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Relationship between threatened vascular plants and the human population in Japan

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Abstract

Using data sets for Japan as a whole, as arranged with approximately 10 × 10 km squares (a secondary grid), we investigated the relationship between population density and the habitats of threatened vascular plants listed in the Japanese Red Data Book; depopulated areas in the present and future, areas where under-use may be serious, and those with a predominance of elderly people; and the present state of the habitats in terms of a characteristic land use pattern. Regarding the habitats of threatened vascular plants, the progress of deterioration [$(N_{CR} + N_{EN}) / (N_{CR} + N_{EN} + N_{VU})$] in depopulated areas has been confirmed, where N_{CR}, N_{EN}, and N_{VU} are the numbers of species classified as critically endangered, endangered, and vulnerable, respectively. Moreover, in grid squares used by a human such as farmland, the progress of the deterioration simply increases when population density becomes low. However, for many vascular plants, they are particularly endangered in populous areas. Local populations will decrease throughout Japan with the rate of depopulation in and around large cities being relatively slow. We also propose some issues that need further study. The deterioration by human activity may be reduced. On the other hand, some vascular plants may be adversely influenced by depopulation. Additionally, we should keep a close watch on grasslands and water areas in large cities to preserve vascular plants.

Key words: depopulation, hilly and mountainous area, land use

INTRODUCTION

The disruption of the global ecosystem by anthropogenic factors has long been an issue of global scale. Such cases are usually based on the premise that the collapse of an ecosystem is caused by population growth or economic development. For example, the population growth rate in biodiversity hotspots (1995-2000) globally is 1.8%/y, and is higher than the global average (Cincotta et al. 2000). Because of population growth, the number of threatened mammal and bird species is expected to increase 7% by 2020, and 14% by 2050 (McKee et al. 2003).

In contrast, the population in hilly and mountainous areas of Japan has been decreasing due to migration to large cities since the mid-1950s, which was the beginning of a high economic growth period. Additionally, the population in Japan as a whole has been decreasing since 2005, and is estimated to decrease from 126 million in 2005 to ca. 63 million in 2080 (National Institute of Population and Social Security Research 2007).

As for ecological research, we have focused on Japan Satoyama Satoumi Assessment (JSSA), which can be regarded as the Sub-global assessment of Millennium Ecosystem Assessment (MA). “Satoyama” is a Japanese term for a mosaic landscape of different ecosystem types: woodlands, plantation, grasslands, farmlands, pasture, irrigation ponds, and canals (Japan Satoyama Satoumi Assessment 2010). Likewise, “Satoumi” indicates coastal

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ecosystems. Satoyama and Satoumi are considered to be landscapes that are sustainably used by human.

We have placed a high value on the JSSA as it has adopted under-use (e.g., succession) as one of the direct drivers to change ecosystem services such as provision of food and flood control. Actually, there is much abandoned farmland in Japan. The important point to note is that under-use is mainly associated with depopulation, and in addition, MA has not described under-use (Millennium Ecosystem Assessment 2005). Needless to say, JSSA has acknowledged another factor such as urbanization and pollution.

Succession is an important cause of the deterioration of habitats of vascular plants listed in the Japanese Red Data Book (hereafter called "RDB vascular plants") (Japanese Biodiversity Outlook Science Committee and The Ministry of the Environment 2010). Succession is caused by under-use mainly in farmland, because cultivating farms and mowing surrounding farms prevent the succession of RDB vascular plants that inhabit the region.

However, when viewed as a whole, JSSA is still in the process of conceptual development. It does not even provide the numbers of residents in each area around the country; nevertheless, depopulation partly causes a reduction in biodiversity and a deterioration in ecosystems via under-use.

This article intends to address the following questions: 1) Have the habitats of organisms deteriorated in depopulated areas of Japan?; 2) How will local human populations in Japan change in the long term?; 3) How might habitats change? Needless to say, it is impossible to evaluate "all creatures", so this article focuses on threatened RDB vascular plants. We also focus on the land use pattern, which is related to the quality of habitats.

MATERIALS AND METHODS

Data

Table 1 shows the geographical data sets used in our analysis. All data sets are arranged in the Standard grid cells of Japan. There are several classes of grid squares in use such as 10 × 10 km grid squares, 1 × 1 km, and 100 × 100 m grid squares. In addition, the data set for the Japanese population in 2010, as arranged in a grid, is not yet available, and so, data from 2000 and 2005 has been applied in its stead.

In our analysis, 10 × 10 km grid squares, or the 'secondary grid', are used because the data set for RDB vascular plants is arranged on this same grid scale. We regard the area of each grid square as 100 km^2 here. As for the human population in 2000 and 2005, the data sets arranged in this gird scale are available. The data set on land use, as arranged on 100 × 100 m grid squares, is available. In this data set, each grid square (100 × 100 m) is classified into one of eleven land use categories (described later). We characterize a 10 × 10 km grid square by the number of 100 × 100 m grid squares that belongs to each of the eleven land use categories. In other words, in terms of land use, each 10 × 10 km grid square is characterized by a vector of eleven variables.

