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Impacts of partial greenery facade to indoor light illuminance and thermal

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Abstract. This paper reported a research of facade greenery impacts to indoor light and thermal using two models. The first was without greenery as base case, and the other was with climbing ivy plants as greenery facade. Besides the indoor light illuminance, the air temperature and relative humidity (RH) were measured for thermal data. The experiments were done for west orientation, on dry season in March to April 2018 and for south orientation, on dry season on 14 to 22 November 2018. The result for west orientation, the facade with vegetation reduced more (31.18 to 51.71) % sunlight compared to facade without vegetation. The highest reduction was on 4.30 pm to 6.00 pm. For south orientation, the facade with vegetation reduced more (28.4 to 54.87) % sunlight compared to facade without vegetation. The highest reduction was on 05.15 am in the morning and 4.30 pm to 5.00 pm in the afternoon. Meanwhile, the indoor thermal impact was insignificant, reduction for air temperature only (0.5 to 1) °C, and only 1 % reduction for the RH. For greenery facades, vegetation impacts to light were determined by its orientation, depth and surface area it covered, while for thermal impact, the bigger LAI was the better.

Keywords: Light impact, thermal impact, vertical greenery.

1. Introduction

In tropical climate region, besides bringing natural aesthetics to indoor environment, building facade has an important role as filter from outdoor climate components such as, excessive sun radiation and irradiation, high air temperature, and high relative humidity. Based on Surabaya Government [1, 2], Surabaya, Indonesia as a city in tropical climate usually has warm air temperature with high relative humidity. The sky condition is usually clear and tends to partly cloudy on dry season and cloudy on rainy days. The dry season is usually from April to October, while the rainy season is from October to April. From statistics center bureau [1] data of Surabaya in 2016, the average air temperature was ranging from 27.8 °C to 30.5 °C, average RH was 68 % to 84 %, average air velocity 3.5 m s⁻¹ to 3.65 m s⁻¹.

Being declared as a green city and winning the Global Green City award in 2017 from Global Forum in Human Settlements [3], in Surabaya building with vegetation enclosed its facades now emerged. There are some of public buildings in Surabaya with vegetation such as the Esa Sampoerna building, Pasar Wonokromo and Joyoboyo terminal. Thus, it brings a further idea on its impacts to indoor light and thermal.





Figure 1. Building with vegetation on its facade.

2. Theoretical review

Vegetation has been widely used as building facade in the tropical region. Many researches on greenery facade in warm humid climate have been done and have brought positive results to save energy for indoor cooling, reduce air velocity and air pollution; hence, its contribution to indoor illuminance and visual comfort has not been researched widely.

Kellert *et al.* [4] stated that “plants are fundamental to human existence as sources for food, fiber, fodder, and other aspects of sustenance and security. The mere insertion of plants into the built environment can enhance comfort, satisfaction, well-being and performance. Buildings with vegetative facades, as ivy walls or green roofs often provoke interest and satisfaction”. Grabowiecki *et al.* [5] have investigated greenery in building envelope to energy balance. By modelling on TRNSYS for based model climbing foliage on facade of European shopping malls, they found different techno-economical effectiveness of climbing foliage on facade, when climatic constrains varied. The result and validation confirmed the remarkable impact of climbing plant foliage onto facade during summer time.

Jaafar *et al.* [6] found that vertical greenery system created a climate in an intermediate space which characterized lower temperature and higher humidity; so that it significantly contributed to energy reduction. Coma *et al.* [7], by planting greenery on green wall and green facades, showed a high potential for energy savings during cooling season for green wall (58.9 %) and double-skin green facade (33.8 %) in comparison to the reference system. On the other hand, for heating periods no extra energy consumption was observed for evergreen system. Another research from Hatifah *et al.* [8] on vegetation impact to air velocity got a lowest result from three different vegetation thicknesses, 0.21 m s^{-1} .

