

Evaluation of the Degree of the Sufficiency of Public Green Spaces as an Indicator of Urban Density in the Chubu Metropolitan Area in Japan

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Abstract—This study uses GIS (Geographic Information Systems) to conduct an evaluation of the degree of the sufficiency of public green spaces such as parks and urban green areas as an indicator of the density of metropolitan areas, in particular the Chubu metropolitan area, in Japan. To that end, it first grasps the distribution situation of green spaces in the three metropolitan areas in Japan, especially in the Chubu metropolitan area, using GIS digital maps. And based on this result, it conducts a GIS evaluation of the degree of sufficiency of public green spaces and arranges the result for every distance belt from the central part to compare and exam for every distance belt away from the center in the Chubu metropolitan area. Furthermore, after pointing out the insufficient areas of public green spaces based on the result, it also proposes the improvement policy which can be introduced in the Chubu metropolitan area.

Keywords—Public Green Spaces, Urban Density, Metropolitan Areas, Land Use, Urbanization, GIS (Geographic Information Systems)

I. INTRODUCTION

MOST large cities in Asia are extraordinarily high-density compared with their counterparts in Europe, North America and Oceania (Yamamoto, 2006, 2008a, 2008b, 2009) [1] [2] [3] [4]. An acute lack of green spaces in the metropolitan areas in Japan, in particular, has given rise not only to problems in land use but also to deterioration of the quality of the urban environment. Quite apart from the problem of environmental conservation, green spaces fulfill a number of diverse functions for recreation, disaster prevention and local topography, and are thus one of the most important elements in urban areas. Furthermore, in Japan, the potential danger of high-density cities was made very real in people's minds in the Great Hanshin Earthquake in 1995, and several proposals have since been made strongly arguing for the necessity of disaster prevention city planning based on the provision of green spaces (Yamamoto, 2000) [5]. This is because the weak areas have increased in disaster since and the flexibility of construction is large as compared with the

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advanced nations of others in Japan.

This study uses GIS (Geographic Information Systems) to conduct an evaluation of the degree of the sufficiency of public green spaces such as parks and urban green areas as an indicator of the density of metropolitan areas, in particular the Chubu metropolitan area, in Japan. For the purpose of this study, a "public green space" is defined as a "public space such as parks and green areas that is secured as an open space within a city and not used for any other purpose" based on the result of Yamamoto (2007a, 2007b) [6] [7].

II. FRAMEWORK AND METHOD

In this study, first, Section III performs the comparison with the metropolitan areas in foreign countries to illustrate the current state of green spaces of the characteristics of Japan's major metropolitan areas, especially in the Chubu metropolitan area. Section IV introduces the use data of this study and the process which processed the form which can be used by this study is shown.

Based on these, Section V shows the distribution situation of green spaces in the three metropolitan areas in Japan, especially in the Chubu metropolitan area, using GIS digital maps. And based on this result, Section VI conducts a GIS evaluation of the degree of sufficiency of public green spaces and arranges the result for every distance belt from the central part to compare and exam for every distance belt away from the center in the Chubu metropolitan area. Furthermore, after pointing out the insufficient areas of public green spaces based on the result, it also proposes the improvement policy which can be introduced in the Chubu metropolitan area. Finally, Section VII shows the conclusion and future research of this study.

In addition, the application soft wares of GIS used by this study are ArcGIS and ArcView developed by ESRI. In this study, using these soft wares, the data is processed in Section IV and the degree evaluation of sufficiency of public green spaces is performed in Section VI.

III. THE CHARACTERISTICS OF STUDY AREA

A. Study area description

The region for this research is the Chubu metropolitan area centering on Nagoya city which showed the position in Fig. 1.

This is Japan's third largest metropolitan area, which together with the Tokyo and Keihanshin (or Kyoto, Osaka and Kobe) metropolitan areas constitute the Big Three metropolitan areas of Japan. The population flowed in centering on adjacent prefectures around from the 1950s in these three metropolises.

TABLE I shows the population of three major metropolitan areas in Japan. From this table, the Chubu metropolitan area, as compared to the other two of the Big Three metropolitan areas, is larger in land area and smaller in population. Because of the relatively low population density, urban districts within the Chubu metropolitan area are less crowded. The gaps are huge particularly when compared to the Tokyo metropolitan area, the largest metropolitan area of Japan, whose population and population density are respectively three and five times greater

the most favorable in Japan. The World Exposition 2005, Aichi, Japan, was held in the northeast suburbs of Nagoya.

