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Relationships between recent land-use change and legal land-use classification in the area of greater Sapporo

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Abstract

Recent land-use changes in expanding urban areas were studied by using two land-use area files (1976 file and 1991 file) of the Digital National Land Information in Japan. The purpose of this study was to clarify the relationship of increases and decreases in the use of four land types (agricultural land, urban land, barren land, natural land) to the legal land-use classification. The areas studied were seven municipalities in the area of greater Sapporo (Sapporo City, Ebetsu City, Chitose City, Eniwa City, Kita-Hiroshima City, Ishikari City, Tobetsu Town).

Urban land-use significantly increased in all of the seven study areas, while the use of agricultural and natural land decreased in varying degrees in the study areas : a notable decrease in agricultural land-use in four municipalities (Sapporo City, Ebetsu City, Eniwa City and Ishikari City), a notable decrease in the use of natural land (mainly forest land) in two municipalities (Chitose City and Tobetsu Town), and a similar degree of decrease in the use of agricultural and natural land in Kita-Hiroshima City. The area of barren land increased in three municipalities (Sapporo City, Kita-Hiroshima City and Ishikari City) and decreased in the other four municipalities.

The area of land-use change was greatest in Sapporo City, followed by Ishikari City, Chitose City and Ebetsu City. In terms of population, the area of land-use change was greatest in Ishikari City. In terms of legal land-use classification, land-use change was greatest in the urbanization-promotion area of five municipalities (Sapporo City, Ebetsu City, Eniwa City, Kita-Hiroshima City and Ishikari City), while the greatest changes in land-use in Tobetsu Town and Chitose City were in the agricultural land zone and in the area of other land, respectively. In many of the municipalities, the second-greatest area of land-use change was in the white zone of the agriculture-promotion area.

Land-use change in the urbanization-promotion area was mainly change from agricultural land-use to urban land-use, although change from agricultural land-use to barren land was also a significant factor in Ishikari City. In the agricul-

tural land zones, agricultural land-use increased in all of the municipalities except Sapporo City and Ebetsu City, while natural land (forest) and barren land (peat-land) decreased, reflecting an increase in agricultural land reclamation. In the white zone of agriculture-promotion areas, urban land-use and barren land increased, while the use of agricultural land and natural land (forest) decreased. In the area of other land, there was a notable change from the use of natural land-use (forest) to urban land-use in Chitose City due to the construction of a new airport.

As for the relationship between land-use change and the regional environment, the notable increase in barren land in Ishikari City and Sapporo City indicates that there is a continuous change from agricultural land to barren land (unused land) in the white zone of agriculture-promotion areas in the suburbs. In order to maintain a good regional environment, effective utilization of barren land is important.

Introduction

Sapporo City and nine surrounding municipalities (Ebetsu City, Chitose City, Eniwa City, Kita-Hiroshima City, Ishikari City, Tobetsu Town, Atsuta Village, Otaru City, and Nanporo Town) comprise the area of greater Sapporo[1]. Urban land-use in most of these municipalities is increasing due to the increasing population. An increase in urban land-use generally means encroachment on agricultural and forest land, which changes the regional environment. Urbanization is controlled by a legal land-use plan, and the main zoning divisions are the urbanization-promotion area and urbanization-control area, regulated by the City Planning Act, and the agricultural land zone and white zone, regulated by the Agriculture-Promotion Areas Act. Thus, in order to clarify the relationship between increase in urban land-use and changes in the area of agricultural and forest land, the characteristics of land-use changes and the relationship between land-use change and environment in each zoning area of the legal land-use plan must be investigated. For this purpose, data from 1976 and 1991 land-use area files of the Digital National Land Information in Japan[2] can be used to analyze land-use changes during the period of 1976–1991 by the third mesh level of the Japanese standard regional mesh system[3].

The purpose of this study was to clarify the relationship between recent land-use changes in the area of greater Sapporo and the legal land-use classification and to examine the effects of an increase in urban land-use on agricultural and forest land and on the regional environment.

Methods

1. Study areas

The areas studied were Sapporo City and six surrounding municipalities (Ebetsu City, Chitose City, Eniwa City, Kita-Hiroshima City, Ishikari City, and Tobetsu Town) (see Figure 1). Table 1 shows the population, number of farm households, rate of increase or decrease in population and number of farm households, total land area, and percentage of each landform.