To represent the vegetation condition, this research used Leaf Area Index (LAI) that was defined as one half the total green leaf area per unit horizontal ground surface. It was an important structural property of vegetation. Because leaf surfaces are the primary border of energy and mass exchange, important processes such as canopy interception, evapotranspiration and gross photosynthesis are directly proportional to LAI [9]. This paper reported a preliminary research of facade greenery impacts to indoor illuminance and thermal.

3. Experimental equipments

The experiments were done by using two unit models $1 \text{ m} \times 1 \text{ m} \times 1 \text{ m}$ dimension. The first was without greenery as base case, and the other was with climbing ivy [10] plants as greenery facade. The devices to measure the indoor illuminance, air temperature, and relative humidity were hobo data logger U12-012 family and hobo pendant for outdoor measurement. The point of measurement was taken in the middle of the model.



Figure 2. Two unit models: with and without vegetation.

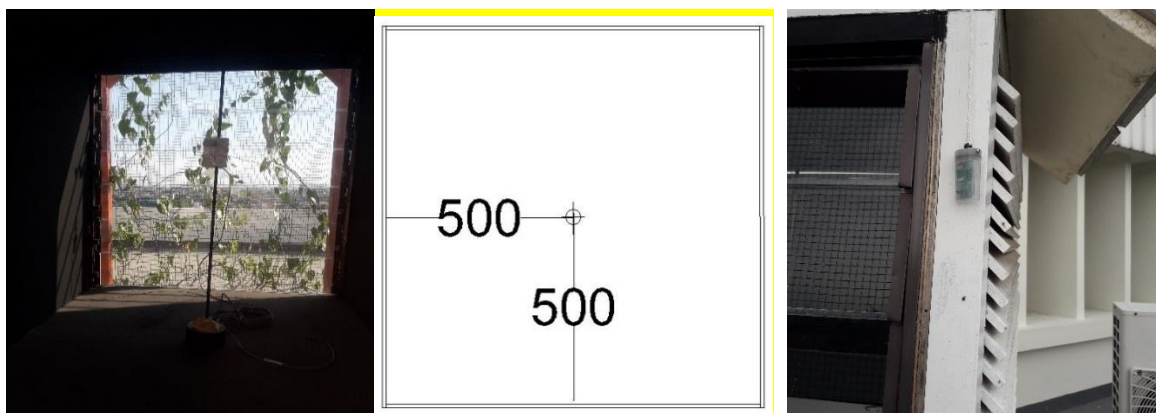


Figure 3. Inside the model hobo data logger indoor, point of measurement, hobo pendant outdoor.

The experiments were done two times following the sunpath of Surabaya which was located on 07' 21' SL and 112' 36'' to 112' 54'' EL; the first was for west orientation on dry season on 24 March to 2 April 2018, and the second was for south orientation, measured on dry season on 14 to 22 November 2018. The west orientation was taken because its solar radiation intensity was high throughout the year. Whereas, south orientation taken because on November, the sun was moving to south hemisphere [11].

4. Result and analysis

4.1. Dry season periode, west orientation

On 24 March to 2 April 2018, the vegetation was just blooming, with leaves width 6 cm to 8 cm and the average depth 20 cm. However, only one third of its foliage, almost 40 cm high, enclosed the facade. The vegetation LAI was 1.2.



Figure 4. Climbing ivy seen from the front and from the side in March to April 2018.

4.1.1. Indoor light condition. From the measurement, sunlight outdoor illuminance was ranging from 10.8 lx to 143 289 lx. The base case was ranging from 3.9 lx to 32 280 lx; while the greenery facade illuminance was ranging from 3.9 lx to 24 412 lx. Being shown that condition with vegetation compared to condition without vegetation, the vegetation gave reduction on illuminance ranging from 31.18 % to 51.71 % at 2 pm to 6 pm. The highest daylight reduction was at 4.30 pm to 6 pm. This meant it was effective to reduce excessive brightness from low altitude of west sunlight penetration. The average illuminance reduction of condition with vegetation compared to condition without vegetation from 24 March to 2 April 2018 was 27.51 %.

