International Journal of GEOMATE, April, 2020, Vol.18, Issue 68, pp. 233-240
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.68.ICGeo33
Special Issue on Science, Engineering and Environment

THE IMPACT OF GREENING THE NARROW ALLEYS OF DENSELY POPULATED SETTLEMENTS ON THE REDUCTION OF URBAN HEAT IN JAKARTA

Hayuning Anggrahita[1,4], Maria Hedwig Dewi Susilowati[1], Guswandi[2,4,*], and Semiarto Aji Purwanto[3,4]

[1] Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, [2] Faculty of Economics and Business, Universitas Sultan Ageng Tirtayasa, [3] Department of Anthropology, Faculty of Social and Political Sciences, Universitas Indonesia, [4] Abdurrahman Wahid Center for Peace and Humanities, Universitas Indonesia

*Corresponding Author, Received: 17 Oct. 2019, Revised: 27 Nov. 2019, Accepted: 28 Jan. 2020

ABSTRACT: Urbanization and industrialization have led physical changes in urban spaces. These changes cause environmental degradation such as urban heat. It stimulates negative impacts to human living condition including in densely populated settlements characterized by small yards, even no yard, and small alleys. Inhabitants of these settlements respond the urban heat by greening their neighborhoods, supported by the technical and financial assistants of the Government of Jakarta, namely "Green Narrow Alley / Gang Hijau". Based on the issues above, this research aims to measure the impacts of green narrow alleys on the reduction of air temperature and relative humidity. We study five Jakarta's municipalities: North Jakarta, West Jakarta, Center Jakarta, East Jakarta, and South Jakarta. In each municipality, we chose four green narrow alleys and measure their temperature and humidity. Meanwhile, we chose four non-green narrow alleys as the green narrow alley's counterparts and measure those indicators in order to make comparison. Our findings are that firstly, the temperature of the green narrow alleys is lower than that of their counterparts. Secondly, the relative humidity of green narrow alleys is higher than those counterparts. Thus, the greening activities in densely populated settlements reduce the negative impacts of urban heat.

Keywords: Urban greening, Green Infrastructure, Urban Agriculture, Urban Heat Island, Community Greening

1. INTRODUCTION

Urbanization and industrialization have led physical changes in urban spaces. This condition generates the air temperature of urban areas slightly higher than the surrounding rural areas. It creates urban heat island (herein after abbreviated UHI), indicating that there is a temperature difference between urban and its surrounding rural. There are three important factors that influence the UHI, including: urban materials of built-up areas (such as asphalt, concrete, and metal) [1], anthropogenic activities [2,3], surface albedo [4,5], urban geometry (canyons and layouts) [6]. Furthermore, climate change at global level could exacerbate urban air temperature that is already hotter than its surrounding area.

Increasing temperature in urban areas can affect inhabitants' health, especially regarding 'heat stress', which is related to physical maladies such as hyperthermia and even the most fatal: death [7,8], and psychological discomfort problems [9]. However, in these human-environment relations, human have always possibilities to overcome difficulties towards changing nature, even, when they are determined almost totally by the nature. Thus, these difficulties can be considered as a pressuring stimulus for human to change and re-adapt. It is necessity to create new human intervention to overcome current and future increases in temperatures in urban areas. One direct human intervention to cool urban areas is to "green" them, essentially by increasing the density and the cover of vegetation [10,11]. The effect of urban vegetation differs with that of non-green urban materials such as black asphalt and/or Portland-cemented concrete [12].

