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Landscape ecological characteristics in temporal changes of riverside open space in urbanized area

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Abstract—The aim of this paper is to clarify the pattern and process of changes of landscape in riverside open spaces in urbanized area. The area between the old banks of the Furukawa River in Hiroshima City was examined in this research. The land-use maps of the study area were drawn at seven different times were analyzed, and the number, sizes and perimeters of all patches of all land-use types were measured. In these areas, temporal patterns of land-use change over the past 30 years were divided to three stages: 1966—1976, 1976—1988 and 1988—1997. As a result of human disturbance, the riparian forest patches in urbanized areas have decreased in average size and have also become longer and narrower.

Keywords: human disturbance, landscape index, park planning, riparian vegetation, urbanization.

1 Introduction

Recently in Japan, the river space in urban areas is changing into river parks, river open space and nature-oriented bank. Consequently, it is necessary to re-evaluate river open space from multiple aspects: hydraulics, landscape architecture, ecology, economics and so on. Particularly, ecological evaluation of river space has attracted significant attention from the scientific community.

To detect patterns of human impact in landscape development, a gradient of landscape modification, extending from natural landscape to urban landscape, has been observed (Forman, 1986). A few studies investigated temporal change in landscape structure in urbanized area in Japan (Osawa, 1987). Such studies reported the landscape changes and the landscape structure of forest patches in urbanized areas systematically. Landscape changes in riparian zones were studied by Maekawa and Nakagoshi (Maekawa, 1997). However, none of the reports (including other case studies), have clarified landscape structure of the riverside open space in urbanized area.

The purposes of this study are (1) to reveal the pattern and process of land-use change in urbanized areas in relation to the socio-economical background; and (2) to reveal characteristics of landscape structure in relation to change in riverside open space in urbanized areas.

2 Study area

The Furukawa River is 6.1 km long, flows through a suburb of Hiroshima City and is tributary of the Ota River. This river is 9 km north of the central part of Hiroshima City (Fig. 1). Its drainage area and design-flood discharge are 9.5 km^2, 100 t/s, respectively. This river is the remainder of the Ota River that was changed to its current state by the deluge of 1609. Before 1969, this river had drained one fourth of design-flood of the Ota River. Conservation works in 1969 divided this river from the main stream of the Ota River, and created a vast and convenient area for development. The study site was set in an area between the old banks of the Furukawa River. The area covers 72 hm^2 in the upstream where urbanization seems most conspicuous.

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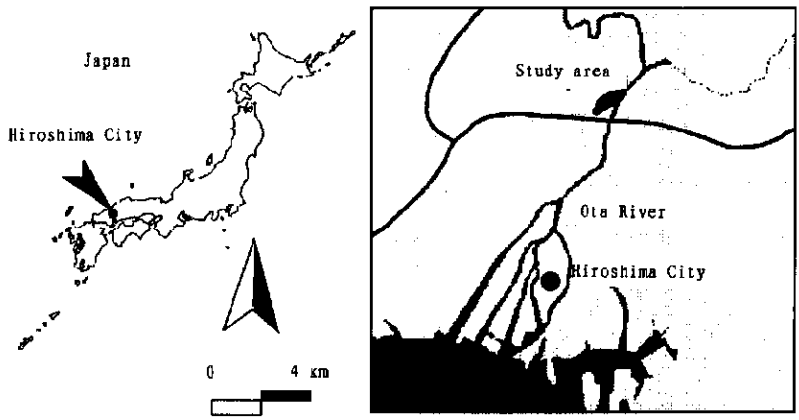

Fig.1 Location of the study area within Hiroshima City

3 Methods

To study the changes in the landscape, we made land-use maps at a scale of 1 : 5000. Procedures of land-use mapping are as follows. The land-use map in 1997 was made based on field surveys and the planning map of Hiroshima City (drafted in 1991, scale 1 : 2500), land-use and precedents for land-use types were established. The land-use maps from 1981 to 1995 were made by interpreting aerial photographs taken in 1981, 1988 and 1995 (1 : 10000). The past land-use maps were made by interpreting actual vegetation maps from three different years 1966, 1972 and 1976(1 : 5000; Ando, 1977).