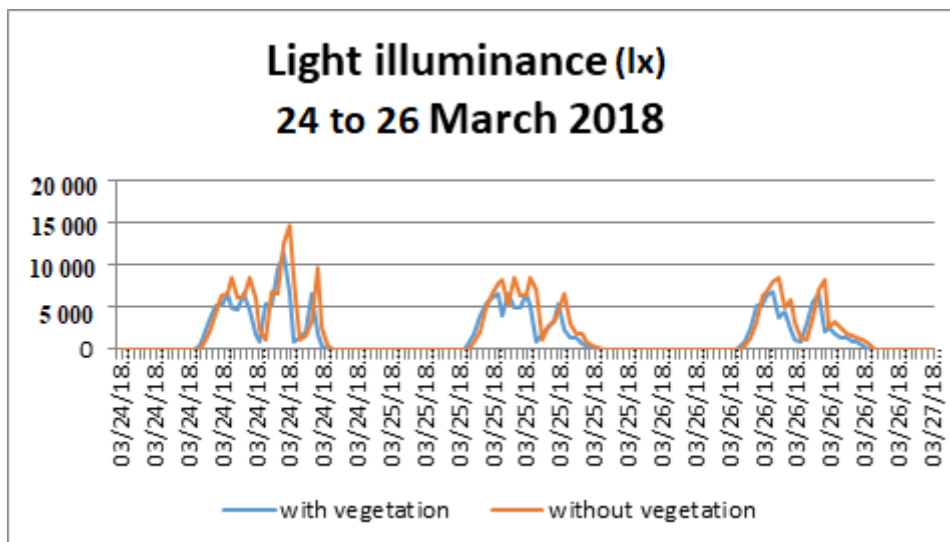


Figure 5. Light illuminance with and without vegetation on 24 to 26 March 2018.

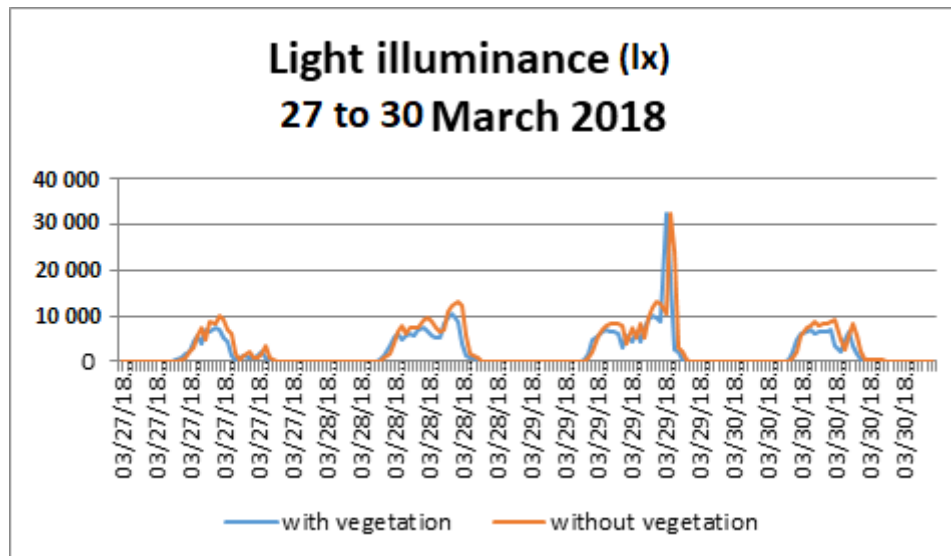


Figure 6. Light illuminance with and without vegetation on 27 to 30 March 2018.