The above-mentioned eleven land use categories are the follows: 1) paddy field, 2) other agricultural land, 3) forest, 4) wasteland, 5) land for building, 6) truck transportation land (e.g., a wide road), 7) other land, 8) rivers and lakes, 9) beaches, 10) bodies of seawater, and 11) golf courses. The main contents of "other land" are playing fields, airports, and vacant land. Note that wasteland includes land with weeds. We call 1) "paddy", 2) "farmland without paddy", 4) "rough land", 8) "river", and 10) "seawater." In addition, the number of categories will be reduced to eight in a later part of this study.

Estimation of deterioration of habitats

As mentioned above, we focused on RDB vascular plants. The deterioration of habitats is estimated in two values as stated below. In each grid square, D_{BR} value ($N_{CR} + N_{EN} + N_{VU}$) and D_{PR} value [$(N_{CR} + N_{EN}) / (N_{CR} + N_{EN} + N_{VU})$] are calculated, where N_{CR}, N_{EN}, and N_{VU} are the numbers of species of RDB vascular plants classified as critically endangered, endangered, and vulnerable, respectively. Note that the D_{PR} value is not calculated when the denominator ($N_{CR} + N_{EN} + N_{VU}$) is zero. Moreover, the grid squares without a D_{PR} values are ignored when we calculate the mean value.

Table 1. Geographical data sets used in analysis

Title	Year	Source
RDB vascular plants	1994-1995	Data of the red list (Threatened Species Committee, the Japan Society of Plant Taxonomists)
Population	2000, 2005	National census: regional mesh statistics, Tokyo Datum (edited by Sinfonica)
Land use	2009	National land numerical information: land use mesh, Tokyo Datum (Ministry of Land, Infrastructure, Transport and Tourism)

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D_{BR} shows the “broadness of deterioration” in one grid square; nevertheless, it is often a high value due to the rarity of a habitat (e.g., for an isolated island). On the other hand, we suppose that D_{PR} shows the “progress of deterioration”, which is based on Fujii (1999). It should be noted that D_{PR} evaluates the habitats of threatened vascular plants in one grid square.

Estimation of future population (cohort rate method)

The human population in each grid square was estimated from the Japanese population censes in 2000 and 2005 using the “cohort rate method” (Ishikawa 1993). In this estimation, we ignored the population of indeterminate age defined by Japanese population census; however, this has few effects because the percentage of this group was only 0.38% in 2005 (Japanese population census).

The important point to note is that the population is calculated in terms of gender and age groups. The population in the year (n + 5) is estimated from that in the year n and the cohort change rate. For example, the male population aged 20-24 years in 2010 is the product of that aged 15-19 in 2005 and the male cohort change rate from 15-19 to 20-24. The calculation of the population aged ≥85 y (the oldest group) in the year (n + 5) is slightly different; it is the product of that aged ≥80 in the year n and the cohort change rate from ≥80 to ≥85.

The cohort change rate is calculated from the actual population in 2000 and that in 2005. For example, the male cohort change rate from 15-19 to 20-24 is the quotient of the male population aged 20-24 in 2005, divided by that aged 15-19 in 2000. Note that these are calculated in each grid square. We assumed that there was no change in the cohort change rate from that of 2000 to 2005.

The population aged 0-4 is the product of the female population aged 15-49 in the same year and the child/woman ratio. Moreover, the population aged 0-4 is divided into male and female populations using the male/female child ratio.

The child/woman ratio, which is calculated in each grid square, is the quotient of the population aged 0-4 in 2005 divided by the female population aged 15-49 in 2005. The male/female child ratio was 1.048 in 2005 (Japanese population census). We assumed there was no change in the child/woman ratio or in the male/female child ratio.

In this way, if the population in 2010 is determined; the population in 2015 is projected using the population in 2010. In a similar way, the population in 2050 was obtained.

The cohort change rate is calculated by division, and therefore, “division by zero errors” can appear. In this paragraph, we explain the method used to adjust for these errors. 1) One of the cohort change rates (e.g., the male cohort change rate from 15-19 to 20-24) is focused on. 2) The values of all inhabited grid squares are gathered. 3) The median, the upper bound $[Q_3 + 1.5(Q_3 - Q_1)]$, and the lower bound $[Q_1 - 1.5(Q_3 - Q_1)]$ figures are calculated, where Q_3 is the third quartile and Q_1 is the first quartile. These upper and lower bound figures are commonly used to find outliers. 4) “0/0 errors” are replaced with the median, and “x/0 (x > 0) errors” are replaced with the upper bound. The lower bound figure, which is not used in this process, is used in the adjustment of overestimation or underestimation as stated below. In this way, the errors are adjusted for. Likewise, the errors of the child/woman ratio are also adjusted, where the lower bound figures are not utilized.

Generally, the cohort change rates in depopulated areas can be easily overestimated or underestimated, which also requires adjustment. 1) One of the cohort change rates is focused on. 2) If we find a value over the above-mentioned upper bound figure, we replace it by the upper bound figure. On the other hand, the values under the lower bound figure are raised to that of the lower bound. In this way, the overestimates and underestimates are also adjusted for.