B. The distribution situation of the green spaces in the study areas

TABLE II shows the park and green space per population of the central cities of three metropolitan areas in Japan, New York, London, and Paris. From this table, it is evident that the large cities in Japan have remarkably few amounts of green spaces compared with other large cities of advanced nations.

This is because the land use control are too weak in Japan that it is easy to make green spaces applicable to development as compared with many foreign countries. This table also shows the park and green space per population of Nagoya is remarkably less than the ones of large cities in foreign countries, and it is more than the ones of Tokyo and Osaka.

Moreover, these photographs show the central parts of metropolitan areas in Japan and other Asian countries. Fig. 2 shows Yoyogi Park and Meiji-jingu shrine which are located near the Shinjuku subcenter of Tokyo. In the central part of Tokyo, except for these, there are no large-scale parks and green spaces, and the high density urban areas continue to the suburbs.

Fig. 3 and the Fig. 4 show respectively Osaka which is maximum city and Kobe of the Keihanshin metropolitan areas in Japan. In the center of Osaka of Fig. 3, the urban density is the highest and there are very few open spaces. Furthermore, concretely speaking, except for Osaka Castle, Osaka Castle Park, etc. in the central part, there are very few parks and green spaces. Kobe of Fig. 4 is the city which the great earthquake happened in January, 1995, and the revival enterprises have been promoted even now. However, since there are very little flat grounds, the high-density urban areas have been formed in the narrow areas and housing developments have been progressing in the mountains and marine reclaimed land.

Fig. 5 shows Nagoya and Fig. 6 shows its nearby areas. Fig. 5 shows Nagoya's city center and Central Park as seen from the TV Tower in the central district of the city, whereas Fig. 6, showing the city center and nearby areas, have been taken from the Higashiyama Tower in the eastern part of Nagoya.

Although urban density in the central district of Nagoya is high, there still remain several open spaces even within the city center. The wide roadways running through the city center and the relatively modest presence of high-rise buildings – as compared with the other two metropolitan areas – are the major characteristics of the Chubu metropolitan area. Also, suburban areas in the Chubu metropolitan area have more forests and farmlands than those in the other two metropolitan areas.

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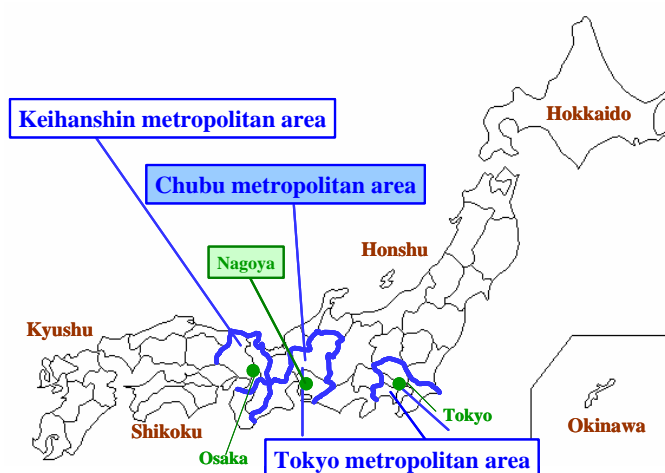


Fig. 1 Location of Chubu metropolitan area in Japan

TABLE I

THE DENSITY OF THE THREE LARGEST METROPOLITAN AREAS IN JAPAN (2005)

Metropolitan area	Prefecture	Population (Person)	Area (km ²)	Population density (person/km ²)
Tokyo metropolitan Area	Tokyo	12,577,819	2,187.1	5,751.0
	Saitama	7,053,689	3,797.3	1,857.6
	Chiba	6,062,202	5,156.6	1,175.6
	Kanagawa	8,785,638	2,415.5	3,637.2
	Sum	34,479,348	13,556.4	2,543.4
Chubu metropolitan Area	Aichi	7,262,164	5,158.0	1,407.9
	Gifu	2,107,000	10,598.2	198.8
	Mie	1,867,166	5,776.4	323.2
	Sum	11,236,330	21,532.6	521.8
Keihanshin metropolitan Area	Osaka	8,817,010	1,893.9	4,655.4
	Kyoto	2,647,523	4,612.7	574.0
	Hyogo	5,595,212	8,393.3	666.6
	Sum	17,059,745	14,900.0	1,145.0

Note) The data of population and area is quoted from the homepage of each all prefectures.

than those of the Chubu metropolitan area. However, due to the increasing industrial activities in the recent years especially in the manufacturing sector, the Chubu metropolitan area is now being pointed to as an area where the economic conditions are

TABLE II
 THE PER CAPITA PARK AREA OF LARGE CITIES (1994)

City	m ² /person
Tokyo	4.5
Nagoya	5.3
Osaka	2.9
Kobe	13.5
New York	14.0
London	17.0
Paris	19.0

Note: The data is quoted from Tokyo city white paper (1994) [8].



