An Investigation on the Thermoscape Patterns at High Densely Inhabited Area in Jakarta, Indonesia, and it's Presentation by Mapping Technique on Aerial Photograph

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ABSTRACT

This paper describes the results of observation on the patterns of thermoscape at six places of high densely inhabited area in Jakarta, Indonesia, and the mapping the ratio of isothermal area on aerial photographs of two kind sample areas of two districts. The thermoscape patterns were caught out by infra-red thermovision camera, and analysis of those image data and the mapping on aerial photographs were carried out using computerized system.

We found that the thermoscape scene which contains the wider greenery open space showed holding the larger RIA (ratio of isothermal area) with temperature less than 35°C. Evaluating through two areas, it was clear that the area which contains wider and a well distribution of greenery open spaces indicated wider and a well distribution of IA (isothermal area) <35°C. On the contrary, the area which contains rare and a worse distribution of greenery open space indicated smaller and a worse distribution of IA <35°C. This gives evidence that when any site in urban area is well designed with greenery open spaces, the site holds a capacity to make up a better and comfortable design of urban residential environment.

INTRODUCTION

Urban development leads to the concentration of population, implying on the increasing of building constructions, and decreasing in greenery open space. As everyone mentions, this process effects on the disturbing of human comfort for their life because of the degradation of natural elements in urban area.

Thus, the study on the role of landscape elements in urban area in making the variation of environmental comfortness is very important.

Some researchers have already conducted researches related to the characteristics of landscape elements[11,4,5,6,7,8]. Tashiro, Y. and B. Sulistyantara [17,41] described that urban man-made element holds high surface temperature, contrasting with that of vegetation that holds low surface temperature. Similar results were also reported by Hoyano et al[11] and Maruta et al [4], which they described that vegetation has a good effect in controlling the increasing of temperature above the ground which is mostly caused by the existence of the man-made landscape elements.

Those researches mentioned above were conducted only in temperate country. However, the study on the role of landscape elements in urban areas of tropical countries has become important, because the tropical area actually has a big problem in managing urban heat environment to meet the cool living environment.

This paper describes the results of the explorative observation of thermoscape in small scale, which was conducted at Jakarta, Indonesia, in order to clarify the characteristics and patterns of it's thermoscape, and to clarify the map of thermoscape located in the city center. The authors use the term 'thermoscape' as this term has the connotation of a study or an analytical method on the characteristics of surface temperature of landscape elements which are especially located in urban area, through the thermograph image analysis.

RESEARCH CONTENTS

The content of this study involves five steps (Fig.
1), namely: 1. evaluation on the characteristics of theroscapes, 2. evaluation on the state of surface temperature of nine landscape elements, 3. formulation of RIA (ratio of isothermal area), 4. plotting IA (isothermal area) on the aerial photograph, and 5. evaluation on the RIA distribution and pattern plotted on aerial photograph.

(1) Evaluation on Thermoscape Characteristics
To study the characteristics of thermoscape in Jakarta, we conducted observation tours at six different places located throughout Jakarta. Observation was carried out mobile by car on 20–24 April 1995. The observation was done during day-time from 11 AM to 3 PM due to grasp the hot and relatively stable thermoscape images.

1) Description of Study Area and Time
Study area and times of observation are described below:

- **Street Thermoscape**
Observation on street thermoscape was conducted at two selected main streets: R. Said street and Tamrin street. These streets have different designs, which R. Said street has a row of road trees in the middle of street, while Tamrin street doesn’t have it and most of the scene of the street has very few road trees. The scene of thermoscape was grasped from the pedestrian crossing bridge. Observations at these two streets were conducted on 24 April 1995.

- **Park Thermoscape**
Two parks were selected i.e. Suropati Park and Lembang Park. These parks are located in the city center where the surrounding is densely inhabited. Suropati park represents a well planted park with big trees combined with lawn and ground cover, and water fountain. Lembang park represents a wide scale of natural pond. Nine scenes at Suropati park and three scenes of Lembang park were selected to catch its thermoscapes. Observation in these parks was conducted on 24 April 1995.