Urban/Farming grid squares

We discriminate between “natural grid squares” (e.g., vast woodland; originally low population density) and “urban and farming grid squares” (e.g., an agricultural village). 1) As for the data set on land use, we integrate Land for building, truck transportation land, other land, and golf courses into the single category of “city”. Hence, the number of area categories of land use is reduced to eight, where an area is the number of 100 × 100 m grid squares. 2) In each gird square, R_{HU} $[(A_{PA} + A_{FA} + A_{CI})/(10{,}000 - A_{SE})]$ are calculated, where A_{PA}, A_{FA}, A_{CI}, A_{SE} are areas of Paddy, Farmland without paddy, City, and Seawater, respectively. Then, we regard grid squares where R_{HU} is <0.05 and those where R_{HU} is ≥0.05 as “natural grid squares” and “urban/farming grid square”, respectively.

Classification of grid squares based on land use pattern

Apart from above-mentioned classification, grid squares are classified based on a land use patterns. 1) Standard-

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ization is performed for each variable (integrated eight variables). 2) Categorization is performed using K-means clustering. Analysis is conducted repeatedly with an increased number of clusters for each step. In this paper, we call the group formed using K-means clustering "cluster".

Additionally, the total number of cases (grid squares) used in this analysis was 4,703. K-means clustering is particularly effective in studies like this with a large number of data (Oda 2007). This analysis was performed using STATISTICA 06J (default setting), software program (StatSoft, Tulsa, OK, USA).

RESULTS

Deterioration of habitats and population

The deterioration of habitats was estimated using D_{BR} (BRoadness) and D_{PR} (PRogress). In Japan as a whole, the mean value of D_{BR} is 1.77 and that of D_{PR} is 0.229. The number of grid squares without a D_{PR} value is 2,453 (52.1%).

The mean values of D_{BR}, those of D_{PR}, and the percentages of grid squares without a D_{PR} value are calculated in terms of groups related to the population density in 2005 (Figs. 1 and 2). D_{BR} simply increases when the population density becomes high. On the other hand, D_{PR} becomes relatively high when the population density is under 20 (people/km^2). Here, we divide the grid squares that have a D_{PR} value into two groups: "under 20 people/km^2" and "20 people/km^2 or higher." Then, the significant difference between two groups in the mean values of D_{PR} is confirmed (Welch's test: two-sided test, $t_0 = 4.36$, df = 671, $P < 0.01$). We used Welch's test because the difference in variance (each group) is relatively large. Hereafter, we call the grid squares where the population density is under 20 "depopulated grid squares."

According to the Japanese Ministry of Agriculture, Forestry and Fisheries (2002), the population densities of urban areas, flat farming areas, hilly farming areas, and mountainous areas were 1,517.7, 179.3, 79.6, and 26.0 people/km^2, respectively, when we assume that the people/household ratio is 2.58 (Japanese population census in 2005). Note that the population density of depopulated grid squares is lower than that of Mountainous areas.

As for depopulated grid squares, we should discriminate between "natural grid squares" and "urban/farming grid squares." Including this point, we arrange the relationship between population density and D_{PR} again (Fig. 3). In urban/farming grid squares, D_{PR} simply increases when the population density becomes low. On the other

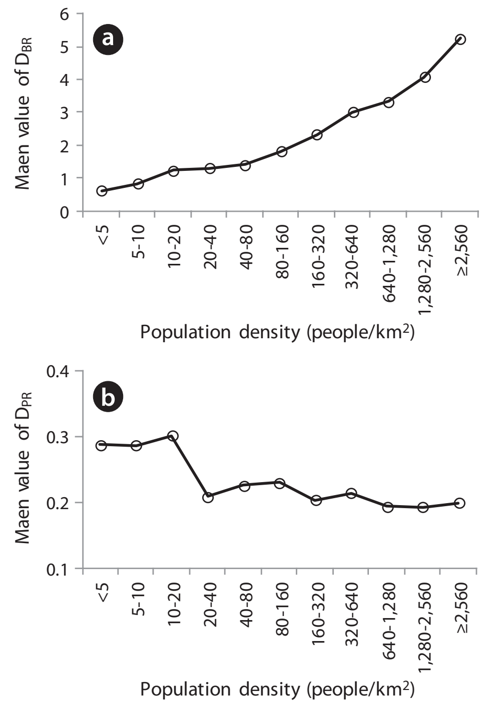

Fig. 1. Relationship between population density and deterioration in habitats: mean values of (a) D_{BR} and (b) D_{PR} in each grid square.

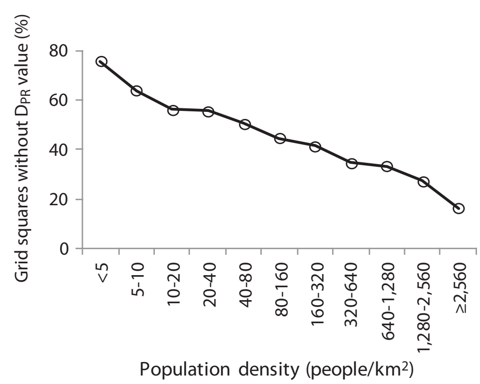

Fig. 2. Relationship between population density and percentage of grid squares without D_{PR} value.