Fig. 2 Shinjuku sub-center in the Tokyo metropolitan area (December, 2006)



Fig. 3 Osaka station in the central part of the Keihanshin metropolitan area (June, 2002)



Fig. 4 Kobe in the Keihanshin metropolitan area (August, 2000)



Fig. 5 Central Park in the central part of Nagoya in the Chubu metropolitan area (October, 2000)



Fig. 6 Eastern part of Nagoya in the Chubu metropolitan area (March, 2004)

IV. COLLECTION AND PROCESSING OF DATA

In this study, the detailed digital maps (10m mesh) for three major metropolitan areas created by the Geographical Survey Institute of the Ministry of Land, Infrastructure and Transport were used in the analysis evaluation stage of Section V and Section VI. These detailed digital maps are 10m mesh land use data mainly deciphered and created from the aerial photos. They were created by 5 times in the five whole years about three major metropolitan areas in Japan such as the Tokyo metropolitan area, the Keihanshin metropolitan area and the Chubu metropolitan area.

The land uses are classified into 15 items such as forest, paddy field, dry field, open space, and developed areas, industrial area, general low layer residential section, high density low layer residential section, middle and high layer residential section, commercial section, road, park and green open space, other public spaces, river and lake and others. In addition, the public green spaces of this study are mainly pointed to parks and green open space among these land use classifications of minute numerical value maps, and this was set as the object of analysis evaluation. In this study, by ArcGIS, these digital maps are processed into the form which can be used was and they are used for the analysis evaluation subsequent to Section V and Section VI.

V. THE CHARACTERISTICS OF STUDY AREA

This section compares the distribution situations of public green spaces of three metropolitan areas in Japan using the detailed digital maps. In these maps shown below, the areas shown in red are urban districts and those blue are industrial zones, whereas the areas shown in dark green, light green, and yellow respectively represent forests, parks and green spaces, and farmlands. "Public green spaces," which are the main focus of this study, refer to parks and green spaces, i.e. the areas shown in light green on the digital maps.

A. Tokyo metropolitan area

The digital maps of Fig. 7 show the land uses in the Tokyo metropolitan area in 1974, 1984 and 1994. There are four ordinance-designated cities in addition to Tokyo and the urban areas are connected in the Tokyo metropolitan area. In the Tokyo metropolitan area, the high-density areas continue to the area about 40km away from the city center and the shortage of green spaces poses a serious problem. When we compare land uses among the two different points of time, we can see that the distribution of urban districts has expanded further into the suburbs and public green spaces diminished over the 20-year period. Particularly in areas surrounding Yokohama on the southwestern side, forests decreased significantly with substantial portions of the hilly areas converted into residential areas over the years.

B. Keihanshin metropolitan area

The digital maps of Fig. 8 show the land uses in the Keihanshin metropolitan area in 1976, 1986 and 1996. Three ordinance-designated cities such as Osaka, Kobe and Kyoto are located in the Keihanshin metropolitan area, and Osaka is the central city. Moreover, many middle-scale cities of bedroom suburb locate around three ordinance-designated cities. From these digital maps showing the land uses at the three different points of time, we can see that the distribution of urban districts has expanded further into the suburban areas over the 20-year period. A particularly acute depletion of forests can be observed in areas surrounding Kobe in the northwest, with the hilly terrain rapidly turned into residential areas. However, what is noticeable about the Keihanshin metropolitan area is that there remain substantial public green spaces and forests in the suburban areas, even though public green spaces are extremely scarce in the city center of Osaka.

C. Chubu metropolitan area

The digital maps of Fig. 9 show the land uses in the Chubu metropolitan area in 1977, 1987 and 1997. Nagoya is the only ordinance-designated cities in the Chubu metropolitan area and no other major cities are located within the region. Instead, there are a number of mid- and small-size cities located in areas surrounding Nagoya. The formation of conurbations is less observable here as compared to the other two major metropolitan areas. Thus, areas characterized with high urban