Fig. 1. Location of study areas (■Municipal office)

The rate of population increase from 1970 to 1995 exceeded 50% in all of the municipalities except Tobetsu Town. The increases in the populations of Kita-Hiroshima and Ishikari were especially large, and these two municipalities changed from town to city status in 1996. On the other hand, the number of farm households decreased significantly (by more than 30%) during the same period. In Sapporo City, the rate of decrease in farm households during this period was more than 50%. There is a large variation in topography of the study areas: Sapporo City, Chitose City, Eniwa City and Tobetsu Town, municipalities with large total land areas, have large areas of mountains, hills and plateaus, whereas the topography of Ebetsu City and Ishikari City is mainly lowland and more than

Table 1. Outline of each municipality

Municipality	Population	No. of farm households	Rate of increase or decrease (%)		Total land area(km²)	Percentage of each landform(%)			
			Population	Farm households		Mountain	Hill	Plateau	Lowland
Sapporo	1,757,025	1,800	73.9	−57.0	1,120.2	61.5	8.5	7.4	22.6
Ebetsu	115,495	724	81.1	−45.4	187.3	0.0	0.0	27.0	73.0
Chitose	84,860	415	51.2	−44.0	594.7	28.8	7.2	47.8	16.2
Eniwa	62,351	559	81.0	−45.0	293.9	22.4	39.0	13.9	24.7
Kita-Hirosihma	53,356	333	449.3	−46.7	119.1	3.3	26.5	57.0	13.2
Ishikari	52,209	447	397.1	−45.6	118.5	1.6	8.2	10.7	79.5
Tobetsu	19,672	1,104	6.1	−33.7	421.1	50.1	18.2	4.6	27.1

Note: Data of population and no. of farm households are for 1995, and the rate of increace is the change from 1970 to 1995.

50% of the topography of Kita-Hiroshima City is plateau.

Table 2 shows the number of third-mesh units in each of four legal land-use areas (urbanization-promotion area, agricultural land zone, white zone, and area of other land) for each municipality. The number of third-mesh units in each area was calculated by using the latest publications of city planning and agriculture-promotion maps for each municipality. The area of other land is the area that does not correspond to the urbanization-promotion area or the agriculture-promotion area (agricultural land zone and white zone), which includes most of the mountainous area (outer part of the city planning area and outer part of the agriculture-promotion area) and the urbanization control area that does not overlap with the agriculture-promotion area. Third meshes which include plural kinds of legal land-use area were classified as one with maximum area.

Table 2. Legal land-use classification and third meshes

Municipality	Numbers and percentages (in parenthesis) of third meshes				
	Urbanization-promotion area	Agricultural land zone	White zone	Area of other land	Total
Sapporo	276(22.9)	12(1.0)	149(12.3)	769(63.8)	1206(100.0)
Ebetsu	33(16.1)	108(52.7)	16(7.8)	48(23.4)	205(100.0)
Chitose	36(5.6)	100(15.6)	23(3.6)	483(75.2)	642(100.0)
Eniwa	23(7.2)	58(18.1)	12(3.8)	227(70.9)	320(100.0)
Kita-Hiroshima	17(13.2)	33(25.6)	57(44.2)	22(17.0)	129(100.0)
Ishikari	33(24.8)	39(29.3)	49(36.9)	12(9.0)	133(100.0)
Tobetsu	9(2.0)	133(28.8)	53(11.5)	266(57.7)	461(100.0)

The size of the urbanization-promotion area (number of third-mesh units), which is largest in Sapporo City and smallest in Tobetsu Town, is roughly proportional to the population size of each municipality. The reason why the number of third-mesh units in Chitose City and Ishikari City is similar to, or larger than, that in Ebetsu City, which has a larger population, is because both Chitose City and Ishikari City have large-scale industrial complexes included in their urbanization-promotion areas (the airport industrial complex in Chitose City and the new port industrial complex of Ishikari Bay in Ishikari City). The areas of the agricultural land zones in Ebetsu City, Chitose City and Tobetsu Town cover more than 100 mesh units, while the area of the agricultural land zones in Sapporo City covers only 12 mesh units. On the other hand, Sapporo has the largest white zone, followed by Kita-Hiroshima City, Ishikari City and Tobetsu Town. The area of other land comprises more than 50% of the total land areas of Sapporo City, Chitose City, Eniwa City and Tobetsu Town, municipalities that include large areas of mountains, hills and plateaus.

2. Analysis of land-use change

Table 3 shows eight land-use items for four land-use types, based on the

land-use classification in the 1976 and 1991 files of the Digital National Land Information in Japan. In order to estimate land-use change, i.e., increase or decrease in the area of each land-use type (area in the 1991 file — area in the 1976 file), the rate of land-use change (LUCR) and area of land-use change (LUCA) were calculated by the following equations.

$$LUCR=(\sum_{i=1}^{4}|\Delta LURi|)/2 \quad (1)$$

$$LUCA=(LUCR)\times(MLA) \quad (2)$$

where △ LURi is the percentage change in the area of each land-use type, and MLA is the municipal land area (Table 1).

Table 3. Land-use types and land-use items

Land-use type	Land-use item	Details
Agricultural	Paddy field	Paddy field
	Upland field	Ordinary upland, temporary meadows
	Orchard	Orchard (including land for other permanent crops)
Urban	Built-up area	Residential, commercial, industrial, main traffic, etc.
	Other urban	Urban open, airport, golf course, athletic field, stadium, etc.
Barren	Barren land	Bushland, wetland, open land, etc.
Natural	Forest land	Hardwood, softwood, mixed forest
	Water	Inland water(river, lake, pond), riverbed, etc.

