American Journal of Environmental Sciences 10 (3): 210-218, 2014
ISSN: 1553-345X

doi:10.3844/ajessp.2014.210.218 Published Online 10 (3) 2014 (http://www.thescipub.com/ajes.toc)

HEAT INTENSITY OF URBAN BUILT ENVIRONMENT IN HOT HUMID CLIMATE REGION

Beta Paramita and Hiroatsu Fukuda

The University of Kitakyushu, 1-1 Hibikino, Wakamatsu-ku Kitakyushu 808-0135 Japan

Received 2014-03-23; Revised 2014-04-01; Accepted 2014-04-16

ABSTRACT

Large numbers of inhabitants in a dense area require land coverage for sheltering purposes. The anthropogenic heat emission potentially reduces ventilation of urban areas and significantly brings changes in air temperature. This study is aimed at finding the correlations between urban form and the alteration of urban microclimate in different land-uses. This study has been carried out in Bandung, Indonesia, in its educational, high dense settlement and industrial areas, covering around 37 ha each. The measurement of air Temperature (Ta), globe Temperature (Tg) and wind speed (Va) describes mean radiant Temperature (Tmrt), which gives direct impact on the quality of outdoor spaces in urbanized areas. 3D modeling based on a Sketch-up and introducing Chronolux, as a simple model has given a description of the Sky View Factor (SVF) in urban form. Urban form that is presented by building coverage is giving significant impact to Tmrt as shown in high-dense settlement with R = 0.82. Tmrt and SVF at all study areas show positive correlations, eventhough not insignificant values where at educational area R = 0.029; meanwhile at high-dense settlement R = 0.2 and finally at industrial area R = 0.28.

Keywords: Urban Microclimate, Heat Intensity, Urban Land-Use, Sky View Factor, Hot Humid Climate

INTRODUCTION

Bandung is the third largest metropolitan city in Indonesia. Paramita (2011) has shown that as the capital city of West Java Province, the increasing urbanization has caused several problems, especially the demographical and environmental ones such as over dense settlement in illegal land and inappropriate sanitation and infrastructure. Increasing population density gives significant impact to land coverage, like the increase in surface roughness, which in turn reduces ventilation of urban areas and significantly causes higher air temperature.

Recent studies on the relationships between urban geometry and outdoor thermal in a hot humid region context include: Land-use and heat island phenomenon by (Goh and Chang, 1999; Tursilowati, 2005; Jusuf *et al*., 2007) and air quality studies by (Emmanuel and Johansson, 2006). Meanwhile, studies about mean radiant thermal that corresponds with the levels of outdoor thermal comfort perceptions have been done by (Johansson and Emmanuel, 2006; Kakon *et al*., 2010; Tan *et al*., 2013). These studies indicate that researches in the hot humid climate region of the urban geometry and outdoor thermal comfort as well as the urban heat island have not been widely done if compared with those in the other climate regions.

With total area of 16,730 m^2, Bandung's physical built environment dominates the land use functions; those are: 55% for settlement, 15% for industry and 5% for public facilities. Tursilowati (2005) has shown that land-use and coverage in Bandung have increased as the implication of population growth and significantly impact into changes of air temperature, humidity index and evapotranspiration, which thus yield higher surface temperature. An assessment study on five flats in Bandung (Paramita, 2011) also found that the more value of Height/Width ratio the more surface area, which implies to heat gain and directly gives impact to mean radiant temperature.

Corresponding Author: Beta Paramita, The University of Kitakyushu, 1-1 Hibikino, Wakamatsu-Ku Kitakyushu 808-0135, Japan

On the other hand, that urban geometry is an important control on heat island intensity is not new. In his study, Oke (1988) has mentioned about previous study on the heat island intensity, such as: Howard (1833; Lauscher, 1934; Parry and Walker, 1966), furthermore he has stated that warm side of building potentially influence the air temperature as the effect of the increase cold 'sky' proportion as well as a raising of Height/Width ratio.

Most of the study of heat island intensity is in mid-latitude cities in Australia, Europe and North America as mentioned by Goh and Chang (1999), he has stated that sky view factor, aerodynamics and roughness length as the result of urban canyon geometry may exert its influence on the radiation budget, air budget (advection) and the humidity-water budget of the heat island development. Thus, it is necessary to consider urban land use as the main factor in increasing the surface roughness, which in turn contributes to mean radiant temperature with sky view factor controlling heat intensity of urban built environment, especially in hot humid climate region.

2. OBJECTIVE AND METHODOLOGY

The objective of this study is to give statistical correlations between mean radiant Temperature (Tmrt) and Sky View Factor (SVF) from three different land- uses in Bandung, which are: Educational area, high-dense settlement and industrial areas. Microclimate data were obtained, such as: Air Temperature (Ta), globe Temperature (Tg) and wind speed (Va) taken with the mobile method for three different weathers (sunny, rainy and cloudy) in the hottest season between August and September. Six spot samples of each area were taken with different urban geometry characteristics. Simple 3D modelling was built with sketch-up to visualize urban form then to calculate the sky view factor by Chronolux.