Previous studies show that green intervention take many forms such as the creation of urban parks, tree planting on roadside including between street and sidewalk, the creation of green parking, the creation of green roofs, and tree planting on riverside [11,13,14,15]. Most of those green infrastructures employ top-down approach and, on other hand, do not much involve local community initiatives, who, is in fact, touched directly by the negative impact of UHI. Those types of urban greening are generally initiated by government (both national and local) or private sector such as in luxurious residential areas and in commercial centers. However, on green roof, local community and local individual can be on the hearth of green intervention. Besides green roof, there is lack of researches on greening infrastructures initiated by local initiatives, and supported by external actors

such as government or private sector. With more local participation, green intervention is potential to create "new" urban greening type(s) linked to specific local settlements and local need. It is also potential to enlarge and to distribute spatially the green intervention into the corner of the cities and towns. There is also lack of researches on greening types situated in dense informal settlements in the cities of the South countries, especially Jakarta.

Jakarta, as metropolitan city, has experienced urbanization and industrialization due to rapid population growth, since the era of post-Independence. It has made the capital of having less than 200 000 inhabitants in 1950 to almost 10 million in the municipality of Jakarta (DKI Jakarta) in 2010. This phenomenon has led great physical changes in Jakarta especially from non-built up area to built-up area, where in 30 years (from 1970 to 2000), approximately 70 % of non-built up areas has been converted to built-up areas [16].

Built-up areas are humanly-made structures that change natural processes in big city like Jakarta. These areas consist of urban materials, such as asphalt and concrete, which quickly absorb and retain heat when exposed to solar radiation [12]. Therefore, the air temperature of Jakarta is higher than the surrounding rural areas. Consequently, Jakarta experiences UHI [17].

In order to overcome negative impact of UHI in Jakarta, urban greening has been carried out by local initiatives in dense informal settlements in the city. These dense informal settlements are called of Jakarta's Kampungs (or often abbreviated as the Kampungs). The Kampungs vary in the condition of their built structures and their history, dated from the colonial states, where the inhabitants have lived for generations, to our days under current post-colonial state, where the inhabitants are the first generation of poor urban migrants living on very dense settlements [18]. However, there are the similarities. The Kampungs are characterized by small yards, even no yard, and narrow alleys. Inside the Kampungs, there are narrow passages between, in front of, or behind houses that can only be access by walking and riding motorcycle. Bigger vehicles such as car and mini truck cannot enter the narrow alleys. Moreover, the Government of Jakarta (here in after abbreviated GoJ) through Food Security, Marine and Agriculture Office/ Dinas Ketahanan Pangan, Kelautan dan Pertanian (here in after abbreviated DKPKP) has also realized the problem of Jakarta's UHI so that the DKPKP has supported those initiatives by providing technical and (a part of) financial assistances since 2016 under the "Green Narrow Alley Program" (*Program Gang Hijau*). These local initiatives aim to green their neighborhood especially their narrow alleys, under main constraint: limited spaces. In the case of Jakarta, urban materials such as asphalt and cemented concrete are generally used for street construction including Kampung's narrow alleys. Moreover, there are other urban materials for the construction of the roof and wall of houses such as asbestos, bricks, and metals. These materials quickly lose their attached water during the process of evaporation. Moreover, they are easily heated by sun light.

The inhabitants of Kampungs plant various crops. They are vegetables such as Pokcoy (*Brassical Rapa L*) and Kangkung Air (*Ipomoea Aquatica Forsk*); seasoning plants (*bumbu dapur*) such as Chili, Pandanus and Galangal; and medicinal plants such as *Kunyit* (Turmeric) and *Jahe* (Ginger). Urban agriculture can be in line with urban greening when similarities between green spaces and urban agriculture identified as ways to create more green spaces in urban areas especially in developing country [19]. When the GoJ, through Urban Garden and Urban Forest Office / Dinas Pertamanan dan Hutan Kota (here in after abbreviated DPHK), has faced difficulties to provide new green spaces such as urban parks and squares, Kampung's inhabitants initiate a "local green infrastructure" to provide ecosystem services for themselves by doing urban agriculture as well as greening their neighborhood. Thus, food production function still exists and integrates with other functions. It is multiple functions of urban agriculture. After looking at people initiatives, the DKPKP, not the DPHK, have supported the development of greening communities because the inhabitants do urban agriculture and produce foods, even though they are not professional farmers. They do not do "conventional" greening activities such as creating and maintaining of urban parks and squares because those activities are directly managed by the DPHK

