Analysis on Factors of Summer Temperature Distribution in the Basin City

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ABSTRACT: The purpose of this study is to reveal the factors of the summer temperature distribution in basin city in summer and create an "Urban Environmental Climate Map (Klimaatlas)" that shows the guidelines for urban planning. In general, the basin is likely to be hot during the daytime. Therefore it is required to mitigate summer thermal environment for the comfortable life and saving energy consumption. Actually at first, authors measured the air temperature of 46 points in Hadano city during the summer (8/1-9/31) in 2012. Consequently, the distribution patterns of the maximum and minimum temperatures are different from each other. It is considered that there are different factors of temperature distribution in the daytime and night-time. Secondly, authors analyzed the wind direction and speed in Hadano. Major wind directions are southerly in the daytime and northwesterly in the night-time. Thirdly, we found the main factors are green coverage, buildings that block the wind, amount of solar radiation and elevation. In these analyses, GIS was used. Authors investigated the relationship between the each factor and the temperature for every hour by using correlation coefficients. Finally, authors produced zone maps that show the guidelines for each zone based on the analyses above.
Keywords: Klimaatlas, GIS, Air Temperature Observation

INTRODUCTION

High-temperature phenomena such as global warming and urban heat island effects must be addressed. Steps must be taken to address high-temperature phenomena in summer to assure people's comfort and to reduce energy consumption allocated to cooling. Many studies have been made of large cities such as Tokyo and Osaka [1, 2]. Sasaki [3] reported a tendency of higher temperatures in urban areas, even in small and medium cities. For basin cities, the daytime temperature is likely to be high. The mitigation of high temperatures is also necessary in basin cities. As factors contributing to higher temperatures, which are putatively attributable to increased anthropogenic heat, the modification of land cover, and worsening ventilation are implicated. The degree of each factor's effect differs depending on general regional characteristics.

This study was conducted to investigate the main factors of the air temperature distribution in a basin city in summer. The target area of this study was Hadano city, a basin city located in Kanagawa.

TARGET AREA DETAILS

• Population: 169,951
• Population density: 1,640/km^2
• Number of households: 69,849
• Area: 103.61 km^2 (census data, 2010)

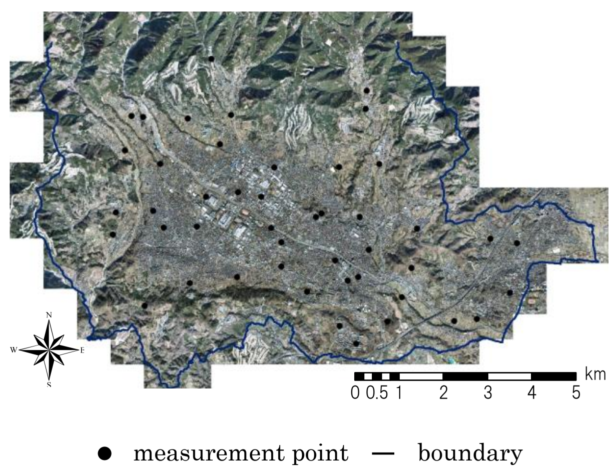

Figure 1: Aerial photograph and measurement points.

Figure 1 shows an aerial photograph of Hadano. The Tanzawa Mountains rise in the north of the city, and the Shibusawa hills range east and west south of the city. An urban area has formed in the basin.

Figure 2 presents the transition of daily maximum temperatures of Tsujido and Hadano in summer 2011. Tsujido is located in a coastal area (Fig. 3). On sunny days such as 7/13 – 7/17 and 8/8 – 8/18, the air temperatures are higher in Hadano: approximately 2 degrees. Characteristics of the basin are apparent during the daytime in summer.

MEASUREMENT DETAILS

The authors made fixed-point observations of temperature in Hadano, installing 46 devices inside of instrument shelters. The observation period is 8/5 – 9/30 in summer 2012. We installed equipment directly under the place of natural covering such as parks and green spaces. Measurement points are shown in Fig. 1.

DISTRIBUTIONS OF AIR TEMPERATURE

Figure 4 shows a distribution of the average of daily maximum temperatures. Figure 5 shows that of daily minimum temperatures. These figures are produced using observations made only on sunny days of 8/5 – 9/30. A difference seems to exist between maximum and minimum temperatures. Different factors of temperature are believed to exist during daytime and night-time.

