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Evaluation of Forest Fragmentation in Japan

By

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S u m m a r y

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Evaluation of the distribution of forest landscapes and their fragmentation can provide useful information for ecosystem conservation management and for understanding the state of forests and their rates of change. We analyzed distribution patterns and fragmentation in the Japanese forest landscape from 1983 to 1998 on a national scale. We used vector-type vegetation data and GIS software to: (1) determine the changing state of Japan's forests from 1983 to 1998, (2) clarify the distribution pattern of forests associated with various landforms, and (3) evaluate the forest fragmentation associated with these landforms. Results showed that in the past Japan was covered by a high percentage area of forest and that it was highly contiguous. Patches larger than 1000 ha accounted for more than 90% of the total forested area from 1983 to 1998. However, our results also clearly demonstrated that forest fragmentation increased greatly between 1983 and 1998, because during this time the area of forest decreased and the number of forest patches increased. Our results also indicated that the type of forest fragmentation varied among regions, which were difined by specific landforms. In regions with 'high-relief mountains', the decrease in forested areas was relatively large. In regions with 'low-relief mountains and hills', serious fragmentation occurred, accompanied by a relatively large decrease in forest area. In regions with 'plains', fragmentation was evident, but thus far without a relatively large decrease in forest area.

I n t r o d u c t i o n

Habitat loss and fragmentation in forest landscapes are caused by human activities such as logging, conversion to agriculture, and the development of residential areas. As a result, forests are fragmented into smaller pieces surrounded by

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agricultural areas, urban landscapes, plantation forests, and wastelands. In general, forest fragmentation can be expected to cause local extinctions of the endemic species, and fragmented forests contain fewer of the original forest species than do continuous forests (ZUIDEMA & al. 1996). The negative impacts of habitat loss and fragmentation on species and communities are a decline in species richness (BOULINIER & al. 2001, SUMMERVILLE & CRIST 2001) and in fecundity (DONOVAN & LAMBERSON 2001), and an increase in rates of local extinction (BOULINIER & al. 2001).

In Japan, the relationship between habitat area and the number of species has been studied in birds (HIGUCHI & al. 1982, ICHINOSE & KATOH 1994), trees (IIDA & NAKASHIZUKA 1995), and amphibians (OSAWA & KATSUNO 2000). These studies suggest that the number of species has a significant positive correlation with the habitat area. Japan is in the middle latitudes, and forest covers more than half of the nation's land. Forest ecosystems are the most developed terrestrial ecosystems in Japan. Species composition and the nature of an animal's life are significantly affected by the existence of forest (HORIKOSHI & al. 1996) and, thus, decrease in area or fragmentation of the forest could be a major threat. The area of forest in Japan has been roughly constant at approximately 25 million ha for the past 150 years (HIMIYAMA & al. 1995). However, Japanese land use has changed greatly, and forest areas have been converted to other land uses, such as manufacturing (17772 ha), residential (19082 ha), leisure facilities (36102 ha), agriculture (86677 ha), public land (37571 ha), and others (34543 ha) in the 1980s (FORESTRY AGENCY 2000). These changes in land use may have influenced the distribution pattern of forests.

Evaluation of the distribution patterns of forests and of fragmentation in the forest landscape can provide useful information for ecosystem conservation management and for understanding the state of forests. Quantitative analysis of the area of Japanese forest is made possible by the use of statistical data such as those provided by the FORESTRY AGENCY 2000. However, such data cannot support a spatial analysis that would reveal distribution patterns in the forest landscape. In a previous study of spatial analysis of forests, HARASHINA & al. 1999 evaluated forest connectivity in Japan by using raster data on 1-km × 1-km grids, but they did not evaluate the distribution pattern spatially because of the low spatial resolution of these data. However, conditions improved in 2000, when the Environment Agency of Japan released vector-type vegetation data that covered all of Japan for use in GIS analysis, which can make both spatial analysis and detailed quantitative analysis of forests possible on a national scale. Taking full advantage of these data, we aimed to evaluate forest distribution patterns and fragmentation in the Japanese forest landscape from 1983 to 1998 on a national scale, an analysis that has never been performed before. In this analysis, we also tried to characterize the forest fragmentation associated with various landforms, because Japan's national landscape consists of undulating mountains, hills, and plains, and none of them is geographically predominant. Forests can be transformed in accordance with changes in geographical features. Therefore, we assumed that the type of forest fragmentation would be a function of various geographical features. In this context, we posed the

following questions. What is the percentage of forest cover and how contiguous is it in Japan? What is the association between forest cover or contiguity and geographical features? Further, does forest fragmentation occur differently in each geographical landform?