Based on the issues above, this research aims to measure the impacts of green narrow alleys as a green infrastructure on air temperature and relative humidity

2. METHODOLOGY

There are some ways to measure urban air temperatures. Some previous researches employed remote sensing, by acquiring the reflection of electromagnetic wave from the canopy, to make the estimation of earth surface temperature and the index cover of vegetation. Moreover, mathematical expression and simulations are also used to forecast on the imminent coverage effects of urban vegetation on the reduction of its climates [20,21]. However, in this paper, we employ different method. Empirical quantitative method is used. We measure directly urban temperature by

collecting their data on the ground using the Lutron LM-8000A Type K of "Digital Instrument™" (Fig. 1).

Fig.1 Tools Used for Temperature and Relative Humidity Measurement

Previous studies show that green intervention take many forms such as the making of urban parks, green roofs, tree planting on the roadside including between street and sidewalk, and green parking lots [11,13]. However, in this paper, we chose green narrow alleys in Jakarta as one of green intervention. We measure air temperature in the green narrow alleys, representing a particular greening type, rather than the cover of vegetation in order to calculate the effects of green narrow alleys as a green type rather than green cover for itself.

Furthermore, we collect air temperature within green narrow alleys, representing green sites, and non-green narrow alleys, representing non-green sites, within the intra urban area of Jakarta, the capital of Indonesia and a major tropical metropolitan of South countries. We use non-green narrow alleys as a control because they are need for comparing a green narrow alley chosen as a sample with its opposite reference.

We use purposive sampling technique to choose the samples of green narrow alleys and non-green narrow alleys pairs. We study five Jakarta's municipalities: North Jakarta, West Jakarta, Center Jakarta, East Jakarta, and South Jakarta. In each municipality, we chose four green narrow alley locations and measure their temperature and relative humidity in a day. Two locations are measured in the morning and before noon. The two latter are measured in the afternoon and before sunset. We measure air temperature and relative humidity in the day (with sun light), rather than at the night (without sun light). In each pair of green narrow alley and non-green alley, we noted the temperature and relative humidity every five minutes, during one-hour interval. Fig. 2 shows the location measurement of 20 pairs of green narrow alley and non-green narrow alley. Moreover, Table 1 shows the time of measurement.

Table 1 Precise Time Measurement of Temperature and Relative Humidity in five municipalities of DKI Jakarta Province

Items	1st Location (Morning)	2nd Location (Before Noon)	3rd Location (After Noon)	4th Location (Before Sunset)
South Jakarta (Friday, 26th July 2019)	08.25 am	10.10 am	14.32 pm	16.15 pm
East Jakarta (Monday, 29th July 2019)	08.45 am	11.25 am	14.00 pm	16.15 pm
Central Jakarta (Wednesday, 31th July 2019)	09.10 am	11.30 am	14.10 pm	16.35 pm
West Jakarta (Thurs-day, 1st August 2019)	08.20 am	10.30 am	13.10 pm	14.50 pm
North Jakarta (Mon-day, 3rd August 2019)	08.15 am	10.50 am	14.10 pm	15.50 pm