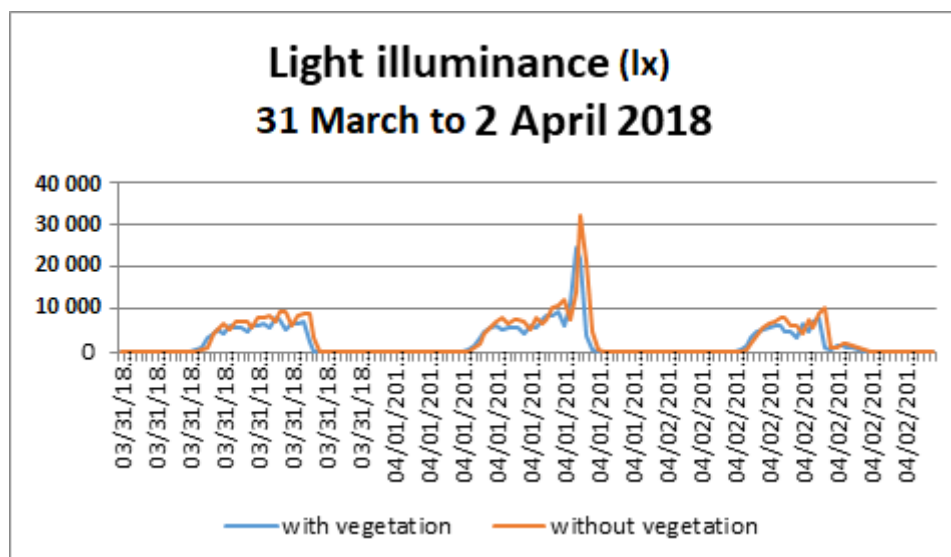


Figure 7. Light illuminance with and without vegetation on 31 March to 2 April 2018.

4.1.2. *Indoor thermal condition (Air temperature & RH%).* From figure 8 to figure 9, temperature base case was ranging from 24.2 °C to 49.9 °C, and temperature with greenery was ranging from 24.2 °C to 48.6 °C, RH base case was ranging from 28.1 % to 90.4 % , and RH with greenery was ranging from 30.7 % to 88.9 %. The temperature indoor with vegetation was averagely higher than without vegetation at 06.00 am to 12.30 pm. After that, at 12.30 pm to 18.30 pm, the condition with vegetation was on average 1 °C lower than the condition without vegetation. After that time, the temperature of both conditions were found to be similar.

The graphic showed that the RH % was highest at night until early morning, 70 % to 90 %. At night until 1 pm, the RH of the condition with vegetation was lower averagely 1 % than condition without vegetation. Contrary, from 1 pm to 9 pm the RH % was lowest, 30 %. The condition with vegetation was averagely higher 1 % than condition without vegetation. From 9 pm until late at night, the RH % of both condition tended to be the same.

