

Factors affecting the dynamics of vegetation in the landscapes of Shimokamagari Island, southwestern Japan*

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Abstract

On Shimokamagari, an island of the Seto Island Sea, patterns of vegetation in the landscape were studied using vegetation maps. Relationships between social and economic changes, site conditions and the vegetation were examined from a historical perspective. In the process of economic development, mandarin orange production became important on this island. However, over-production, a reduction in the price of mandarin oranges and low-temperature damage to orange trees caused large citrus orchards to be abandoned. A plant community dominated by kudzu appeared in the abandoned orchards and the pine forests, as well. These changes in orchards were connected with the natural site conditions, such as soil, geology, inclination, elevation, direction of slope, and also with artificial conditions, such as density of working paths. Another factor causing change was the replacement of the organic fertilizer of litter from forests by chemical fertilizer since the 1960's. As a result, medium and small forests of pine became tall forests and tall forests of pine changed into tall oak forests. In the human-dominated areas, the major factors affecting the process of vegetation were economic activities, and after the abandonment of the farm-lands, forest succession were controlled by natural site conditions.

Introduction

Landscape is a spatial concept that is based on biotic communities, environments, and artificial features created by humans arranged in an area (Naveh and Lieberman 1984). Primarily it is formed by features of the natural environment, such as climate and topography. It's also influenced and altered by the intensities of human impacts (Forman and Godron 1986). When we examine a landscape, we do not understand it until we can consider visible groups of biotic communities (particularly plant

communities), the natural conditions as their background and the impact of human activities (Turner and Ruscher 1988).

An island is a good place to study landscape ecology because it is isolated and vegetation processes are limited within its territory. For these reasons, we have studied a small island where thousands of people live and the vegetation has been influenced by these people. On this kind of island it is possible to examine the impact of human activities as one of the factors affecting the process of the vegetation in the landscape. We can understand easily the chang-

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ing structure of vegetation distribution on the island and the relations between the vegetation and natural site conditions and artificial conditions caused by human activities. The objective of the research is to compare and explain changes on this island landscape over time.

Nature and social conditions in Shimokamagari Island

The study area, Shimokamagari Island (with an area of 7.91 km²) is the biggest island of Shimokamagari-cho town municipality. The highest altitude on the island is on Mt. Oh-hira (275 m above sea level), the bedrocks are sedimentary rocks of the Tertiary in the northern area and granite in the southern area (Suga and Oho 1989). The soil is the yellow-brown and brown forest soils on the north side, and immature soils originating from granite on the south side. The climate is summer dry, with an annual average temperature of 15.4°C, and an annual precipitation of 1318 mm. River water is partly used for agriculture. But, to assure a constant supply, the drinking water and most of the agricultural water is provided from Kure City through submarine pipes.

Shimokamagari-cho, including Shimokamagari Island, has a written history from the 17th century. This municipality is located near Kure City, which developed rapidly before and after World War II. The island had the benefit of sea transportation for agricultural products and it also developed rapidly. But, the land had been used for a long time before and since most land was on slopes, available lands for houses and agricultural facilities were limited. As a result, the residents used the lands that were not suited to cultivation for the farm villages. These villages now face problems of the advanced ages of the farmers and a decrease of the farming population.

The total population of Shimokamagari-cho was 3536 in 1990. The percentage working in primary industry was 22.5%, and the ratio of the secondary and tertiary industries was 77.5%. The farming population formed 16% of the primary working population. Most of people working in the second-

dary and tertiary industries work outside the town.

The islands in southern area of Hiroshima Prefecture are famous for the production of citrus fruits in Japan. Citrus fruits are produced on terraced fields that make use of the steep slopes. This agricultural landscape is a representative landscape of the Seto Island Sea (Taniguchi *et al.* 1978). In Shimokamagari-cho, 'Hamikan', which is a small domestic orange used for an ornament of the new year, has been a famous product since the Edo era. But in the Meiji era mandarin oranges were introduced and production of citrus fruits became more popular. Especially from the early 1950's mandarin orange production became prosperous.