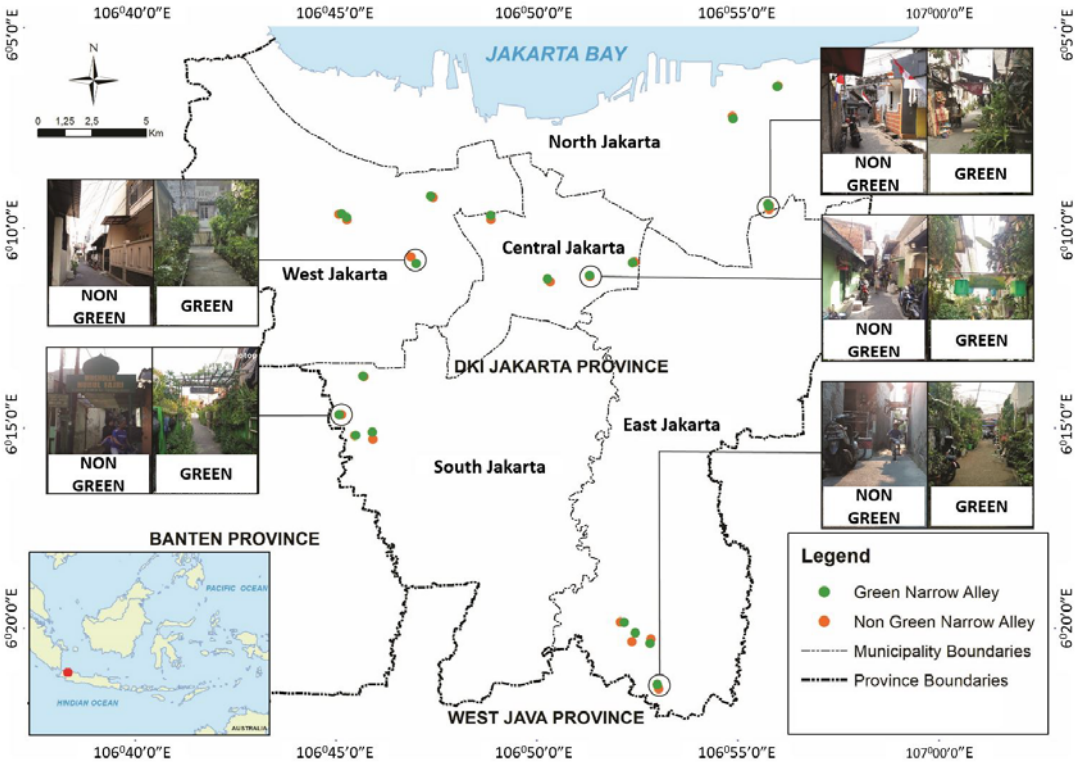

Fig.2 Location Measurement of Green Narrow Alley and Non-Green Narrow Alley

Finally, we analyze the differences of temperature as well as relative humidity between green narrow alleys and non-green narrow alleys. To be more rigorous, we construct formal hypothesis and test it statistically. We use Independent Sample T-Test, a test for differences between means of our two data groups, temperature and relative humidity in green narrow alleys and that in non-green narrow alleys, with small sample sizes: 20 samples per group [22]. We formulate our hypothesis as follow:

For temperature:

1. Null hypothesis (H_0): There is no difference temperature between green narrow alley and non-green narrow alley ($\mu_1 = \mu_2$)
2. Alternative hypothesis (H_1): There is difference temperature between green narrow alley and non-green narrow alley ($\mu_1 \neq \mu_2$)

For relative humidity (RH):

1. Null hypothesis (H_0): There is no difference RH between green narrow alley and non-green narrow alley ($\mu_1 = \mu_2$)
2. Alternative hypothesis (H_1): There is difference RH between green narrow alley and non-green narrow alley ($\mu_1 \neq \mu_2$)

We execute Independent Sample T-test with the help of software SPSS IBM Statistics 20, with level of significance (α) = 5 %. The decision to reject or retain H_0 is based on the comparison between *p-value* (Sig. 2-tailed) with level of significance (α). H_0 will be rejected if: *p-value* > α, whereas H_0 will be retained if: *p-value* < α.

3. RESULT AND DISCUSSION

Firstly, we provide descriptive analysis of air temperature and relative humidity in green narrow alleys and their controls in five municipalities. We provide five graphics representing each municipalities. In each graphic, we provide four 'column bar' representing 4 locations chosen in each municipalities.

