Evaluation of Thermal Comforts and Utilizations of Some Green Open Spaces in Cilegon City

A Nuraini¹ and T Budiarti²
¹ Student, Department of Landscape Architecture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Bogor, Indonesia
² Lecturer, Department of Landscape Architecture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Bogor, Indonesia

*Email: ¹ayustinnuraini@gmail.com; ²tatibudiarti2@gmail.com

Abstract. Green Open Space (GOS) in urban areas is significant for the community and plays a role in improving the comfort of microclimate. There is very limited public GOS in Cilegon City, so the local government continues to increase the number of public green areas in each sub-district. Evaluation of thermal comfort and the utilization by the public’s in GOS of Cilegon City was essential for improving the quality and developing the green area in the city. This research was carried out in the Jogging Track Krakatau Junction (JKJ), Taman Kota Layak Anak (TLA), and Taman Kecamatan Jombang (TKJ), from March until June 2019. The research used descriptive qualitative methods (visitors' perceptions and preferences) and quantitative methods (THI). The result showed that in JKJ, there were 50 species – 2462 trees which mostly have shaded function; in TLA, 14 species – 98 trees; and at TKJ, 39 species – 540 trees, both of those parks, the trees have shaded and aesthetic functions. JKJ is the best to reduce temperature; such as 2.4-3.7ºC, then the second was TLA that 1.2-2.9ºC; and TKJ 0.8-2.3ºC. The average Thermal Humidity Index (THI) at JKJ was 27.6; then TLA was 28.0; JKJ was 28.3. These values were not comfortable, but mostly the visitors came to the three GOS in the morning or the afternoon. Thus 67-73% of respondents said that three GOS were comfortable, and 6-7% very comfortable at JKJ and TLA. The result of utilization of GOS according to user's activities showed that JKJ was used for jogging/sports (55%), recreation (26%); TLA for recreation (47%), family gathering (38%); TKJ for recreation (67%). The others were used for playing with children, taking pictures, and shopping for a culinary delight. There were 60-73% of visitors expressed their satisfaction with the existence of GOS. Recommendation for improving GOS such as; 1) JKJ: Pruning the trees to reduce the humidity therefore THI is more comfortable; adding the ornamental plants in the welcome area, benches, trash cans, and planting food crops and vegetable crops at agricultural areas; 2) TLA and TKJ: Adding the shaded trees at children’s play areas and near the benches, some ornamental scrubs, and some benches.

Keywords: evaluation, green open space, thermal comfort, utilization

1. Introduction
Based on Regional Regulation No. 15 of 2002 [1], Cilegon City has an area of ± 17,550 ha, divided into eight districts, which have quite extensive industrial estates. Cilegon City is one of the most densely populated cities, with a total of 406,974 inhabitants in June 2018 [2]. The number of residents has increased every year, resulting in the needs of residents for the construction of dwellings, vehicles, and facilities. Increased urban development can lead to land conversion from green open spaces to built spaces, so that land for green open space (GOS) decreases. Green open space in urban areas is significant for the community and play a role in improving the comfort of the microclimate. Public green open spaces in Cilegon City are very limited in number. Limited green open space in urban areas can reduce the quality of the
urban environment, such as rising temperatures, air pollution, dust, and noise due to a factory and motor vehicle activities.

National law No. 26 of 2007 [3] on Spatial Planning states that the city government must have a green open space (GOS) of at least 30% of the city area consisting of 20% of public green space and 10% private green space to preserve the environment. The purpose of establishing green open space in urban areas, among others, is improving the quality of the urban environment as means of securing the urban environment and creating a harmony of the natural environment and the built environment that is useful for the interests of the community. The public green open space must be available in Cilegon City is 3,510 ha (20% of the total area of Cilegon City). The Department of Housing and Settlements of the Cilegon City stated that the area of green open space in Cilegon City as of July 2017 was 43,94 ha or only 1.25% of green space was fulfilled, consisting of city parks, sub-district parks, residential parks, and green lanes. The need for 20% of public green open space in 2017 in Cilegon City has still not been fulfilled.