Results and Discussion

1. Outline of municipal land-use

Table 4 shows the rates of land-use in the 1991 file for each municipality. The largest rate of agricultural land-use was in Ebetsu City (56.6%), followed by Ishikari City (40.2%) and Kita-Hiroshima City (30.8%). In Tobetsu Town, the rate of use of paddy fields was larger than that of upland fields and orchard . In the other municipalities, the rate of use of upland fields was larger than that of paddy fields. The rate of urban land-use is high in Kita-Hiroshima City (20.8%) and Sapporo City (20.4%) and lowest in Tobetsu Town (1.95). Sapporo City and Ebetsu City are the only municipalities in which the rate of use of built-up area

Table 4. Rates of land-use in 1991 file for each municipality

Municipality	Agricultural (%)			Urban (%)		Barren	Natural (%)	
	Paddy	Upland	Orchard	Built-up	Other urban	(%)	Forest	Water
Sapporo	0.62	6.11	0.30	13.39	7.01	7.46	63.38	1.73
Ebetsu	24.61	31.77	0.17	9.15	4.36	3.84	11.91	14.20
Chitose	1.17	13.14	0.04	2.11	5.14	5.04	59.37	14.00
Eniwa	9.18	10.35	0.17	2.65	3.69	17.51	55.18	1.27
Kita-Hiroshima	6.91	23.47	0.43	5.90	14.94	0.74	36.65	0.96
Ishikari	11.25	28.53	0.41	6.34	7.33	19.87	14.45	11.82
Tobetsu	15.83	9.94	0.00	0.88	1.02	7.77	61.72	2.84

is higher than that of other urban land. In the other municipalities, the rate of use of other urban land is higher, especially in Kita-Hiroshima City, which has many golf courses (7 courses in the city comprising a total area of 1,010ha)[4], and in Chitose City, in which a large area of land (1,692ha)[5] is used for the airport. Ishikari City and Eniwa City have large percentages of barren land. This is due to the large area of unused land in the new port industrial complex of Ishikari Bay in Ishikari City and the maneuvers fields (Shimamatsu and Eniwa, 6,864ha)[6] of the Self-Defence Forces in Eniwa City. Sapporo City, Chitose City, Eniwa City and Tobetsu Town, municipalities in which a large percentage of the land area consists of mountains, hills and plateaus, have high rates of use of natural land, with forest land accounting for more than 50%. The percentage of water area is relatively high (more than 10%) in Ebetsu City and Ishikari City, areas through which the Ishikari River flows, and in Chitose City, where Lake Shikotsu is located.

Figure 2 shows the rates of land-use for each legal land-use area. The graphs clearly show that the main types of land use in the urbanization-promotion area, agricultural land zone and the area of other land are urban land-use, agricultural land-use and natural land-use, respectively. However, in the white

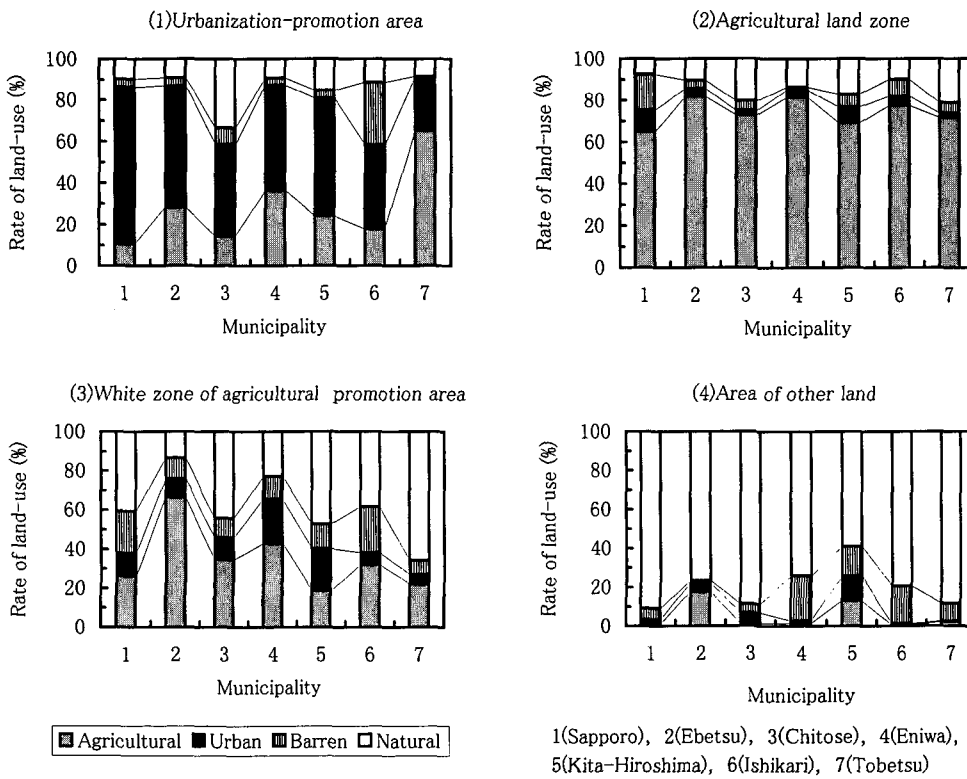

Fig. 2. Land-use characteristic of each legal land-use area (1991 file)