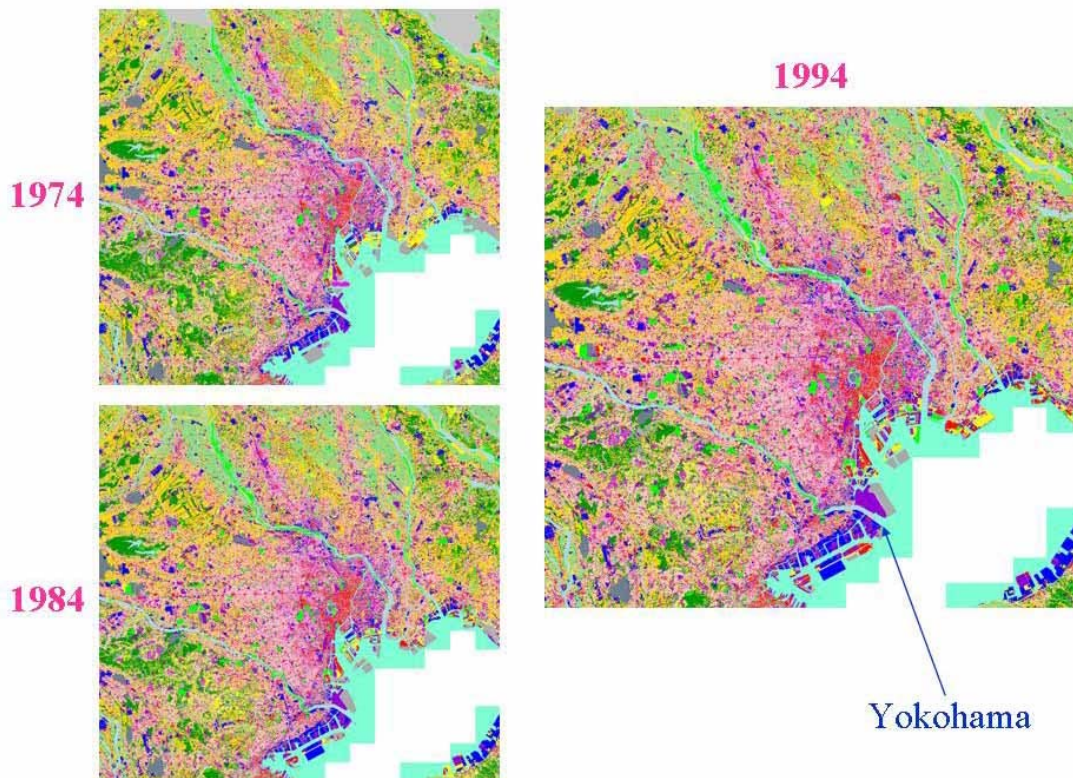


Fig. 7 The land use transformation in the Tokyo metropolitan area (1974-1994)

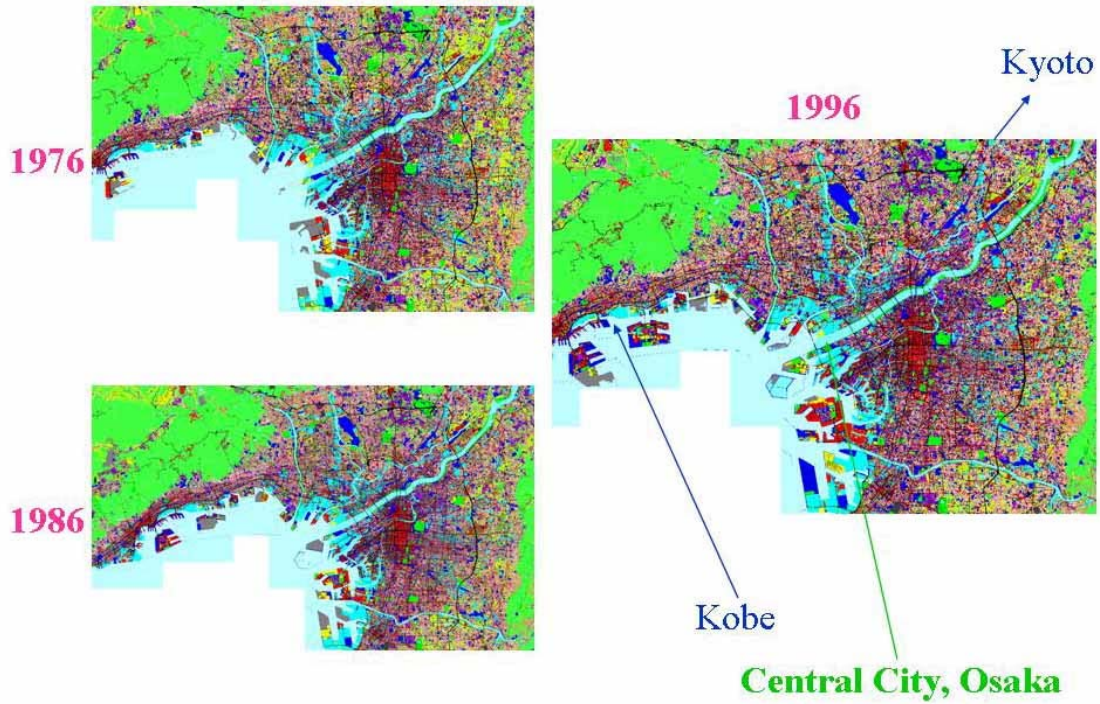


Fig. 8 The land use transformation in the Keihanshin metropolitan area (1976-1996)