Rice production was always low due to a shortage of irrigation water. The major products were barley and sweet potatoes until citrus fruit production became most prosperous. The farmers collected litter from pine forests and oak forests and gathered herbage from field and road margins, and used these organic materials for fertilizer of the fields and for daily fuel. At present, chemical fertilizer is used, resulting in less use of rural forests. Over-production of citrus fruits, the reduced price for mandarin oranges and the import of orange juice and oranges have made farmers abandon the citrus orchards and change products. As a consequence the landscape of this island have been changing rapidly in recent decades.

Methods

Vegetation maps (Nakagoshi and Ohta 1991) were made by the physiognomic method (Nakagoshi *et al.* 1988; Kamada and Nakagoshi 1990) for different periods of time:

1947: at about the time of food shortage after the World War II

1962: at about the time when mandarin orange production became prosperous

1976: at about the time when mandarin orange production began to decline

1990: the recent period.

To clarify the internal structure of vegetation types and to identify the plant communities, a phytosociological study was made on 45 plots (Fig.

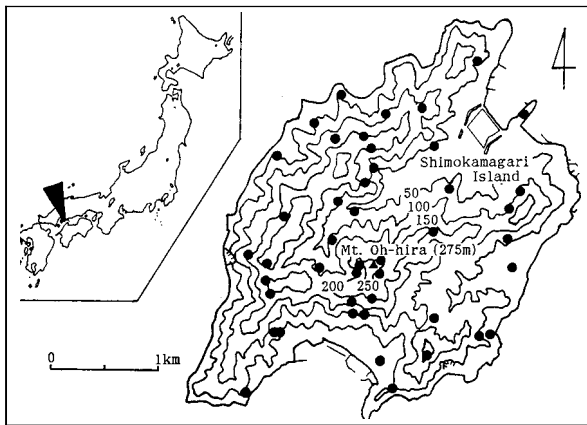


Fig. 1. Maps showing the study area and the plots where phytosociological investigations and questionnaire research were done.

1), over the period of 1987 to 1991 (Nakagoshi and Ohta 1991). Thus, vegetation types have a phytosociological background. On each map of these four dates, the ratio of area of the major vegetation types and the character of the site conditions was analyzed. Then, the area of each vegetation element (the area surrounded by a boundary on the vegetation map) in each vegetation type was measured, and compared over years.

These two units (vegetation element and type) are derived from vegetation science and they represent a landscape unit, the type, and a lower unit of scale, the element. In standard landscape ecology the type would be a land-use unit of some description and the vegetation element would be equivalent to an ecotope (Haber 1990).

To determine the amount of change over time, two vegetation maps were overlaid, and the areas of change for each of the 14 years were measured. Moreover, during the last period 1976 to 1990, for which there is adequate information, the most rapidly changing vegetation types were selected for study of the relations between the rates of change and the site conditions. The site conditions included soil (Hiroshima Prefectural Government 1986), geology, inclination, slope direction, elevation and density of working paths (Fig. 2). In Fig. 2 the vegetation elements in 1976 could be divided into three ecotopes, and in 1990 into seven ecotopes. Thus, an ecotope has attributes of a vegetation type and a site condition.

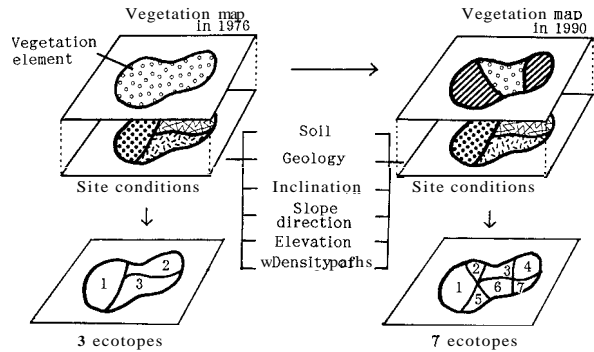


Fig. 2. The concept of correspondence between vegetation change and site conditions in different years.