ANALYSIS OF WIND

The authors created a wind rose (shown in Fig. 6) from official observational data of wind direction and velocity from July 1, 2011 to September 30, 2011 at Hadano Fire Station Headquarters. The interval is 1 hr, and the height is 10 m above the ground. The wind velocity, which is less than 0.2 [m/s] was quiet. Figure 6 shows that the prevailing wind directions are to the south and west–northwest.

Figure 7 shows the time transition of the average wind velocity and the wind direction frequency of southerly winds. Figure 8 shows those of west–northwesterly winds. The wind direction frequency is shown only if the wind velocity is greater than 1.0 [m/s]. The average wind velocity is shown only if the wind direction frequency is greater than 5 [%]. As portrayed in Fig. 7, the wind velocity is high in the daytime. It reaches the 2.5–3.5 [m/s]. The south coastline is at a distance of about 10 km from the observation points. Therefore the wind in the daytime is regarded as a sea breeze from here. As presented in Fig. 8, it is apparent that the west–northwest wind has blown from evening until early morning. The wind velocity is about 2.5 [m/s]. A large valley extends from the northwesterly mountains, ranging over the urban area. It is considered that the wind from the mountains blows down through the valley at night. This is a characteristic phenomenon of a basin city.

ANALYSIS OF AIR TEMPERATURE FACTORS

In this study, the authors extracted main factors of air temperature referring to previous studies [4, 5, 6]. In this paper, we focus on green coverage and buildings that block the wind. The following is an analysis of the relation between these factors and air temperature. The average temperature by time is used in these analysis.

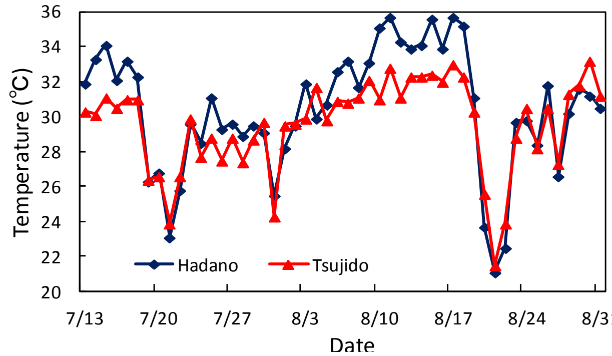

Figure 2: Transition of daily maximum temperature of Tsujido and Hadano.

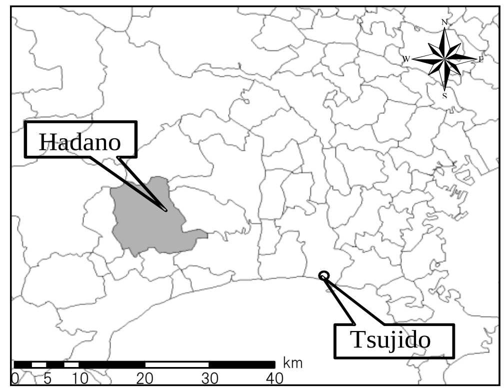

Figure 3: Location of Hadano and Tsujido.

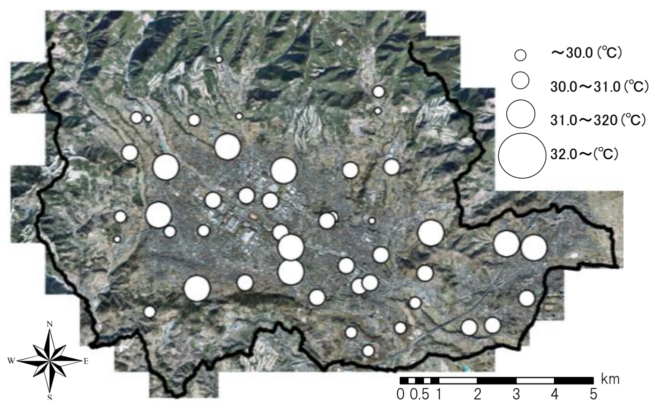

Figure 4: Distribution of the maximum temperatures.

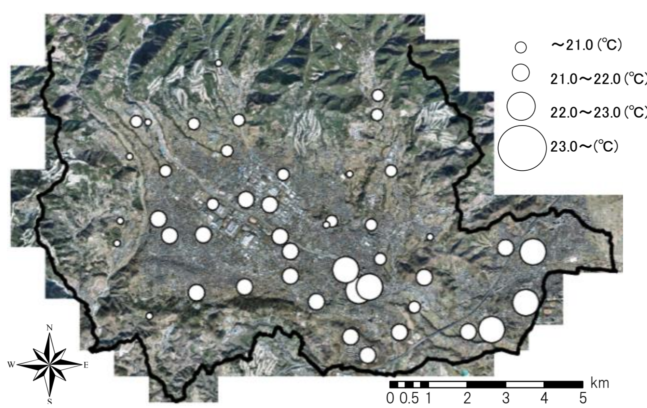

Figure 5: Distribution of the minimum temperatures.