3. LITERATURE

3.1. Urban Form

Urban form, including building morphology and its configuration, creates specific microclimate. The density of buildings then becomes the matter of gaining urban thermal by keeping the heat on their surroundings, such as the ground open space, the roof and the wall.

Recent studies about heat transfer have recorded that building wall keeps the heat from the solar radiation during the daytime much longer than the roof and the ground area (Krüger *et al*., 2011; Alhaddad and Jun, 2013; Ketterer and Matzarakis, 2014). This means building surface area becomes an important factor to determine heat loss and gain in the sense that the larger the surface area the more the heat is trapped and it significantly rises the mean radiant Temperature (Tmrt). Hence, building density plays an important role firstly by shaping the urban form and its urban geometry such as Floor Area Ratio (FAR), Building Coverage (BC), H/W ratio and space between them are giving direct influence to incoming and outgoing radiation also wind speeds that become the main thermal properties of urban surface as mentioned by Oke (1988).

3.2. Sky View Factor (SVF)

Previous studies have been done to characterize urban canyon geometry by knowing its sky view factor (ψ_s). Oke (1988) has defined that simple canyon as an H/W ratio can be related to sky view factor directly. Furthermore, he mentions that radiation geometry for a first approximation of street is infinitely long and pointed at the center of the floor of the canyon cross-section. The view factor of each wall (ψ_w)can be described as Equation 1:

$$\psi w = \left(1\text{-}\cos\theta\right)/2 \text{ where } \theta = \tan^{-1}\left(H/0.5W\right)$$

Therefore the sky view factor is:

$$\psi_s = \left(1\text{-}\left(\psi_{w1} + \psi_{w2}\right)\right) \quad (1)$$

Similar calculation can be conducted for any point on the canyon floor or walls, which each of the surface area has its own radiation geometry. Various methods have then been developed to measure sky view factor, especially using softwares to facilitate rapid measurement. Hämmerle *et al*. (2011) have compared the sky view factor models of calculation used for urban climate investigations, such as: Sky Helios by Matzarakis and Mastuschek (2011); SOLWEIG by Lindberg *et al*. (2008) and the ArcView SVF-Extension by Gál *et al*. (2009). Recently, modern 3D model provides an opportunity to describe the complex of urban surface and the principle of radiation geometry explained above brings the ability to calculate SVF.

This study introduces Chronolux, an extension for Sketch Up for insolation duration and SVF tests. Using 3D based model of urban form, Chronolux describes sky view factor at the specified points by calculating the insolation duration and graphical representation (Bannov, 2013). The principle of surface radiation has been developed by Chronolux which performs approximate calculation of SVF and it has the following measurement: Approximation of a hemisphere with a center at a test point, then algorithm calculates the total area of approximated hemisphere by summing up areas of all hemisphere's faces which are designated as a visible part and finally it estimates sky view factor by dividing total area of the visible part with total hemisphere's area (in percentage) as shown in **Fig. 1**.

3.3. Urban Microclimate

A microclimate is a local atmospheric zone where the climate differs from the surrounding area. As mentioned above, some researches have reported that urban form gives significant impact to urban microclimates, especially in air circulation and temperature distribution. Here in this study, variables of microclimate are focused on globe temperature, air temperature, humidity and wind speed to calculate mean radiant Temperature (Tmrt). The Tmrt is defined as the 'uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure' (ASHRAE, 2001). During sunny weather in summer, this Tmrt is the most important meteorological input parameter for the human energy balance (Herrmann and Matzarakis, 2011). The value of Tmrt derived from all relevant radiant fluxes, it is also can be calculated its short-wave and long-wave radiation flux. Globe temperature then become the essential part as a represents of the weighted average of radiant and ambient temperature. Therefore, based on ASHRAE (2001) Tmrt can be calculated by knowing its globe temperature and air temperature also wind speed according to:

$$\text{Tmrt} = \left[(\text{tg}+273.15)^4 + \frac{1.1\text{x}10^8\text{Va}^{0.6}}{\text{D}^{0.4}} \text{x} (\text{tg-ta}) \right]^{0.25} - 273.15 \quad (2)$$

Where:

Tmrt = Mean radiant temperature (°C)
Tg = Globe temperature (°C)
V = Wind speed (m/s)
Ta = Air temperature (°C)
D = Diameter of globe
E = The emissivity of the human body. According to Krichhoff's laws ε is equal to the absorption coefficient for long-wave radiation (standard value = 0.97)