Legends for the land-use are (1) riparian forest (including bamboo); (2) grassland; (3) agricultural land; (4) park areas; (5) residential areas (including bare area) and (6) others (streams etc.). We analyzed each of the land-use types. Moreover, with land-use maps from 1976, 1995 and 1997, we measured the number of all patches of each land-use type and their sizes were measured in three land-use maps with an electric planimeter. In addition, we researched the exploitation history in this area through several publications.

4 Results

4.1 Landscape dynamics

Land-use maps of the study area are shown in Fig.2. The research indicated that riparian forest and agricultural land have decreased and residential areas have increased in this time period. This can be explained by noting that the urban development accelerated within the study period time frame.

The changes in relative dominance of land-use types since 1966 are shown in Fig.3. We discovered that the changes in land-use in the study underwent three stages of urbanization.

During the first stage, from 1966 to 1976, the land-use was gradually changed from riparian forest to residential area, and agricultural land did not decrease. In this stage, the dominance of residential areas in the study area increased from 17% in 1966 to 49% in 1976. The study area was transformed from an agriculture landscape to a suburban landscape.

In the second stage, from 1976 to 1988, the landscape did not dramatically change as it had in first stage. Agricultural land hardly changed but residential areas and riparian forest slightly decreased, park areas increased.

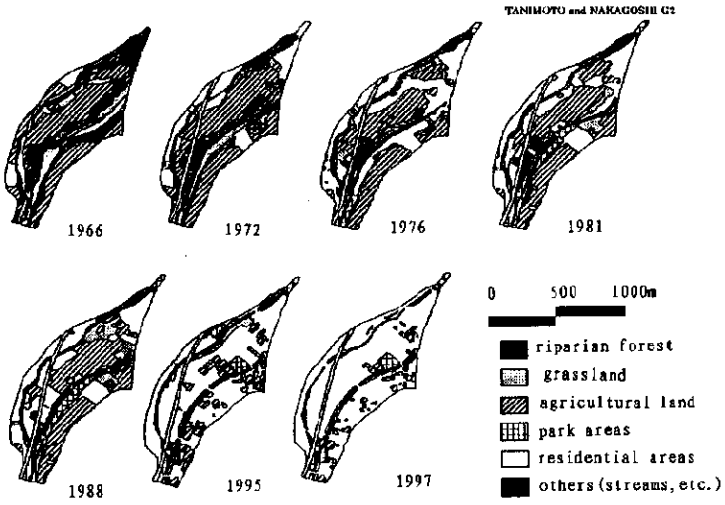

Fig. 2 Land-use maps of the study area (1966—1997)

During the third stage, from 1988 to 1997, agricultural land rapidly converted into residential areas. The dominance of residential areas increased from 41% in 1988 to 82% in 1997. In this stage, the study area tended to change to urbanized landscape.

4.2 Landscape characteristics of the patches related to greenery space

Landscape characteristics of greenery space (riparian forest, grassland, agricultural land and park areas) were measured and summarized in 1976, 1995 and 1997 as shown in Table 1 and Table 2. Numbers of patches and mean patch size are shown in Table 1. Both the total number of patches and the total mean patch size increased from 1976 to 1997. This resulted in a decrease of greenery space. Riparian forest patches and grassland patches changed with the same trend. However, agricultural land patches decreased in size, but increased in number. This suggests that agricultural land patches were fragmented. Accordingly, park area patches increased in number, but hardly changed in size.

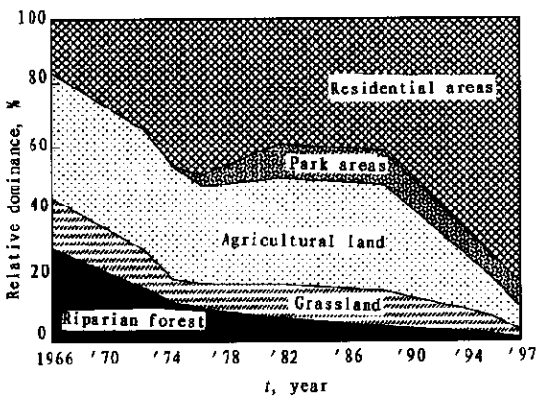

Fig. 3 Change of land-use proportions in the Furukawa area in Hiroshima City showing by relative dominance (1966—1997)

Table 1 Temporal change in number of patches and mean patch size

Land-use type	Landscape character					
	Number of patches			Mean patch size, hm^2		
	1976	1995	1997	1976	1995	1997
Riparian forest	36	20	15	0.18	0.08	0.04
Grassland	66	16	12	0.13	0.24	0.08
Agricultural land	18	37	34	1.26	0.25	0.14
Park areas	5	15	17	0.38	0.36	0.39
Total	125	8	78	0.32	0.23	0.17

Mean perimeter of patches and shape index(the perimeter of a patch divided by the perimeter of a circle of the same size; Forman, 1986) are summarized in Table 2. This indicates that total mean perimeter decreased while total shape index hardly changed. The point to be emphasized in Table 2 is the overall increase in the shape index of riparian forest units.