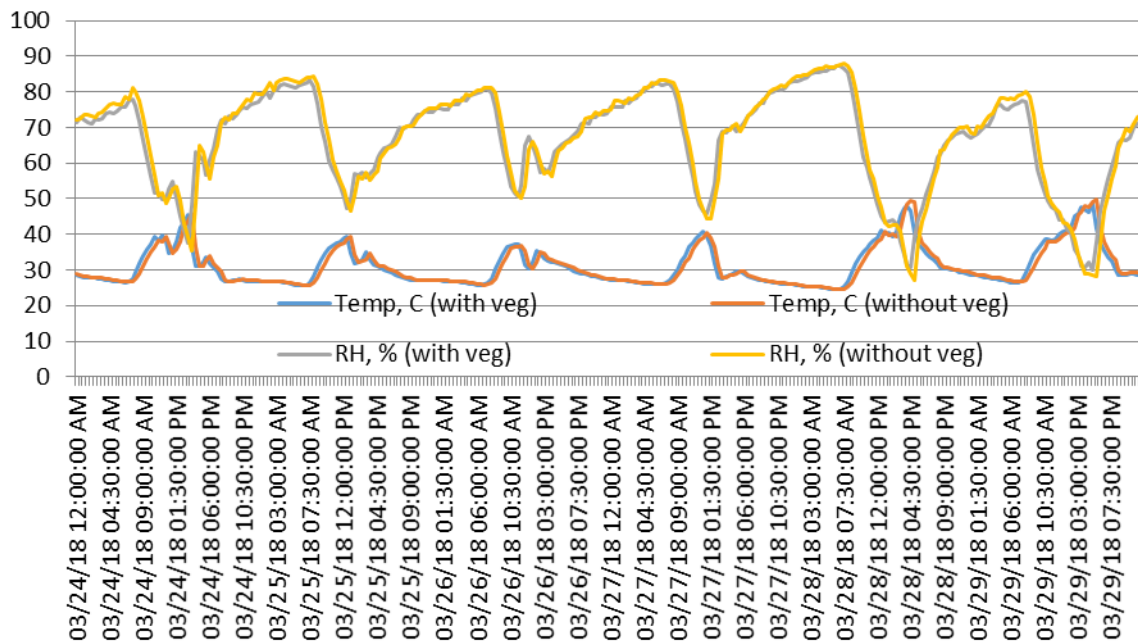


Figure 8. Indoor temperature and RH %, with and without vegetation on 24 to 29 March 2018.

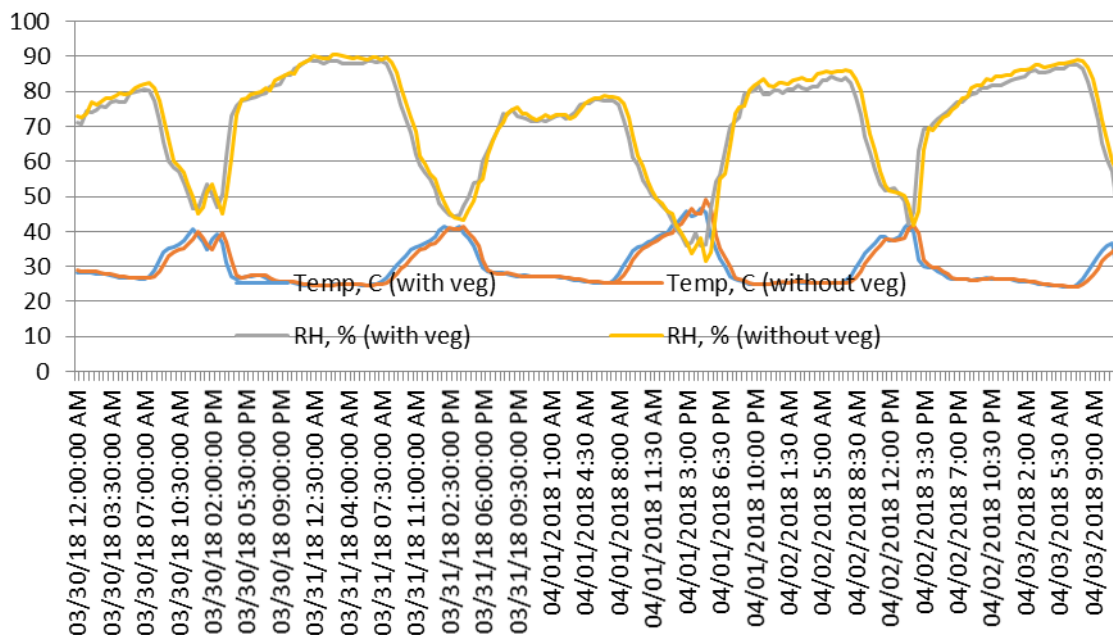


Figure 9. Indoor temperature and RH %, with and without vegetation on 30 March to 2 April 2018.

4.2 Dry Season Periode, South Orientation

On 14 to 22 November 2018, the vegetation was grown spreadly enclosed the facade, with leaves width 4 cm to 6 cm and the depth 5 cm to 15 cm; the vegetation was less fertile than the former. Its LAI was 0.54.



Figure 10. Climbing ivy seen from the front and from the side in November 2018.