Data on social conditions were obtained from census reports and agricultural censuses. Questionnaires were used to obtain detailed information about the past vegetation type and styles of land use in each plot and the social changes of the region.

Results

In Shimokamagari Island the area of each vegetation type and the number of vegetation elements are shown for four different years (Table 1). We will consider the change in area first, then consider the dynamics of vegetation elements, searching for the affecting factors.

Change in area

From 1947 to 1990, citrus orchards occupied from 34 to 46% of the total area. Tall pine (*Pinus densiflora*) forests dominated the forest vegetation, and occupied from 30 to 35% of the area. Farm lands, such as upland fields and paddy fields, have been less than 5% of the total area since 1962.

In 1962, upland fields had decreased in all part of the island, and almost all of them were converted to citrus orchards. But, the area of the farm lands, such as citrus orchards, upland fields and paddy fields, inhabited land, and forests did not fluctuate more than 12% in relative area.

In 1976, upland fields remained on small areas all through the island. The total area of citrus orchards

Table 1. Change in area of vegetation type, number and area of vegetation elements from 1947 to 1990

The items of analysis	Year	Vegetation type*											total
		O	Pdt	Pdm	Pds	QQt	PA	Pl	EE	UF	IH	others	
Area of vegetation type (%)	1947	38	32	4	2	4				11	3	6	100
	1962	42	32	4	3	5	3			3	3	5	100
	1976	46	34	2	1	7		1	2	1 >	3	4	100
	1990	34	33	1	1	13		9	3	1	4	1	100
Number of vegetation element	1947	34	106	25	13	28				29	7	47	276
	1962	49	91	43	37	36	14			19	7	77	371
	1976	31	79	26	15	37		10	7	6	11	84	306
	1990	42	67	9	5	42		96	32	17	9	80	399
Average area of vegetation element (ha)	1947	8.7	2.3	1.1	1.1	1.2				3.3	2.9	1.2	2.9
	1962	7.1	2.9	0.7	0.6	1.0	1.5			1.3	3.7	0.6	2.2
	1976	12.6	3.4	0.5	0.6	1.5		0.6	1.8	0.4	2.3	0.4	2.7
	1990	6.4	3.7	0.9	0.7	2.3		0.7	0.7	0.4	3.0	0.6	1.9

* Vegetation type: O. Citrus orchard, Pdt. Tall pine forest, Pdm. Medium pine forest, Pds. small pine forest, QQt. Tall oak forest, PA. *Pinus thunbergii-Alnus sieboldiana* plantation, Pl. *Pueraria lobata* community, EE. *Erigeron canadensis-Erigeron sumatrensis* community, UF. Upland field, IH. Inhabited area.

reached 46% of the total area. Citrus fruit production was most prosperous in 1976. Medium and small pine forests that had occupied about 4% of total area until 1962, decreased in 1976. On the other hand, oak forests increased. In 1990, citrus orchards had decreased considerably. The area of citrus orchards in 1990 were less than citrus orchards in 1947.

Dynamics of vegetation elements

Tall pine forests had the largest number of vegetation elements from 1947 to 1976, but in 1990 was replaced by the kudzu (*Puerarialobata*) community in abandoned orchards (Table 1). The number of vegetation elements of tall oak forests increased from 1947 to 1990. Upland fields decreased in 1976, and then increased in 1990.

Concerning the average areas of these vegetation elements, the area of citrus orchards increased from 1962 to 1976. The average area of tall pine forests increased gradually through time. Though the average area of tall oak forests was reduced in 1962, it also increased in 1990.

For change of vegetation types year to year, we chose five major vegetation types with an area of

change of more than 10 ha. These were orchards, upland fields, tall and medium pine forests, and bare lands. Then we identified what type of vegetation changed to another and the areas were calculated (Fig. 3).

