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Landscape structure and the disturbance regime at three rural regions in Hiroshima Prefecture, Japan

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Abstract

Using the vegetation maps of island, inland and mountainous rural regions in Hiroshima Prefecture in western Japan, landscape structures in terms of the size and number of patches are compared, and the characteristics of the disturbance regimes creating each landscape are discussed. Landscape structure in the island rural region is the most heterogeneous, because factors which alter the landscape structure are the most complex. This heterogeneity is established and kept by the agricultural land uses and natural disturbances such as forest fire and pine-disease. At the mountainous rural region, the landscape mosaic is characterized by the relatively large patches composed of conifer plantations and secondary deciduous oak forests. This is the result of the forestry. The inland region landscape is the most homogeneous, because factors which alter landscape structure are now absent. The complex of the physical, biological and anthropogenic forces makes the landscape unique to each region.

Introduction

Landscape ecology focuses on the structure, function and changes in landscapes, and on the ecological consequences of landscape heterogeneity (Forman and Godron 1986; Turner 1987, 1989). Landscape pattern can influence a variety of ecological phenomena, like population or community structure (*e.g.* Hansson 1979; Danielson 1991; Soulé *et al.* 1992; Pulliam *et al.* 1992) and the spread of disturbances (*e.g.* Franklin and Forman 1987; Turner 1987; Turner *et al.* 1989).

Factors causing landscape heterogeneity are identified to natural and anthropogenic disturbances. Natural disturbances such as typhoons and landslides, induce new patches in a matrix and produce heterogeneous landscape. Its occurrence depends on the natural conditions. Anthropogenic disturbances such as agricultural and forestry activities, induce new patches such as crop lands and clear cutting area in a forested matrix. However, the occurrence of anthropogenic disturbance depends on socio-economical environments (Kamada *et al.* 1991). The regime of the anthropogenic disturbances changes in accordance with a social change. The landscape structures, for example the number and size of patches, are changed as a resultant with a social change.

Landscape structure is maintained or changed under a balance of the effectiveness between natural and anthropogenic disturbances. The dynamics of structural change as the relative importance of these disturbances change under different human-land relationships. In a human dominated region, anthropogenic factors are a more prominent force altering landscape structure than natural disturbances (*e.g.* Birks *et al.* 1988; Kamada *et al.* 1991; Bastian and Bernhardt 1993). When population decreases from a region and social activities decline, relative importance of natural disturbances increase.

The regime of human land use and natural disturbance varies in each local region in relation to the social and natural environments. The factors

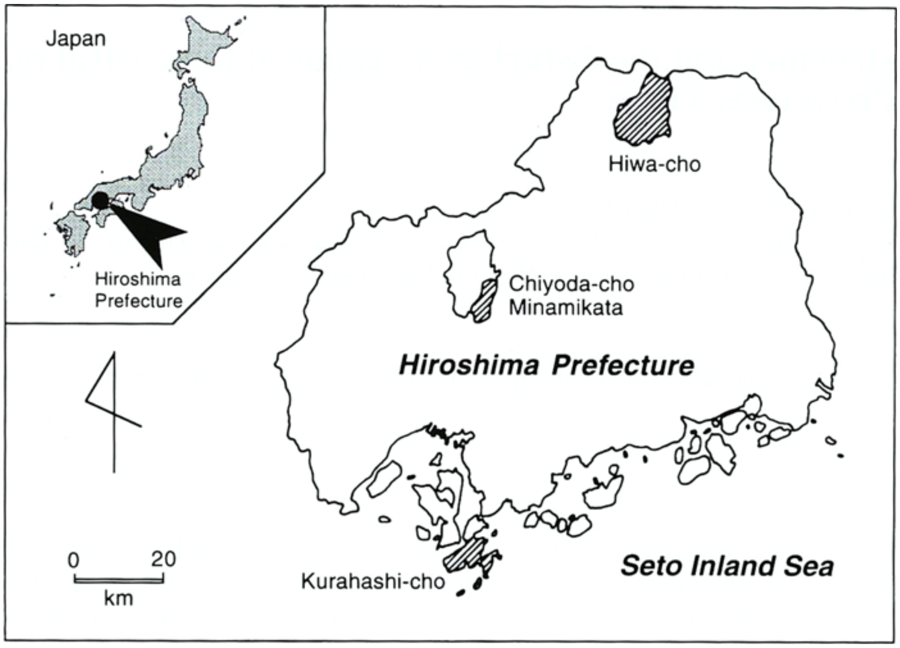


Fig. 1. Map showing the study regions.

making the unique landscape in each region can be specified by comparing the several landscapes (Turner and Ruscher 1988). We selected three geographically different districts for comparing the landscape structure: island, inland and mountainous rural regions. Relative effect between natural and anthropogenic disturbances for creating the landscape heterogeneity is discussed from the comparison of these rural regions.