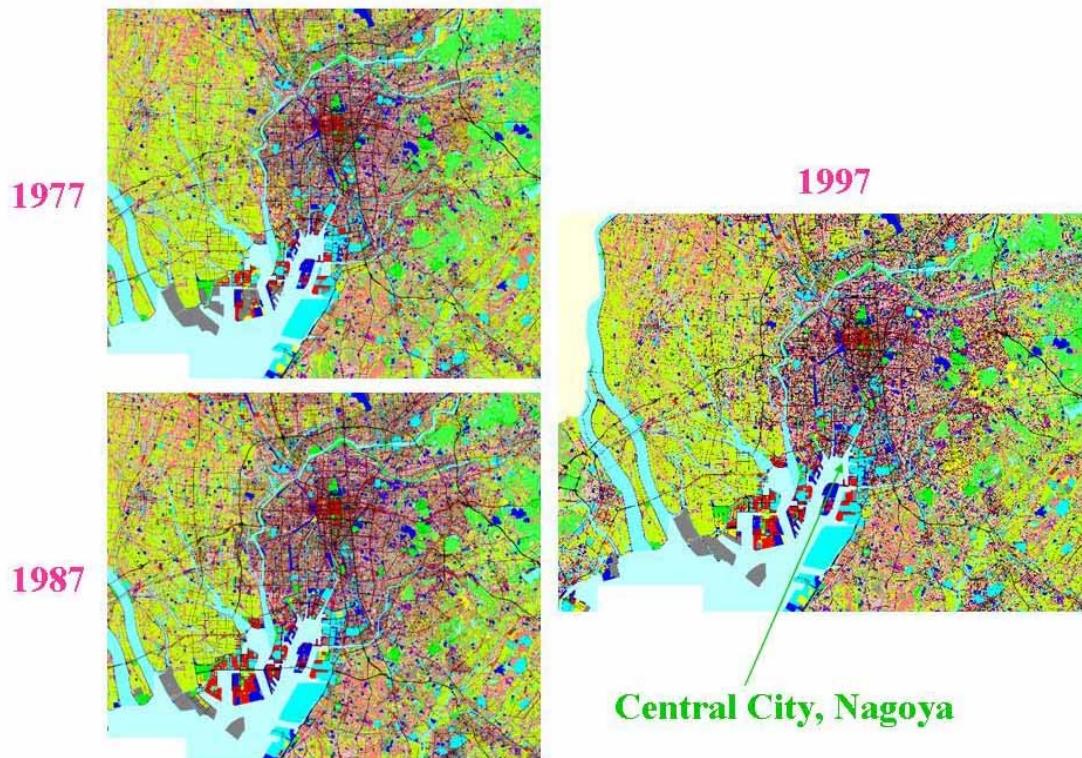


Fig. 9 The land use transformation in the Chubu metropolitan area (1977-1997)

density are relatively scarce in the Chubu metropolitan area, which is also relatively rich in public green spaces. Comparison of land uses among the three different points of time reveals that, despite the progress of suburbanization over the 20-year period, the depletion of public green spaces and forests has been less acute than in the Tokyo metropolitan area. Farmlands in the northwestern and southeastern parts of the Chubu metropolitan area have been converted into urban districts and so have been forests in the northeastern part.

D. Comparison of the three metropolitan areas in Japan

From these observations of Japan's three major metropolitan areas, it is fair to say that the lack of green spaces is posing a grave problem particularly in the Tokyo metropolitan area in which highly dense areas extend as far as 40 kilometers from the city center. This is also causing a serious land use problem in the Tokyo metropolitan area. In the Chubu metropolitan area, which is the prime focus of this study, urban density is not as high as in the Tokyo and Keihanshin metropolitan areas. However, the economic growth and reinvigorated industrial activities, as witnessed in the recent years, may result in greater urbanization of the Chubu metropolitan area.