zone of the agriculture-promotion area, there is a large variation in the rates of land-use, indicating vagueness in the legal land-use classification. The large rate of agricultural land-use in the urbanization-promotion area of Tobetsu Town is due to the small area designated for urbanization-promotion because of the small population of the town, which meant that there was a higher probability of the agricultural land zone surrounding the urbanization-promotion area being included in the urbanization-promotion area in third-mesh mapping.

2. Recent land-use changes

Figure 3 shows the differences between rates of land-use in the 1976 file and 1991 file for the four land-use types in each municipality. The changes in land-use in all municipalities are relatively simple : urban land-use increased in all municipalities, while the use of agricultural land and natural land (forest) decreased in most of the municipalities. The largest decrease in the rate of agricultural land-use was in Ishikari City (14.1%), followed by Ebetsu City (6.2%) and Sapporo City (4.1%). The decrease in the rate of natural land-use was largest in Chitose City (2.3%), followed by Ishikari City (1.9%) and Kita-Hiroshima City (1.3%). On the other hand, the rate of agricultural land-use increased in Chitose City and Tobetsu Town, and the rate of natural land-use increased in Ebetsu City. Changes in the area of barren land were the most complex ; the area of barren land increased in three municipalities (Ishikari City, Sapporo City and Kita-Hiroshima City) and decreased in four municipalities

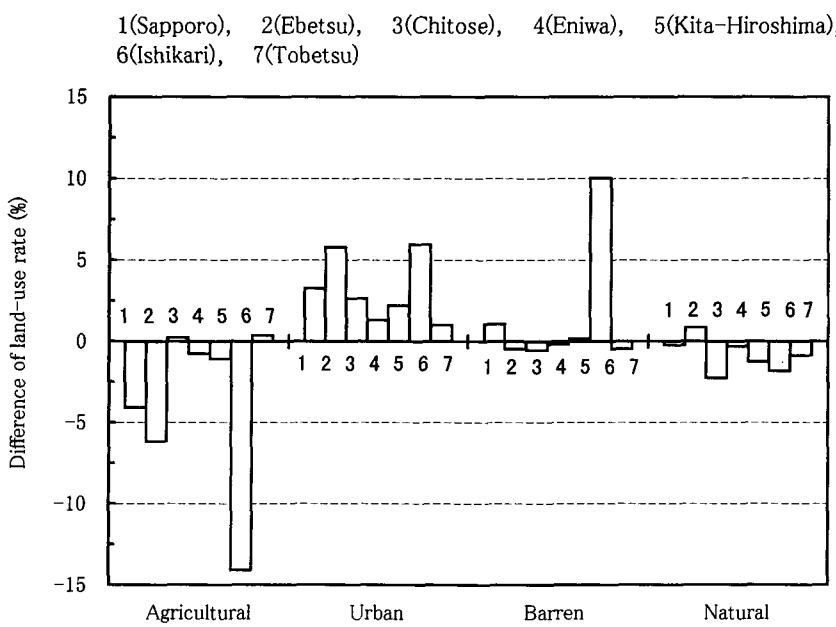

Fig. 3. Difference of land-use rate from 1976 file to 1991 file on each whole municipal area

(Ebetsu City, Chitose City, Eniwa City and Tobetsu Town). The increase in the area of barren land in Ishikari City (10%) was particularly notable. The overall picture shows that the main sources of the increase in urban land-use were agricultural and natural (forest) land, while behaviors of barren land depend on each municipality.

Figure 4 shows the rate of land-use change (LUCR) and the area of land-use change (LUCA), calculated from the differences in rates of land-use by using equations (1) and (2), for each municipality. LUCR was by far the largest in Ishikari City (16.0%), followed by Ebetsu City (6.7%), Sapporo City (4.3%), Chitose City (2.9%), Kita-Hiroshima City (2.4%), Tobetsu Town (1.4%) and Eniwa City (1.3%). This means that the use of about 15 % of the total land area of Ishikari City changed. Since LUCR is the percentage change in the total land area of the municipality, it would be an underestimation of land-use change in large municipalities with large areas of mountains. In terms of area of land-use change (LUCA), Sapporo City was by far the largest (48.5 km^2), followed by Ishikari City (18.9 km^2), Chitose City (17.0 km^2) and Ebetsu City (12.5 km^2). The fact that both the LUCR and LUCA were large in Ishikari City, which has a relatively small population, is thought to be due to the previously mentioned development of the new port industrial complex of Ishikari Bay.