The availability of green open space in urban areas is a necessity that must be met in order to improve the quality and comfort of the environment. The study sites are Taman Kota Layak Anak, Taman Kecamatan Jombang, and Jogging Track Krakatau Junction. The three green open spaces were chosen because they have diverse types of vegetation, strategic locations, and most frequently visited by the community. Viewed from its thermal comfort, the presence of green open space can reduce temperature, control humidity, and reduce dust, air pollution, and noise due to factory or vehicle activities. Evaluation of thermal comfort and utilization by the public in the green open spaces of Cilegon City is essential to improve quality and develop green areas in the city. The thermal comfort and utilization of each of the green open space were assessed in this study. If the THI (Thermal Humidity Index) value and utilization from some of the green open spaces are good, each green open spaces can be maintained and increased. However, if the THI value and utilizations are produced; otherwise, it is necessary to improve the green space following the standard green space criteria should be. This research will produce information about the thermal comfort and utilization of some green open spaces in Cilegon City, which can be recommendations for improving the green layout (structuring of plants) of some green open spaces in Cilegon City.

The objectives of this study are as follows:

1. evaluating the thermal comfort and utilizations of Jogging Track Krakatau Junction, Taman Kota Layak Anak, and Taman Kecamatan Jombang;
2. compiling recommendations for the improvement of plant arrangement in Jogging Track Krakatau Junction, Taman Kota Layak Anak, and Taman Kecamatan Jombang.

2. Methods

2.1 Research Location and Time

The study was conducted on three green open spaces of Cilegon City, including Jogging Track Krakatau Junction (JKJ), Taman Kota Layak Anak (TLA), and Taman Kecamatan Jombang (TKJ). The study took place from March to June 2019.
2.2 Research Methods

2.2.1 Preparation

The preparation are including making proposals, administrative preparations in the form of licensing to relevant agencies, secondary data collection, and preparation of research tools and materials.

2.2.2 Data collection

At this stage, the primary and secondary data were collected. Primary data obtained through direct observation and measurement on the site, photo-shoot, and interviews with a questionnaire guide to 90 respondents. Secondary data was obtained through searching data in related agencies and collecting literature and literature studies. Primary data obtained are temperature and humidity data as well as community perceptions and preferences.

The inventory stage was done by collecting primary and secondary data. Primary data were obtained from the results of the field survey by 1) measurement of air temperature, air humidity, and noise on the site, 3) interview using questionnaire guides to 90 respondents, 4) taking pictures as a supplementary appendix. Secondary data were obtained from the collection of literature and literature studies as well as interviews with related agencies.

2.2.3 Data Analysis

Thermal Comfort Analysis. Thermal comfort analysis is done by calculating the air temperature and humidity to get the value of the Thermal Humidity Index (THI) at each research location and through the respondent's perceptions. THI formula is, THI = 0.8T + (RHxT)/500 (Nieuwolt 1975).

Utilizations function, Visitors’ Perceptions and Preferences Analysis. Analysis of the utility function is done by concluding the results of the interviews with a questionnaire sets. Visitors' perceptions and preferences are obtained through questionnaires. Data on the utilization function, visitors' perceptions and preferences were processed using simple statistical methods, then analyzed descriptively. Utilizations function is needed to find out what is used in each green open space and the desired utilization in the future. Visitors' perceptions and preferences were needed as a description of the general description of visitors and advice in making recommendations.
2.2.4 Synthesis and Drafting of Recommendations

The results of the subsequent analysis were synthesized, and then recommendations were made for the improvement of plants arrangement in JKJ, TLA, and TKJ.