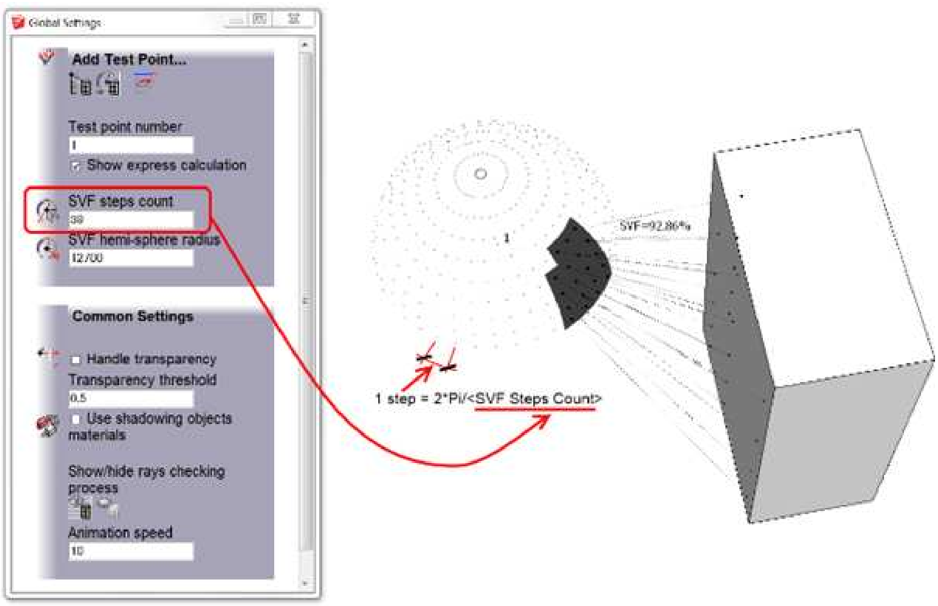

Fig. 1. SVF calculation step

4. STUDY AREA

Geographic location of Bandung is at 6.54°S and 107.36°E, 706.29 m (2,317.22 ft) above sea level. This city is cooler than most other Indonesian cities since its, average temperature of 24.72°C (76.5°F) throughout the year. This geographical location give an influence for microclimate, especially for the down-town which located in Bandung Basin, meanwhile in the northern and southern part are surrounded by mountain and hills. High humidity that noted as more than 70% average in everyday with maximum of 90% where the wind speed is on average lower than 3 m s^{-1}. Thus, it is classified as tropical monsoon "Am" by (Lippsmeier, 1997; BMKG Bandung, 2013). The study areas are as follow.

4.1. Universitas Pendidikan Indonesia (UPI)

UPI has been chosen since it has the largest land area among universities in Bandung. It occupies around 61 ha, while other universities' areas are around 25 ha or less (BPSB, 2013). For this research, the land area is bordered in 37 ha. As shown in **Fig. 2**, the study case map, UPI is located in northern Bandung with the highest altitude compared to other case studies, that is 920.587 m.

4.2. Tamansari, a High-Dense Settlement

Tamansari is one of subdivisions/*kelurahan* in West Bandung Sub-district/*kecamatan*. This study area is 35.7 ha and located on an altitude of 729.153 m. Based on a previous study, this *kelurahan* is one of the high dense settlements in Bandung. This area is part of the downtown of Bandung with the worst slum neighborhood. Its building density is above 80 units/ha, while the population density is above 500 people/ha and the BC is more than 70% (Paramita and Koerniawan, 2013; Paramita and Fukuda, 2013).

4.3. Cigondewah, an Industrial Area

Southern part of Bandung is dominated by industrial areas and the biggest one is located in Cigondewah Kaler Sub-district. The study area is 36.7 ha and located on an elevation of 684.15 m. Unlike the other study areas, this site is in a suburb of Bandung and part of this area contains paddy field. The building density is less than 50 units/ha and much vacant land is still there.