VI. EVALUATION OF THE DEGREE OF THE SUFFICIENCY OF PUBLIC GREEN SPACES IN THE CHUBU METROPOLITAN AREA

A. Extraction of areas under evaluation

City areas in Aichi Prefecture are designated as areas subject to evaluation for the purpose of this study. This is because detailed digital maps are available for almost all city areas in the prefecture and various statistical data, collected under the conditions identical to those used in this study, are obtainable. The areas for which detailed digital map data are available have been divided into Nagoya as the central city and two outer areas based on the direct distance from Nagoya's city center, namely, suburban areas within 20-kilometer radius from the city center and outskirt areas within 40-kilometer radius.

Four cities from each of these areas have been picked as representative cities subject to evaluation. TABLE III shows the regional characteristics of the cities under evaluation, and Fig. 10 provides summaries of locational conditions of these representative cities focusing on the direct distance from Nagoya's city center. When a per capita area is seen especially among public green spaces based on TABLE III paying attention to urban park, it turns out that this areas of the suburban areas and outskirt areas are necessarily large than the one of Nagoya.

Fig. 11 provides an overview of the relationships between population density and per capita urban park area observed in 32 cities in Aichi Prefecture. We can see that most of these cities in the prefecture fall under the range of population density of 5,000 to 6,000 persons per square kilometer, with per capita urban park area mostly within the range of 5 to 10 square meters. Cities located within the 10 to 20 kilometer radius from the central district of Nagoya and those within the 20 to 30 kilometers respectively have the common features as

shown in Fig. 11. The cities subject to evaluation under this study generally follow the average trend with the only exception of Nagoya whose population density is conspicuously higher than those of other cities.

Meanwhile, the impact of distance from the central district of Nagoya is visibly reflected in population density but not so much in per capita urban park area. More specifically, cities closer to Nagoya tend to have high population density but per capita urban park area in these cities are not necessarily small. Of the cities subject to evaluation under this study, Ichinomiya and Inuyama have less urban park space per person than Nagoya.

Below based on these things, the evaluation results are arranged for every distance belt.

TABLE III
 REGIONAL CHARACTERISTICS OF THE CITIES FOR EVALUATION

Evaluation area	City	Direct distance from Nagoya's city center	Population (Person)	Urban park area per population (m ²)
Central part	Nagoya	-	2,202,111	6.8
Suburban area	Seto	16.7	132,380	7.9
	Ichinomiya	16.7	378,503	4.9
Outskirt areas	Inuyama	21.2	74,670	4.9
	Kariya	21.3	139,178	8.2
	Okazaki	35.2	367,792	10.1

Note) The data of population and urban park area is quoted from the homepage of Aichi Prefecture.

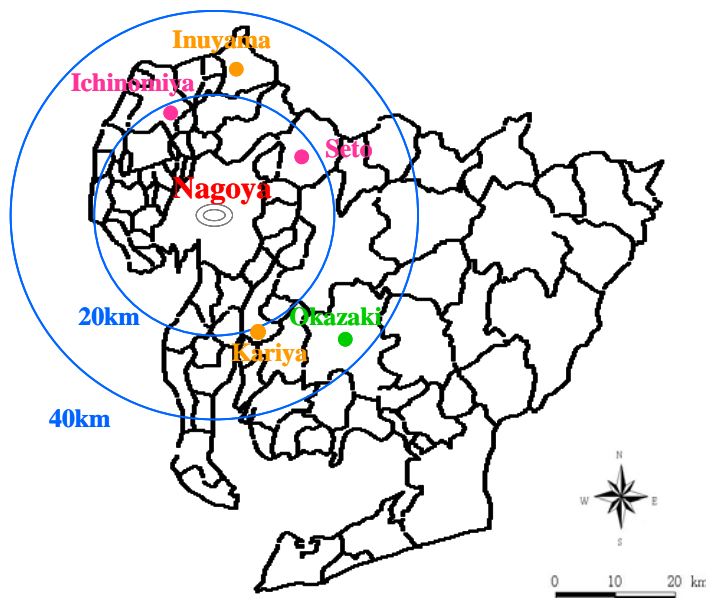


Fig. 10 Evaluation cities (Aichi Prefecture)

B. Evaluation results

The maps in Fig. 12 and Fig. 13 show how land is used in Nagoya as well as in two suburban cities located within the 20-kilometer radius from Nagoya, namely, Seto in the northeast and Ichinomiya in the northwest. Zones shown in light green represent public green spaces. In the city of

Nagoya, there exist few public green spaces apart from Nagoya Castle Park and Central Park. The city of Seto abounds in forest-covered hills with the extensive distribution of public green spaces observable in areas along urban districts in the central to southwest part of the city. In Ichinomiya, urban districts are densely located in the city center but areas surrounding these districts abound in public green spaces.