Material and Methods

Our analysis used vegetation survey data provided by the Environment Agency of Japan (now the Ministry of the Environment) in the form of the National Survey on the Natural Environment. Vector data from the third, fourth, and fifth surveys (1983–1987, 1988–1992, and 1993–1998, respectively, with midpoints at around 1985, 1990, and 1995) were digitized from actual vegetation maps at a scale of 1:50000 (originally in DLG format, with UTM projection). We also use a region file containing vectorized data that were reclassified from raster-type landform classification data in a 1-km × 1-km grid into high-relief mountains, low-relief mountains and hills, plains, and open water (in ArcInfo coverage format, with Geographic projection) (Table 1). The data were analyzed by means of ESRI's ArcInfo 8 GIS software.

In this analysis, "forest" is defined as vegetation types that correspond to numbers 6 through 9 of the Vegetation Naturalness ranking of the Ministry of the Environment (Table 2). The original vegetation data, which contained 766 plant communities classified according to their structure, were reclassified first on the basis of the Vegetation Naturalness number, and then into forest, open water, and non-forest land.

Next, all projections were converted into Lambert Azimuthal Equal Area equivalents to permit accurate area calculations. Japan has 47 prefectures. ArcInfo coverage files (the polygons data set in vector format) were initially overlaid for each prefecture, then 47 coverage files for the prefectures were joined to make a single coverage file for all Japan. These files were created for the 3 surveys mentioned earlier, and represent the whole of Japan for ranges of dates centered on 1985, 1990, and 1995, respectively. The vegetation data for 1990 and 1995 contain only updated land-use polygons. These were overlaid on the 1985 data to create coverage files for 1990 and 1995, then a statistical approach was used to calculate the number of forest patches and forested areas in these coverage files. The frequency distribution of the forest patches was computed for 5 area classes: <1 ha, 1 ha to <10 ha, 10 ha to <100 ha, 100 ha to <1000 ha, and 1000 ha or greater.

Finally, each coverage file was overlaid on the region file to allow calculation of the number of forest patches and forested areas and the frequency distribution of forest patches in the 3 types of landform defined in this paper: "high-relief mountains", "low-relief mountains and hills", and "plains". In this analysis, fragmentation was defined as a decrease in the forested area accompanied by an increase in the number of forest patches.

Table 1. Landforms used in the present study, reclassified on the basis of the original landform classification data.

Reclassified landform	Original landform
High-relief mountains	High-relief mountains
	High-relief volcanoes
Low-relief mountains and hills	Low-relief mountains
	Low-relief volcanoes
	Hills
Plains	Uplands
	Lowlands
Open Water	Lakes and Marshes
	Rivers

Table 2. Criteria for the Vegetation Naturalness Classification (degree of human disturbance of vegetation), based on the Ministry of the Environment ranking system. (Source: http://www.biodic.go.jp/english/kiso/vg/vg_kiso_e.html).

Vegetation Naturalness	Description
10	Natural vegetation of grassland and moorland
9	Natural vegetation of forest
8	Substitutional vegetation close to natural vegetation of forest
7	Substitutional vegetation of secondary forest
6	Planted forest
5	Substitutional vegetation of high-profile grassland
4	Substitutional vegetation of low-profile grasslands
3	Fruit orchards, mulberry plantations, tea gardens and other horticultural areas
2	Paddies, fields, and other arable land; residential areas with abundant trees
1	Urban land, developed tracts, and other zones where plant life is virtually nonexistent

Results and Discussion

The analysis indicated that over the period 1983 through 1998, total forested area in Japan decreased by 551965 ha (ca. 2.2%) whereas the number of forest patches increased by 28614 (ca. 25%) (Fig. 1). The analysis also demonstrated high overall contiguity of forests in Japan, because large forest patches (1000 ha and greater) accounted for more than 90% of the total forested area throughout this period (Table 3). However, it appears that the contiguity of the forests decreased owing to fragmentation of large forest patches, because the forested area decreased only in this class, whereas the number of forest patches and total forested area increased in all other classes from 1983 to 1998. Most notably, the number of forest patches in the < 1 ha class increased greatly.