In all municipalities of Jakarta, the temperature increase from morning to noon, and decrease from afternoon to before sunset because the change of the angel of sun light in the day (Fig. 3,4,5,6,7). Moreover, 19 of 20 locations, the temperature of green narrow alleys is lower than that of non green narrow alleys. However, there is an exception. Of 20 locations in Jakarta, only one location of South Jakarta 2 (Fig. 3), the temperature of green narrow alleys is slightly higher than that of non green narrow alleys.

Moreover, in all municipalities of Jakarta, relative humidity decreases from morning to noon, and increases from afternoon to before sunset (Fig. 8,9,10,11,12). 19 of 20 locations, the humidity of green narrow alleys is higher than that of non green narrow alleys. However, there is an exception. Of 20 locations in Jakarta, only one location of South Jakarta 2 (Fig. 8), the relative humidity of green narrow alleys is slightly lower than that of non green narrow alleys.

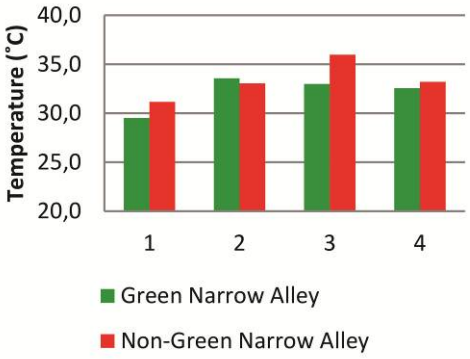

Fig.3 Air Temperature in South Jakarta

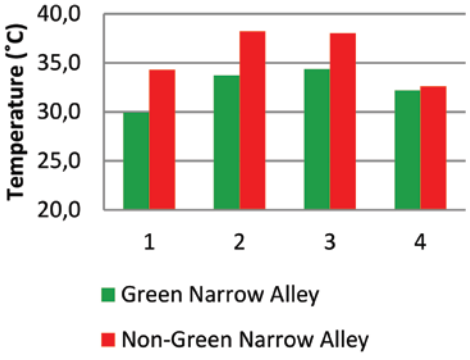

Fig.4 Air Temperature in East Jakarta

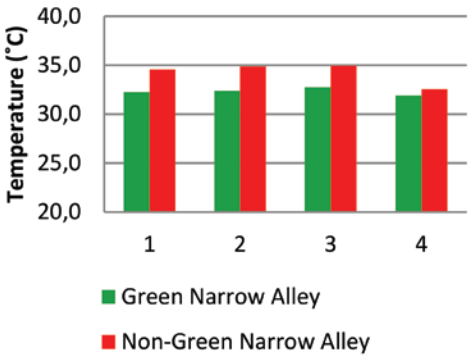