During 1947 to 1962, new citrus orchards appeared in the area of upland fields and pine forests. Most of upland fields changed into citrus orchards, this change was the significantly largest among all changes. Forty percent of all pine forests changed into citrus orchards and another 40% of the remaining pine forests changed into medium and small pine forests, showing the cyclic use of pine forests (Kamada and Nakagoshi 1990). On the other hand, citrus orchards changed into other vegetation types. Seventy percent of the orchards were abandoned and became tall pine forests. This conversion was significant in the area of higher elevation. But on the whole, citrus orchards increased in this period. In contrast, from 1962 to 1976, conversion into tall pine forests was the greatest of the areal changes. Citrus orchards still increased through conversion from upland fields and from tall pine forests.

During 1976 to 1990, citrus orchards were largely abandoned. Fifty percent of the orchards in 1976 changed into the kudzu community, and about

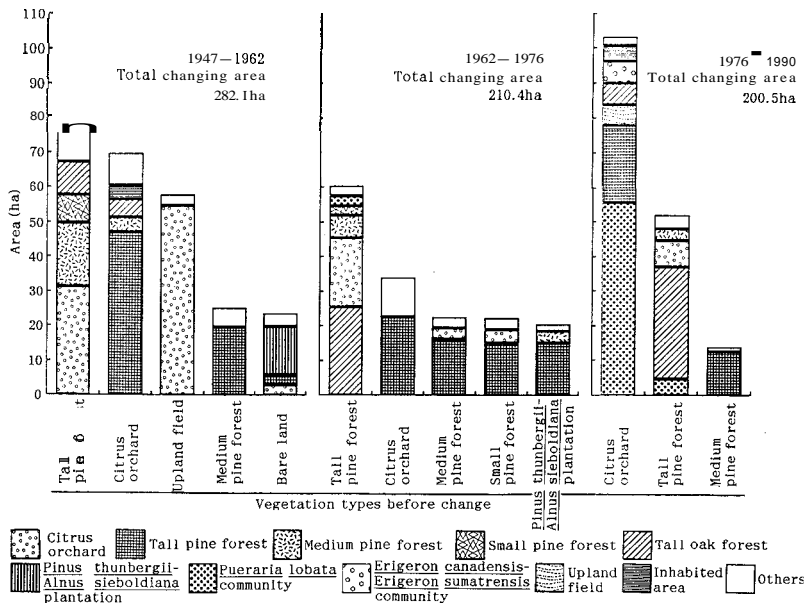


Fig. 3. The areal changes of vegetation types in each period.

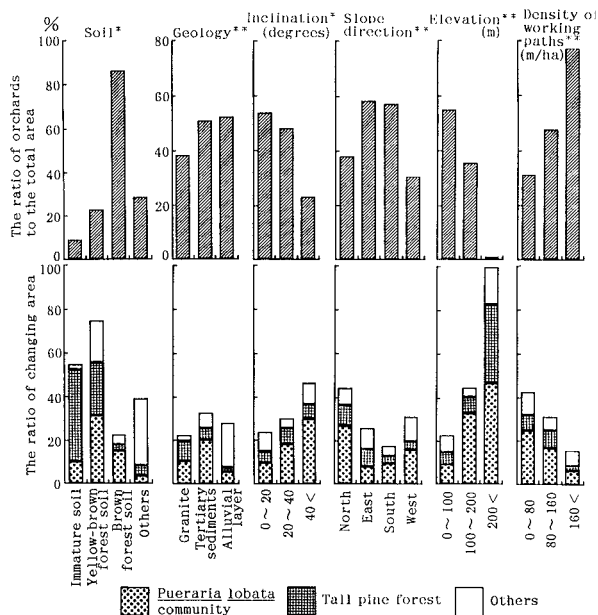


Fig. 4. The site conditions of orchards in 1976 (a: top) and the correspondence between the change of orchards and site conditions during 1976 to 1990 (b: bottom).

