GEOGRAPHICAL REPORTS
OF TOKYO METROPOLITAN UNIVERSITY 39 (2004) 21-26

ESTIMATION OF A POTENTIAL SPACE FOR THE ROOFTOP GREENING IN THE TOKYO METROPOLITAN REGION

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Abstract A potential space for the rooftop greening in the Tokyo metropolitan region was estimated by analyzing the polygon data of buildings and the digital areal photographs of the Shinjuku ward. The usage of buildings and the number of floors in buildings in the 23 wards of the Tokyo metropolitan region were almost same as those in the Shinjuku ward, therefore, a ratio of the potential space for the rooftop greening in the Shinjuku ward was estimated by a random sampling method at first. Then, a potential space for the rooftop greening in the 23 wards was estimated, based on a result of the Shinjuku ward.

The ratio of the potential space for the rooftop greening varied from 37.8% to 93.6%, depending on the usage of buildings and the number of floors in buildings. By then, the invariable ratio of 86 % had been suggested by the Ministry of Construction (1995), however, the present study manifested that this ratio did not always hold true. The potential space for the rooftop greening in the 23 wards was estimated at 5,069 ha, which was as large as about 8% of the 23 wards' area. In comparison with the ratios of the potential space for the rooftop greening in low-rise buildings and in medium-rise buildings, those in high-rise buildings and in skyscrapers were smaller. Since the latter buildings directly warm the upper part of the urban atmosphere through the sensible heat flux, the results of the present study can be important when the energy balance of the urban atmosphere is investigated.

Key words: rooftop greening, polygon data of buildings, digital areal photograph, urban heat island

1. Introduction

Recently, the urban heat island has been attracting attention especially due to the increase of temperature in summer. Some methods have been considered to weaken the heat island, and the rooftop greening has been regarded as one of effective methods.

A potential space for the rooftop greening was estimated by the Ministry of Construction (1995, hereafter referred to as MC95), by analyzing areal photographs of 11 large cities in Japan. The results of MC95 have been used as the basic data for greening policies by some local authorities, as well as for greening strategies by some private enterprises (e.g., Yamada, 2001). In near future, these results can be incorporated as the boundary conditions of some meso-scale climate models to predict the effectiveness of the greening scenarios.

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A method employed by MC95, however, had problems as follows. (1) The unit space of the rooftop space for each land use was defined by investigating 3-5 samples per 1 ha quadrate, prepared for each land use. Then, the rooftop space was estimated by multiplying this unit space and the land use space for each category. By MC95, informations on the concrete sampling sites were not provided, so that the estimation errors can be large depending on the way how 1 ha quadrate was selected. (2) The ratio of the potential rooftop greening was uniformly set 86% regardless of the types of buildings. This ratio can be different depending on the usage of buildings and/or the number of floors in buildings.

The objectives of our study were (1) to evaluate the uniform ratio of the potential rooftop greening (86%) suggested by MC95, and (2) to provide more precise estimation of the potential space for the rooftop greening, by analyzing digital areal photographs and the polygon data of buildings as derived from the basic survey of the city planning. In our study, the Tokyo metropolitan region was selected as the study area where the heat island was regarded as one of the important problems to be solved in the "Environmental Basic Plans" designed on January, 2001.

2. Data and Methods

The data used in our study were (1) the polygon data of buildings in the Tokyo metropolitan region in 1996 provided by the Tokyo metropolitan government city planning map system, and (2) the orthogonally-corrected digital areal photographs of the Shinjuku ward taken in 2001 and provided by the Digital Earth Technology Corp. Inc. The former was one of the vector data, and represented shapes of buildings, while the latter had the spatial resolution of 25 cm.

Since the original polygon data of buildings were separated into 208 independent pieces, these 208 data were attached to one by use of the geographical information system (ArcGIS/info, ESRI Japan Corp. Inc.). Then, the rooftop space was estimated considering the usage of buildings and the number of floors in buildings, because shapes of rooftops were considered to be different when the usage of buildings and the number of floors in buildings were different. The information on the usage of buildings and the number of floors in buildings was included in the polygon data of buildings.

For the investigation, MC95 selected the strong buildings with the roofs which could withstand medium and heavy burdens. Of these roofs, the slope was smaller than 0.2, while we selected fireproof buildings with flat roofs. The reasons of this selection were that non-woody buildings with concrete frame and/or heavy steel frame were suitable for the rooftop greening, and they were considered to meet the conditions of the strong buildings selected by MC95. Since one of the objective of our study was to evaluate the results of MC95, it was desirable to select the almost-same types of buildings which were investigated by MC95.

Next, the usage of buildings and the number of floors in buildings were classified into 4 categories, respectively (Table 1). The buildings were selected by way of the random sampling, and the inspections on the roofs of these buildings were conducted using the digital areal photographs (Fig. 1). Based on these visual inspections, the space where rooftop greening was impossible was omitted. In the omitted space on the rooftop, cooling towers and other facilities were established. With this procedure, the ratio of the potential rooftop greening could be evaluated.