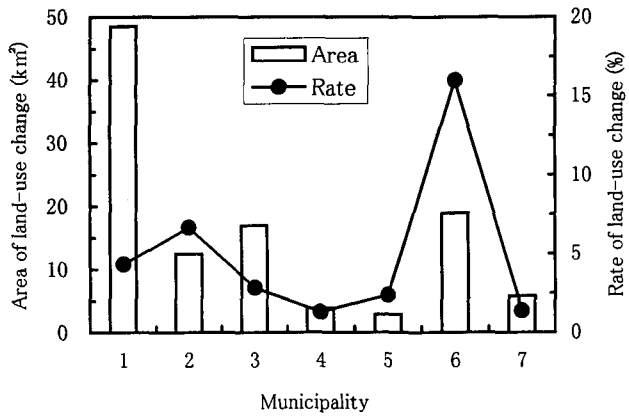

Fig. 4. Area and rate of land-use change in each whole municipal area (numbers representing municipalities are the same as those in Fig.2)

Next, in order to compare the degrees of land-use change in each legal land-use area, the contribution of change in each legal land-use area to change in the total land area was calculated. The results are shown in Figure 5. Changes in land-use in the urbanization-promotion area accounted for more than 50% of total land-use change in four municipalities (Sapporo City, Ebetsu City, Eniwa City and Ishikari City). In Chitose City and Tobetsu Town, the largest contributions to total land-use change were changes in the area of other land and

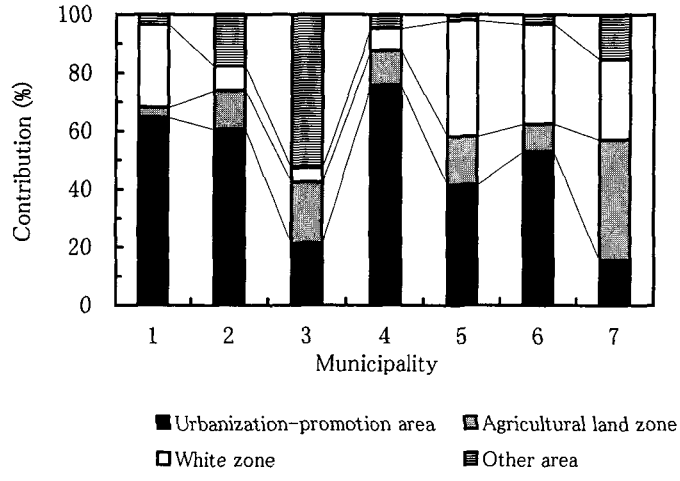

Fig. 5. Contribution of each legal land-use area to whole area of land-use change (numbers representing municipalities are the same as those in Fig. 2)

agricultural land zone, respectively. In Kita-Hiroshima City, land-use changes in the urbanization-promotion area and white zone were both around 40% of total land-use changes. Moreover, land-use change in the white zone was the second-largest contribution to total land-use change in three other municipalities (Sapporo City, Ishikari City and Tobetsu Town). These four municipalities (Kita-Hiroshima City, Sapporo City, Ishikari City and Tobetsu Town) all have relatively large designated areas of white zone (see Table 2).

Next, in order to examine the land-use changes in each legal land-use area, the contributions of change in each land-use type to the total land-use change were calculated for each municipality. The results are shown in Figures 6~9.

Figure 6 shows the land-use changes in the urbanization-promotion area. In all of the municipalities except Ishikari City, the only notable increase was in urban land-use ; the other three land-use types all showed a decrease in almost all of the municipalities. The decrease in agricultural land-use was especially notable, indicating that the main pattern of land-use change in the urbanization-promotion area was from agricultural land-use to urban land-use. In other words, it is thought that the built-up area expanded due to the inclusion of agricultural land, designated as either an agricultural land zone or a white zone of the agriculture-promotion area, in the urbanization-promotion area as a result of housing development accompanying an increase in population. In Ishikari City, although the increase in the area of barren land was larger than the increase in urban land-use, the large decrease in agricultural land-use was similar to that in the other six municipalities. In Sapporo City, Ebetsu City, Eniwa City and Ishikari City, both the decrease in agricultural land-use and the increase in urban