4.2.1 *Indoor light condition.* From figure 11 to figure 13, sunlight outdoor illuminance was ranging from 10.8 lx to 154 312 lx. The base case was ranging from 11.8 lx to 23 292 lx; while the greenery facade illuminance was ranging from 11.8 lx to 17 805 lx. Being shown that reduction of condition with vegetation compared to condition without vegetation, the vegetation gave reduction on illuminance ranging from 28.4 % to 54.87 %. The highest daylight reduction was at 5.00 am to 5.15 am before sunrise and 4.30 pm to 5.15 pm before sunset. It made sense since south was the facade orientation. The average illuminance reduction of condition with vegetation compared to condition without vegetation from 14 to 22 November 2018 was 26.27 %.

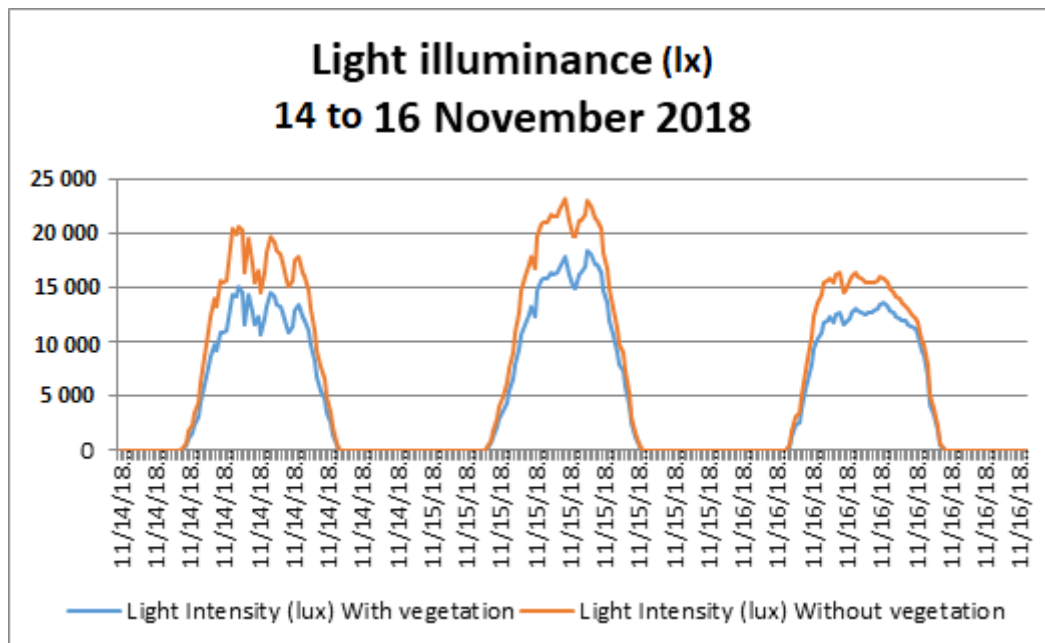


Figure 11. Light illuminance with and without vegetation on 14 to 16 November 2018.