RELATION WITH GREEN COVERAGE

The authors created a NDVI map on GIS from remote sensing data (May 6, 2008). Data were taken by the ASTER sensor installed in the Terra satellite.

NDVI is a typical index reflecting the degree of activity, quantity, and existence of vegetation. NDVI data have been known to correlate with the ratio of green coverage[7]. NDVI was calculated from the following equation.

$$NDVI = \frac{Band3(IR) - Band2(R)}{Band3(IR) + Band2(R)}$$

The NDVI map that the authors created is shown in Fig. 9. The higher NDVI is, the more the ground is covered by green. The spatial resolution of this map is 15 [m]. Temperature observation points and NDVI map were superimposed on the GIS, then we calculated the average NDVI within a radius of 100 – 800 [m] (100 [m] each) of each observation points.

Figure 10 portrays the correlation coefficient between the average temperature by time (6:00, 12:00, 18:00, 24:00) and the average NDVI which are calculated for a radius of 100[m] each up to 800[m]. The average NDVI whose average radius is 300[m] have the highest negative correlation with the air temperature in any hours. Therefore, a radius of 300[m] average NDVI was used in the following analysis.

Figure 11 represents the time transition of the correlation coefficient between the average temperature by time and the average NDVI. A negative correlation was found between the air temperature and the average NDVI. Therefore, a tendency exists of decreased air temperature if the ground is covered more by green. This negative correlation is especially high from 18:00 at night to 6:00 before sunrise. A similar tendency is also apparent from results of a previous study[7]. We consider that the effect of temperature reduction from the effects of greenery appear at night because the nighttime wind velocity is less than that during the daytime. However, little correlation is apparent for the daytime. Probably, other factors exert strong effects during the daytime.

Authors produced a map of zones based on the analyses above (Fig. 12). This zone map shows the areas whose average NDVI (a radius of 300 [m]) less than a certain borderline. The borderlines of NDVI were determined by the average of daily minimum temperatures of each measurement points. The borderlines are 0.03 (over 24 deg C), 0.10 (over 23 deg C) and 0.20 (over 22 deg C) in increasing order of value. As presented in zone map of NDVI, high-temperature areas in the night-time are anticipated. The temperatures in the central area and the east area of Hadano are likely

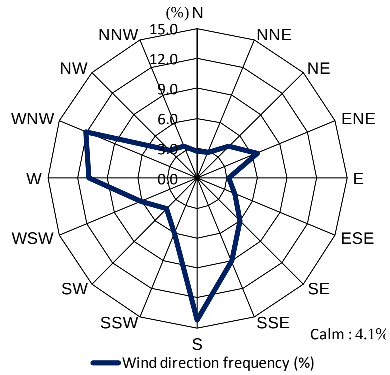

Figure 6: Wind rose of Hadano.

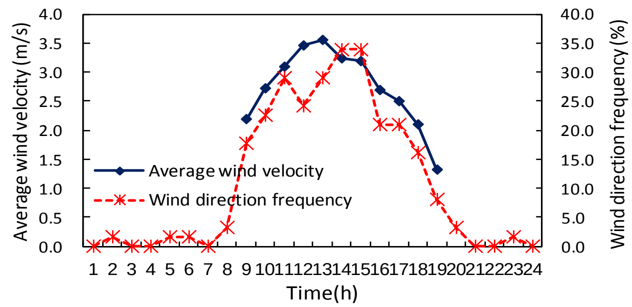

Figure 7: Time transition of southern winds.

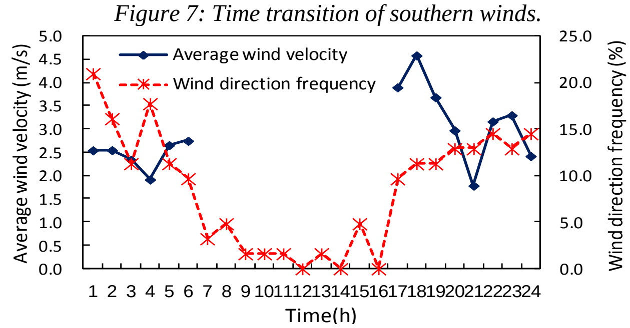

Figure 8: Time transition of west–northwestern winds.