- **Residential Thermoscape**
In order to grasp thermoscapes at residential area, we selected two places, i.e. Pondok Indah and Puri Indah. Pondok Indah represents a residential area which has been already well planted with greenery, while Puri Indah represents an area in the process of development where some spots have not been well planted yet. For each of this location we selected twenty spots to grasp its thermoscape. The observation was conducted on 20 (Puri Indah) and 23 (Pondok Indah) April 1994.

2) Equipments and Operation
Referred elsewhere\(^{(6,7)}\), the equipments used in this observation were as follows: 1. Infrared Themoscopic Camera (ITC) – AGEMA450 (made in Sweden) and tripod, 2. Video Tape Recorder (VTR) and VHS tape, 3. VHS-Video camera and VHS-C tape, 4. Computer and software. The equipments no. 1-3 were essential in field observation. The using of equipments in the process of analysis is illustrated in Fig. 2.

ITC was used to grasp the scene of thermoscape. The digital control panel of ITC was adjusted as follows: Emissivity was adjusted to 0.98; Level was adjusted to the value depending on the scene to get a

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Fig. 1 Flowchart of Research Contents
clear view of thermograph, so that the range of minimum–maximum value covers 30–40°C. Level was also adjusted to higher value when it was used to grasp the extremely higher temperature (e.g., asphalt). Scale was adjusted to 128 gray scale. Distance was adjusted depending on the field scale; observation at streets was done by adjusting Distance at 500 m, but observation at parks and residential areas was done by adjusting Distance at 100 m. In order to find a stable scene during operation of ITC, we used tripod.

ITC was connected with VTR. The scene (image data) that had been grasped (or thermograph) by ITC was directly recorded into VHS-tape. In this study, we considered the area of a scene 20°×20° as the capacity of ITC lens we used.

VHS-Video camera was used to grasp the same scene as was shot by ITC. In order to find a closely similar scene, the direction of both ITC and VHS-Video camera was adjusted in the same angle.

Image data of thermographs of all locations recorded in VHS-tape were then used as a source of data-base for computerized analysis to produce thermoscope images. Software Photoshop was used to get input the thermograph and separation of isothermal area, and software Ultimage was used to produce the thermoscope images and to calculate the ratio of isothermal area in its scene. By using this system, we analyzed the characteristics of thermoscope images of all observation areas. The scenes which were shot by VHS-Video camera were also employed as image database for evaluation of the greenery area and analysis by overlay. Note that, the next steps from step-2 to step-5, were also conducted by using computerized system.

(2) Temperature of Landscape Elements

Thermoscope images produced in step-1 were represented in 128 scaled images. The scale indicates state of surface temperature (hereinafter named 'temperature') of landscape element drawn in the scene of thermoscope image ranging from minimum to maximum temperature. Referring to this scale, temperature of each kind of landscape element can be evaluated. Using a software Ultimage, the degree of temperature can be watched more precisely.

Evaluating through all of the thermoscope images of all observation areas, we could make a table of temperature for nine kinds of landscape elements. In this case, we distinguished landscape elements into: trees, shrub, ground cover, lawn, water, asphalt, concrete, wall and roof.

(3) Formulation of RIA

Isothermal area (IA) is the area in the scene of thermoscope image which is showing the similar temperature. Therefore, Ratio of isothermal area (RIA) is defined as a ratio between an area in the thermoscope image scene which is indicating the similar temperature (or isothermal area) and the total area of the scene. Distribution and pattern of isothermal area in the scene of thermoscope image is specific for each observation area, by which we can evaluate the 'stability' of any landscape element's temperature. Referred elsewhere[1] was a study on RIA for observation areas in Tokyo during summer. In this study we used the same grading of RIA due to the assumption that the basic characteristics of landscape elements were the same with those located in tropical Jakarta. We also referred to the grading of RIA conducted by
Sulistyantara and Tashiro[5] who evaluated RIA for Bogor City, Indonesia. In this study RIA was classified into: 1. RIA < 30°C, 2. RIA 30-35°C, 3. RIA 35-40°C and 4. RIA > 40°C.

(4) Plotting of IA on Aerial Photograph

As we have known the temperature of landscape elements and the relation with RIA as observed in steps mentioned above, we made an assumption that those characteristics can be analogized to the landscape elements drawn in aerial photograph. Doing this method, we can trace the distribution and pattern of IA in a wide scale of area. By this assumption we plotted IA to two sampled aerial photographs (produced by Jakarta Mapping Department) of two different urban districts.