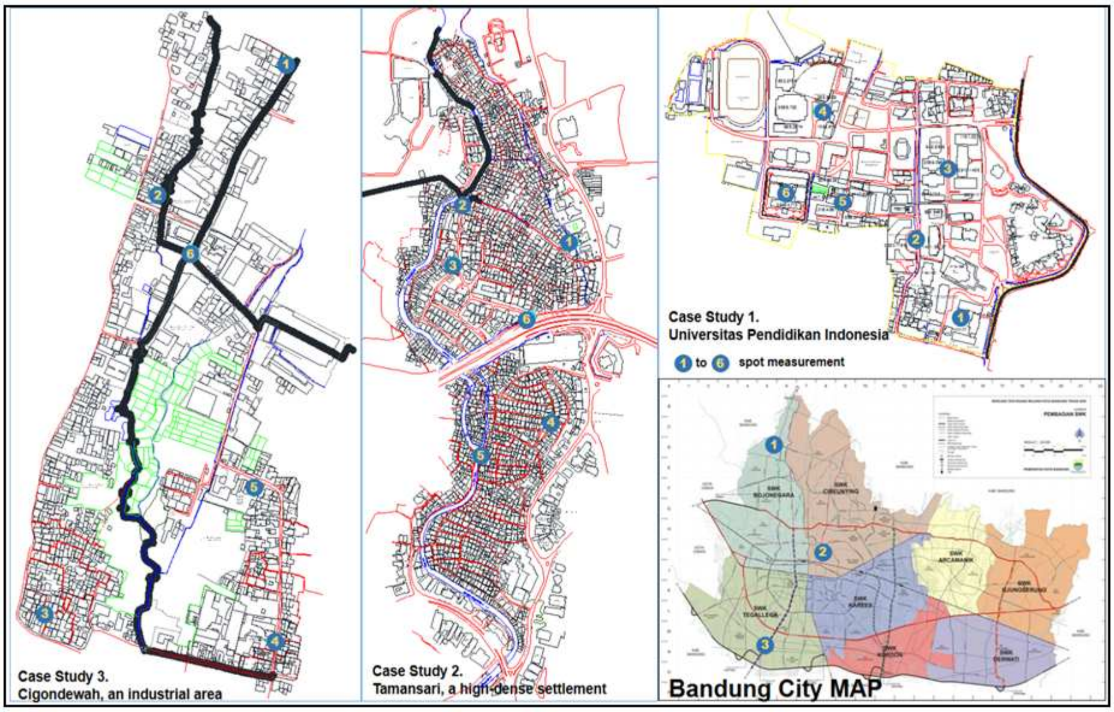

Fig. 2. Case study

5. FINDINGS AND DISCUSSION

5.1. Field Measurement of Urban Microclimate

Previous researches regarding Bandung's heat phenomenon (Tursilowati, 2005; Wonorahardjo, 2012) and data set of Bandung's meteorology (BMKG Bandung, 2013) have shown the trend of increasing average temperature for the past 25 years as shown at **Fig. 3**.

Again, a field measurement during the hot season from July 31, 2013 until September 10, 2013 was done on four different spots, i.e., North Bandung, East Bandung, South Bandung and West Bandung **Fig. 4** shows diurnal temperatures on hottest day.

This field measurement shows that the temperature reached its maximum at 4 pm on 28.7°C and minimum at 07.00 am on 18.5°C for North Bandung; for East Bandung maximum at 11am on 28.1°C and minimum on 24.5°C at 04.00 am; for South Bandung maximum at 11 am on 28°C and minimum at 6 am on 24.3°C; and for West Bandung maximum at 4 pm on 30.7°C and minimum at 6 am 24.3°C. Meanwhile, BMKG Bandung's data shows maximum temperature at 1pm on 27.1°C and minimum temperature at 6 am on 15.6°C.

BMKG Bandung's weather station has recorded Central Bandung for its longest diurnal temperature range between Tmax and Tmin, i.e., 11.5°C. It is followed by North Bandung with 10.2°C, West Bandung with 6.4°C, South Bandung with 3.7°C and finally East Bandung with 3.6°C. These results are in line with Tursilowati (2005), which has found that the land-use and coverage within Central Bandung and West Bandung are rapidly changing which in turn significantly rises the diurnal temperature.