Fig.5 Air Temperature in Central Jakarta

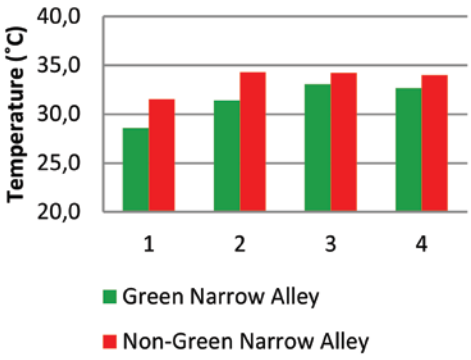

Fig.6 Air Temperature in West Jakarta

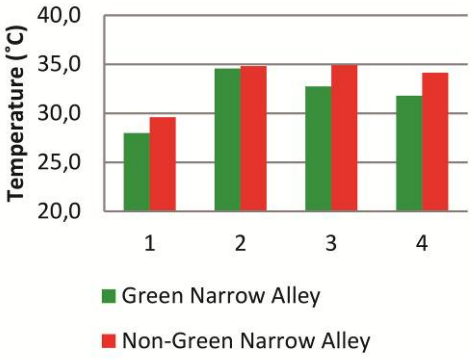

Fig.7 Air Temperature in North Jakarta

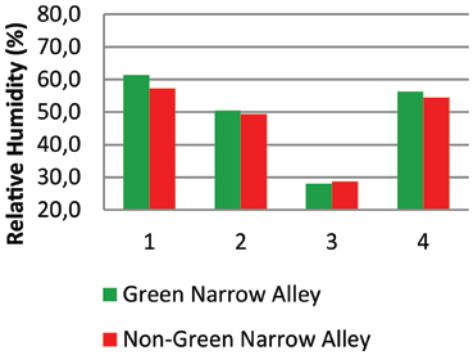

Fig.8 Relative Humidity in South Jakarta

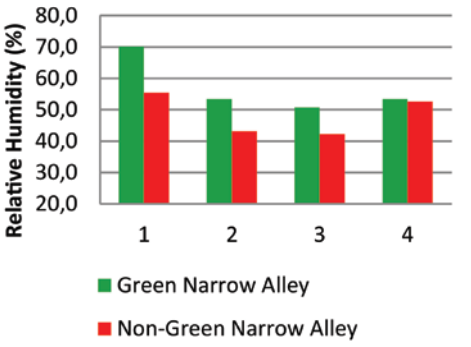

Fig.9 Relative Humidity in East Jakarta

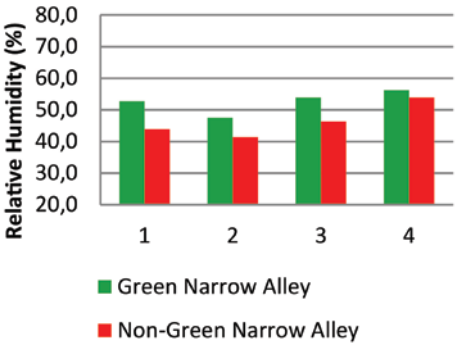

Fig.10 Relative Humidity in Central Jakarta

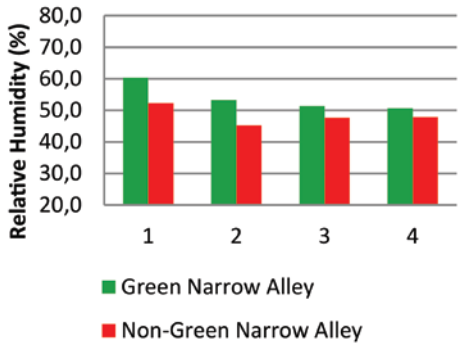

Fig.11 Relative Humidity in West Jakarta

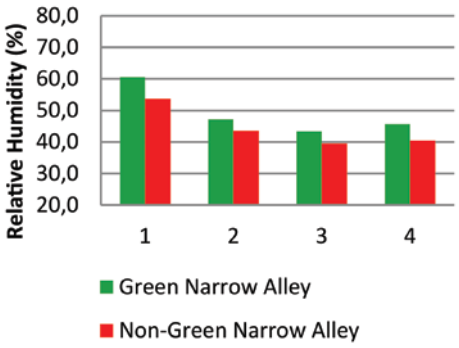

Fig.12 Relative Humidity in North Jakarta

Table 2 Mean Differences of Temperature between Green Alleys and Non-Green Alley

Group Statistics

Greenness		N	Mean	Std. Deviation	Std. Error Mean
temperature	green site	20	32.045	1.78251	.39858
	non green site	20	34.050	2.05772	.46012

Secondly, based on SPSS output of the independent sample t-test, we find that there is means differences of temperature between green narrow alleys (32.045°C) and non-green narrow alleys (34.05°C). It can be concluded that ΔT = 2.005°C, where temperature in green narrow alleys is lower than that of non-green narrow alleys (Table 2).