Two kinds of urban districts were selected in this study to plot IA on aerial photograph. The first district represents an area which was structured with many tall buildings, many crowded traffic roads, and poor with greenery open space. This location spread out along part of Tamrin street and its vicinity, and was named as Tamrin district. Second, was the district spread out in Menteng district, which was structured by low rise buildings, well designed road network, and more rich greenery open spaces. In this study this location was named as Menteng district. The areas of both urban districts were 82 ha. Fig. 3 shows the location of Tamrin district and Menteng district in Jakarta City.

(5) Evaluation of RIA and IA Distribution and Pattern

The last step was the evaluation of RIA and IA distribution and pattern for each district which was made up in step-4. Calculation of RIA was conducted using software Ultimage. In comparing between two kinds of districts, we evaluated the advantage of district based on the distribution and pattern of greenery open space and its RIA.

RESULTS AND DISCUSSION

(1) Evaluation on Thermoscape Characteristics

Using computerized system, all thermoscape images of all observation areas were successfully produced. Each thermoscape image showed a specific pattern of the distribution of minimum-maximum temperature of elements involved in the scenes. The state of temperature of any element in the scene was indicated by the temperature scale ranging from the minimum to maximum value. Though we have observed the thermoscapes of six different places, we here present one representative sample for each place.

1) Street Thermoscape

Fig. 4 shows the results of the observation of thermoscape at two places of R. Said street and Tamrin street. Thermoscape of R. Said street is presented in Fig. 4a, while thermoscape of Tamrin street is presented in Fig. 4b. The left side of the picture is the photograph of each place, and the right picture is the thermoscape image. The left and right pictures are set up in the same size, and the two pictures show the
same position of landscape elements, so that it is clear to evaluate the state of landscape elements located in the same position in the scene.

Road–trees planted in a row at R. Said street indicated low temperature of 29–34°C. Part of tree canopies exposed to the sun showed a little higher (33–34°C) than that of the lower part canopies (29–30°C). The vast view of road trees which spread out over the scene affected the temperature area in the thermoscape scene. Beside the trees, ground covers which were planted in plant–row also showed low temperature (35–36°C) though it was a little higher than tree canopies.

Asphalt showed exceedingly high temperature, that in the gray scale of thermoscape image it appeared in white. It was very clear that as the asphalt of the road spread out along the street, asphalt made up high temperature area in the scene. By adjusting the Level of ITC to the higher value, it was clear that temperature of asphalt reached up to 56°C. Concrete of plant–row indicated high temperature too, it reached up to 52°C. Wall of the building which was located under shadow showed a temperature of 34–35°C.

Fig. 4b shows the similar arrangement of temperature made by landscape elements involved in the scene. Trees which were rarely planted at road side formed a small part of low temperature area in the scene of thermoscape. The tree canopies showed temperature of 28–29°C. Shrub and lawn also showed low temperature at about 29–30°C.
a) Suropati Park

![Suropati Park Photograph](image)

![Suropati Park Thermoscape](image)

b) Lembang Park

![Lembang Park Photograph](image)

![Lembang Park Thermoscape](image)

Fig. 5 Park Thermoscapes

However, asphalt of Tamrin street indicated a vast view of high temperature area in thermoscape scene. Adjusting the Level of ITC it was found that asphalt reached a temperature of up to 60°C. Walls of buildings around Tamrin street showed a temperature of up to 42°C. From these two different thermoscape scenes, it was known that the appearance of high and low temperature area in the scene was affected by the composition of landscape elements. When the site has a wider greenery, the site forms a wider arrangement of low temperature area. On the contrary, when a site has more asphalt and/or concrete, the site forms a wider high temperature area.

2) Park Thermoscapes

Fig. 5 shows the samples of park thermoscapes of two different places which were observed at Suropati Park (a), and at Lembang Park (b). Tree canopies at Suropati park (Fig. 5a) formed low temperature area in thermoscape scene, with temperature of 28-30°C. Two kinds of ground cover showed different appearance, one showed temperature of 27-28°C and the other one showed 30-32°C. Water fountain also formed low temperature area in thermoscape scene, with a temperature of 27-28°C. In Suropati park scene, there was only concrete block that formed high temperature area. This concrete block reached temperature of up to 45°C.