3. Results and Discussion

3.1 General Conditions

Jogging Track Krakatau Junction (JKJ) is located on Purwakarta Sub-district (5°59'51"LS 106°02'19"BT) has an area of 4 ha with the Northern boundary of Kotasari Street, the west boundary of Kotabumi Street, South boundary of KH. Yasin Beji Street and the Eastern boundary is Krakatau Junction. Taman Kota Layak Anak (TLA) is located in Purwakarta Sub-district (6°00'40"LS 106°02'33"BT). It has an area of 0.895 ha, North of Jenderal Sudirman Street, East boundary of Cilegon City Intersection Roundabout, West boundary of Cilegon City DPRD Government Office, and the Southern boundary of Letnan Jenderal R. Suprapto Street. Taman Kecamatan Jombang (TKJ) is located in Jombang Sub-district (6°00'48"LS 106°03'31"BT) and has an area of 2.2 ha. The Northern boundary of Pegantungan Baru Street, the East of Pacar Putih Street, the South of Pasar Kranggot Street, and the West directly bordering residential settlements.

3.2 Identification of Plant Types and Functions

JKJ has an estimated 70 species of plants, but only 50 species have been identified because of the author's limitations in achieving the presence of trees. The total number of trees was 2462 trees. Most of the plants in the JKJ function as shade plants, some other plants function as steering and aesthetic plants. TLA has 14 species with a total of 98 individuals. Plants in TLA functions mostly as shade and aesthetics plants. TKJ has 39 species with a total of 540 individual plants. TKJ is also dominated by plants that function as shade and aesthetics.

3.3 Evaluation of Thermal Comfort

3.3.1 Temperature Modification Function

Based on the results of measurements of air temperature at the Jogging Track Krakatau Junction (JKJ), the lowest average temperature was measured in the morning on pavement under trees shading of 27.6 °C (Table 1). The average air temperature outside the JKJ is high at 31.4 °C because there is no tree shade. The difference in average air temperature inside the JKJ with outside the JKJ is 2.4°C. This shows that JKJ has a significant influence in modifying temperature.

| Time      | In the JKJ | Average in the JKJ (°C) | Average outside the JKJ (°C) | Difference (°C) |
|-----------|------------|-------------------------|----------------------------|-----------------|
| Morning   | 28.3       | 27.7                    | 28.1                       | 27.6            | 27.7            | 27.9            | 3.5             |
| Noon      | 31.9       | 29.9                    | 31.2                       | 29.7            | 30.7            | 33.3            | 2.6             |
| Afternoon | 30.2       | 29.5                    | 30.0                       | 29.5            | 29.8            | 30.0            | 0.1             |
| Daily temperature | 29.7 | 28.7 | 29.4 | 28.6 | 29.1 | 31.5 | 2.4 |

Explanation: 1 = on the grass without shade 2 = on the grass with shade 3 = on the pavement without shade 4 = on the pavement with shade

Based on the results of temperature measurements in Taman Kota Layak Anak (TLA), the lowest average of air temperature was measured on the grass under shade of trees that is 29.2 °C (Table 2). Unlike the JKJ, the grasses on TLA grow well enough and contribute to
modify air temperatures. Area measurement outside the TLA in the form of pavement. The difference between the average air temperature in the TLA with outside the TLA is 1.2 ℃. The difference proves that TLA quite influential in modifying the ambient temperature.

| Time          | In the TLA | Average in the TLA (℃) | Average outside the TLA (℃) | Difference (℃) |
|---------------|------------|------------------------|-----------------------------|----------------|
| Morning       | 28.9       | 28.5                   | 29.5                        | 28.9           | 30.4 | 1.4 |
| Noon          | 33.5       | 30.7                   | 33.7                        | 30.8           | 32.2 | 1.5 |
| Afternoon     | 30.1       | 29.3                   | 30.7                        | 29.7           | 29.9 | 0.5 |
| Daily temperature | 30.4 | 29.2                   | 30.8                        | 29.6           | 30.0 | 1.2 |

Explanations: 1 = on the grass without shade, 2 = on the grass with shade, 3 = on the pavement without shade, 4 = on the pavement with shade.