Table 2 Temporal changes in mean perimeter shape index of patches

Land-use type	Landscape character					
	Mean Perimeter, m			Shape index		
	1976	1995	1997	1976	1995	1997
Riparian forest	191	156	135	1.26	1.54	1.85
Grassland	316	397	188	2.50	2.28	1.83
Agricultural land	498	216	160	1.25	1.23	1.20
Park areas	432	458	444	1.97	2.15	1.99
Total	311	276	221	1.56	1.63	1.52

5 Discussion

Historical data concerning the study area are shown in Table 3. The land-use in the study area began to change in accordance with urbanization in the north part of Hiroshima City.

Table 3 History around the study area

Year	Event
1967	The opening of route 54 Sato bypass construction
1969	The completion of Furukawa River closed dyke construction
1973	Merger with Hiroshima City
1981	The completion of Furukawa Seseragi Park construction
1987	The commencement of Furukawa land re-adjustment

During the first stage, land-use was gradually changed after the construction of roads and bridges in 1967. Many suburban type shops, such as used are shops and car dealers, were built over riparian forests including bamboo.

In the second stage, land-use did not change significantly. This is the effect that most of the study area was urbanization coordination area on Hiroshima City Plan in those days. In accordance with furukawa Seseragi Park construction, bare areas (a part of residential areas) have changed only slightly into park areas.

In the third stage, the rapid land-use changes occurred simultaneously with the land-re-adjustment witch began in 1987. The change led to the creation of housing, park areas, promenades and commercial facilities. In contrast, agricultural land area was extremely reduced. The loss of agricultural land is caused by the area having become an urbanization promotion area and the value of housing sites having become larger rather than agricultural land. Consequently, it seems that the loss of riparian forest was minimal because the area of riparian forest that could be developed disappeared.

It can be postulated that the first stage was a natural urbanization process and the third stage was a planned urbanization process.

Artificial greenery spaces (park areas) have expanded. In Japan, river parks began to make up for lack of open space in urban zones from the 1970s. Base on this and in response to demands of the study area residents, Furukawa Seseragi Park planned and constructed by the Ministry of Construction. Bridges were made in equal intervals with the result the patches of park areas became same size. Park areas were then expanded in accordance with development of the river

construction.

Natural green space (riparian forest, grassland and agricultural land) were fragmented, reduced and gradually disappeared. The grasslands that was in river park construction areas also disappeared. Riparian forest patches decreased in size and their shape index became larger. From an ecological perspective, these results represent unfortunate consequences, but riparian forest might become easy to use for the residents of these areas.

The fragmentation of forest patches is the inevitable phenomena in urbanized areas(Burgess, 1981; Hariss, 1984). In Japan, it is reported that forest patch size has decreasing and a number of patches show a pattern of increase in urbanized areas(Ohsawa, 1987). They also indicate the shape of forest patches is trending to be circular in shape. In contract, we found that the shape of riparian forest units has actually become narrower and longer. We assumed that each landscape characteristic is different from the others because the original differences in the landscape systems and the scale of the investigation. We must accurately gauge the extent and effects of urbanization in suburban areas surrounding Japanese cities.

In conclusions, the landscape ecological approach to the changing landscapes in the northern part of Hiroshima City can be summarized as follows:

Patches of agricultural lands increased in number and patch size became smaller. Furthermore, the overall number of parches decreased in 1997 and many patches have been converted into residential areas after landscape fragmentation.

Patches of artificial vegetation areas(such as river areas) increased in number but there was no change in the mean size of patches. This shows an expansion tendency in the area.

The shape index generally became smaller according to the reduction of patch size, which was caused by urbanization. In contrast to this, the shape index of riparian forest units included bamboo units became larger. It seems quite reasonable to conclude that long and narrow patch is a reflection of human impacts.

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