In this paper, we summarize the characteristics of these landscape structures. Secondly, we compare the landscape structures in terms of the kinds, number and size of patches in landscape, and discuss the characteristics of the human land uses and disturbances causing the structural differences in these landscapes. Considerable differences are recognized in factors for creating landscape heterogeneities and in created landscape structures among those rural regions.

Main part of this paper was presented in the symposium of IALE World Congress (organizers Dr. Almo Farina and Dr. Jean M. Hartman) held at Ottawa, Canada in 1991, entitled "Landscape changing of rural area in Hiroshima Prefecture after the rapid economic growth era".

Study regions

Study regions were set longitudinally from the sea to mountain in Hiroshima Prefecture, western Japan (Fig. 1). The selected regions are Kurahashi-cho as an island rural region, Minamikata in Chiyoda-cho as an inland rural region and Hiwa-cho as a mountainous rural region. Cho corresponds to town in English administration.

Natural and social environments affecting to distribution of vegetations and landscape structures are compared in Table 1. The altitude becomes high from island to mountainous region, therefore annual mean temperature becomes low in the same order. Annual precipitation is small in Kurahashi and large in Hiwa. The region around Seto Inland Sea, which locates between the Chugoku mountains at northward and the Shikoku mountains at southward, is the driest in Japan. Kurahashi locates in this region. Forest fire is frequently occurred in Kurahashi due to dry condition. Hiwa, which locates in the Chugoku mountains, is humid due to cool climate, summer rain and winter snow.

Climatically, evergreen oak forests of *Castanopsis* spp. and *Quercus* spp. are potential natural vegetation in Kurahashi and Minamikata. Hiwa

Table 1. Characteristics of environments in three rural regions.

	Kurahashi	Minamikata	Hiwa
Natural Environment			
Area (km^2)	54.3	36.0	120.9
Alluvial plain area (km^2)	4.1	3.7	11.3
Altitude range (m)	0–460	250–816	350–1280
Annual mean temperature (°C)	16.3	12.7	11.8
Annual precipitation (mm)	1,585	1,715	2,100
Social Environment			
Population			
in 1950	20,018	1,919	5,341
[density; person/km^2]	[368.7]	[53.1]	[40.4]
in 1990*	9,253	1,021	2,392
[density; person/km^2]	[170.4]	[28.3]	[18.1]
Ratio of 1990*/1950 (%)	46.2	53.4	44.8
Population engaged in agriculture and forestry			
in 1950	5,005	1,026	2,081
[ratio to total population; %]	[25.0]	[88.3]	[78.6]
in 1990*	518	239	603
[ratio to total population; %]	[5.6]	[38.1]	[41.4]
Ratio of 1990*/1950 (%)	10.3	23.3	29.0

* in 1985 for Hiwa

includes two natural vegetation zones, evergreen oak forest below 700 m in altitude and deciduous broad-leaved forest of *Fagus crenata* above 700 m. On the actual vegetations, however, secondary forest of *Pinus densiflora* is predominant both in Kurahashi and Minamikata, and *Quercus serrata* and *Q. mongolica* var. *grosseserrata* forests are dominant in Hiwa, as results of human activities.

The young people have left three regions to look for a employment in urban areas. Many of the remaining people changed their jobs from agriculture to the secondary or tertiary industries. Total population in Kurahashi and Minamikata in 1990 and in Hiwa in 1985 decreased to about a half in 1950, based on data of "Population Census of Japan". Population density is extremely high in Kurahashi among three regions.

Agriculture and forestry have directly influenced the landscape structure. Population engaged in these works in 1990 (Hiwa in 1985) became 10 to 30% of the number in 1950, based on data of "Agriculture and Forestry Census of Japan". Before 1960s, farmers in these regions used forest products as their source of heat energy, fertilizer for cultivating crops, and feed for livestock such as cattle. In addition to population decrease, energy sources have suddenly altered from plant materials to propane and electricity, and fertilizer has also altered to the chemical products. The number of labor livestock have decreased due to the popularization of machines. Dependency on local bioresources has become absent and traditional usage of the forest was discontinued.