Moreover, Table 3 below shows that *p-value* (Sig. 2-tailed) = 0.002. This value is lower than level of significance (α) of 5 % (0.05). Therefore, H_0 can be rejected, because: *p-value* (0.002) < α (0.05). It can be concluded that the difference in temperature mean (ΔT = 2.005°C) between green narrow alleys and non-green alleys is significant at the 0.05 level.

Table 3 Independence Sample T-test of Temperature

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
tem pera ture	Equal variances assumed	.134	.717	-3.29	38	.002	-2.00500	.60875	-3.23735	-.77265
	Equal variances not assumed			-3.29	37.24	.002	-2.00500	.60875	-3.23818	-.77182

Moreover, we also find that there are mean differences of relative humidity (RH) between green narrow alley (52.365%) and non-green narrow alley (46.96%).

It can be concluded that ΔRH = 5.4%, where RH in green narrow alley is higher than that of non-green narrow alley (Table 4).

Table 4 Mean Differences of Relative Humidity between Green Alley and Non-Green Alley

Group Statistics

greenness		N	Mean	Std. Deviation	Std. Error Mean
relative humidity	green site	20	52.365	8.39638	1.87749
	non green site	20	46.960	6.95159	1.55442

Moreover, Table 5 below shows that *p-value* (Sig. 2-tailed) = 0.033. This value is lower than level of significance (α) of 5 % (0.005). Therefore, H_0 can be rejected, because: *p-value* (0.033) < α (0.05). It can be concluded that the difference in relative humidity mean (ΔRH = 5.4%) between green narrow alley and non-green alley is significant at the 0.05 level.

Table 5 Independence Sample T-test of Relative Humidity

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Relative humidity	Equal variances assumed	.004	.948	2.22	38	.033	5.41	2.43746	.47063	10.33937
	Equal variances not assumed			2.22	36.72	.033	5.41	2.43746	.46498	10.34502

4. CONCLUSION

This research finds that, on average, temperature in green narrow alleys is around 2 °C lower than non-green narrow alleys as the control sites. Meanwhile, relative humidity in green narrow alleys is around 5% higher than non-green narrow alleys. The lower the temperature, the higher the relative humidity. Thus, greening activities in narrow urban alleys in Kampungs, dense informal settlements, reduce the negative impacts of city's urban heat island with tropical-rainforest climate. Nonetheless, findings are fully based on the ground observation of existing green narrow alleys as a green type/infrastructure, and based on 20 samples, which can be categorized as small sample size. For those reasons, in the future, following research can be implemented with more sample size under more proper management of green narrow alleys program. This management is supposed to incorporate collecting the data of air temperature and relative humidity before and after the creation of green narrow alley as a new green infrastructure. As policy recommendation, Green Narrow Alleys is effective for reducing urban heat in densely populated settlement such as Kampung in Jakarta so that the GoJ should continue and improve Green Narrow Alley Program.

5. ACKNOWLEDGMENTS

We received the financial support for the research, authorship, and publication of this article by a PDUPT Grant (Number: NKB-1597/UN2.R3.1/HKP.05.00/2019) of the Ministry of Higher Education, Research, and Technology, the Republic of Indonesia. We thank very much to the ministry.

6. REFERENCES

[1] Golden J.S., Carison J., Kaloush K.E., Phelan P., A Comparative Study of the Thermal and Radiative Impact of Photovoltaic Canopies on Pavement Surfaces Temperatures, Sol. Energy, 2007, Vol. 81, pp. 872-883.

[2] Bonan G.B., Effects of Land Use on the Climate of the United States, Climate Change, 1997, Vol. 37, pp. 449-486.

