6]. The on-site measurement program was designed and the real-time microclimate conditions were measured in the campus environment at the pedestrian level. Then, the level of greening was increased via a simulation model of ENVI-Met. Results from this study presented that these green areas had a pronounced low temperature and reduced the ambient outdoor summer temperature. It has been shown the importance of greening as a potential method for passive cooling and for use in reducing ambient air temperatures, especially at a pedestrian level in university campus.

The microclimatic simulation model by ENVI-Met can provide more detailed features for evaluating trees and vegetation effects to the surrounding urban areas. The study aims to model an environmental microclimate for new Built Environment and Design Complex UiTM Puncak Alam. ENVI-Met is used because this software capable of simulating built environments from a microclimate scale in a local area at a campus location.

3. Methodology

3.1 Site study

The selected site for this study is located in the new campus of Built Environment and Design Complex, which are consist of Faculty of Architecture, Planning and Surveying (FSPU), and Faculty of Art and Design (FSSR), Universiti Teknologi MARA, Puncak Alam, Selangor. The visual image is shown in Figure 1. The age of these new developments was around two years. The area is located in the hot and humid tropical climate, at 3°N Latitude and 101°E Longitude with average elevation 159 meters. The total site study areas are around 40,000 sq m. The microclimate environmental model was built on 24th September 2017. The campus building area that has been selected to be stimulated was
supported by other buildings such as hostels, library, vehicle depot, cafeteria and musallah. The physical elements involved in this selected area are vegetation, multi-storey buildings, roads, paving areas, courts, and green/open areas. Natural or soft-scape element such as water elements (lake) and small secondary forest located on the east side. Most of trees planted in this campus include around the lake and park, roadside and parking were in small size and in pre-mature condition.

![Site Study Image]

**Figure 1.** The site study of new Built Environment and Design complex, UiTM Puncak Alam

3.2 ENVI-met microclimate simulation model

ENVI-met is a multidisciplinary simulation consultancy with a core services portfolio, including architecture, building physics and microclimate, landscape architecture and garden design. The ENVI-met Tree Pass is a comprehensive overview of plants’ requirements and the site conditions match to obtain the best possible thermal benefits for landscape designs and to ensure optimal growing conditions. The climatic factors include temperature, humidity and wind speed simulation were set up using the ENVI-Met software as well as to evaluate the accuracy of the simulation model. The simulated climatic maps were used to analyse the pattern. For this study, hourly climatic simulation for a period of 24 hours was carried out. The hourly data obtained from the simulated process were later compared to the weather data gained from the Malaysian Meteorological Department station in Subang Jaya, Malaysia. The real-time comparison was carried out between the permanent weather station and simulated weather data, which was of the same date and same time observation. The models generated from the ENVI-Met numerical model were essential to identify the heat pattern and its effects to the surrounding campus environment at any time.

The ENVI-Met modelling program has four user interfaces. Firstly, editing the input and preparing digital maps of the layout. Secondly, only the environmental domain is chosen to work and high-resolution aspects of the program enable the users to go into finer details in smaller scales (0.5) or to be coarser (and less detailed) in lower scales. For example, a 10m square area in the campus study area is represented by 1km square in a model. Third, databases for soil types, humidity, temperature, temporal input, etc. are entered as the modelling area and where additional parameters are present, the modelling process takes place. Fourth, the output data can be interpreted and visualized in LEONARDO. ENVI-Met generates hourly fields of climatology simulation (i.e. temperature, relative humidity (RH), radiation) variables [7]. Bruse also defined that the integration of ENVI-Met 4.0 and LEONARDO 2017 has the capacity to project small to large-scale climatic impacts. The model can evaluate future parkways in the areas of optimal outdoor comfort, optimal citizen use, and minimal
environmental damage. As a non-hydrostatic model that simulates surface-plant-air interactions inside urban environments on a three-dimensional rectangular grid with variable spacing in x-, y-, and z-directions, the model functions over a range of spatial scales

4. Results and Discussion
The open space within the build-up areas can resulted low temperature. The role of open spaces in alleviating an urban microclimate has been examined all over the globe. The green space within this Built and Environment campus complex consists of large coverage area of small tree’s age around two years old, supported by a small amount of shrubs, water bodies, and turf to cover earth surfaces. This coverage of pre-mature trees will possible in providing a minimum shade and evaporative process. The minimum cooling effects of the open space will affect the thermal surrounding environment of PSPU and FSSR areas. Evaluating the open space cooling consequences around this new building complex were validated via simulation models.