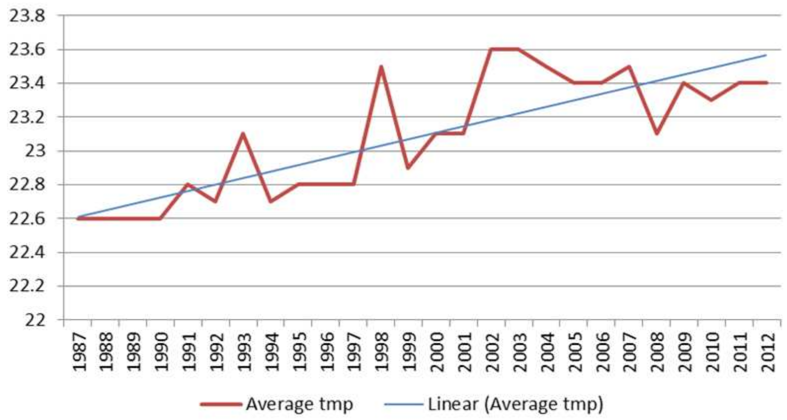

Fig. 3. Average temperatures of Bandung 1987-2012

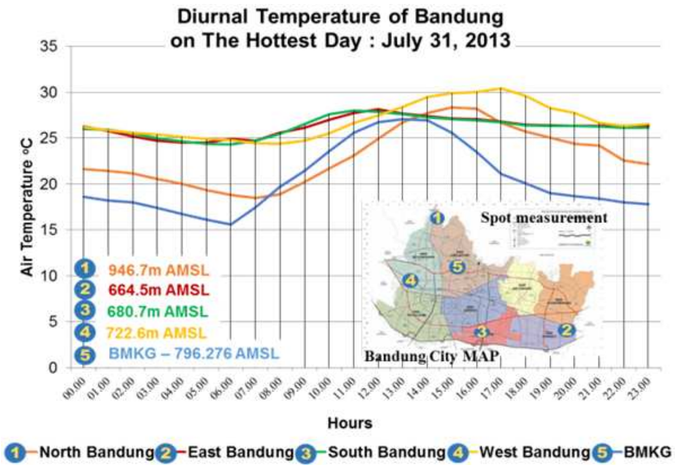

Fig. 4. Diurnal temperatures of bandung on the hottest day

5.1.1. Mean Radiant Temperature

Further investigation on urban microclimate was conducted at the study areas in six spots, the results of which are shown in **Fig. 5**. Globe temperature was measured using a 38 mm table tennis ball which was adjusted into Thermo Recorder RT-13 (Espec mic Corp). The tennis ball's method has been tested and shown to be effective in outdoor conditions (Thorsson *et al*., 2007). Additional tool of LM-8000 Lutron was used to measure air temperature, humidity and wind speed.

Measurement results for all study areas show positive relationship between air and globe temperatures. **Figure 6** presents the highest Tmrt for three different land-uses, which is reached on sunny day for educational area and high-density settlement and on the contrary, on rainy day for industrial area. It means that radiation caused by direct solar illumination is still the main impact to gain heat in outdoor urban built-environment. Meanwhile, in industrial area where much vacant land is still available, the Tmrt is lower than that in other areas.

The highest Tmrt in educational area was reached on 62.1°C at 11am for sunny day; 57.3°C at 12 am for cloudy day and 61.4°C at 12 am for rainy day. Meanwhile, in the study case of high-density settlement, it was on 56.47°C at 12 pm for sunny day; 60.3°C at 11.00 am for cloudy day and 52.2°C at 1 pm for rainy day. The last is in industrial area, where the highest Tmrt was reached on 51.18°C at 10 am for sunny day; 51.89°C at 12 pm for cloudy day and 55.77°C at 12.00 pm for rainy day.

5.2. Urban Ebuilt Environment and Microclimate

5.2.1. Universitas Pendidikan Indonesia (UPI)

Based on the field measurement results shown in **Fig. 6**, Tmrt in educational area shows the highest rate compared with those of the two other study areas. Although located at more than 200 m (AMSL) higher than the other two study areas and also has a lower average temperature, it does not reduce the outdoor microclimate since it has higher H/W and wide space between building as shown at **Fig. 6**. The land coverage in this university is mostly asphalt, followed by concrete and then some green open space. It indicates that radiation in local area is more important than the regional condition. This heat intensity is explained by the correlation of urban form and microclimate at UPI.