Based on the results of measurements of the temperature in Taman Kecamatan Jombang (TKJ), average air temperature the lowest is at the point on the grass with the shade of 29.5 ℃. This is the same as the results of measurements at TLA, where the lowest average air temperature is on the grass with shade. The highest average air temperature is at the point on the pavement without the shade of 31.3 ℃. The difference between the average air temperature inside and outside the TKJ is 0.8 ℃ (Table 3). Not too much difference proves that TKJ is less influential in modifying the ambient temperature well.

| Time          | In the TKJ | Average in the TKJ (℃) | Average outside the TKJ (℃) | Difference (℃) |
|---------------|------------|------------------------|-----------------------------|----------------|
| Morning       | 29.0       | 28.4                   | 29.5                        | 28.9           | 30.1 | 1.2 |
| Noon          | 34.7       | 31.6                   | 35.3                        | 32.7           | 33.6 | 0.9 |
| Afternoon     | 30.2       | 29.5                   | 31.0                        | 30.1           | 30.2 | 0.1 |
| Daily temperature | 30.7 | 29.5                   | 31.3                        | 30.2           | 30.4 | 0.8 |

Explanations: 1 = on the grass without shade, 2 = on the grass with shade, 3 = on the pavement without shade, 4 = on the pavement with shade.

The overall assessment results show that the JKJ has an average lower temperature compared to TLA and TKJ, which is 29.1 ℃ (Table 4).

| Research Location | In the green open space (GOS) | Average in the GOS (℃) | Average outside the GOS (℃) | Difference (℃) |
|-------------------|--------------------------------|------------------------|-----------------------------|----------------|
| JKJ               | 29.7                           | 28.7                   | 29.4                        | 28.6           | 29.1 | 31.5 | 2.4 |
| TLA               | 30.4                           | 29.2                   | 30.8                        | 29.6           | 30   | 31.2 | 1.2 |
| TKJ               | 30.7                           | 29.5                   | 31.3                        | 30.2           | 30.4 | 31.3 | 0.9 |

*P1, P2, P3, and P4 are the average data from time repetition at 3 or 4 measurement points in the green open space.
3.3.2 Humidity Control Function

Optimal thermal comfort will be obtained if the air humidity is at a value that is neither too high nor too low. Optimum air humidity is ranged between 40-75% (Laurie 1986) [3]. Plants as air humidity control maintain moisture content under the canopy. JKJ has the highest average humidity compared to the other two green open spaces, which is 75%. The three green open space was included in the good category in line with the measurement of the average humidity of the air in the three study sites where the measurement results are still at an ideal level ranged between 66-75% (Table 5).

Table 5. The average humidity of the Jogging Track Krakatau Junction, Taman Kota Layak Anak, and Taman Kecamatan Jombang

| Research Location | In the green open space (GOS) | Average in the GOS (%) | Average outside the GOS (%) | Difference (%) |
|-------------------|-------------------------------|------------------------|-----------------------------|---------------|
| JKJ               | P1* 73                        | P2* 77                 | P3* 73                      | P4* 77        | 68           | 7            |
| TLA               | 66                            | 70                     | 63                          | 67            | 62           | 5            |
| TKJ               | 65                            | 68                     | 63                          | 66            | 63           | 3            |

*P1, P2, P3, and P4 are the average data from time repetition at 3 or 4 measurement points in the green open space

Explanations: P1 = on the grass without shade
P2 = on the grass with shade
P3 = on the pavement without shade
P4 = on the pavement with shade

3.3.3 Noise Reducer Function

The results of noise level measurements show that the difference between the noise outside the TLA and the highest TLA compared to the other two research sites, which is 6.5 dB (Table 6). The presence of noise reducer vegetation can influence this, is the glodokan tiang trees (Polyalthia longifolia) that is outside the boundaries of the TLA with quite a lot of plants and closely-covered.