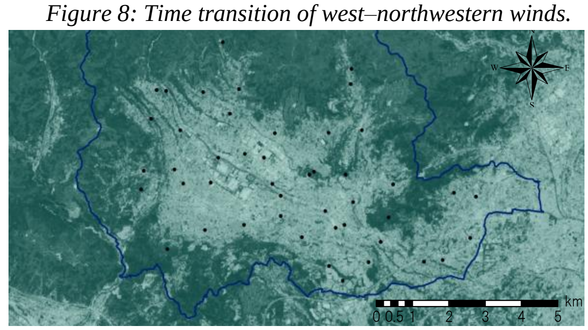

Figure 9: NDVI map.

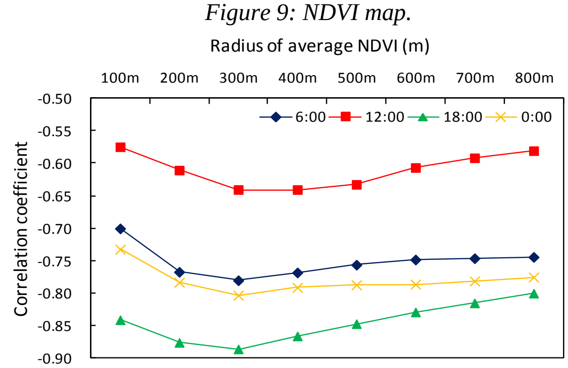

Figure 10: Correlation of each radius of average NDVI.

to be high. For the future guideline, greenery is required as the mitigation of high temperature phenomena at night in these areas.

RELATION WITH BUILDINGS THAT BLOCK WIND

The placement and density of surrounding buildings probably affect the ventilation and air temperature at a given location. Herein, we propose a "rate of building blocking" as an indicator for evaluating ventilation on the GIS. To calculate the "rate of building blocking", the authors used 3D analysis of features (3D Analyst) on GIS (ArcGIS, Inc., ESRI). The following is description of the method used to calculate the "rate of building blocking."

1) Polygon data of buildings are put into 3D representing by their height. Observation points were also placed at the height of 1.5 [m] of the instrument shelters.
2) We set up a base point of which the height was H [m] and distance is R [m] from the measurement point. Then we draw the outlook baseline from the observation point to the base point (Fig. 13a). If the outlook baseline from the building is blocked, then we set up the outlook area as far as the blocked point (Fig. 13b).
3) Outlook areas were created in all directions (360°), and were divided into those of the north, south, east, and west (Figs. 13c). This is the outlook area in each direction (Y).
4) The total area of the sector with radius of R [m] (X) was fixed. The rate of building blocking (*A*) is defined as the following equation.

$A=(X-Y) / X\times 100$
A: Rate of building blocking [%]
X: Total area of the sector in each direction [m^2]
Y: Outlook area in each direction [m^2]

The authors considered the appropriate setting conditions of the base point. 12 conditions were set by the combination of the height (H= 5 [m], 10 [m], 20 [m], 30 [m]) and the distance (R= 25 [m], 50 [m], 75 [m]).

As described above, prevailing winds are to the south and west. We especially focused on the south wind in this analysis for the reason that southerly wind is stronger than westerly wind. Figure 14, 15, 16 shows the time transition of the correlation coefficient of each condition between the average temperature by time and the rate of southern building blocking. Only air temperature data of the sunny days of August and September were used.

As presented in these Figures, positive correlation

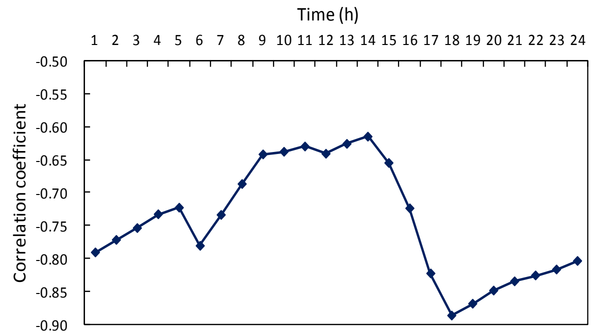

Figure 11: Time transition of the correlation coefficient (NDVI).