30% changed through ecological succession to tall pine forests. Nearly 70% of the change of tall pine forests were to tall oak forests in 1990.

Comparing the area of citrus orchards and those

of tall pine forests in 1976, under different site conditions, we could understand what kind of site conditions promote succession (Fig. 4). In Fig. 4-a, the site conditions of citrus orchards and the pattern of change of citrus orchards are shown. We can compare the site conditions of these orchards with each other. From the results, citrus orchards appeared mostly on the brown forest soils, in the low lands, on gentle slopes, and in the area of Tertiary sediments. Also, they appeared where the slope inclination was less than 20 degrees with a mainly southern direction. The elevations of these areas was less than 100m. They also appeared where the densities of working paths were more than 160 m per ha.

Changes of vegetation types and their site conditions

We examined the site of citrus orchards in 1976 (Fig. 4-a) where another vegetation type appeared by 1990 (Fig. 4-b). The vertical axis in Fig. 4-b shows the proportion of the area of change from citrus orchards during 1976 to 1990 to the area of citrus orchards in 1976. Asterisks show significant differences by the χ^2 test, an asterisk indicates the 5% level of probability; two asterisks the less than

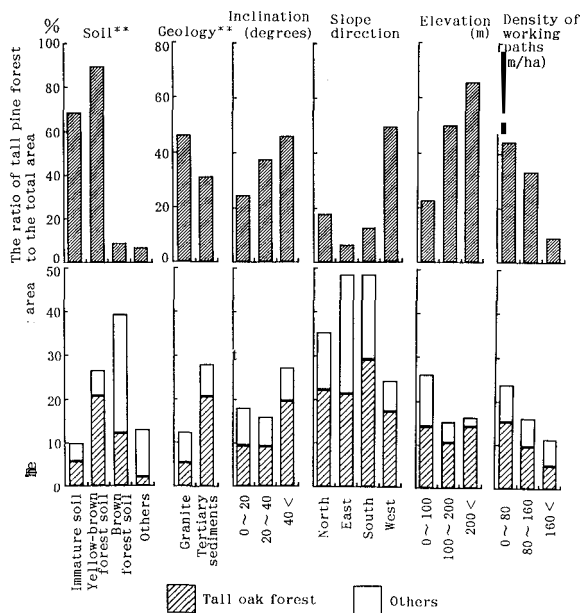


Fig. 5. The site conditions of tall pine forests in 1976 (a: top) and the correspondence between the change of tall forest of pine and site conditions during 1976 to 1990 (b: bottom).

1% level of probability. This figure shows the particular site conditions of the changing orchards and the area of these orchards. The vegetation changes from orchards to other types were classified into the kudzu community, tall pine forest and the other types.

For these 14 years, citrus orchards which appeared on various sites in 1976 ought to change uniformly by 1990 without specific selection pressure due to site conditions. If this assumption is true, then the changing area ought to show the same pattern as citrus orchards in 1976; that is, the pattern in Fig. 4-b should show the same features as the upper figure, Fig. 4-a. They did not do so. The sites of changing orchards during 1976 to 1990 appeared on immature soils originating from granite and yellow-brown forest soil, and on Tertiary sediments. Also they appeared on the slopes with an inclination of more than 40 degrees, facing to the north and west. These areas were located more than 200 m above sea level, where the densities of working paths were less than 160 m per ha.

Areas that changed into the kudzu community appeared on yellow-brown forest soils and Tertiary

sediments. They also occurred on slopes where their inclination was more than 20 degrees and they mainly faced to the north. The elevation of these areas was more than 200 m high above sea level, and the densities of working paths were less than 80 m per ha. Orchards changing into tall pine forests by 1990 appeared on immature soil and their elevations were more than 200 m high.

We also analyzed tall pine forests in 1976 in the same way (Fig. 5-a). Tall pine forests in 1976 mainly appeared on yellow-brown forest, on immature soils and on the granite. They also appeared where the slope inclination was more than 20 degrees, with a westerly direction. The elevation of these areas was more than 100 m. The density of working paths was less than 160 m per ha.