Table 6. Average noise reducer of Jogging Track Krakatau Junction, Taman Kota Layak Anak, and Taman Kecamatan Jombang

| Research Location | In the green open space (GOS) | Average in the GOS (dB) | Average outside the GOS (dB) | Difference (dB) |
|-------------------|-------------------------------|-------------------------|-----------------------------|-----------------|
| JKJ               | 55.4                          | 64.6                    | 58.9                        | 54.8            | 62.7          | 4.3           |
| TLA               | 65.5                          | 65.6                    | 65.6                        | 58.4            | 72.1          | 6.5           |
| TKJ               | 62.4                          | 62.3                    | 59.8                        | 63.7            | 67.2          | 5.2           |

*1, 2, 3, and 4 are the average data from time repetition at 3 or 4 measurement segments in the green open space

3.4 THI (Thermal Humidity Index) Assessment

Thermal comfort is one of the things to be achieved in an area, one of which is in a green open space. Thermal comfort is assessed by the THI method. According to Laurie 1986 [4], the comfort index (THI) in a location is considered convenient if the THI is at a value of 21-27, whereas if the THI >27 and <21 were categorized as uncomfortable. The results of the THI
assessment in all three green open spaces >27 indicate that the three study sites did not meet ideal thermal comfort.

Table 7. The results of THI assessment in the morning, noon, and afternoon at the Jogging Track Krakatau Junction, Taman Kota Layak Anak, and Taman Kecamatan Jombang

| Research Location | THI in the green open spaces | THI outside the green open spaces |
|-------------------|-----------------------------|----------------------------------|
|                   | Morning | Noon  | Afternoon | Morning | Noon  | Afternoon |
| JKJ               | 27.0    | 28.5  | 27.9      | 29.8    | 30.2  | 28.2      |
| TLA               | 27.3    | 29.4  | 27.7      | 28.3    | 30.2  | 28.4      |
| TKJ               | 27.2    | 30.5  | 28.1      | 28.0    | 31.2  | 28.3      |

Table 8. The results of average THI assessment in the Jogging Track Krakatau Junction, Taman Kota Layak Anak, and Taman Kecamatan Jombang

| Research Location | In the GOS | Outside the GOS | Difference |
|-------------------|------------|-----------------|------------|
|                   | T Average (°C) | RH Average (%) | T Average (°C) | RH Average (%) | THI in the GOS | THI outside the GOS |
| JKJ               | 29.1 | 75 | 31.5 | 68 | 27.6 | 29.5 | 1.8 |
| TLA               | 30.0 | 67.0 | 31.2 | 62.0 | 28.0 | 28.8 | 0.8 |
| TKJ               | 30.4 | 66.0 | 31.3 | 63.0 | 28.3 | 29.0 | 0.7 |

3.5 Evaluation of Utilizations
The three research sites have different benefits and functions. JKJ is used by visitors for jogging (sports), while TLA and TKJ have been by visitors for recreation (Figure 2). The existing facilities in each GOS already exist, but many are poorly maintained so that they are not comfortable to be used by visitors. Many facilities have been damaged, such as benches, gazebos, children's games, and lights. Each GOS has a toilet, but the toilet is dirty, so some visitors are reluctant to use it.

3.6 Perception and Preference of Respondents
The majority of respondents in Taman Kota Layak Anak (TLA) and Taman Kecamatan Jombang (TKJ) want to add protective plants because 53% of respondents in TLA and 42% of respondents in TKJ majority said the air temperature was still medium. Respondents in the
Jogging Track Krakatau Junction (JKJ) wanted to add ornamental plants because 63% of respondents in JKJ said the air temperature in JKJ was already cold. The desired facilities of respondents in JKJ and TKJ predominantly want seats (benches), while the majority of respondents in TLA want the addition of musholla facilities.

Most respondents in each green open space felt that the activities in green open space were following what they wanted, namely gathering with friends/family. Respondents in the three study locations felt that RTH could provide benefits for environmental comfort, reduced air pollution, and physical and spiritual health. The majority of respondents in the three green open spaces felt comfortable in each green open space, with the percentage of comfort in JKJ and TLA 67%, and TKJ at 73%. Visitors feel comfortable at TKJ because many children’s play facilities are available at TKJ. Suggestions and expectations most respondents gave were the addition of shade plants to increase the coolness and ornamental plants in certain areas, improvement of cleanliness, as well as the addition, repair, and maintenance of facilities.