Mapping data and methods

To compare the landscapes, their structures must be described by the same methods or criteria. Basic studies on landscape ecology had already been conducted in these regions. Actual vegetation maps (1:25,000) have been prepared for all three regions; Nakagoshi *et al.* (1990) for Kurahashi in 1988, Kamada and Nakagoshi (1990) for Minamikata in 1987, and Nakagoshi *et al.* (1989) for Hiwa in 1989. These vegetation maps were made by field surveys referring to the phytosociological method (Braun-Blanquet 1964). In addition, all forest patches were classified to three height classes by using aerial photographs; small (establishing phase;

$H<3$ m), middle (developing phase; $3 \leq H<8$ m) and tall (matured phase; $H \geq 8$ m) forests. Stereoheight can be seen by studying "subsequent overlapping" photographs in the run in their proper position under the stereoscope (Kannegieter 1988). The threshold value for stereoscopic detectability of height for analyzed photographs (focus = 153 mm, scale = 1:22,000) is about 1.1 m, based on the formula of Kannegieter (1988). This classification of forest vegetation is useful to consider the landscape structure of populated area. Because forest heights represent durations from the time of forest cutting, we can judge whether disturbances were occurred in recent past or not. Using these vegetation maps, the size and number of patched landscape elements were measured.

Land use history in each region was mainly recognized by interviews from local farmers and land owners. Some books on the history of Hiwa were available for understanding land managements (Someya *et al.* 1989). History and area of all forest fires occurred in Kurahashi after 1960 were confirmed from local newspapers.

Characteristics of the landscape structure in each region

Kurahashi-cho

The landscape element types identified from the vegetation map (Nakagoshi *et al.* 1990) are summarized in Table 2. Landscape element types are identified to secondary vegetation occurred as natural succession and artificially induced vegetation as forestry and agricultural activities. Two landscape element types which dominate in the region are *Pinus densiflora* forests of tall and middle height. The pine forest has been maintained under the intensive use of forest and the disturbances such as forest fire, because *P. densiflora* which regenerates only from seeds needs a bare land to establish (Kamada *et al.* 1991). Traditionally, the farmers had collected litter, herbage and shrub from pine forests, and used these plant products as a fertilizer of the fields and for daily fuel. These usages of pine forest are now completely abandoned.

Many patches of orchards of mandarin orange and bamboo, *Phyllostachys*, plantations are distributed around the hamlets. Mandarin orange was introduced in the Meiji era (1867–1912), and its production has prospered since the early 1950s. Only the orange was as a good cash harvest under the conditions of seldom irrigated steep slopes that characterize Kurahashi. Bamboo plantations are managed for producing the bamboo-shoot, a food product, and poles. Bamboo poles are used to hang and dry the agricultural products such as rice straw, and for the construction of rafts used for the aquaculture of oysters in Seto Inland Sea.

Many farmers, 5,005 people in 1950, has owned their lands, and cultivated the terraced orchards and bamboo plantations separately. The occurrence of many small patches of orchards and bamboo plantations in Kurahashi should be resulted from segmentation of the ownership of land. This is the direct effect of farmer's land use for creating the landscape heterogeneity.

One of the factors driving the landscape dynamics in Kurahashi is forest fire. In Kurahashi, like in the other regions of Seto Inland Sea, the frequency of forest fire is extremely high due to dry conditions. Figure 2 shows the history of large forest fires and their areas in Kurahashi after 1960. Fire frequently occurred at the regenerate forests in the post-fire stand. At the areas burnt in 1986 and 1987, shrub community of *Lespedeza cyrtobotrya – Mallotus japonica* established in 1988. At the areas burnt in 1967 and 1971, pine forests of middle height established in 1988 (Nakagoshi *et al.* 1990). In the course of succession after the fire, a weed community of *Crassocephalum crepidioides – Erechtites hieracifolia* establishes at first, and it develops to *Lespedeza – Mallotus* scrub and then it is followed by *Pinus – Rhododendron* forest in the coastal region of Seto Inland Sea (Nakagoshi *et al.* 1987).