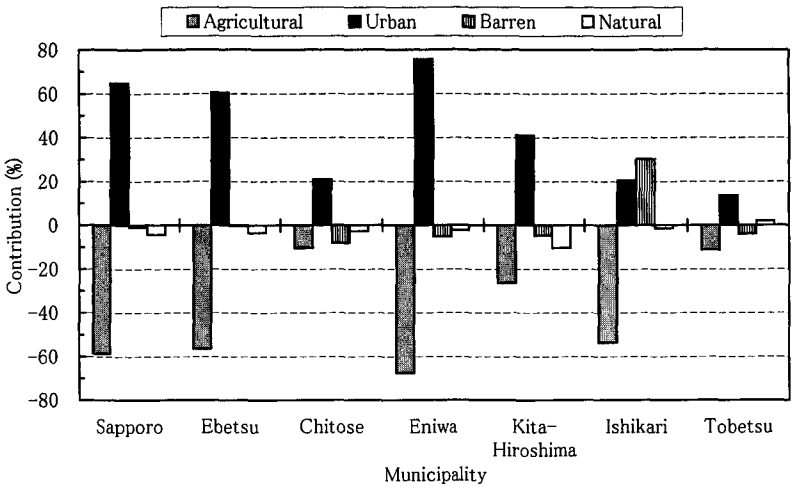

Fig. 6. Land-use change in the urbanization-promotion area

land-use (as well as the increase in barren land in Ishikari City) contributed to more than 50% of the total land-use change, indicating that this is the predominant change in whole land-use change in these municipalities.

Figure 7 shows the land-use changes in the agricultural land zone of the agriculture-promotion area. The largest increase in all municipalities except for Sapporo City and Ebetsu City was in agricultural land-use. The increases in agricultural land-use in Chitose City and Tobetsu Town were especially notable. On the other hand, two land-use types showed the largest decrease in these five municipalities in which agricultural land-use increased : natural land-use in three

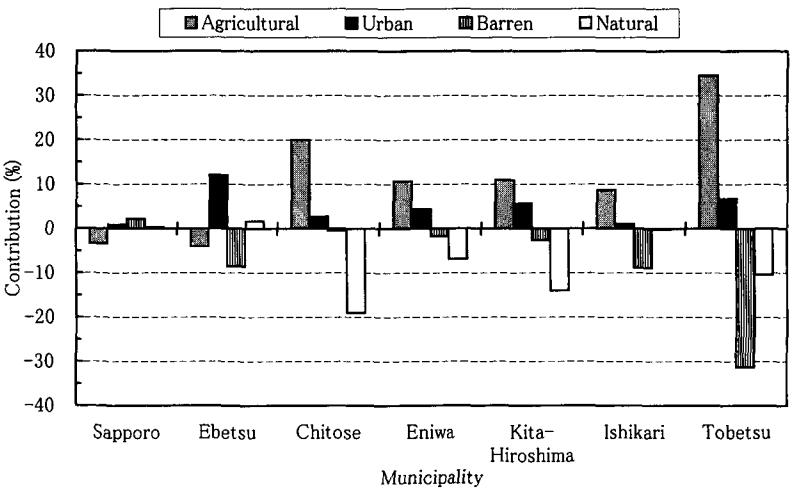

Fig. 7. Land-use change in the agricultural land zone of the agriculture-promotion area

municipalities (Chitose City, Eniwa City and Kita-Hiroshima City) and barren land in two municipalities (Ishikari City and Tobetsu Town). The fact that the rate of whole agricultural land-use decreased in all municipalities except Chitose City and Tobetsu Town indicates that the large decrease in agricultural land-use in the urbanization-promotion areas of Eniwa City, Kita-Hiroshima City and Ishikari City was compensated for, to some degree, by the agricultural land zone of the agriculture-promotion area. Moreover, the results in this figure indicate that in Chitose City and Tobetsu Town, agricultural land reclamation on a scale exceeding the decrease in agricultural land-use in the urbanization-promotion areas was carried out in the agricultural land zone. The main sources of an increase in agricultural land-use are forest land in the case of natural land-use and peatland in the case of barren land. As is the case in Ebetsu City, not only agricultural land-use but also urban land-use increases to some degree in the agricultural land zone of the agriculture-promotion area in many municipalities.

Figure 8 shows the land-use changes in the white zone of the agriculture-promotion area. The notable land-use changes in this area were large increases in urban land-use in Kita-Hiroshima City and Tobetsu Town and large increases in barren land in Sapporo City and Ishikari City. Most of the increase in urban land-use in Kita-Hiroshima City and Tobetsu Town was not in the built-up area but in the other urban land (golf courses or industrial sites). The source of land for the increase in urban land-use was natural land-use (forest land) or agricultural land, reflecting the mixture of land-uses in the white zone of the agriculture-promotion area. The main source of land for the increase in barren land in Sapporo City and Ishikari City was agricultural land ; surveys showed that many areas of agricultural land for development had been left unused. Similar