Figure 2. Temperature during peak time of the day, 15.00 hours (left) and 17.00 hours (right)

Figure 3. Temperature and RH in 24 hours. Peak time of the day at 17.00 hours.
The simulation models were generated 6 times in 24 hours. The simulation shows that the lowest temperature was 25.5°C which is 8.00 hours in the morning. The temperature began to rise around the building blocks, which is the data recorded around 26.94°C to 29.98°C, represented as paved areas which are parking lots, roads, building entrances and plaza. This is due to the trees that are small size and premature within the site. The physical of trees have a very minimum canopy size and those trees were replanted and not yet reach to the age of mature trees. Therefore, it’s unable to give the shades as well as to lower the temperature. Conversely, made the areas become hot and uncomfortable for people. While Figures 2 and 3 also shows that at 13.00 and 17.00 hours, the temperature of surrounding building recorded in 31.90°C to 33.00°C. The high temperature range is due to the paved areas absorbing the heat during day time and emit the heat in the evening when the surrounding starting being cool. The other area within the park, which most of the areas were covered by turf and small trees, surrounded by water element was lower it ambient temperature as much as 1°C compared to built-up areas. The surrounded building with small and premature trees exposed the direct sunlight towards buildings as well as unable provide adequate shade over peak hours of the day. They received and absorbs heat from direct sunlight and reached its heat storage capacity as much as 33.00°C at 17.00 hours in the evening.

When the sun rises early in the morning, the RH is usually high due to low temperature overnight near the dew point. Similarly, the highest RH was during the early morning at 8.00 hours as much as 87.12%. The RH was gradually decreasing until reach the lowest level of around 45% between 15.00 and 17.00 hours located around building blocks as shown in Figures 3 and 4. The highest RH recorded in green areas which is 75.74%. This is because of the areas were surrounded by water/lake and plantation. Water element can generate the high RH 60% toward the surrounding. The combination of water, soil and premature trees with turf cover can generate evapotranspiration process during the day and contributed to the reading of RH. The reading of RH is lower as much as 10%. Meanwhile, premature trees and small shrubs that located surround parking lots, entrance and buildings generate very low RH reading during its photosynthesis process. The dark blue colours located at the parking space and road and surround buildings recorded at lower RH because of the built-up and paved area made the areas hot and dry.

According to meteorology report, this is the most suitable time wind flow along the day in this area between 1.1 and 3.5m/s. Wind flow/speed in the study area is stable below 3m/s from the south, southwest, and west directions. Wind speed in surrounding the buildings during peak time of the day is the lowest reading around 0.33–1m/s as shown in Figures 5 and 6. While the surrounding green area the speed is more stable, around 1–3m/s. This is because of all of tree sizes are small and unable to provide the proper movement of the wind in this environment. If the evapotranspiration and shade from the tree are well produced, with this stable wind flow, the cool and comfortable environment will
be provided, even during peak hours. The findings of wind flow further revealed that most of the high wind flow is located at surrounding the site study.

![Wind Flow Diagram](image)

**Figure 5.** Wind flow during peak time of the day, 15.00 hours (left) and 17.00 hours (right)

![Wind Speed Chart](image)

**Figure 6.** Wind speed in 24 hours; higher at 11.00 to 17.00 hours

The findings show that the increasing of temperature moving surrounds the green area. The built-up areas were recorded with higher temperature readings as compared to green spaces. It reveals a dramatic effects of greens park (tree, shrubs and turf) in lessening the ambience temperature of the campus areas. Furthermore, it also indicates that mature tree with sufficient canopy size and have dense of the leaves are more effective in reducing the temperature as compared to small vegetation such as shrubs and grass. Thus, in order to reduce the temperature in this campus complex, greener area should be preserved and planting more shade tree to reduce the surrounding temperature. Trees planted with other vegetation, located in a strategic location around buildings are the most effective mitigation strategy to reduce high temperature.

The microclimate model for this campus complex shows the highest temperature during peak time of the day is 33˚C at 17.00 hours in the evening, with RH 45% and wind speed around 2.5–2.8m/s. This temperature reading is high because of surrounding shade trees are in premature conditions is unable to contribute shade and evapotranspiration cooling. The matured park in tropical climate can provide an ambient temperature as low as 31˚C during peak time of the day [8][9].
Figure 7 shows a 3D microclimate model of the FSPU and FSSR campus complex surrounded by a park with mature trees and water elements will be generated after 10 to 15 years after development. These mature green surrounding can reduce as much as 3°C ambience temperature. The low temperature will be supported by maximum shaded by mature trees, the evapotranspiration process of vegetation, water element and earth surfaces as well as encourage the wind flow surround the buildings and the park. While the secondary forest that located at the east and southwest of the campus complex, should be maintained. The network of these forests/green areas will be continued into the campus building complex forming a harmony and sustainable greenbelt, and furthermore friendly to wildlife. Cool and comfort campus environment is suitable for outdoor learning activities and for the students work out in the evening.

5. Conclusion

ENVI-met is a software to stimulate the microclimate of an environment. The microclimate simulation by ENVI-met can be used to estimate the effect of changing climate conditions in the outdoor comfort within the area. As this study shows, green spaces and are normally considered to help improving the outdoor comfort by reducing air temperature. The microclimate model for this campus complex shows the highest temperature during peak time of the day is 33°C at 17.00 hours in the evening, with RH 56% and wind speed around 1-3 m/s. This temperature reading is high because of surrounding shade trees are in premature conditions can not contribute to reduce the hot and humid tropical climate in surrounding them. The predicted/future 3D microclimate model illustrates the huge green spaces contribute a significant impact in the microclimate. The cooling effect of park can dominate the immediate surroundings, especially when the evapotranspiration process is in the maximum. It mainly consequences by natural shading, lower ambience temperature and humidity level in the environments. Finally, the cooling performance in the park depends on the density of the foliage in the green space.

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