The amount of litter, which acts as fuel for fires, increases due to litterfall and self-thinning in the developing pine forest (Nakagoshi *et al.* 1987; Kamada *et al.* 1991). Area of developing and matured pine forest became to increase due to the cessation of traditional forest uses after 1950s in Kurahashi.

Forest fires are almost always caused by humans in Japan, *e.g.*, misuse of fire for afforestation and cultivation, open-air fires and burning rubbish, cig-

Table 2. Landscape structure of forest area in Kurahashi-cho in 1988.

Landscape element type	Total area (ha)	Number of patches	Mean size of patches (ha)
Landscape element types of secondary vegetation			
Quercus serrata forest			
Tall height forest	312.2	155	2.0
Middle height forest	39.3	17	2.3
Pinus densiflora forest			
Tall height forest	1395.3	186	7.5
Middle height forest	1672.9	55	30.4
Small height forest	158.4	24	6.6
Pinus thunbergii forest			
Tall height forest	51.8	43	1.2
Middle height forest	13.8	7	2.0
Small height forest	0.9	2	0.5
Post-fire site			
Crassocephalum crepidioides – Erechtites hieracifolia community	28.1	3	9.4
Lespedeza cyrtobtrya – Mallotus japonica community	441.9	3	147.3
Subtotal	4114.6	495	8.3
Landscape element types originated in forestry			
Chamaecyparis obtusa and *Cryptomeria japonica* plantation			
Tall height forest	11.3	7	1.6
Middle height forest	0.5	1	0.5
Subtotal	11.8	8	2.5
Landscape element types originated in agriculture			
Phyllostachys heterocycla f. *pubescens* plantation	104.1	301	0.3
Orange orchard	764.4	204	3.7
Upland field	106.7	105	1.0
Subtotal	975.2	610	1.6
Others	29.0	21	0.5
Total	5130.6	1134	4.5

arettes, matches and fireworks. Occurrence of fires in Kurahashi is enhanced under the conditions of dry climate and of increased area of developing pine forest due to succession. Pine forest should be kept as a sub-climax vegetation by periodical fires (Isagi and Nakagoshi 1990).

Another factor changing the landscape structure in Kurahashi is pine-disease infected by a pine wood nematode (*Bursaphelenchus xylophilus*). This nematode is carried and dispersed by the Japanese pine sawyer (*Monochamus alternatus*), and kills the pine tree. Vegetational replacement from pine forests to deciduous oak forests can easily occur. The deciduous oaks, *Quercus serrata, Q. variabilis* etc., have grown under pine canopy, and successive pine trees do not exist in matured pine forest (Kamada *et al.* 1991). Therefore when the upper pine trees are killed by the nematode, oak forests immediately establish when the oak saplings have existed. This landscape change is caused by epidemic disturbance.

Landscape heterogeneity in Kurahashi has been formed by complication of anthropogenic and natural disturbances. Effect of the natural disturbance

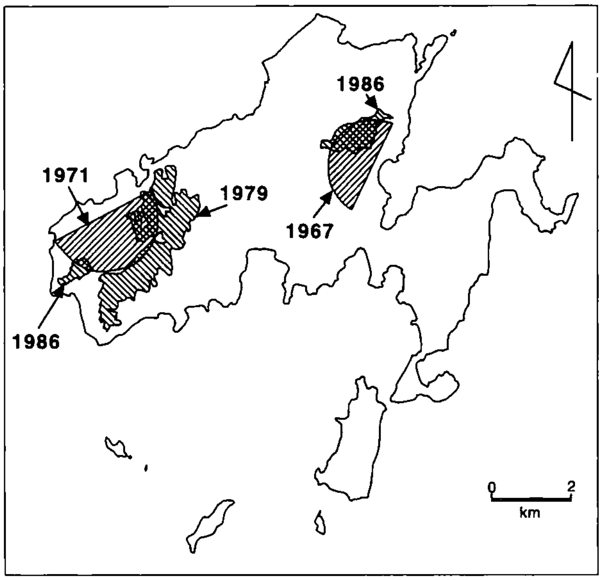


Fig. 2. History and area of the forest fire in Kurahashi-cho after 1960. For the forest fire in 1967 and 1971, only the size could be detectable; the exact boundary of the area was undetectable.

for creating landscape heterogeneity, however, will become greater than anthropogenic one in the future.