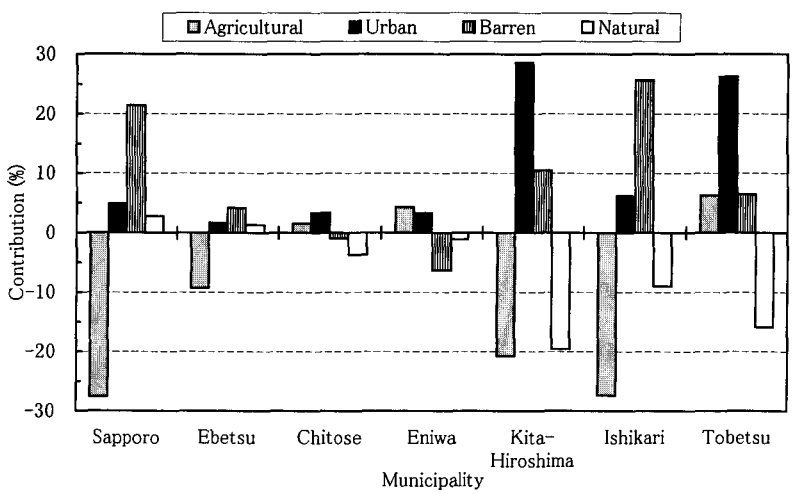

Fig. 8. Land-use change in the white zone of the agriculture-promotion area

increases in such areas of barren land were also seen in other municipalities with large areas of designated white zone (Kita-Hiroshima City and Tobetsu Town).

Figure 9 shows the land-use changes in the area of other land. The large increase in urban land-use in Chitose City is especially notable. This increase in urban land-use was not in the built-up area but in the other urban land (i.e., airport site), where the New Chitose airport had been constructed. The main source of land for construction of the new airport was natural land-use (forest land). Another notable change was the increase in natural land-use in Ebetsu City. This was due to the the growth of saplings (agricultural land-use) into trees (natural land-use) in the Nopporo forest park.

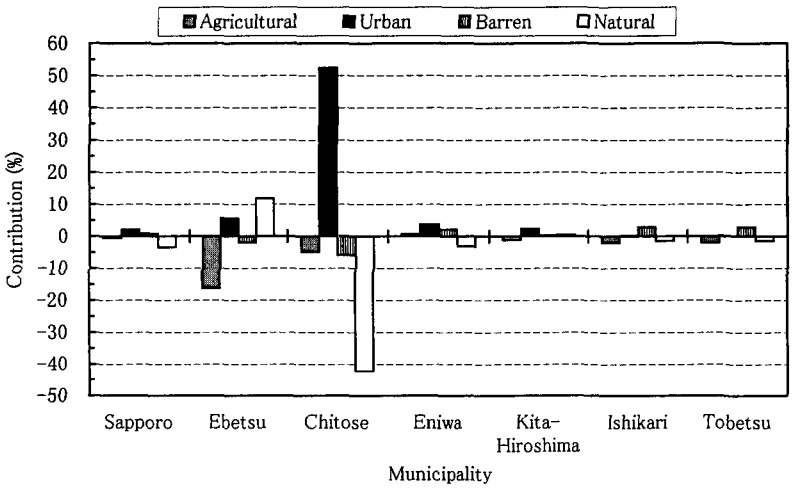

Fig. 9. Land-use change in the area of other land

3. Land-use change and the regional environment

Among the various land-use changes in each legal land-use area, the one that has the least-clearest purpose is the increased area of barren land. An increase in unused land in a large urban area such as Sapporo causes a deterioration in the esthetic quality of the city. Areas of unused land may be used as dumpsites for various types of waste products, which naturally has an adverse effect on the creation of a congenial regional environment. Figures 10 and 11 show distributions of the large increases (over 10ha) in barren land in each legal land-use type in Ishikari City and Sapporo City, respectively. The reason for only representing increases in barren land of over 10ha was because the ratio of increase in area of barren land to total land area in Ishikari City was about 10% (Fig. 3), which corresponds to about 10ha in a third-mesh unit area (about 100ha). Moreover, since the increased areas of barren land are concentrated in certain third-meshes, the increases in areas of barren land were divided into three classes (10～25ha, 25～50ha, over 50ha).

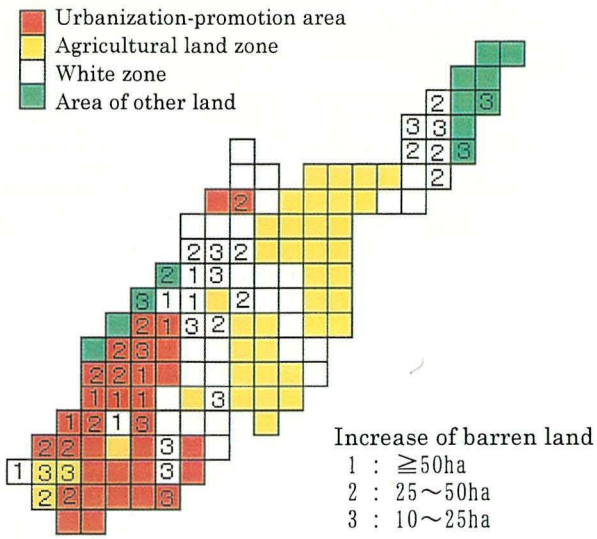

Fig. 10. Distribution of third meshes showing a large increase in barren land in Ishikari