Fig. 5b also shows clear scene indicating distribution of temperature of some kinds of landscape elements. Tree canopies showed a temperature in varia-
a) Residence-1

<table>
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<td><img src="image" alt="Residence-1 Thermoscape" /></td>
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b) Residence-2

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<td><img src="image" alt="Residence-2 Thermoscape" /></td>
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<tr>
<td>trees</td>
<td>≥ 42.9°C</td>
</tr>
<tr>
<td>wall</td>
<td>≤ 27.0°C</td>
</tr>
<tr>
<td>asphalt</td>
<td>≤ 30.4°C</td>
</tr>
</tbody>
</table>

Fig. 6 Residential Thermoscape

Values, ranging from 29 to 35°C. Lawn showed a temperature of 33-35°C. It was also clear that paving and bench made of concrete formed high temperature area in the thermoscape scene, with its' temperature reaching up to 46°C. However, the shaded part of concrete showed a lower temperature (34-36°C).

In overall view, Fig. 5 shows the patterns of park thermoscapes which mostly were formed by low temperature area. The high temperature area was made up by the concrete, but because the existence of concrete is in small portion in the scene, the forming of high temperature area in thermoscape image scene was also in small portion.

3) Residential Thermoscapes

Fig. 6 shows the appearance of thermoscapes in two places of residential areas, Fig. 6a shows the situation at Pondok Indah which was established with planted trees, and Fig. 6b shows the situation at Puri Indah of a new housing development.

Palm tree canopies in Fig. 6a showed temperature of 28-31°C. Lawn exposed to the sun showed temperature of 32-34°C. Shrubs showed temperature of 33-35°C. In contrast to vegetations, asphalt formed high temperature area in thermoscape scene, and showed a temperature of up to 52°C. And concrete wall showed a temperature of 34-35°C.

Fig. 6b shows the different pattern of thermoscape image. Small tree canopy showed its temperature of 31-32°C. Asphalt of road formed high temperature area in thermoscape scene with temperature reaching
up to 57°C. Concrete block also formed high temperature area with the temperature of 52°C. Shaded wall of building showed a variation of temperature, ranging from 31 to 35°C. Roofs of buildings also formed high temperature area in thermoscape scene, and its temperature reached up to 56-57°C.

It was clear that tree canopies were very important to make up structure of thermoscape with low temperature, though the area of canopy was small. And it was clear that residential area which was mostly composed of man-made landscape elements (asphalt, concrete, wall and roof) formed the extremely hot environment of residential area.

(2) Temperature of Landscape Elements

With the same method as described in (1) mentioned above, we have evaluated the temperature of landscape elements in the scene of thermoscape for all observation area. Based on this evaluation here we present a list of temperature as shown in Table-1.

In this study we distinguished landscape elements into nine groups: tree canopy, shrub canopy, ground cover, lawn, water, asphalt, concrete, wall, and roof. Except for water and roof, the position of landscape elements to the sunlight were distinguished as exposed to the sun and shaded.

It was clear that the position of landscape element to the sunlight affected its temperature. The difference of plants’ temperature between when exposed to the sun and when shaded was small, ranging at about 2-8°C. But, the difference for asphalt and concrete was high, ranging at about 15-20°C. While the difference for wall was at about 8-13°C. It was an evidence that all kinds of plants showed as a stable landscape elements in holding its low temperature. When they were arranged in open or shaded condition, their temperature was relatively stable. But, the man-made landscape elements showed very responsive to sunlight. This evidence was also reported by Tashiro and Sulistyantara(5).

(3) Formulation of RIA (Ratio of Isothermal Area)

RIA is very important to trace which landscape element is located in the thermoscape scene that has the same temperature. Because of the range of minimum-maximum temperature in the thermoscape scene was wide enough, this range was segmented into several RIA. Considering to the distribution of temperature of landscape elements as shown in Table -1, RIA was graded with an interval of 5°C, as follows: 1. RIA<30°C, 2. RIA 30-35°C, 3. RIA 35-40°C and 4. RIA>40°C.