Minamikata in Chiyoda-cho

The landscape element types identified from the vegetation map (Kamada and Nakagoshi 1990) are summarized in Table 3. *Pinus densiflora* forests of tall height is the dominant landscape element type. In Minamikata before the 1960s, tall pine trees had been harvested for timber production on about a 40 to 60 year cycle. Deciduous oak trees growing under pine canopy had been cut to produce charcoal on about a 20 year cycle. Shrubs had been cut for firewood, and herbaceous plants, including *Miscanthus sinensis*, at forest floor had been mowed to make compost and had been used for fields (Kamada and Nakagoshi 1990; Kamada *et al.* 1991). Under these managements, the mosaic landscape which composed of pine forests of different height classes and clear cutting sites was established in 1960s (Kamada and Nakagoshi 1990). These usages of pine forest has been completely abandoned after 1960s. Therefore, pine forests of small and middle height classes grew and tall pine forests became dominant due to succession.

Tall height forest of oaks including *Quercus serrata* is the second dominant landscape element type. This forest was occurred by the vegetational replacement from pine forest. Deciduous oaks have grown under pine canopy, and successive pine trees do not exist in abandoned pine forest. Large amount of the litter is accumulated on the floor of abandoned pine forest. When the abandoned pine forest is cut, accumulated litter inhibits the establishment of pine seedlings, and deciduous oaks can regenerate by the sprouts. Oak forest established through this process, in addition to successional process from pine to oak forest (Kamada *et al.* 1991).

In Minamikata, anthropogenic disturbance has not occurred except forestry activities for small and few conifer plantations. Natural disturbance such as fire and pine-disease also has not occurred. Only natural succession is the main factor for altering landscape structure, and its landscape will become more homogeneous in the future.

Hiwa-cho

The landscape element types identified from the vegetation map (Nakagoshi *et al.* 1989) are summarized in Table 4. The landscape element types which dominate in this region are tall height forests of *Quercus serrata* and *Q. mongolica* var. *grosseserrata*, tall and middle height conifer plantations of *Cryptomeria japonica* and *Chamaecyparis obtusa*, and scrub communities at clear cutting sites. The clear cutting site is prepared for planting the conifer saplings.

The large area of coniferous plantation of the middle height and the clear cutting site suggests that forest use is still an ongoing economic activity. This human activity is the major factor for creating the landscape heterogeneity in Hiwa. Matrices of deciduous oaks forests are segmented by introduced patches of conifer plantations.

Quercus serrata and *Q. mongolica* var. *grosseserrata* forests had been used to obtain the resources for producing charcoal before 1960s, but the use of oak forests as the energy supply is now abandoned for electricity and propane. Anthropogenic disturbances causing small height oak

Table 3. Landscape structure of forest area in Minamikata in 1987.

Landscape element type	Total area (ha)	Number of patches	Mean size of patches (ha)
Landscape element types of secondary vegetation			
Quercus serrata forest			
Tall height forest	721.8	60	12.0
Middle height forest	45.3	3	15.1
Small height forest	2.1	3	0.7
Pinus densiflora forest			
Tall height forest	1992.3	39	51.1
Middle height forest	76.6	19	4.0
Small height forest	74.6	16	4.7
Subtotal	2912.5	140	20.8
Landscape element types originated in forestry			
Scrub community at clear cutting site	32.8	13	2.5
Cryptomeria japonica and *Chamaecyparis obtusa* plantation			
Tall height forest	86.1	45	1.9
Middle height forest	85.4	27	3.2
Small height forest	77.9	24	3.3
Subtotal	282.1	109	2.6
Others	36.6	27	1.4
Total	3231.3	276	11.7

forests were almost eliminated early, and tall height forests of both oaks became dominant.

Differences in the distribution of *Quercus* species are due to thermal conditions (Nakagoshi *et al.* 1989). *Q. mongolica* var. *grosseserrata* dominates at cooler high elevations (>700 m), and *Q. serrata* dominates at warmer low elevations (≤700 m). This vegetational change in relation to elevational change is a significant factor contributing landscape heterogeneity.

In Hiwa, conifer plantations as human activity and a wide range of climactical conditions as natural environment contribute to landscape heterogeneity.

Comparison of the landscape structure and disturbance regime

Disturbance is defined as "any relative discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (White and Pickett 1985, p.7). Disturbances can be classified as exogenous and endogenous. Disturbances are characterized by the spatial distribution, frequency, return interval, rotation period, predictability, size, magnitude and synergism (White and Pickett 1985), but the focus here is really only on natural versus human. The characteristic of the disturbance, anthropogenic one in particular, is regionally dependent. We would argue that natural disturbances are equally dependent on the regional setting.