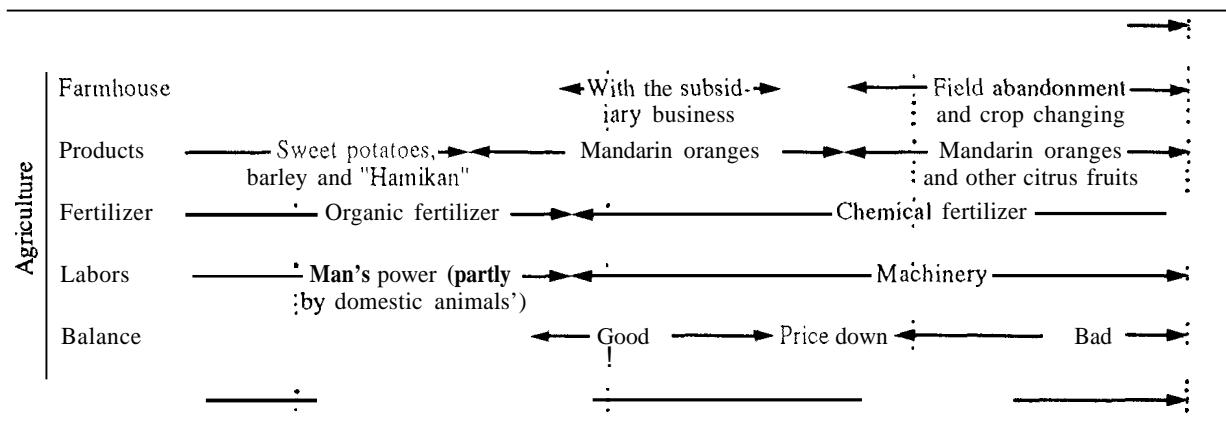
We also compared the pattern of tall pine forests in 1976 to those of the areas which changed by 1990 (Fig. 5-b). Tall pine forests which changed into other vegetation types by 1990 appeared on brown forest soils, originating on the Tertiary sediments. On the east and west facing slopes, and in the area of less than 100 m in altitude, this change was significant. Oak forests developing from pine forest appeared on yellow-brown and brown forest-soils and the Tertiary sediments. On the other hand, the vegetation on immature soil and granite remained in tall pine forests.

Social changes

According to the statistical data, the population of Shimokamagari Island has decreased since 1965; population in 1985 was half that of 1950. People with an age between 15 to 64 years old decreased. The population of farmers also decreased during 1960 to 1965. Table 2 shows the social and economic changes which were connected with orange production. After the food shortage was solved in 1950, the production of mandarin oranges as commercial products became prosperous. The orange production were most prosperous in 1967.

Organic fertilizer was used until the 1950's. The farmers collected litter from pine and oak forests to use directly as organic fertilizer. Or they laid the litter on the floor of sheds for livestock and made fer-

Table 2. Social and economic changes from 1945 to 1990



tilizer from the dung and litter. There was relatively little of this material due to the small number of domestic animals on this island. Forests were under personal (family) ownership, but they played the role of common forests. In certain periods of a year, anyone could enter the forests to collect the litter. Human manure was also used as fertilizer. To transport fertilizers, agricultural products and water for irrigation, human labor was mainly used. Organic fertilizers were replaced by chemical fertilizers in about 1960. At the same time, the utilization of forests was almost stopped.

The primary reason for the abandonment of citrus orchards was that they hardly paid for the new types of fertilizers and labor. The other major reasons were the aging of farmers who could no longer do the hard farm work and an increase in side businesses in farmers families. The forest products, wood and litter, were no longer used as fuel and lost their economic value. As a result, pine and oak forests grew free from human disturbances.