Table 1 The comparison of the usage of buildings and the number of floors in buildings in the 23 wards of the Tokyo metropolitan region (a) and the Shinjuku ward (b) The upper and lower parts of each cell respectively represent the number of buildings and its ratio to the total number of buildings (%)

(a)	public use	commercial use	residential use	industrial use	total
1-2 floors (low-rise buildings)	12,085	14,315	29,265	8,826	64,491
	4.1	4.8	9.6	3.0	21.6
3-5 floors (medium-rise buildings)	9,215	78,751	87,695	14,198	189,659
	3.1	26.4	29.4	4.8	63.7
6-15 floors (high-rise buildings)	1,372	24,620	16,453	962	43,407
	0.5	8.3	5.5	0.3	14.6
16- floors (skyscrapers)	34	265	92	4	395
	0.0	0.1	0.0	0.0	0.1
total	22,706	117,951	133,505	23,990	298,152
	7.6	39.6	44.8	8.0	100.0

(b)	public use	commercial use	residential use	industrial use	total
1-2 floors (low-rise buildings)	457	747	1,736	227	3,167
	2.4	3.9	9.1	3.0	21.6
3-5 floors (medium-rise buildings)	646	5,494	5,776	640	12,556
	3.4	28.7	30.2	3.3	65.7
6-15 floors (high-rise buildings)	121	2,258	937	28	3,344
	0.6	11.8	4.9	0.1	17.5
16- floors (skyscrapers)	7	31	5	0	43
	0.0	0.2	0.0	0.0	0.2
total	1,231	8,530	8,454	895	19,110
	6.4	44.6	44.2	4.7	100.0

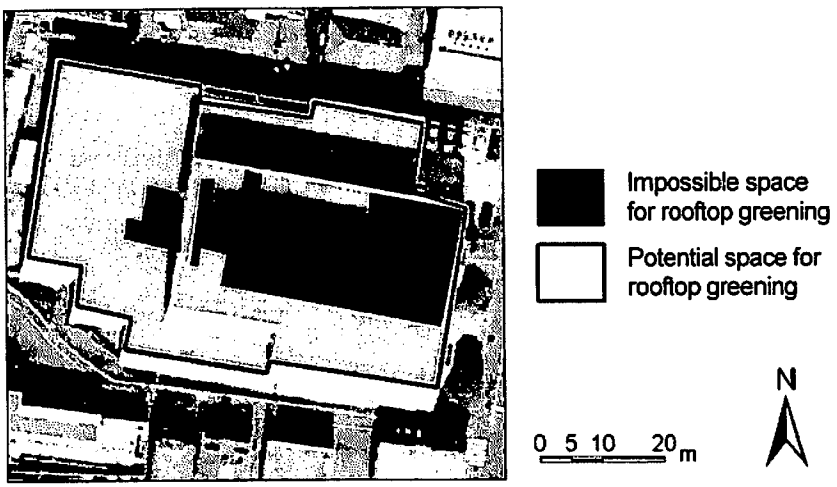

Fig. 1 The example image of estimating the potential space for the rooftop greening.

About 50 samples are selected in each usage of buildings in Table 1. With this sample numbers, the estimation error can be 15% of the average at the 95% confidence interval (Suzuki and Takahashi, 1998). Ideally, samples should be collected from all of the 23 wards in the Tokyo metropolitan region, however, it was difficult to get so many digital areal photographs, and to carry out so many visual inspections of them. The Shinjuku ward was, therefore, selected as the research section in our study, because the ratio of the usage of buildings in the Shinjuku ward was almost same as that of the 23 wards (Table 1). Also, the ratios of low-rise, medium-rise, high-rise buildings, and skyscrapers in the Shinjuku ward were almost same as that of the 23 wards (Table 1).

3. Results

It was found that the ratio of the potential rooftop greening to the entire rooftop space in the Shinjuku ward varied from 37.8% to 93.6%, depending on the usage of buildings and the number of floors in buildings (Table 2). Especially, in the medium-rise and high-rise buildings (76.9 and 64.8%, respectively) of the commercial use which occupied larger parts of the Shinjuku ward, this ratio was 10-20 % smaller than the one (about 86%) in the estimation of MC95.

Based on a result of the Shinjuku ward, the potential space for the rooftop greening in the 23 wards was estimated. It was 5,069 ha (Table 3), which was comparable to Adachi ward, the second largest in the 23 wards. This estimation was fairly larger than that (3,560 ha) of MC95, because the ratio of the potential rooftop greening in our study was generally smaller than that of MC95, while the potential space for the rooftop greening was about 2,000 ha larger than that of MC95. When focused on the usage of buildings, the residential use occupied about half of the potential space for the rooftop greening (Table 3). It was also found that the commercial use and the public use respectively occupied about one fifth. With respect to the number of floors in buildings, it was found that the medium-rise and high-rise buildings occupied about 84% of the potential space for the rooftop greening (Table 3).