[3] Palme M., Lobato A., Carrasco C., Quantitative Analysis of Factors Contributing to Urban Heat Islands Effect in Cities of Latin American Pacific Coast, Procedia Engineering, 2016, Vol. 169, pp. 199-206

[4] Taha H., Urban Climate and Heat Islands: Albedo, Evapotranspiration, and Anthropogenic Heat, Energ. Building, 1997, Vol. 25, pp. 99–103

[5] Archer K., The City the Basics, Routledge, 2013, pp. 1-219

[6] Sobstyl J. M., Emig T., Abdolhosseini-Qomi M. J., Ulm F.J., and Pellenq R. J.M., Role of City Texture in Urban Heat Islands at Nighttime, Phys. Rev. Lett., 2018, Vol. 120, Issue 10, pp. 108701-108707

[7] Stott P.A., Stone D. A., Allen M. R., Human Contribution to the European Heat-wave of 2003, Nature, 2004, Vol. 432, pp. 610–614

[8] Wong K.V., Paddon A., Jimenez A., Review of World Urban Heat Islands: Many Linked to Increased Mortality, J. Energy Resour. Technol, 2013, Vo. 135, Issue 2, pp. 022101-022112

[9] Lafortezza R., Carrus G., Sanesi G., Davies C., Benefits and well-being perceived *by* people visiting green spaces *in* periods of heat stress,

Urban Forestry & Urban Greening, 2009, Vol. 8, Issue 2, pp.97-108.

[10] Givoni, B., Impact of Planted areas on Urban Environmental Quality: A Review, Atmos. Environ., 1991, Vol. 25, pp.289–299.

[11] Gill S.E., Handley J.F., Ennos A.R., Pauleit S., Adapting cities for climate change: the role of the green infrastructure, Built. Environ., 2007, Vol. 30, No. 1, pp.115-133.

[12] Bowler D.E., Buyung-Ali L., Knight T.M., Pullin, A.S., Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence, Landscape and Urban Planning, 2010, Vol. 97, pp. 147-155

[13] Onishi A., Xin C., Takanori I., Feng S., and Hidefumi I., Evaluating the Potential for Urban Heat-Iisland Mitigation by Greening Parking Lots, Urban Forestry & Urban Greening, 2010, Vol. 9, pp.323-332.

[14] Al-Gretawee H., Rayburg S., and Neave M., The Cooling Effect of A Medium Sized Park on An Urban Park on Urban Environment, International Journal of GEOMATE, 2016, Vol. 11, Issue 26, pp. 2541-2546

[15] Nugroho D.A., Soemabrata J., Simarmata H.A., Marthanty D.R., Development of Green Infrastructures in Urban Catchment Area (Case Study: Tanjung Barat Sub-District, South Jakarta), International Journal of GEOMATE, 2019, Vol.17, Issue 59, pp.121-126.

[16] World Bank, Jakarta: Urban Challenges in Changing Climate. Mayors' Task Force on Climate Change, Disaster Risks, and the Urban Poor, World Bank, 2011, pp. 1-45.

[17] Lestari S., Sarwanto S., Moersidik, Syamsudin F., Study on Heat Island Effect Induced by Land Use Change Increased Temperature in Metropolitan Jakarta, Journal Mathematics and Fundamental Sciences, 2015, Vol. 47, No. 2, pp.126-142

[18] Leitner H., Sheppard E., From Kampungs to Condos? Contested accumulations through displacement in Jakarta, Environment and Planning A: Economy and Space, 2018, Vol. 50, Issue 2, pp. 437–456

[19] Contesse M., van Vliet B.J.M., Lenhart J., Is Urban Agriculture Urban Green Space? A Comparison of Policy Arrangements for Urban Green Space and Urban Agriculture in Santiago de Chile, Land Use Policy, 2018, Vol. 71, pp. 566–577

[20] Tiangco M., Lagmay A.M.F., Argete, J., ASTER-Based Study of the Night-Time Urban Heat Island Effect in Metro Manila, Int. J. Remote Sens, 2008, Vol. 29, Issue 10, pp. 2799-2818.

[21] Xue J. and Baofeng S., Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications, Journal of Sensors, 2017, pp. 1-17

[22] Hammond R. and McCullagh, P.S., Quantitative Techniques in Geography: An Introduction, Oxford University Press, 1978, pp. 1-364.