Let me present the evaluation results for outskirts areas, again based on land use maps. The maps in Fig. 14 and Fig. 15 illustrate how land is used in two cities located within the 30-kilometer radius from Nagoya, i.e. Inuyama in the north and Kariya in the southeast, as well as in Okazaki located within the 40-kilometer radius in the southeast of Nagoya. In Inuyama, forest-covered hilly terrain is observed in the eastern and northern parts of the city, while the central part of the city is characterized with modest urban density and the extensive distribution of public green spaces. In the city of Kariya,

urbanization has taken place along major roads, resulting in the widely dispersed location of the urban districts and extensive public green space distribution in the surrounding areas. In Okazaki, with forest-covered hills lying in the eastern part of the city, urban density in the central urban area is greater than in other cities located in the same distant zone but extensive public green space distribution is observed in the southwestern part of the city.

From these observations, we can say that cities in the outskirts areas, as compared with those in the central and suburban areas, feature more extensive forest coverage in the hilly terrain. Cities in the outskirts areas also have extensive public green space distribution observable even in the city centers. As for cities in the central and suburban areas, it is necessary to consider ways to secure adequate public green spaces particularly in the city centers.

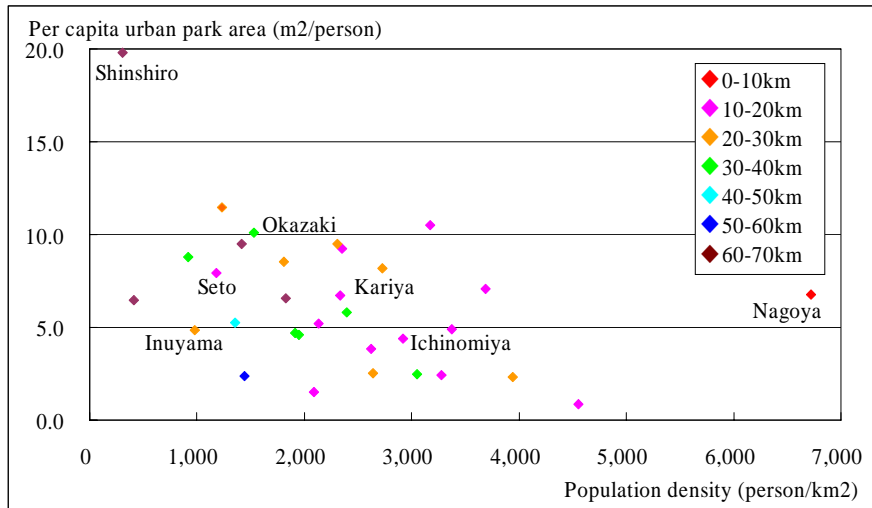


Fig. 11 The relevance of population density and a per capita urban park areas of 32 cities in Aichi Prefecture
 Note: The data of population density and urban park area is quoted from the homepage of Aichi Prefecture.



Fig. 12 Land use in Nagoya in central area (1997)

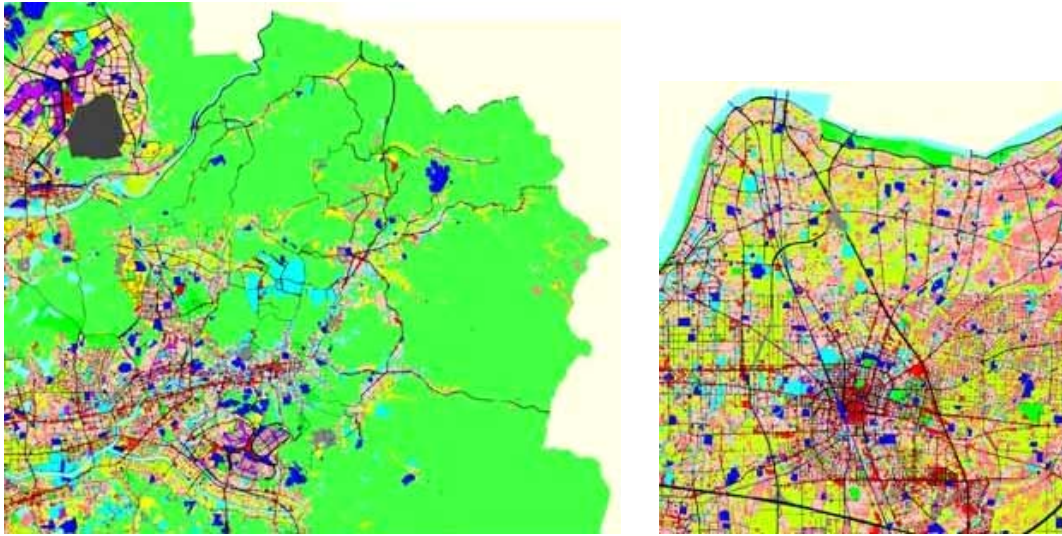


Fig. 13 Land uses in Seto in the direction of northeast (left map) and Ichinomiya in the direction of northwest (right map) within 20km (1997)