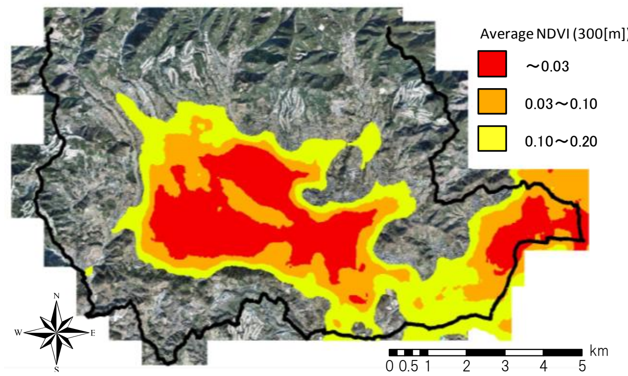

Figure 12: Map of zones for NDVI.

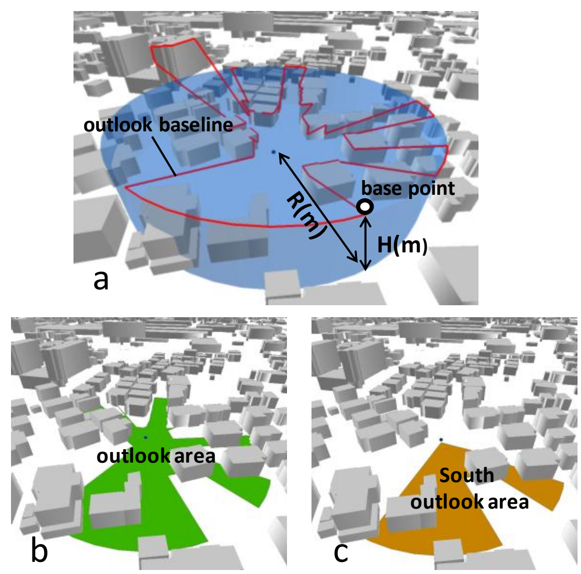

Figure 13: Method of calculating "rate of building blocking".

coefficient is found in the any setting conditions and the positive correlation coefficient is high when southerly winds blow with great velocity. During the early morning and at night, the correlation coefficient is low because of the lower average wind velocity. Therefore, it is considered that the daytime temperature is strongly affected by windward ventilation.

As for the distance (R [m]) from the measurement point, 75 [m] took the highest correlation coefficient.

About the height (H [m]), the most appropriate height is 5 [m] or 10 [m]. After that, we examined the significance of this height by comparing the area ratio of the surrounding southern buildings (Fig. 17). Consequently, the correlation coefficient between the average temperature and the rate of southern building blocking is higher than the correlation coefficient with area ratio in almost all the time.

To consider the relation with ventilation, we investigated the correlation between the average southerly wind velocity and the above mentioned correlation coefficient with rate of southern building blocking or area ratio of the surrounding southern buildings (Fig. 18). The correlation coefficient with rate of southern building blocking is approximately twice that of the area ratio. Rate of building blocking can be used as an indicator of the ventilation compared with the area ratio of the surrounding buildings. Presumably, the effect of ventilation is reflected in the rate of building blocking.

CONCLUSION

In this study, the authors specifically examined a basin city, Hadano, by observing summer temperatures 2012, and by analyzing the summer temperature distribution. The following is a summary of the consequences of this study.

A sea breeze from the south blows during the daytime. Winds from the northwestern mountains blow in urban areas through the valley from the night through the early morning. These phenomena are characteristic of the basin.

From the evening to the early morning, a strong relation can be found between the temperature and NDVI. Temperatures tend to be low at night in areas with much greenery. The most effective radius of the average NDVI is 300 [m]. The authors created a zone

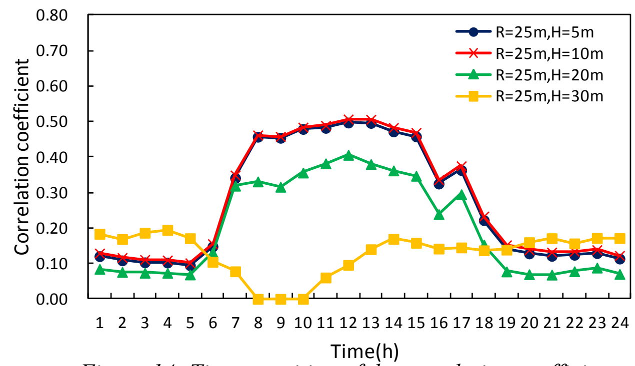

Figure 14: Time transition of the correlation coefficient (rate of southern building blocking (R=25m)).