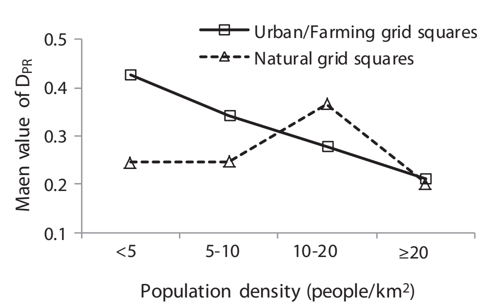

Fig. 3. Relationship between population density and mean value of D_{PR} in each grid square included a viewpoint of land use.

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hand, in natural grid squares, D_{PR} becomes relatively high when the population density is 10-20.

D_{PR} is relatively high in the urban/farming grid squares where population density is <10 (people/km^2). We tentatively call these "under-use grid squares," which will be explained in the Discussion section.

The mean values of D_{BR} and D_{PR} are calculated for groups formed using the percentage of elderly (≥65 y) (Fig. 4). D_{BR} simply decreases when the percentage of elderly becomes high. The percentage seemed to have no relationship with D_{PR}.

Future population

In Japan as a whole, the population density in 2005 was 348 (people/km^2), and that in 2050 has been estimated to be 268. Table 2 shows the relationship between population density in 2005 and that in 2050. This table suggests that depopulation will occur even in grids where the population density is now ≥2,560 people/km^2.

Fig. 5 shows the geographical location of depopulated grid squares in 2005 and 2050. We see from this figure that depopulated grid squares will develop throughout the country. The number of these grid squares will increase from 1,649 in 2005 to 2,431 in 2050.

Assuming that there will be no change in the land use, we determined the under-use grid squares for 2050 (Fig. 6). Many under-use gird squares were in Hokkaido in 2005. These will also develop throughout the country. The number of these grid squares will increase from 440 in 2005 to 964 in 2050.

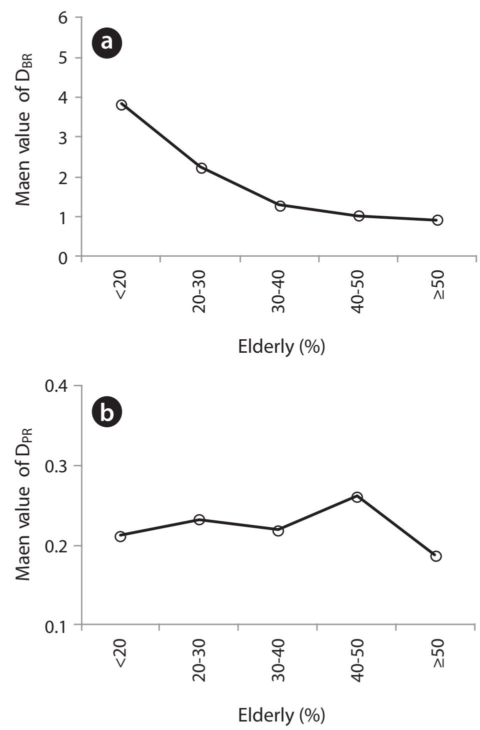

Fig. 4. Relationship between percentage of elderly and deterioration in habitats: mean values of (a) D_{BR} and (b) D_{PR} in each grid square.

In Japan as a whole, the percentage of elderly people in 2005 was 20.2%, and that in 2050 has been estimated to be 35.4%. Fig. 7 shows the location of the grid squares where the percentage is ≥50%; the number of these grid squares is estimated to increase from 182 in 2005 to 1,917 in 2050. In addition, the grid squares where the percent-

Table 2. Relationship between population density in 2005 and 2050 (number of grid squares)

Population density in 2005	Population density in 2050											
	<5	5-10	10-20	20-40	40-80	80-160	160-320	320-640	640-1,280	1,280-2,560	≥2,560	Total
<5	**1,038**	2	1	0	0	0	0	0	0	0	0	1,041
5-10	244	**16**	3	0	1	0	0	0	0	0	0	264
10-20	227	88	**26**	2	1	0	0	0	0	0	0	344
20-40	90	190	166	**36**	14	1	0	0	0	0	0	497
40-80	15	58	206	205	**44**	10	0	0	0	0	0	538
80-160	2	10	41	158	282	**50**	6	2	1	0	0	552
160-320	1	3	3	23	104	295	**73**	4	2	0	0	508
320-640	0	1	0	1	10	61	204	**110**	9	0	0	396
640-1,280	0	0	0	0	1	5	20	127	**108**	3	0	264
1,280-2,560	0	0	0	0	0	1	0	9	78	**72**	2	162
≥2,560	0	0	0	0	0	0	0	2	2	44	**89**	137
Total	1,617	368	446	425	457	423	303	254	200	119	91	4,703