Based on that RIA segmentation, we have evaluated the pattern and distribution of IA for some thermoscape scenes in some observation areas. Fig. 7 represents the samples of six observation areas in six different places which had been discussed before.

It was clear that the pattern and distribution of IA for each area of thermoscape scene was specific. Street thermoscape showed the extremely large value of RIA>40°C (47.09% for R. Said street, and 51.64% for Tamrin street). This RIA occurred because of the existence of asphalt of road. Areas which showed large portion of RIA<30°C were Lembang Park (26.03%) and Suropati Park (57.97%), which occurred because of the existence of plants. However, IA 30-35°C in average dominated the thermoscape scenes. This IA was composed by plant canopies, shaded wall and or shaded concrete.

It was very interesting that plant canopies which were exposed to the sun mostly indicated involving

<table>
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<th>No</th>
<th>Element</th>
<th>Temperature (°C)</th>
</tr>
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<tbody>
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<td>tree canopy</td>
<td>exposed to sun: 32-34 shaded: 26-29</td>
</tr>
<tr>
<td>2</td>
<td>shrub canopy</td>
<td>exposed to sun: 32-35 shaded: 28-29</td>
</tr>
<tr>
<td>3</td>
<td>ground cover</td>
<td>exposed to sun: 33-35 shaded: 28-29</td>
</tr>
<tr>
<td>4</td>
<td>lawn</td>
<td>exposed to sun: 34-36 shaded: 28-32</td>
</tr>
<tr>
<td>5</td>
<td>water</td>
<td>exposed to sun: 27-28</td>
</tr>
<tr>
<td>6</td>
<td>asphalt</td>
<td>exposed to sun: &gt;55°C shaded: 35-45</td>
</tr>
<tr>
<td>7</td>
<td>concrete</td>
<td>exposed to sun: &gt;55°C shaded: 32-42</td>
</tr>
<tr>
<td>8</td>
<td>wall</td>
<td>exposed to sun: 40-45 shaded: 31-38</td>
</tr>
<tr>
<td>9</td>
<td>roof</td>
<td>exposed to sun: &gt;55°C</td>
</tr>
</tbody>
</table>
into IA 30-35°C, but canopies which were shaded indicated IA<30°C. It was clear too that most plant canopies did not occur in the IA 35-40°C. It means that the IA of more than 35°C might be filled by landscape elements other than that of plant canopies. Considering this facts, we can plot the IA onto aerial photograph based on the distinction of landscape elements involved.

(4) Plotting of IA on Aerial Photograph

Landscape elements involved in aerial photograph could be assumed as well as landscape elements in photographs discussed before. The application of IA in plotting on aerial photograph can be thought of as follows: 1. water surface can be plotted by IA <30°C, 2. plant surface (canopy) and shaded wall can be plotted by IA 30-35°C, and 3. the other surfaces can be plotted by IA>35°C.

According to the assumptions mentioned above, we have plotted those three levels of IAs on two different aerial photographs of Tamrin District and Menteng District. Fig. 8 represents aerial photograph of Tamrin District. Plotting those three IAs on this photograph we obtained the pattern and distribution of the IAs as is shown in Fig. 9. And with the same process, we also applied to the aerial photograph of Menteng District (Fig. 10), and the result is presented in Fig. 11.

(5) RIA and IA Distribution and Pattern

Fig. 9 shows the distribution of three IAs (IA<30°C, IA 30-35°C and IA>35°C) at Tamrin District. It was clear that IA<30°C occupied the scene as much as 1.83%. This area existed due to the water surface of canal and huge water fountain in the center area. IA 30-35°C occupied the scene as much as 23.15%. This was so because of the existence of plant canopies. It is clear that the RIA 30-35°C was small for the areas which were densely constructed with tall buildings along the main street of Tamrin street.

The remainder of the area in the scene was occupied by IA>35°C as wide as 75.02%. This was because of the existence of buildings and roads over the scene. The occupation of IA was severe for the area with densely constructed tall buildings.