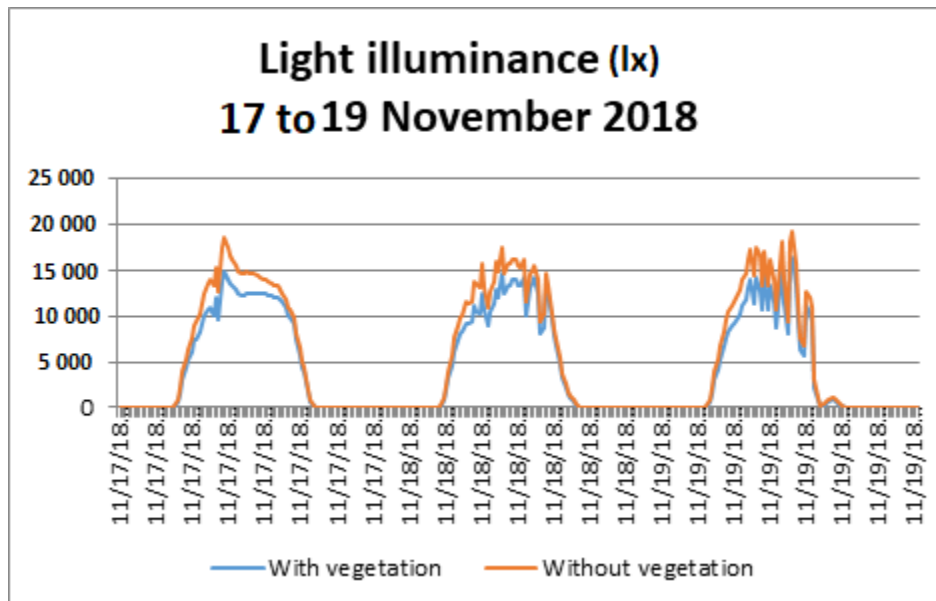


Figure 12. Light illuminance with and without vegetation on 17 to 19 November 2018.

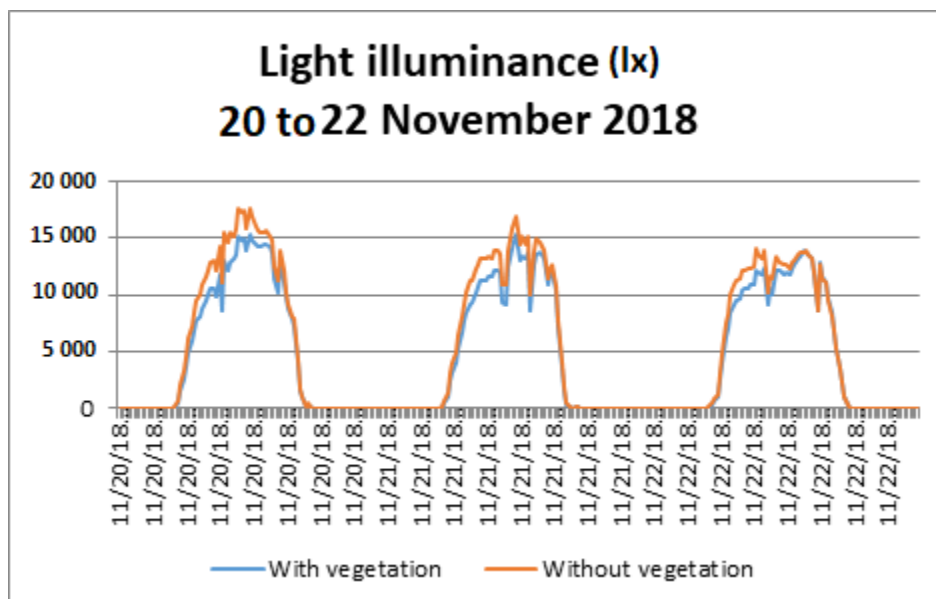


Figure 13. Light illuminance with and without vegetation on 20 to 22 November 2018.

4.2.2 Indoor thermal condition (air temperature and RH)

Figure 14 to 15 showed the temperature for base case ranges from 26.5 °C to 47.9 °C, while temperature with greenery ranges from 26.7 °C to 47.3 °C. Meanwhile, the RH values for base case ranges from 30.2 % to 79.7 %, and the RH values with greenery ranging from 33.1 % to 79.4 %. From the measurement, it was found that for south orientation on dry season, the vegetation did not give any significant impact to the indoor temperature even though it results in higher relative humidity than without vegetation condition due to its evapotranspiration process.