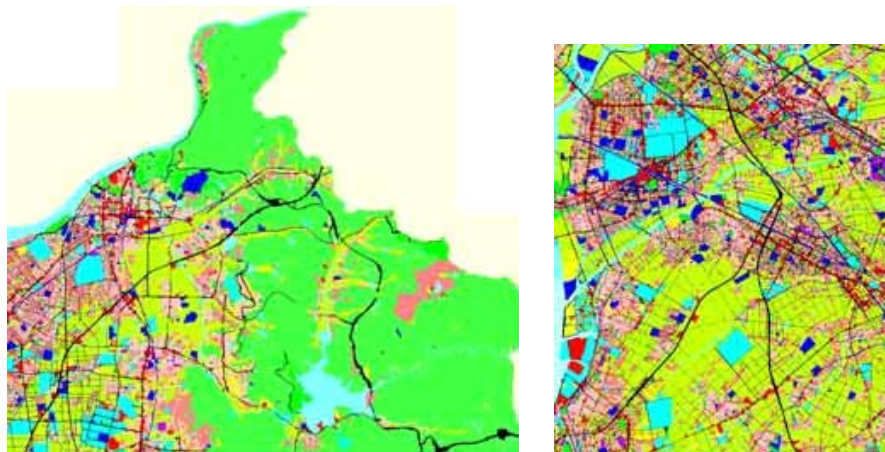


Fig. 14 Land Uses in Inuyama in the direction of north (left map) and Kariya in the direction of southeast (right map) within 30km (1997)

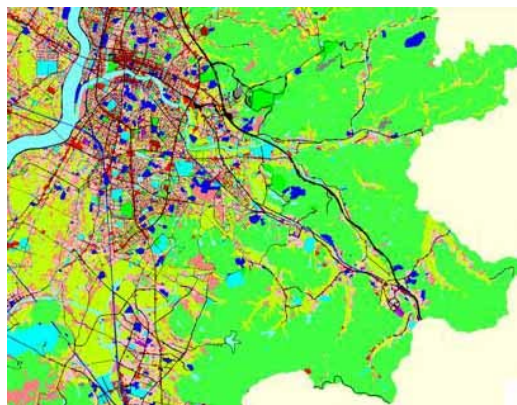


Fig. 15 Land use in Okazaki in the direction of southeast within 40km (1997)

VII. CONCLUSION AND SUBJECT FOR FUTURE RESEARCH

The findings of this study can be summarized into the following three points:

- (1) Lack of green spaces is more acute in Japan's metropolitan areas than in those in other parts of Asia and other developed countries. In the Chubu metropolitan area, urban density is not as high as those in the Tokyo and Keihanshin metropolitan areas but urbanization may accelerate in the future due to the economic growth and further concentration of industrial activities in the region. Yet, the Chubu metropolitan area features the city center that still accommodates several major open spaces and wide roadways, while the suburban areas in the region enjoy greater presence of forests and farmlands than in the other two metropolitan areas.
- (2) The Chubu metropolitan area has suffered green space depletion in the suburban areas in the east of Nagoya over the 20-year period from 1977 to 1997. The impact of distance from the central district of Nagoya can be vividly observed in population density but not so much in per capita urban park area. However, the greater the distance from Nagoya, the greater the forest distribution in the hilly areas and so is the presence of public green spaces within city centers. Meanwhile, green spaces are scarce in the city centers of Nagoya and its suburban areas because urban districts are densely clustered there. It is therefore necessary to secure adequate public green spaces in such city centers.
- (3) Urban density is particularly high in the central parts of Japan's three major metropolitan areas and it is extremely difficult to create new green spaces within the existing urban districts there. It is thus necessary – and important as a way to alleviate the heat island phenomenon and to conserve urban environment – to promote the greening of urban areas, not only public land but also land under private ownership, by means of rooftop and wall gardening of buildings.

As a subject for future study, a more detailed analysis of the areas evaluated in this study is needed to identify – on a district-by-district or grid-by-grid basis – the areas where public green space are scarce, and then to propose a set of viable reform measures.

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