A look at the distribution pattern of forests associated with landforms revealed that large continuous forests were associated with the high-relief mountains, because a small number of forest patches with areas greater than 1000 ha occupied most of the total forested area in this landform. In the low-relief mountains and hills, large forest patches with areas greater than 1000 ha occupied most of the total forested area, but forest patches with areas of less than 1000 ha also accounted for approximately 10% of the area. This indicated that large continuous forest patches and some medium-sized and small forest patches were common in this landform. In the plains, many medium-sized and small forest patches were present: forests with areas of less than 100 ha accounted for approximately 50% of the total forested area, and there were many forest patches with areas of less than 10 ha. Forest fragmentation, which was evaluated from the change in forest coverage and patch density from 1983 to 1998, showed different trends in the 3 types of landform (Fig. 2). In the high-relief mountains, decreases in forest area without increases in the number of patches were frequently observed.

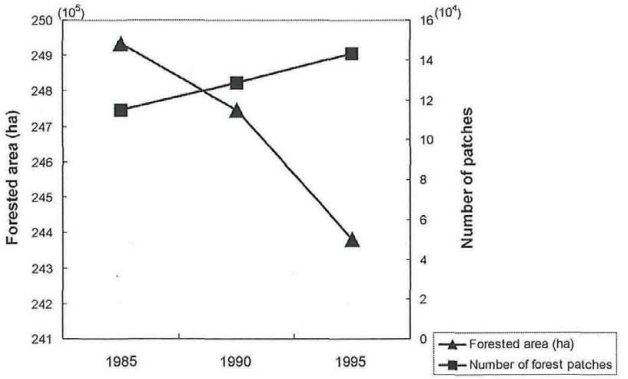

Fig. 1. Changes in the number of forest patches and total forested area from 1985 to 1995 in Japan as a whole.

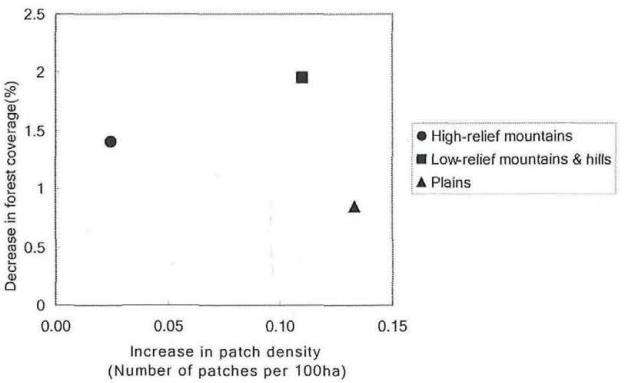

Fig. 2. Plot of decrease in forest coverage (%) against increase in patch density (number of forest patches per 100 ha) from 1985 to 1995 for the 3 types of landform in Japan as a whole.

Table 3. Total areas of landform (high-relief mountains, low-relief mountains and hills, and plains) and forests, and number of forest patches and forested area in 5 classes of patch size in 1985, 1990, and 1995 for each type of landform and all of Japan. The percentages of forested area are based on the total area of the landform.