Discussion

In Shimokamagari Island, where citrus orchards occupied from 34 to 46% of the total area, the change in the vegetation landscape was greatly in-

fluenced by agricultural activity, especially orange production. During economic development after World War II, the commercial value of citrus fruits increased, and made orange production popular. During the period of the rapid economic growth, the need for labor in urban areas increased, and as a consequence farmers' populations decreased. The farmer's economy became dependent on their side businesses. This trend was caused by a policy designed to increase the income of farmers' households, connect agriculture to commercial business and change it from self-sufficient farming (Yamamoto 1988). The political decision was to promote livestock farming and fruit production technologically. Such national politics were connected with the expansion of citrus orchards.

The process of orchard expansion was as follows; first, forests and upland fields were connected with many small orchards. Gradually these were extended to form large orchards. In 1973 the first oil shock occurred, during a period of low economic growth, and agricultural products were generally overproduced. Prices of mandarin oranges declined greatly in 1973. In addition to this price decline, low-temperature damage in winter in 1974 and 1975 caused a lower yield in mandarin orange production. Moreover, political pressures for free imports increased. To reconstruct the economy, a subsidy was provided to the farmers who abandoned their

fields and changed products. Until recently money has been provided to farmers under these politics.

From 1976 to 1990, the decrease of citrus orchards and increase of the kudzu community was closely connected with the economic situation. Because farmers abandoned their fields, the citrus orchards were divided into small pieces. Therefore, the number of vegetation elements increased, but the average area of a vegetation element decreased. The change from tall pine forests to tall oak forests was influenced by this change in orange production. The major factor for the change of tall pine forests was that the farmers started to use chemical fertilizer and abandoned the forests. Pine forests are representative secondary forests in the Setouchi region, including Hiroshima Prefecture (Itow and Kawasoto 1979; Nakagoshi 1988), and they mainly appear on infertile soils originating on granite.

After the adoption of chemical fertilizers, forests were not used to produce litter for fertilizer and fuel and the litter was left accumulating on the forest floors. Pine trees grew weaker, and their seeds did not germinate in the thick litter. When pine trees died or were cut down, broad leaved trees, including oaks, will grow and convert the pine to an oak forest (Manabe *et al.* 1988; Kamada and Nakagoshi 1991).

The number of pine forest vegetation elements decreased from 1947 to 1990. At the same time the average area of the vegetation type increased. This was due to the conversion of the medium and small forests into tall pine forests as the farmers abandoned pine forests. These changes represent ecological succession of rural forest.

Until 1976 most of the available lands had been converted into citrus orchards, then economic change caused their abandonment. The abandoned fields appeared first in the places with the worst conditions for orange production and farm work. These were shade side orchards located on the slopes with an inclination of more than 20 degrees and on shady north slopes. Of course, these conditions were not suitable for orange cultivation. According to the questionnaire data, farmers first abandoned such citrus orchards located on north slopes far from their farmhouses where low quality oranges were produced.

In a human-dominated area, such as Shimokamagari Island, the factors affecting the process of vegetation change are a mixture of natural and artificial conditions and economic activities. In this example, vegetation changes were especially influenced by economic activities, such as commercial orange production. When these activities were terminated ecological succession became operative. Vegetation change on the other islands in Seto Island Sea were similar to those described in this paper. But, on Shimokamagari Island human activities were more intensive than on other islands (Nakagoshi 1988).

In the Setouchi region, the terraced orchards form a characteristic traditional and cultural landscape. This landscape symbolized the efforts of the old farmers. Abandoned terraces destroy this landscape and cause it to change through ecological succession to pine forests or to the kudzu community.

In Japan a pine tree is auspicious, and is used for the decorations of New Year's Day. The pine tree also appears in many Japanese paintings from old times to the present. In Setouchi, pine forests were an important element in the landscape and served many purposes. The combination of white beaches and pine trees have been recognized as attractive scenery in Setouchi and could be a basis for recreation. But at present, lack of management causes these pine forests to change to oak forests under ecological succession. In Setouchi region the traditional landscapes have disappeared rapidly. If we hope to maintain this landscape, an intentional land management scheme will be necessary.

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