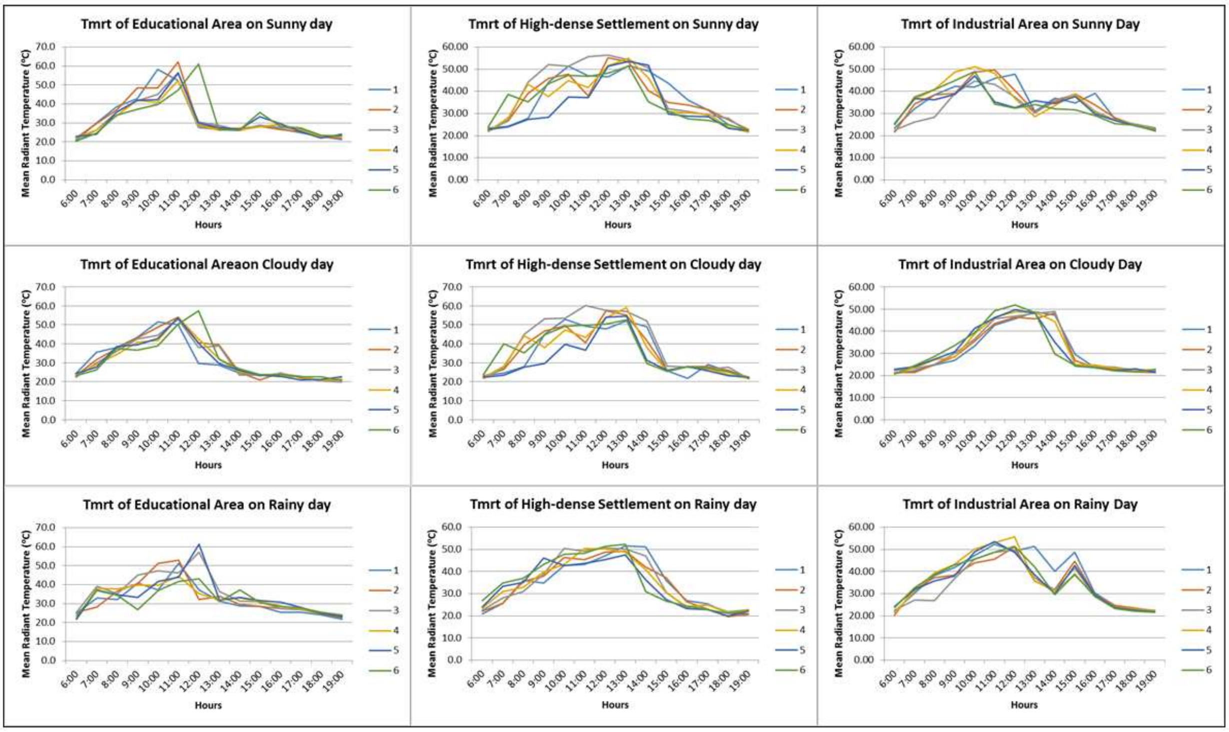

Fig. 5. Mean radiant temperature for three different weather at study areas

Fig. 6. Urban Form and Sky View Factor of UPI-Educational area by Chronolux

Table 1. Urban form parameter and microclimate of UPI

Point	Tmrt (°C)	SVF (%)	BC (%)	FAR	H/W
1	58.31	0.60	0.75	1.500	1.80
2	62.07	0.67	0.70	1.400	0.96
3	57.16	0.41	0.70	1.400	1.38
4	52.39	0.79	0.66	0.990	1.00
5	61.39	0.75	0.55	0.550	2.60
6	57.28	0.32	0.57	1.425	1.50

Table 2. Urban form and microclimate correlation at UPI

	Tmrt	SVF	BC	FAR	H/W
Tmrt	1.000				
Svf	0.029	1.000			
BC	-0.107	0.048	1.000		
Far	-0.070	-0.641	0.644	1.000	
H/W	0.424	0.100	-0.495	-0.581	1.000

As shown in **Table 1 and 2**, Tmrt has positive correlation with H/W, although not a strong correlation. The points of measurements were in the location without shadowing since the buildings distribution and the roughness of the open space significantly impact to the heat intensity of outdoor thermal. Tmrt does not show significant correlation with SVF, while insignificant values are also there for SVF to both BC and H/W. Meanwhile, BC has strong correlation with FAR. Finally, it can be said that the most significant parameter giving the heat intensity in UPI is H/W with the value of R = 0.42.

5.2.2. Tamansari

From **Table 3 and 4** show that Tmrt has strong correlation with BC where its R = 0.82. This is the implication of the building density that is over 100 units/ha. As a high dense settlement, this area has practically no open space or green area (**Fig. 7**). This over building density is giving positive correlations between Tmrt to SVF and FAR.

Table 3. Built environment and microclimate of tamansari

Point	Tmrt (°C)	SVF (%)	BC (%)	FAR	H/W
1	53.00	0.30	0.42	0.84	1.58
2	57.29	0.37	0.64	1.93	1.34
3	60.30	0.68	0.71	0.71	1.56
4	59.15	0.36	0.49	1.24	1.88
5	54.48	0.27	0.39	0.98	1.59
6	52.66	0.67	0.38	0.97	1.89

Table 4. Built environment and microclimate correlation in tamansari

	Tmrt	SVF	BC	FAR	H/W
Tmrt	1.000				
SVF	0.200	1.000			
BC	0.824	0.340	1.000		
FAR	0.172	-0.336	0.270	1.000	
H/W	-0.162	0.293	-0.552	-0.422	1.000

5.2.3. Cigondewah

The field measurement of air and globe temperatures at Cigondewah shows that this area has the lowest temperatures compared with those of the other two cases, which impact into the mean radiant temperature (**Table 5**). As shown in **Table 6**, Tmrt only has positive correlation with SVF. Tmrt does not have any correlation with other urban parameters such as BC, FAR and H/W because of its suburb characteristics.

Roughness, caused by land coverage such as loamy soil and muddy land, gives a benefit to reduce heat intensity. **Figure 8** shows this study area with less numbers of buildings and provides more wind speed and wide penetration that lower the mean radiant temperature. Here, SVF shows positive correlations with BC, FAR and H/W. With these urban characteristics, eventually, the heat intensity in Cigondewah is influenced solely by SVF.