Landform	Date	Area of landform	Area of forest (ha)		Number of patches <1ha	1-10ha	10-100ha	100-1000ha	>1000ha
High	1985	11,493,416	10,411,762		4432	5683	1713	664	484
			90.59(%)	(ha)	1,776	18,784	52,522	247,089	10,091,591
				(%)	0.02	0.16	0.46	2.15	87.80
	1990	11,492,257	10,364,873		5,435	5,853	1,693	656	479
			90.19(%)	(ha)	1,928	19,269	51,618	243,217	10,048,840
				(%)	0.02	0.17	0.45	2.12	87.44
	1995	11,491,678	10,248,106		6,617	6,253	1,773	670	478
			89.18(%)	(ha)	2,166	20,771	53,751	248,992	9,922,426
				(%)	0.02	0.18	0.47	2.17	86.34
Low	1985	15,813,809	12,161,193		17,527	31,460	11,004	3,390	1,128
			76.90(%)	(ha)	7,593	108,987	357,344	1,054,173	10,633,196
				(%)	0.05	0.69	2.26	6.67	67.24
	1990	15,813,206	12,050,160		24,015	32,858	11,460	3,434	1,117
			76.20(%)	(ha)	8,523	113,826	370,029	1,068,544	10,489,238
				(%)	0.05	0.72	2.34	6.76	66.33
	1995	15,813,397	11,850,331		30,492	34,664	12,085	3,475	1,114
			74.94(%)	(ha)	9,657	119,901	389,028	1,075,672	10,256,073
				(%)	0.06	0.76	2.46	6.80	64.86
Plain	1985	9,134,493	2,290,437		29,909	56,210	25,716	3,001	166
			25.07(%)	(ha)	13,812	198,423	817,425	645,318	615,460
				(%)	0.15	2.17	8.95	7.06	6.74
	1990	9,137,358	2,261,545		34,422	57,156	25,812	2,942	162
			24.75(%)	(ha)	14,503	201,366	816,032	634,376	595,268
				(%)	0.16	2.20	8.93	6.94	6.51
	1995	9,139,447	2,213,633		40,092	58,310	25,802	2,850	158
			24.22(%)	(ha)	15,410	205,309	809,283	612,978	570,653
				(%)	0.17	2.25	8.85	6.71	6.24
Total	1985	36,441,718	24,932,390		24,510	69,655	17,716	2,487	408
			68.42(%)	(ha)	15,193	234,786	484,859	678,952	23,518,601
				(%)	0.04	0.64	1.33	1.86	64.54
	1990	36,442,821	24,745,401		35,397	71,765	18,279	2,514	412
			67.90(%)	(ha)	16,761	241,550	498,520	685,614	23,302,955
				(%)	0.05	0.66	1.37	1.88	63.94
	1995	36,444,522	24,380,425		47,014	74,520	18,889	2,555	412
			66.90(%)	(ha)	18,678	250,796	515,361	695,679	22,899,911
				(%)	0.05	0.69	1.41	1.91	62.83

This occurred because forest coverage decreased, whereas patch density did not increase much during this time. Forest patches that decreased in area were estimated to be mainly large forests with areas greater than 1000 ha. In contrast, fragmentation without a great decrease in area was observed in the plains, because forest coverage did not decrease much, whereas patch density increased considerably during this time. Forests that were fragmented were estimated to be mainly patches with areas greater than 100 ha, because forests in these classes declined in both number and area. In the low-relief mountains and hills, fragmentation and a relatively large decrease in area were observed. This resulted from relatively large reductions in forest coverage and patch density in this landform. Forest patches that decreased in area and became fragmented were estimated to be mainly large forests with areas of more than 1000 ha, because decreases in number and area were observed only in the 1000-ha and greater class, whereas increases in both were observed in all other size classes.

From the analysis of forest fragmentation at a national scale, we conclude:

(1) Forest contiguity is high across Japan as a whole, because forest patches with areas greater than 1000 ha accounted for more than 90% of the total forested area from 1983 to 1998. However, forest fragmentation has increased, because during this time the total forested area decreased, whereas the number of forest patches increased. Fragmentation appears to be serious in forest patches larger than 1000 ha.

(2) A small number of contiguous forest patches larger than 1000 ha were distributed in the high-relief mountains. Contiguous forest patches larger than 1000 ha and some medium-sized and small forest patches with areas less than 1000 ha were found in the low-relief mountains and hills, and many medium-sized and small forest patches smaller than 100 ha were found in the plains.

(3) In our evaluation of forests between 1983 and 1998, we found different types of fragmentation in the 3 types of landform. In the high-relief mountains, forested areas decreased significantly. In the low-relief mountains and hills, serious fragmentation accompanied by a relatively large decrease in area occurred. In the plains, fragmentation without a relatively large decrease in area occurred.

We have shown that forests in Japan were fragmented between 1983 to 1998. Forest fragmentation could be a major threat to species whose lives depend on forest ecosystems. Therefore, further investigation of how forest fragmentation affects species is necessary.

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