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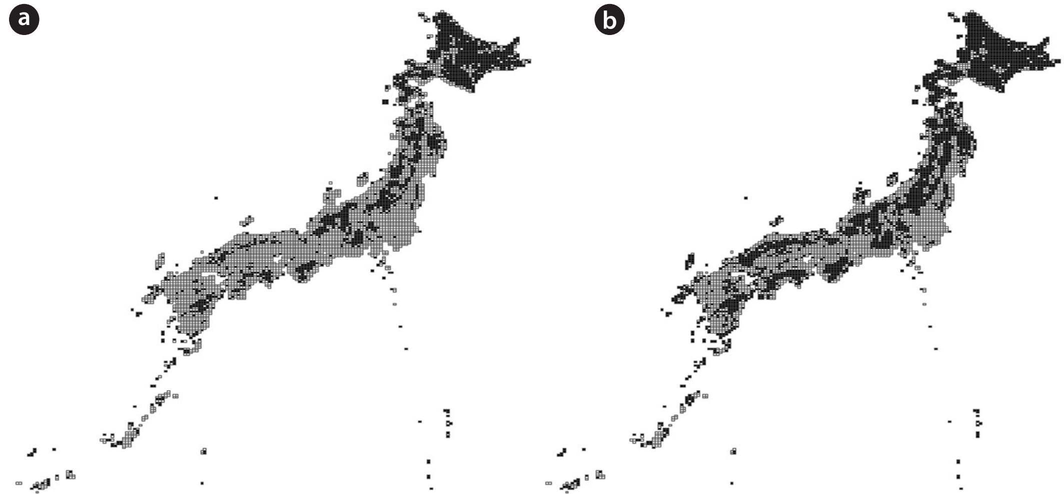

Fig. 5. Depopulated grid squares (see black squares): (a) in 2005 and (b) in 2050.

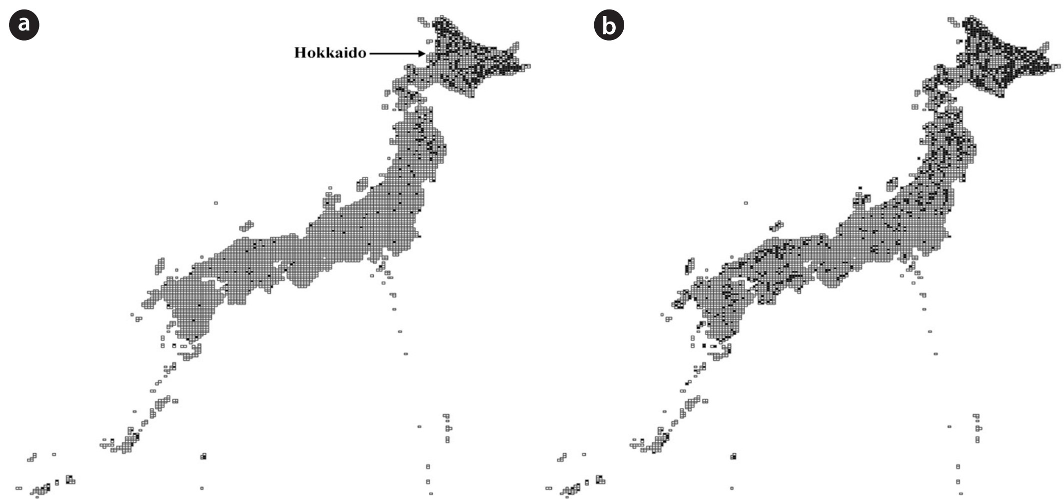

Fig. 6. Under-use grid squares (see black squares): (a) in 2005 and (b) in 2050.

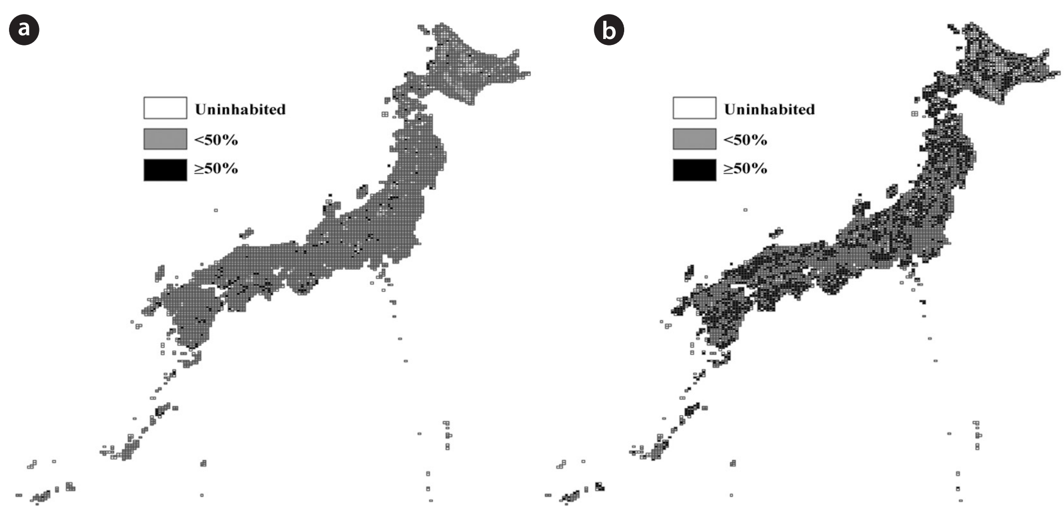

Fig. 7. Percentage of the elderly (≥65 y): (a) in 2005 and (b) in 2050.