### Table 9. The results of vegetation assessment, THI, visitors’ perceptions and preferences

| GOS     | Vegetation assessment | Measurement results | Visitor perceptions and preferences |
|---------|-----------------------|---------------------|-------------------------------------|
|         | T         | H         | N        | TI       | TO       | Difference | C     | S     | ST    |
| JT      | 303 (G)   | 224 (G)   | 215 (M)  | 27.6     | 29.5     | 1.8        | 67%   | 64%   | 7%    |
| TLA     | 255 (M)   | 222 (G)   | 154 (B)  | 28.0     | 28.8     | 0.8        | 67%   | 60%   | 31%   |
| TKJ     | 277 (M)   | 258 (G)   | 202 (M)  | 28.3     | 29.0     | 0.7        | 73%   | 67%   | 35%   |

Explanation: T = Temperature, C = Comfortable, G = Good
H = Humidity, S = Satisfied, M = Medium
W = Wind, ST = Shade Trees, B = Bad
N = Noisy, TI = THI in the GOS, TO = THI outside the GOS

### 3.7 Recommendations for Repair Arrangement of Green Open Space Plants

Each green open space understudy has a different character and problem so that recommendations for crop improvement were based on the problem. Recommendations are made based on the results of evaluating thermal comfort, utilizations function, and perceptions and preferences of respondents.

Recommendations for repair arrangement of Jogging Track Krakatau Junction, namely the addition of ornamental plants in the welcome area, thinning trees that the header too tightly, the addition of benches and trash bins at several points along the jogging track.

Recommendations for repair arrangement of Taman Kota Layak Anak, are the addition of shade trees in the children’s play area and near the park bench, the addition of bushes that are planted tightly in an empty area, the addition of a variety of plants, and replanting of ground cover plants in the grassy area.

Recommendations for repair arrangement of Taman Kecamatan Jombang, namely the addition of shade trees in the green area and children’s play area, replacement damaged/dead plants, and the addition of park benches and trash bins in the area that visitors enjoy.

### 4. Conclusions

The tree on the Jogging Track Krakatau Junction (JKJ) consists of 50 species with a total of 2462 individuals were identified. Trees in Taman Kota Layak Anak (TLA) consist of 14 species with a total of 98 individuals. Trees in Taman Kecamatan Jombang (TKJ) consist of 39 species with 540 total individuals. The results of the assessment showed that the plants in the JKJ were the best in modifying temperatures compared to TLA and TKJ.

Based on the measurement results, JKJ can reduce temperatures up to 2.4°C, TLA by 1.2°C, and TKJ by 0.9°C. JKJ can control the humidity level by 7%, TLA by 5%, and TKJ by 3%. JKJ can reduce noise by 4.3 dB, TLA by 6.5 dB, and TKJ by 5.2 dB. The three green open spaces under study did not meet the standards of thermal comfort. This can be caused by various
factors, one of which is the high temperature and humidity at the site. Even though the measurement of comfort is above THI level, most of respondents on site still feel comfortable.

The results of the utilization evaluation indicate that the presence of the three green spaces is beneficial to the community and the surrounding environment. JKJ is mostly used for jogging activities (sports), while TLA and TKJ are used more for recreational activities. The community showed a response satisfied with the conditions of the three green open spaces, but the community wanted the addition of shade plants in TLA and TKJ, and the addition of quality and quantity of facilities in each green open space.

Acknowledgment
The authors would like to thank the staff of the Cilegon City Housing and Settlement Agency and staff of the Krakatau Steel Cilegon General Division.

References
[1] [Perda] Peraturan Daerah. 2002. Peraturan Daerah (Perda) No. 15 Tahun 2002 tentang luas wilayah Kota Cilegon.
[2] [Disdukcapil Cilegon]. Dinas Kependudukan dan Pencatatan Sipil Pemerintah Kota Cilegon. 2018. http://disdukcapil.cilegon.go.id/.
[3] [__]. 2007. Undang-Undang Republik Indonesia Nomor 26 Tahun 2007 tentang Penataan Ruang. Jakarta (ID): Direktorat Jenderal Penataan Ruang.
[4] Laurie M. 1986. An Introduction to Landscape Architecture. New York (US): American Elsevier Publ. Co. Inc.