In Table 5, the landscape structures of three regions are compared. The landscape of Kurahashi is the most heterogeneous, based on the total number of patches. This landscape heterogeneity is due to a large number of small patches of orange orchards and bamboo plantations, which are maintained by human activities. Natural disturbances also occur frequently in the area of secondary vegetation. Pine-disease accelerates the vegetation change and induces new patches of deciduous oak forests in the matrix of the pine forests. Forest fire also creates greater landscape heterogeneity. The high heterogeneousness of Kurahashi landscape is caused and sustained by a complex of anthro-

Table 4. Landscape structure of forest area in Hiwa-cho in 1989.

Landscape element type	Total area (ha)	Number of patches	Mean size of patches (ha)
Landscape element types of climax vegetation			
Fagus crenata forest (Tall height)	37.3	6	6.2
Pterocarya rhoifolia forest (Tall height)	1.2	3	0.4
Subtotal	38.5	9	4.3
Landscape element types of secondary vegetation			
Quercus mongolica var. *grosseserrata* forest			
Tall height forest	2080.9	113	18.4
Middle height forest	213.3	25	8.5
Small height forest	41.9	14	3.0
Quercus serrata – Q. variabilis forest			
Tall height forest	3163.1	265	11.9
Middle height forest	854.8	95	9.0
Small height forest	68.3	27	2.5
Pinus densiflora forest (Tall height)	186.2	144	1.3
Subtotal	6608.5	683	9.7
Landscape element types originated in forestry			
Scrub community at clear cutting site	1142.8	247	4.6
Chamaecyparis obtusa and *Cryptomeria japonica* plantation			
Tall height forest	1898.0	498	3.8
Middle height forest	2242.6	216	10.4
Small height forest	90.7	8	11.5
Subtotal	5374.0	969	5.5
Landscape element types originated in agriculture			
Phyllostachys heterocycla f. *pubescens* plantation	8.9	35	0.3
Others	67.4	8	8.5
Total	12100.7	1712	7.1

pogenic (agricultural) and natural disturbances.

Orchards and plantations are maintained by anthropogenic disturbances, in terms of the weed management. Frequency, magnitude and spatial distribution of disturbances are related to the socio-economical circumstances. Recently the decrease in the number of workers, the reduced price for mandarin oranges due to over-production, the import of oranges and orange juice have forced farmers to abandon the orange orchards. The abandoned orchards are replaced by the kudzu (*Pueraria lobata*) community and pine forests. These trends in landscape change are common to the other islands in Seto Inland Sea (Nakagoshi and Ohta 1992), and predict greater homogeneity with time in this area of an agricultural landscape.

In Hiwa, climatical conditions diversify distributions of oak communities and increase the heterogeneity of a landscape. Disturbances associated with forestry, however, are the most effective in creating the landscape heterogeneity. About a half of the forest area has been changed to the sites for plantation. Coniferous trees such as *Cryptomeria japonica* and *Chamaecyparis obtusa* are planted to the clear cutting sites. In this case, forest type is converted from native deciduous broad-leaved trees to coniferous trees introduced from the other regions. There are great differences between the oak forest and conifer plantation ecosystems. In the oak forest, several plant species can coexist in the

Table 5. Comparison of the landscape structure of forest area among three regions.

	Landscape element types originated in						
	Secondary vegetation		Forestry		Agriculture		Total**
	Area (%)	Patch number per 1000 ha*	Area (%)	Patch number per 1000 ha*	Area (%)	Patch number per 1000 ha*	Patch number per 1000 ha*
Kurahashi	80.2	96.5	0.2	1.6	19.0	118.9	221.0
Minamikata	90.1	43.3	8.7	33.7	–	–	85.4
Hiwa	54.6	56.4	44.4	80.1	0.1	2.9	141.5

* Patch number of each landscape element type is converted into 1000 ha.
** Including the other landscape element types, which are not listed here.

community. On the contrary, conifer plantation is managed monoculturally, and only few species can exist. Other ecological attributes such as nutrient cycles, root system, water-holding capacity and even soil fauna (Touyama and Nakagoshi 1994) also differ from native ecosystem. The landscape system or regional ecosystem is now changing to a new and different system in Hiwa.