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age is ≥50% could easily become uninhabited (Table 3).

Deterioration of habitats and land use patterns

As mentioned above, K-means clustering was conducted repeatedly with an increased number of clusters for each step. A small cluster with a few grid squares appears when the number of clusters is ≥8 (Fig. 8). For these clusters, the mean values of attributes can be strongly influenced by extreme values (especially D_{BR}). Therefore, in this study, we use analysis results when the number of clusters is seven.

Fig. 9 shows the location of each cluster. To each cluster, the mean values of the areas in terms of the land use (eight categories) are calculated, where the mean values

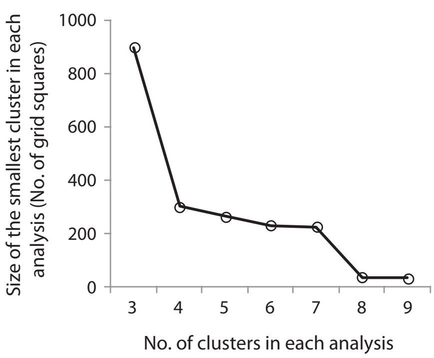

Fig. 8. Size of the smallest cluster in each analysis.

Table 3. Percentage of elderly in 2005 and population density in 2050

Percentage of elderly in 2005	Population density in 2050 (people/km^2)	
	<1	≥1
<50%	397	3,592
≥50%	99	83

Chi-square test: df = 1, $P < 0.01$.

for areas have been standardized (Table 4). In addition, the standardization was performed before K-means clustering. The origin of cluster names, "coast", "city/river", "paddy/city", "forest", "rough land", "farmland without paddy", and "town", is as follows: 1) 'Coast' is derived from the clear characteristic of the geographical location (Fig. 9). 2) 'City/river', 'paddy/city', 'forest', 'rough land', and 'farmland without paddy' are derived from the conspicuous (value in Table 4 is ≥1) land use within each cluster. 3) We name the seventh cluster 'town' because its population density (307.8 people/km^2) is lower than that of urban areas, and is higher than those of the others: 'flat farming area', 'hilly farming area', and 'mountainous area'. 'Forest', 'rough land', and 'farmland without paddy' are used as cluster names hereafter.

The population density, the rate of population growth from 2005 to 2050, the mean value of D_{BR}, and that of D_{PR} are calculated for each cluster (Table 5). The rate of population growth is given by $100(P_{50} - P_{05})/P_{05}$, where P_{05} and P_{50} are the populations in 2005 and 2050, respectively. Rough land in Kyushu, that in Hokkaido, and farmland without paddy in Hokkaido will be explained in the Discussion section. All clusters except 'city/river' are facing considerable depopulation. The depopulation in 'forest' is especially serious (-56.9%). D_{BR} is relatively high in 'city/river', 'paddy/city', and 'town'. On the other hand, D_{PR} is relatively high in 'rough land' and 'farmland without paddy'.

DISCUSSION

Deterioration of habitats caused by low or high population

Regarding the habitats of vascular plants, using D_{PR},

Table 4. Mean values of areas by cluster and land use

Cluster	Mean value of areas (standardized values)							
	Paddy	Farmland without paddy	Forest	Rough land	City	River	Beach	Seawater
1. Coast	-0.489	-0.364	-1.194	-0.346	-0.350	-0.319	0.737	**1.624**
2. City/River	0.404	0.248	-1.018	-0.274	**3.092**	**1.951**	-0.135	-0.464
3. Paddy/City	**3.024**	0.305	-0.903	-0.345	**1.028**	0.698	-0.252	-0.564
4. Forest	-0.381	-0.333	**1.017**	-0.080	-0.426	-0.171	-0.300	-0.586
5. Rough land	-0.497	0.014	0.289	**3.348**	-0.321	-0.103	-0.151	-0.488
6. Farmland without paddy	-0.235	**3.370**	-0.471	0.028	0.080	0.092	-0.165	-0.516
7. Town	0.620	0.154	0.178	-0.187	0.304	0.055	-0.214	-0.496

Note: Boldface shows high mean values (1 or higher).

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we have statistically confirmed that "progress of deterioration" is a relatively serious issue in depopulated grid squares. Moreover, as for urban/farming grid squares, we confirmed that D_{PR} simply increases when the population density is reduced. It is suggested that depopulation partly deteriorates the habitats via under-use. This opinion is in accordance with that of JSSA (Japan Satoyama Satoumi Assessment 2010). Supposing that under-use may be relatively serious, we tentatively call the urban/farming grid squares where population density is <10 (people/km²) "under-use grid squares"; however, needless to say, in these grid squares, we cannot limit the factor to under-use. There may be another factor such as pollution.