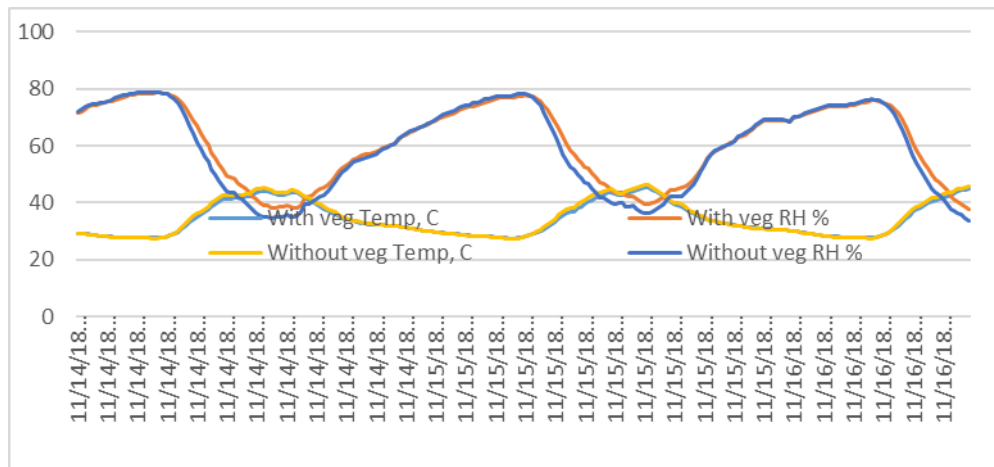


Figure 14. Indoor thermal condition (air temperature and RH %) on 14 to 16 November 2018.

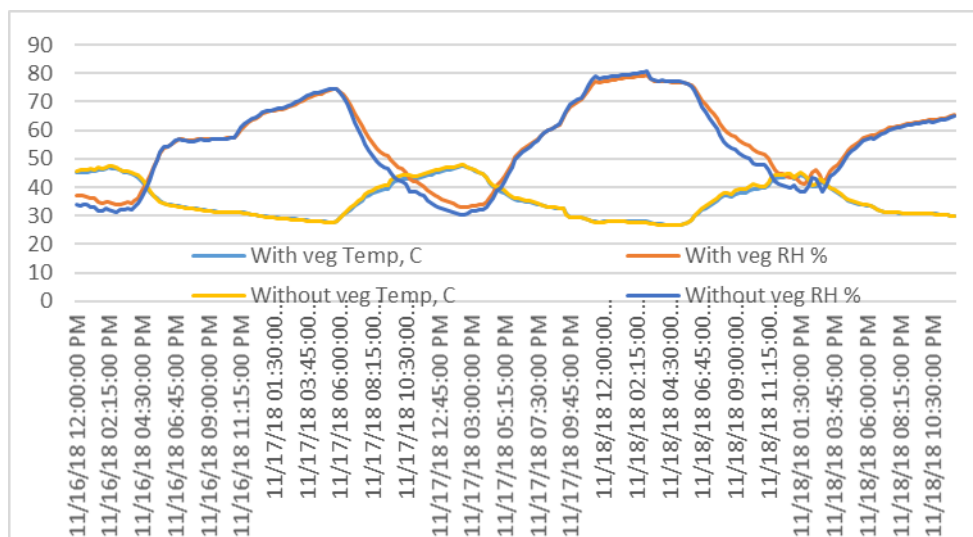


Figure 15. Indoor thermal condition (air temperature and RH %) on 16 to 18 November 2018.

5. Conclusion

For greenery facades, vegetation impacts on daylight intensity are determined by its orientation, depth and surface area it covered, while for thermal impact, the denser or the bigger LAI gives the better impact. In this research, it is found that the vegetation condition on second measurement, even though less fertile and only limited in depth, brought relatively high sunlight reduction to indoor illuminance. Even, it was very effective to reduce excessive sunlight since it grew toward the sunlight. However, for thermal impact, the vegetation condition of first measurement which was denser brought to better impact.

This research also conclude that vegetation impacts to light are far bigger than its thermal impact. Surely better maintenance will bring more effective result. This very simple research will later be developed to the real building facade in order to get more objective result regarding energy balance for cooling versus lighting the building in the tropics, besides improving visual-aural comfort, health and productivity for building user as well.

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