In Minamikata, pine forests have been abandoned after 1960s. The frequencies of anthropogenic disturbances are now very low. Furthermore, the area shows the lowest occurrences of natural disturbances or environmental forces that contribute to heterogeneity. Therefore the number of patches become little and a homogeneous landscape is established in accordance with the growth of the forest.

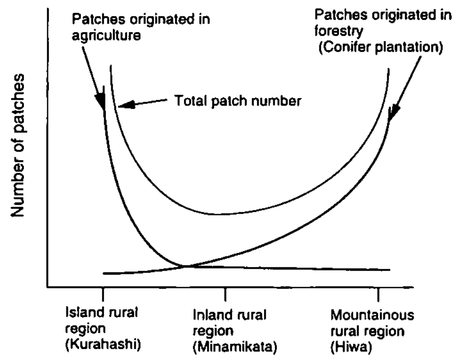
When the disturbance is likely to propagate within a community such as species-specific parasite, the homogeneous landscape enhances the disturbance (Turner 1989). Homogeneous and well developed pine forest in Minamikata may provide the homogeneous habitat for a pine wood nematode and Japanese pine sawyer. Pine forest in Minamikata has a big possibility that pine-disease will occur and spread rapidly. In this case, vegetational change from pine to oak forests will be accelerated and a landscape composed of oak forest patches within pine forest matrix will be occurred temporally. However in the end, a homogeneous landscape composed of oak forests will be established because almost all pine trees will be killed by pine-disease.

Conclusion: the cause and result of the landscape

There are great differences in landscape structure among the rural regions in Hiroshima Prefecture. The complex of the physical, biological and social forces makes the landscape unique to each region. Figure 3 shows the conceptual structure of the rural landscape from island to mountainous regions in Hiroshima Prefecture with reference to the environmental gradient.

In the island rural regions, the heterogeneous landscape is developed by the agricultural use and natural disturbances. The warm temperature with low precipitation in Seto Inland Sea allows farmers to cultivate the mandarin orange as the cash harvest and bamboo as the sub-product in agriculture, but does not provide to commercial conifer production. On the contrary at the mountainous rural region, high precipitation and relatively large forest area give the farmers to establish forestry industry. Orange cultivation assures the annual income to the farmers but needs the greater effort to maintain the orchard in comparison to the conifer plantation, because oranges must be harvested annually and continuous managements against the pest insects and weeds are needed. Conifer plantation can be maintained by relatively extensive management, but it needs large area and takes about 40 to 50 years to harvest the timber. The mean size and total area of the patches originated in the first industry, therefore, is small on the island comparing to that of the mountainous rural region.

The well developed pine forest may enhance the occurrence of the pine-disease as observed in Kura-



	Island rural region (Kurahashi)	Inland rural region (Minamikata)	Mountainous rural region (Hiwa)
Environmental Setting			
Humidity	Dry →		Wet
Temperature	High →		Low
Climate	Warm temperate zone	Warm temperate zone	Cool and warm temperate zone
Dominant vegetation	Pine forest	Pine forest	Deciduous oak forest
Anthropogenic Disturbance			
Land use originated in agriculture	High → Orange orchard Bamboo plantation	Low	Low
Land use originated in forestry	Low ←		High Conifer plantation
Natural Disturbance			
Disturbances in secondary vegetation area	Forest fire Pine-disease	Rare	Rare

Fig. 3. Conceptual landscape structures from coastal to mountain region in Hiroshima Prefecture.

hashi, and the litter accumulated on the forest floor acts as fuel and enhances the chance of the fire (Romme 1982; Johnson and Miyanishi 1991). These are the subtle human effect on the landscape changes (McDonnell and Pickett 1993), because these conditions of pine forest, which is widely distributed in island and inland rural regions, have been caused by the cessation of traditional forest use (Kamada *et al.* 1991; Nakagoshi and Ohta 1992). The climatic condition with the low precipitation and warm temperature also enhances the chance of the forest fire and pine-disease.

In the island region, landscape mosaic will be provided by these disturbances. The landscape in inland regions also under risk from these disturbances. Pine-disease will accelerate landscape change if it occurs in the inland region.

A theoretical framework is useful and important to determine and predict the stability of a landscape (*e.g.* Turner *et al.* 1993), however, the characteristics of the disturbance regime is different in each region. The quantitative and qualitative information on the nature of the disturbance in the well designed landscape system is also necessary.

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