In the introduction, we explained that under-use deteriorates habitats via succession. However, succession is not the only factor of deterioration which is caused by under-use of natural resources. For example, the number of sika deer (*Cervus nippon*) is increasing because the

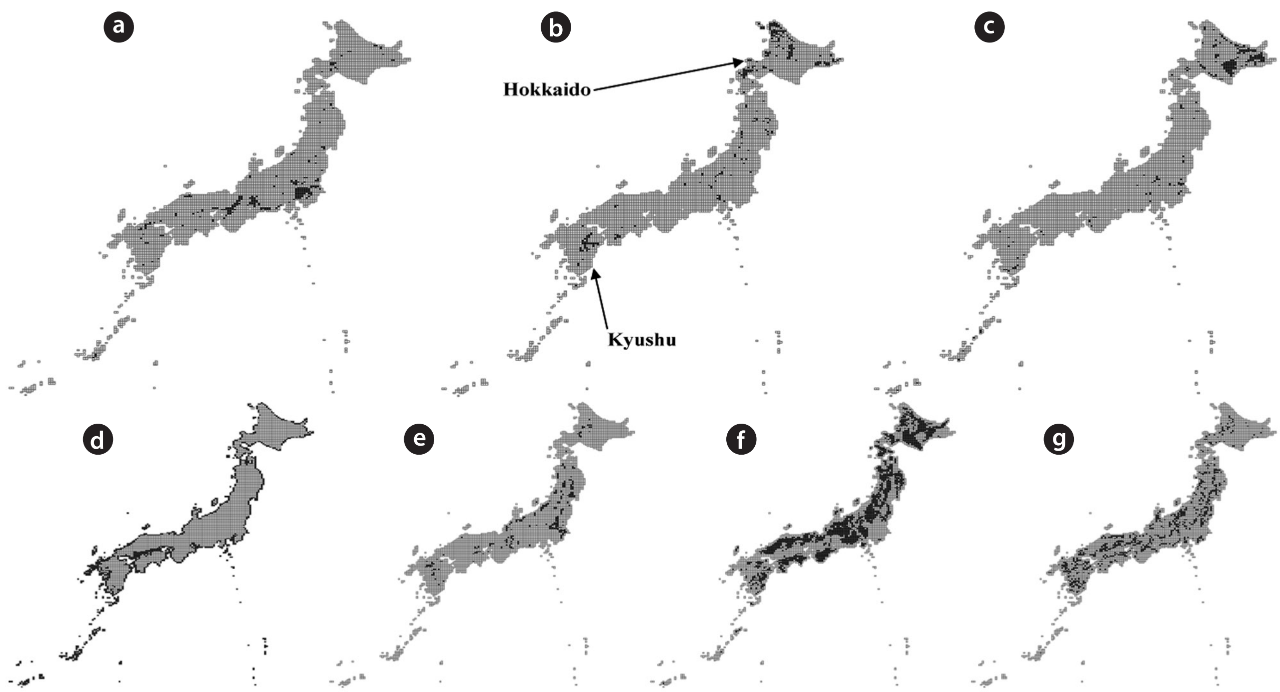

Fig. 9. Location of each cluster based on a land use pattern: (a) city/river, (b) rough land, (c) farmland without paddy, (d) coast, (e) paddy/city, (f) forest, and (g) town.

Table 5. Population and deterioration by cluster

Cluster	Population density (people/km²)		Rate of population growth	Mean value	
	In 2005	In 2050		D_{BR}	D_{PR}
Coast	439.9	281.1	-36.1	0.99	0.241
City/River	3,165.5	2,763.1	-12.7	5.05	0.195
Paddy/City	595.0	446.1	-25.0	3.86	0.170
Forest	29.4	12.7	-56.9	1.23	0.236
Rough land	40.2	27.4	-31.9	1.87	0.336
Farmland without paddy	175.9	124.9	-29.0	1.10	0.327
Town	307.8	194.2	-36.9	2.63	0.209
Rough land in Kyushu	80.9	57.8	-28.5	4.93	0.370
Rough land in Hokkaido	32.7	22.8	-30.4	0.62	0.416
Farmland without paddy in Hokkaido	57.9	39.1	-32.5	0.36	0.414

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number of hunters has decreased in Japan (under-use in hunting). Increased sika deer destroy natural vegetation especially in natural parks and national forests in Japan (Kaji et al. 2010).

We should note that "broadness of deterioration", which is measured by D_{BR}, is relatively slight in Depopulated grid squares. Therefore, it is suggested that deterioration might only be serious for a limited number of species. In other words, Depopulated grid squares should provide a secure space for many endangered vascular plants.

"Broadness of deterioration" is relatively serious in the grid squares with high population densities. Although the question of why "progress of deterioration" is not serious remains, these grid squares constitute areas where many vascular plants are endangered.

Future habitats of vascular plants and measures to improve them

On the basis of predictions of the human population, we describe the associated future habitats of vascular plants here. For vascular plants adversely influenced by human activity, nationwide depopulation implies an expansion of the areas in which they can thrive.

On the other hand, "progress of deterioration" in urban/farming grid squares where the population density is <10 (called under-use grid squares in this article) are relatively serious. If the progress of deterioration is mainly caused by under-use, future depopulation may have further adverse influences on habitats.