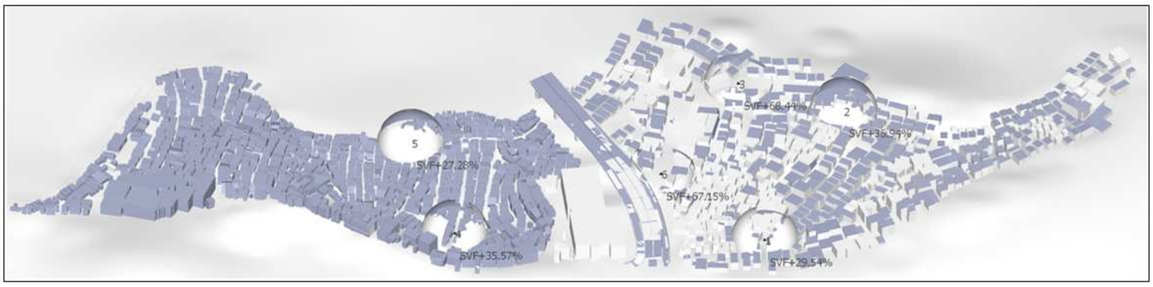

Fig. 7. Urban form and sky view factor of tamansari, a high-dense settlement

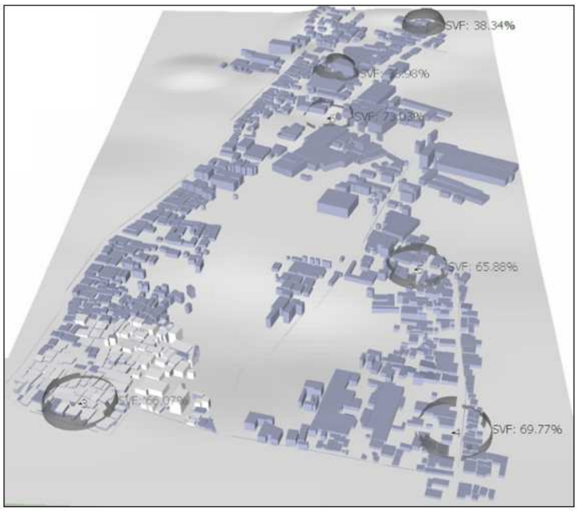

Fig. 8. Urban form and SVF of Cigondewah

Table 5. Built environment and microclimate of cigondewah

Point	Tmrt (°C)	SVF (%)	BC (%)	FAR	H/W
1	52.38	0.383	0.27	1.35	0.58
2	51.18	0.340	0.33	1.65	0.52
3	49.71	0.660	0.36	2.18	0.79
4	55.77	0.700	0.29	1.47	0.43
5	53.48	0.660	0.35	1.42	1.11
6	51.89	0.730	0.37	1.85	0.69

Table 6. Built environment and microclimate correlation in cigondewah

	Tmrt	SVF	BC	FAR	H/W
Tmrt	1.000				
SVF	0.280	1.000			
BC	-0.510	0.495	1.000		
FAR	-0.727	0.340	0.703	1.000	
H/W	-0.191	0.351	0.581	0.095	1.000

6. CONCLUSION

Three different characteristics of urban form show that heat intensity in each site is controlled by roughness of the surface area and also its insolation.

The most important conclusion is that BC and urban open space, which create greenery, are potential to manipulate the sun and the wind to improve the microclimate surrounding the buildings.

Further studies with various spots needs to be carried out to find the significance of urban form parameter into urban microclimate. It is also important to know the influence of micro-variations of the immediate environments, since temperature can be affected by adjective effects from the wider environment

7. ACKNOWLEDGEMENT

Researchers would like to thanks to Sustainable Use of Water (SUW) of The University of Kitakyushu to support the research and to Directorate General of Higher Education (DGHE) Indonesia Minister of Education for the scholarship, also to Indonesia University of Indonesia (UPI) where the first author work.

8. REFERENCES

Alhaddad, M.A. and Z.T. Jun, 2013. A comparative study of the thermal comfort of different building materials in Sana'a. Am. J. Eng. Applied Sci., 6: 20- 23. DOI: 10.3844/ajeassp.2013.20.24

ASHRAE, 2001. ASHRAE Fundamentals Handbook 2001. American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Bannov, K., 2013. LSS chronolux. LSS Chronolux 2013. Manual and Help System. BMKG Bandung, 2013. Bandung climate dataset-badan meteorologi klimatologi dan geofisika stasiun geofisika kelas I.

BPS Bandung, 2013. Bandung city in figure. Badan Pusat Statistik Bandung. pp: 358.