In Ishikari City, the area of barren land increased by more than 10ha in 45 (35%) of the total 129 meshes. The distribution of increases in barren land is concentrated in the urbanization-promotion area and in the white zone or agricultural land zone surrounding the urbanization-promotion area. Most of the increase in barren land in the urbanization-promotion area is in the new port industrial complex of Ishikari Bay. A large portion of the land in the new port complex has remained unused due to a lack of business interest. This barren land is expected to be used in the future if the economic situation improves. A large percentage of the increase in barren land outside the urbanization-promotion area has occurred near the housing complex in the southern part of the city. Much of this unused land was originally agricultural land on which farming had been stopped for conversion to residential land. An increase in barren land, which is thought to be due to land development for construction of a golf course, can also be seen in the white zone in the north part of the city. During this current period of economic recession in Japan, environment-enhancing methods must be found to effectively use these large areas of barren land in the urbanization-promotion area and white zone of Ishikari City.

In Sapporo City, as can be seen in Figure 11, the increase in barren land is concentrated in the white zone of the north and northeastern parts of the city adjoining the urbanization-promotion area. The conversion of farmland to land for development of new residential areas has been progressing in these parts of the city. The results of a survey showed that about half of this area has been converted to residential areas, while about half still remains unused. Thus,

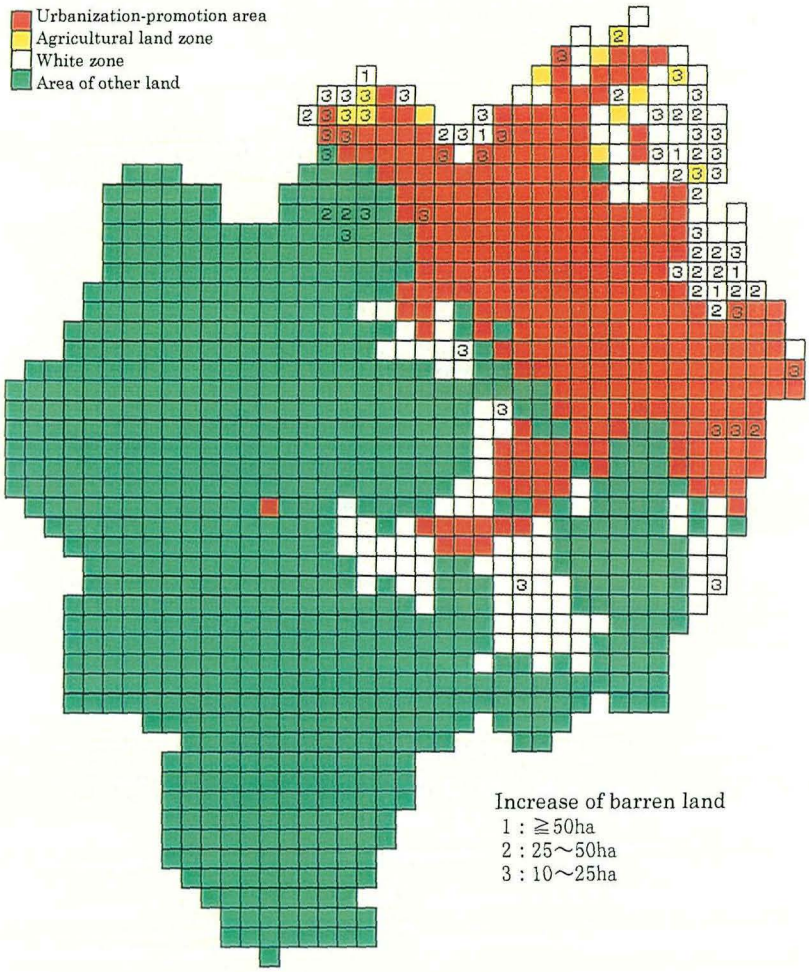

Fig. 11. Distribution of third meshes showing a large increase in barren land in Sapporo

Sapporo City, like Ishikari City, needs an effective land-use plan for the lar remaining areas of barren land in the white zone.

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References

1) Sapporo-Shi : Sapporo Shisei Gaiyo —Heisei 9nen Han—, p. 95, 1997. (in Japanese)
2) Michio NOGAMI : Numerical Land Information in Japan, Trans. Japan. Geomorp. Union, **10-A**, 147-156, 1989.
3) Kokudo-Chiri-In (the Geographic Survey Institute) : Suuchi-Chizu User's Guide, 1-4, 1992. (in Japanese)
4) Hiroshima-Cho : Hiroshima-Cho Toukei-Sho -Heisei 5nen Han -, p. 67, 1993. (in Japanese)
5) Chitose-Shi : Chitose-Shi no Tochi-Riyou Keikaku, p. 6, 1994. (in Japanese)
6) Eniwa-Shi : Eniwa-Shi Nogyo no Gaiyo, p. 3, 1994. (in Japanese)