Table 2 The ratio of the potential space for the rooftop greening in the Shinjuku ward (%) Numbers in the brackets are the results of Izumi and Matsuyama (2004), of which sample numbers are about 400

	public use	commercial use	residential use	industrial use
1-2 floors (low-rise buildings)	90.3 (78.8)	88.0 (86.1)	89.5 (87.3)	93.6 (85.5)
3-5 floors (medium-rise buildings)	80.2 (77.1)	76.9 (77.2)	89.7 (83.4)	83.1 (66.2)
6-15 floors (high-rise buildings)	61.4 (64.2)	64.8 (70.5)	80.8 (76.1)	84.8 (79.0)
16- floors (skyscrapers)	55.2 (55.3)	42.2 (39.7)	37.8 (30.5)	– (–)

Table 3 The potential space for the rooftop greening in the 23 wards of the Tokyo metropolitan region (ha)
Numbers in the brackets are the results of Izumi and Matsuyama (2004), of which sample numbers are about 400

	public use	commercial use	residential use	industrial use	total
1-2 floors (low-rise buildings)	272 (273.6)	169 (163.8)	165 (197.8)	174 (177.5)	780 (812.7)
3-5 floors (medium-rise buildings)	586 (536.8)	460 (469.5)	1,594 (1,513.6)	316 (253.1)	2,956 (2,772.9)
6-15 floors (high-rise buildings)	96 (100.0)	464 (505.3)	655 (616.5)	79 (74.0)	1,294 (1,295.9)
16- floors (skyscrapers)	4 (4.4)	28 (26.7)	6 (4.5)	0 0.0	38 (35.5)
total	958 (914.8)	1,123 (1,165.3)	2,420 (2,332.3)	569 (504.6)	5,069 (4,917.0)

4. Discussion

The results mentioned above were obtained at the end of November, 2002. Then, Izumi and Matsuyama (2004) took over our study, and increased the sample numbers to get statistically significant results. The sample numbers for each usage of buildings employed in the study by Izumi and Matsuyama (2004) were about 400, by which the estimation error can be within 5% of the average at the 95% confidence interval (Suzuki and Takahashi, 1998).

One of the interesting features found in Table 2 is that the estimations of our study, by Izumi and Matsuyama (2004), and by MC95 look similar in the residential use in medium-rise buildings (about 86%). Since this category occupies about one third (1,594 ha) of the total potential space for the rooftop greening in the 23 wards (5,069 ha, Table 3), the invariable estimation of the ratio of the potential rooftop greening (about 86%) by MC95 may be justified so far, regardless of the usage of buildings.

As noted in Section 3, the ratios of the potential rooftop greening in the Shinjuku ward estimated by both our study and Izumi and Matsuyama (2004) can be smaller and step away from 86% when the number of floors in buildings gets larger (Table 2). This gives an important implication in considering the energy balance of the urban atmosphere. Since the exchange of the energy and water occurs in the rooftop and walls of buildings, the overestimation of the ratios of the potential rooftop greening by MC95 would underestimate the sensible heat flux from the rooftop of buildings, if all of the potential space for the rooftop were to be greened. In addition, high-rise buildings and skyscrapers directly warm the upper part of the urban atmosphere through the sensible heat flux, therefore, Table 2 can be very important when the rooftop greening and the energy balance of the urban atmosphere are investigated.

In near future, we are going to propose specific scenarios of the rooftop greening which are to be realized, by considering the usage of buildings and the number of floors in buildings. In that case, regional characteristics of the rooftop greening should be also taken into account. Then the numerical simulations of some meso-scale climate models should be performed to predict the effectiveness of the greening scenarios.

5. Conclusions

A potential space for the rooftop greening in the Tokyo metropolitan region was estimated by

analyzing the polygon data of buildings and the digital areal photographs of the Shinjuku ward. The following conclusions were obtained in our study.

1. The ratio of the potential space for the rooftop greening in the Shinjuku ward was estimated by way of the random sampling. These ratios varied from 37.8% to 93.6%, depending on the usage of buildings and the number of floors in buildings. It was concluded that the invariable ratio of 86%, suggested by the Ministry of Construction (1995), did not always hold true.
2. The potential space for the rooftop greening in the 23 wards of the Tokyo metropolitan region was estimated at 5,069 ha, which was as large as about 8% of the 23 wards' area.
3. In comparison with the ratios of the potential space for the rooftop greening in low-rise and in medium-rise buildings, those in high-rise buildings and in skyscrapers were smaller. Since the latter directly warm the upper part of the urban atmosphere through the sensible heat flux, the results of our study can be important when the energy balance of the urban atmosphere is investigated.

Acknowledgments

A part of the present study was supported by "the Research on the City Policy and the Residence Environment of Big Cities in the Matured Information Society", a cooperative research with the Center for Urban Studies, Tokyo Metropolitan University.

Notes

Mr. Shin'ichi Oka unexpectedly passed away on 2nd. December, 2002. This article was originally planned to be submitted to the Department of Geography, Faculty of Science, Tokyo Metropolitan University as the graduation thesis of the first author. After the second and third authors added some discussions, it was translated in English and published in Geographical Reports of Tokyo Metropolitan University.

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