Fig. 11 showed the different pattern and distribution of those three IAs at Menteng District. IA<30°C occupied the scene area smaller (0.72%) than that at Tamrin District (1.83%), but the IA 30-35°C occupied wider as much as 34.12%. In this district, IA<30°C was formed by the existence of vast water surface located in Lembang park.

It is shown that there were some groups of large areas of IA 30-35°C. This groups lied on the area designed for park and sport field. Besides, this area formed a grid over the scene, so that the area with IA 30-35°C distributed in well balance.

The remainder of the area in the scene which was occupied by area of IA>35°C was 65.16%. Comparing with that of Tamrin District, this area showed a lower percentage. It means that the occupation of
Source: Jakarta Mapping Department [3]

Fig. 8 Aerial Photograph of Tamrin District
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Fig. 9 Map of Isothermal Area of Tamrin District
Source: Jakarta Mapping Department [3]

Fig. 10  Aerial Photograph of Menteng District
Fig. 11 Map of Isothermal Area of Menteng District
landscape elements except plants was smaller than that of Tamrin District.

Sulistyantara and Tashiro obtained the data which was observed in Bogor City, Indonesia to test the human preference of urban environment. The respondents preferred the environment with the smallest area of RIA > 35°C, or the respondents preferred the environment with the largest area of RIA < 35°C. It means that urban areas with larger portion of greenery open space (including water surface) is better than urban area with smaller portion of greenery open space. This argument supports the data in judging the two different districts discussed here. Menteng District showed a well-designed urban area, because it formed a better distribution and larger area of RIA < 35°C (=RIA < 30°C + RIA 30-35°C).

CONCLUSION

In this study, the results made by the analysis of thermocapes which were observed at Jakarta, Indonesia on 20-24 April 1995 can be summarized as follows:

1) Landscape elements made of asphalt, concrete and roof indicated as the landscape elements with high temperature of more than 50°C. All kinds of vegetation (tree, shrub, ground cover and lawn) showed much lower temperature, especially the tree canopy which indicated a maximum temperature of 35°C.

2) Doing evaluation through all thermocape image scenes in all observation areas, it was clear that the scenes which contained wider greenery open space showed the larger RIA (ratio of isothermal area) of less than 35°C.

3) Based on the classification of RIA (ratio of isothermal area) levels, the mapping of three grades of isothermal areas (IA) of IA < 30°C, IA 30-35°C, and IA > 35°C onto aerial photographs of two different urban districts was successfully conducted. A district which contained a wider and well distribution of greenery open space indicated a wider and well distribution area of IA < 35°C. On the contrary, a district which contained a rare and worse distribution of greenery open space indicated a smaller and worse distribution area of IA < 35°C.

These results give an evidence that when any site in urban area is well designed with greenery open spaces, the urban site holds a capacity to make up a better and more comfortable design of urban residential environment. This evidence is so, and it is indicating that the distribution and proportion of greenery open space in urban residential area of tropical country is playing as an important role. The tropical country always meets the very hot environment during the day-time especially in urban area, but, this condition can be controlled by the introducing of greenery open space in a proper distribution and proportion. This method is similar with that of controlling the urban heat environment in temperate country during summer.

REFERENCES


ジャカルタにおける高密度市街地の温熱景による研究及び
空中写真を用いた等温域のマッピング手法

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摘要

この研究では熱帯地域の都市における高密度市街地の
温熱景（サーモスケープ）のパターン把握の結果及び空
中写真を用いた等温域のマッピングの結果についてとり
まとめた。対象地はインドネシア国ジャカルタ市である。
温熱景は赤外線放射温度計を用いて把握した。典型的な
6 地区を選定し地区内の景観要素毎の温度特性を把握し
た。その後をより広域な 2 地区の空中写真にあてはめ、
コンピューターシステムによって等温域マッピングを
行った。

温熱景の画像の解析から緑被オープンスペースのある
エリアでは摂氏 35℃以下の RIA がよりクリティカルな意
味を持ちほぼ緑被率に対応していることが解った。緑被
オープンスペースの量が多いほど上記 RIA の比率が高い
という特徴が明らかになった。このことを通じて高密度
市街地における地区スケールでの快適で良好な住環境形
成における緑被のデザインを実現するための基礎的知見
が得られた。