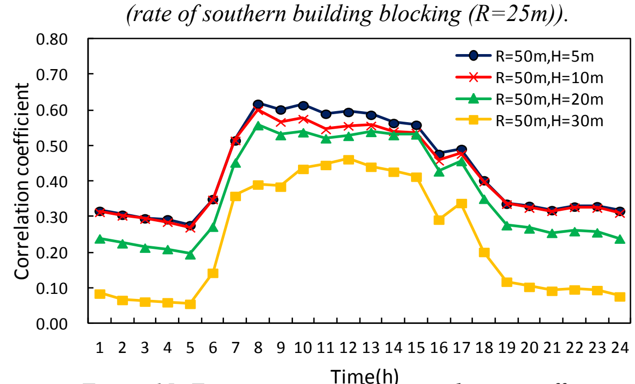

Figure 15: Time transition of the correlation coefficient (rate of southern building blocking (R=50m)).

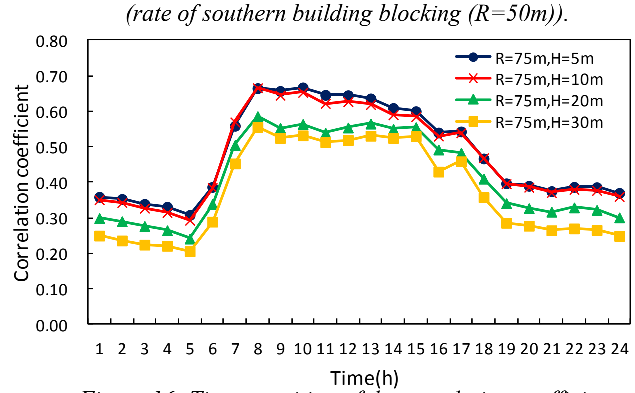

Figure 16: Time transition of the correlation coefficient (rate of southern building shielding (R=75m)).

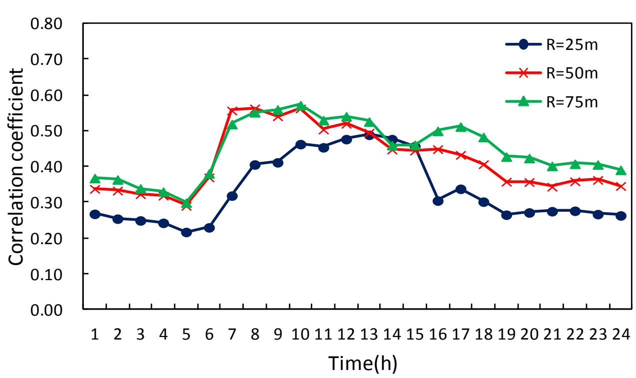

Figure 17: Time transition of the correlation coefficient (area ratio of the surrounding southern buildings).

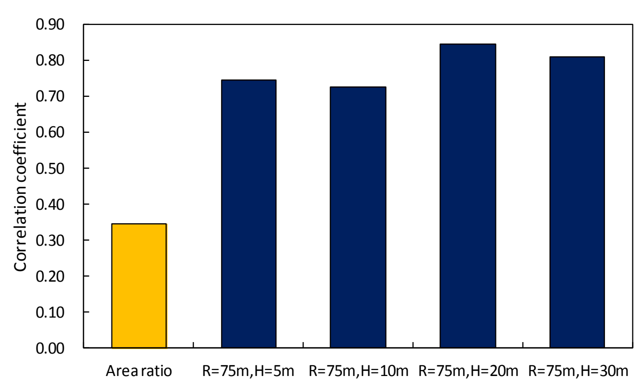

Figure 18: Relation with ventilation of area ratio (R=75m) and rate of southern building shielding (R=75m).

map of NDVI based on 300 [m] average NDVI and estimated high-temperature areas in the night-time. Greening is regarded as an effective countermeasure against high-temperature phenomena during that time period.

The authors proposed a method of calculating "the rate of building blocking" on GIS. It can be a good indicator of ventilation compared with the area ratio of the surrounding buildings. When the prevailing winds blow strongly, the temperature affects the rate of building blocking in each direction. Improving the building location to incorporate the sea breeze is effective as a countermeasure against high-temperature phenomena in the daytime.

The authors plan to produce an Urban Climatic Map (Klimaatlas) showing proposed measures for respective zone. As part of this plan, a zone map of NDVI was created. This map would like to promote the creation of a guideline for the city planning of greenery. Maps of zones for each characteristic such as wind and solar radiation are also necessary for the next plan in order to create a Klimaatlas.

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