Fundamental measures to prevent deterioration of habitats by under-use is to preserve a local population. In recent years, the increase in migration of young people to depopulated areas has been noted. However, the size of these migrations is insufficient to prevent future depopulation. Needless to say, the estimation of future population in this article has taken into account of these migrations. Therefore, we sought an alternative measure to reduce the adverse influence of depopulation. For instance, to prevent succession of these ecosystems caused by under-use, abandoned paddy fields should be changed to pastureland, which can be maintained with a smaller workforce (Hayashi 2011).

We should closely monitor the aging population. The grid squares where the percentage of elderly is ≥50% may become uninhabited in the near future, or significantly reduced, resulting in an increase in under-use. Additionally, according to Oono (1991), settlements where the percentage of elderly is ≥50% are very likely to become completely uninhabited in the future.

Habitats in particular regions

Thus far, we have discussed the countrywide state of the habitat of vascular plants. As a supplement, we focus here on land use patterns seen in particular regions, that is to say, city/river, rough land, and farmland without paddy (Fig. 9).

The mean value of D_{PR} in rough land is the highest in the seven clusters. The grid squares of rough land are often seen in Kyushu and Hokkaido. As for this cluster, we focus on Kyushu. Both "broadness of deterioration" and "progress of deterioration" are serious in Rough land in Kyushu (Table 5).

In Kyushu, the grid squares of rough land are concentrated in the center of the region. This area includes an active volcano (Mt. Aso), which relatively keep quiet. At the very least, it is known that the area contained rough land (not cluster name) in the year ca. 1850 (Arizono 1995). Although the cluster name is "rough" land, we often see vast grasslands within this area, which are maintained by human activity, weed burning, or grazing.

The grasslands are in danger of being abandoned because Rough land in Kyushu is facing considerable depopulation (Table 5). Abandoned grasslands will change to forest over many years (Yamamoto et al. 2002) and as a result, many vascular plants that inhabit the grasslands may disappear. Needless to say, changing to forests is not destruction of nature. However, as for Japan, which has vast forest, loss of limited grassland may reduce biodiversity.

Additionally, for the Rough land in Hokkaido, we could not find a notable peculiarity in terms of land use, which is a result of the ambiguity of the category Rough land (Wasteland) in the original data.

The grid squares of 'farmland without paddy' are common in Hokkaido. As for this cluster, we focus on Hokkaido. "Progress of deterioration" in farmland without paddy in Hokkaido is also serious, whereas "Broadness of deterioration" is relatively slight. We suppose that the deterioration in this area is a partial (local) phenomenon. Although they are not native grasslands, we often see vast grasslands as cultivated land there. Regarding the vast grasslands, the scenery is similar to that of rough land in the middle part of Kyushu. Therefore, we suppose that "grassland" is important for the preservation of threatened vascular plants in Japan. However, in general, much grassland in Hokkaido has been developed recently by national projects; there was little grassland in the year ca. 1850 (Arizono 1995).

'Farmland without paddy' in Hokkaido is also facing

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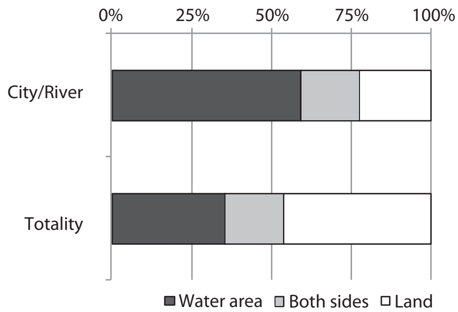

Fig. 10. Type of habitats: proportion of number of species.

considerable depopulation. Without management (e.g., mowing), almost all grasslands will change to forest, even in Hokkaido, the coldest region of Japan (Numata and Iwase 2002). Therefore, the abandonment of grassland, succession, and disappearance of vascular plants in grassland may also occur in Hokkaido.

The grid squares of 'city/river' are often seen in and around the large cities of Tokyo, Nagoya, and Osaka. The population density in city/river is the highest among the seven clusters. In addition, it is not surprising that cities and rivers categorized together because large cities have often formed on the alluvial plains of wide rivers.

"Broadness of deterioration" is the most serious among the seven clusters. We suppose that it is mainly caused by deterioration in the rivers, as well as lakes (Fig. 10). "Water area in a large city" is also important for the preservation of threatened vascular plants. The biodiversity loss in inland water systems is also serious within Japan (Japanese Biodiversity Outlook Science Committee and The Ministry of the Environment 2010).

The rate of depopulation in 'city/river' is relatively low; therefore, the effect that the population density has on the habitats will not change greatly. However, habitats in and around rivers may be improved by "Neo-Natural River Reconstruction" established in 1990, involving efforts such as the reproducing deep pools and rapids in rivers.

Finally, we should mention some future issues to be studied. We have to clarify the relationship between past (from mid-1950s) changes of population and deterioration of habitats. As for each species, the factor of change on habitats should be clarified. Organisms other than vascular plants should also be focused on.

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