Emmanuel, R. and E. Johansson, 2006. Influence of urban morphology and sea breeze on hot humid microclimate: The case of colombo, Sri Lanka. Climate Res., 30: 189-200. DOI: 10.3354/cr030189

Gál, T., F. Lindberg and J. Unger, 2009. Computing continuous sky view factors using 3D urban raster and vector databases: Comparison and application to urban climate. Int. J. Climatol., 95: 111-123 DOI: 10.1007/s00704-007-0362-9

Goh, K.C. and C.H. Chang, 1999. The relationship between height to width ratios and the heat island intensity at 22:00 h for Singapore. Int. J. Climatol., 19: 1011-1023. DOI: 10.1002/(SICI)1097-0088(199907)19:9<1011::AID-JOC411>3.0.CO;2-U

Hämmerle, M., T. Gál, J. Unger and A. Matzarakis, 2011. Comparison of models calculating the sky view factor used for urban climate investigations. Theor Applied Climatol., 105: 521-527. DOI: 10.1007/s00704-011-0402-3

Herrmann, J. and A. Matzarakis, 2011. Mean radiant temperature in idealised urban canyons--examples from freiburg, Germany. Int. J. Biometeorol., 56: 199-203. DOI: 10.1007/s00484-010-0394-1

Howard, L., 1833. The Climate of London: Deduced from Meteorological Observations Made in the Metropolis and at Various Places Around it. 1st Edn., Harvey and Darton.

Johansson, E. and R. Emmanuel, 2006. The influence of urban design on outdoor thermal comfort in the hot, humid city of Colombo, Sri Lanka. Int. J. Biometeorol., 51: 119-133. DOI: 10.1007/s00484-006-0047-6

Jusuf, S.K., N.H. Wong, E. Hagen, R. Anggoro and Y. Hong, 2007. The influence of land use on the urban Heat Island in Singapore. Habitat Int., 31: 232-242. DOI: 10.1016/j.habitatint.2007.02.006

Kakon, A.N., M. Nobuo, S. Kojima and T. Yoko, 2010. Assessment of thermal comfort in respect to building height in a high-density city in the tropics. Am. J. Eng. Applied Sci.. 3: 545-551. DOI: 10.3844/ajeassp.2010.545.551

Ketterer, C. and A. Matzarakis, 2014. Human-biometeorological assessment of the urban heat island in a city with complex topography-The case of Stuttgart, Germany. Urban Climate. DOI: 10.1016/j.uclim.2014.01.003

Krüger, E.L., F.O. Minella and F. Rasia, 2011. Impact of urban geometry on outdoor thermal comfort and air quality from field measurements in Curitiba, Brazil. Build. Environ., 46: 621-634. DOI: 10.1016/j.buildenv.2010.09.006

Lindberg, F., B. Holmer and S. Thorsson, 2008. SOLWEIG1.0--Modelling spatial variations of 3D radiant fluxes and mean radiant temperature in complex urban settings. Int. J. Biometeorol., 52: 697-713. DOI: 10.1007/s00484-008-0162-7

Lippsmeier, G., 1994. Bangunan Tropis. 1st Edn., Erlangga, Jakarta, ISBN: 33000333, pp: 201.

Matzarakis, A. and O. Mastuschek, 2011. Sky view factor as a parameter in applied climatology-Rapid estimation by the skyhelios model. Meteorol. Zeitschrift, 20: 39-45. DOI: 10.1127/0941-2948/2011/0499

Oke, T.R., 1988. Street design and urban canopy layer climate. Energy Build., 11: 103-113. DOI: 10.1016/0378-7788(88)90026-6

Paramita, B. and H. Fukuda, 2013. Building groups design strategies in hot-humid climate: A dense residential planning in bandung, Indonesia. in PLEA 29th Conferene Sustainable Architecture for a Renewable Future, Sept. 10-12, Munich, Germany.

Paramita, B. and M.D. Koerniawan, 2013. Solar envelope assessment in tropical region building case study: Vertical settlement in bandung, Indonesia. Proc. Environ. Sci., 17: 757-766. DOI: 10.1016/j.proenv.2013.02.093

Paramita, B., 2011. Shapping Urban Spatial Structure. In: Sekiguchi Global Research Asosiasion 42. Tokyo.

Tan, C.L., N.H. Wong and S.K. Jusuf, 2013. Outdoor mean radiant temperature estimation in the tropical urban environment. Build. Environ., 64: 118-129. DOI: 10.1016/j.buildenv.2013.03.012

Thorsson, S., F. Lindberg, I. Eliasson and B. Holmer, 2007. Different methods for estimating the mean radiant temperature in an outdoor urban setting. Int. J. Climatol., 27: 1983-1993. DOI: 10.1002/joc.1537

Tursilowati, L., 2005. Pulau panas perkotaan akibat perubahan tata guna dan penutup lahan di bandung dan bogor. Sains Dirgantara, 3: 43-64

Wonorahardjo, S., 2012. New concepts in districts planning, based on Heat Island investigation. Proc. Social Behav. Sci. DOI: 10.1016/j.sbspro.2012.03.026