

Actual vegetation of Shimokamagari-cho, Hiroshima Prefecture

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Abstract: An actual vegetation map of Shimokamagari-cho was produced at a scale of 1:25 000 in original. Field surveys were carried out in 2001 and 2002. Aerial photographs taken in 2000 were used to confirm the boundary of each vegetation patch. The map shows 26 physiognomic vegetation and land-use types belonging to 19 main types. Rapid changes of vegetation structure have occurred recently in Shimokamagari-cho, due mainly to human activities. People have abandoned orchards and stopped managing rural forests owing to socioeconomic changes. On the other hand, new types of land use for tourism appeared in 2002.

Keywords: Agricultural landscape, Human activities, Orange production, Seto Inland Sea, Tourism

I. Introduction

Vegetation is an important element of the landscape. Actual vegetation is strongly related to both the natural environment and human activities. The relationship between the spatial pattern of vegetation and its driving factors is a main research theme in landscape ecology, and it is expected to contribute to land conservation and landscape management (Golley 1996). Vegetation maps based on ecological concepts are useful for comprehending the distribution of vegetation (Alexander and Millington 2000) and contribute to regional design and planning.

In Hiroshima Prefecture, a series of landscape ecological studies have been undertaken (Nakagoshi and Ohta 1992; Ikegami and Nakagoshi 1995; Kamada and Nakagoshi 1996). In the region around the Seto Inland Sea, several vegetation maps have been made (Nakagoshi *et al.* 1988, 1990; Nakagoshi and Ikegami 1988; Nakagoshi and Ohta 1991) and are used in research on landscape ecology (Ikegami and Nakagoshi 2001; Nakagoshi *et al.* 2001). In this region, orange production and tourism are the main local industries. However, because of depopulation of rural communities, it is becoming difficult to maintain the farmland and the cultural and historical landscape. It is easy to imagine that the landscape will change greatly in the near future (Nakagoshi and Ohta 2000).

We have studied landscape dynamics in Shimokamagari-cho (Nakagoshi and Ohta 1992, 2000, 2001), and made an actual vegetation map from basic data on the natural environment in 2002 to detect changes in island vegetation and land use. This report uses survey data for the History of Shimokamagari-cho, which will be issued in 2004.

II. Study Area

The survey area is the whole of Shimokamagari-cho (lat. 34 °11' N, long. 132 °39' E), which covers 8.6 km² and lies southeast of Kure City, in the southern part of Hiroshima Prefecture, on the Seto Inland Sea (Fig. 1). The mean annual temperature and precipitation are 15.4 °C and 1318 mm. The climate is warm with relatively moderate precipitation (Yoshino, 1968). The highest point is 275 m above sea level. Shimokamagari-cho comprises 4 islands: Shimokamagari (7.9 km²), Kami-kuroshima (0.4 km²), Shimo-kuroshima (0.3 km²), and Hikube (0.001 km²).

People live only on Shimokamagari Island. The population was 2223 in 2000, distributed mainly along the shorefront. The main industry is the production of oranges. Most people work outside the town; 15.2% of the populace work in agriculture and fishing industry.

Shimokamagari Island was connected with Honshu by the Akinada Bridge in 2000, and the municipality was absorbed by Kure City in 2003.



Fig. 1. Map showing the study area. The three altitudinal zones are (◻): <100m, (▨): 100-200m, and (■): >200m.

III. Methods

A physiognomic vegetation map was drawn at a scale of 1:25 000 (in original) for the whole of Shimokamagari-cho (Fig. 2). Four such maps for 1947, 1962, 1976, and 1990 already exist (Nakagoshi and Ohta 1991). Legends for vegetation types (and some land-use types) in these past maps were used and new types were added. The vegetation types have heterogeneous physiognomy confirmed by phytosociology (Braun-Blanquet 1964), and each plant community was identified from diagnostic species and from the dominant species of particular plant coenoses (Miyawaki 1983). In the early stage of the survey, vegetation types were checked and roughly recorded on a topographic map at a scale of 1:25 000. Field surveys were carried out in 2001 and 2002; vegetation surveys were carried out in the autumn of 2002.

The boundary of each vegetation patch was determined from aerial photographs taken in 2000 at a scale of 1:40 000. From these photographs, we could classify the vegetation patches in unreachable places. The smallest vegetation patch is about 625 m² (25 m × 25 m). Patches smaller than this were neglected, because their size and shape would be uncertain on a 1:25 000 map.

The height of natural vegetation has been considered to reflect the biometeorological conditions of the particular community. In this sense, Raunkiaer's life form system (1934) is widely used in vegetation science (Ellenberg 1978). Considering the plant biomass and the degree of forest development, we used a similar method (Nakagoshi et al. 1988, 1989):

- a. Tall tree forest: above 8 m in height
- b. Medium tree forest: between 3 and 8 m in height
- c. Small tree forest: less than 3 m in height.

We created the vegetation map in a digital database using ArcView GIS 3.2a, a geographic information system, which measured area and number of patches of each vegetation type.

IV. Explanation of the Vegetation Map

The vegetation and land use of Shimokamagari-cho were classified into 19 main types and 11 subtypes divided by vegetation height. In total, 26 land-use types appear in the 2002 map (Table 1). The vegetation types and codes (in parentheses) are explained below.

1. Evergreen broad-leaved forest (CCt, CCm)

This climax forest type grows around the Seto Inland Sea. On Shimokamagari, it is restricted to around Shinto shrines and a slope in the Shimojima district. *Castanopsis cuspidata* is the dominant tree. Other species of evergreen broad-leaved trees include *Dendropanax trifidus*, *Quercus glauca*, *Ilex chinensis*, and *I. integra*. *Damnanthus indicus* and *Trachelospermum asiaticum* cover the forest floor. On Kami-kuroshima and Shimo-kuroshima, some evergreen broad-leaved forests remain. People settled there in 1960s and cut the forests, but disturbances were mild. This forest type is divided into two subtypes by the height of the tree layer:

- a. Tall tree forests (CCt) appear at two places on Shimokamagari, and on Kami-kuroshima and Shimo-kuroshima.
- b. Medium tree forests (CCm) appear on Kami-kuroshima.

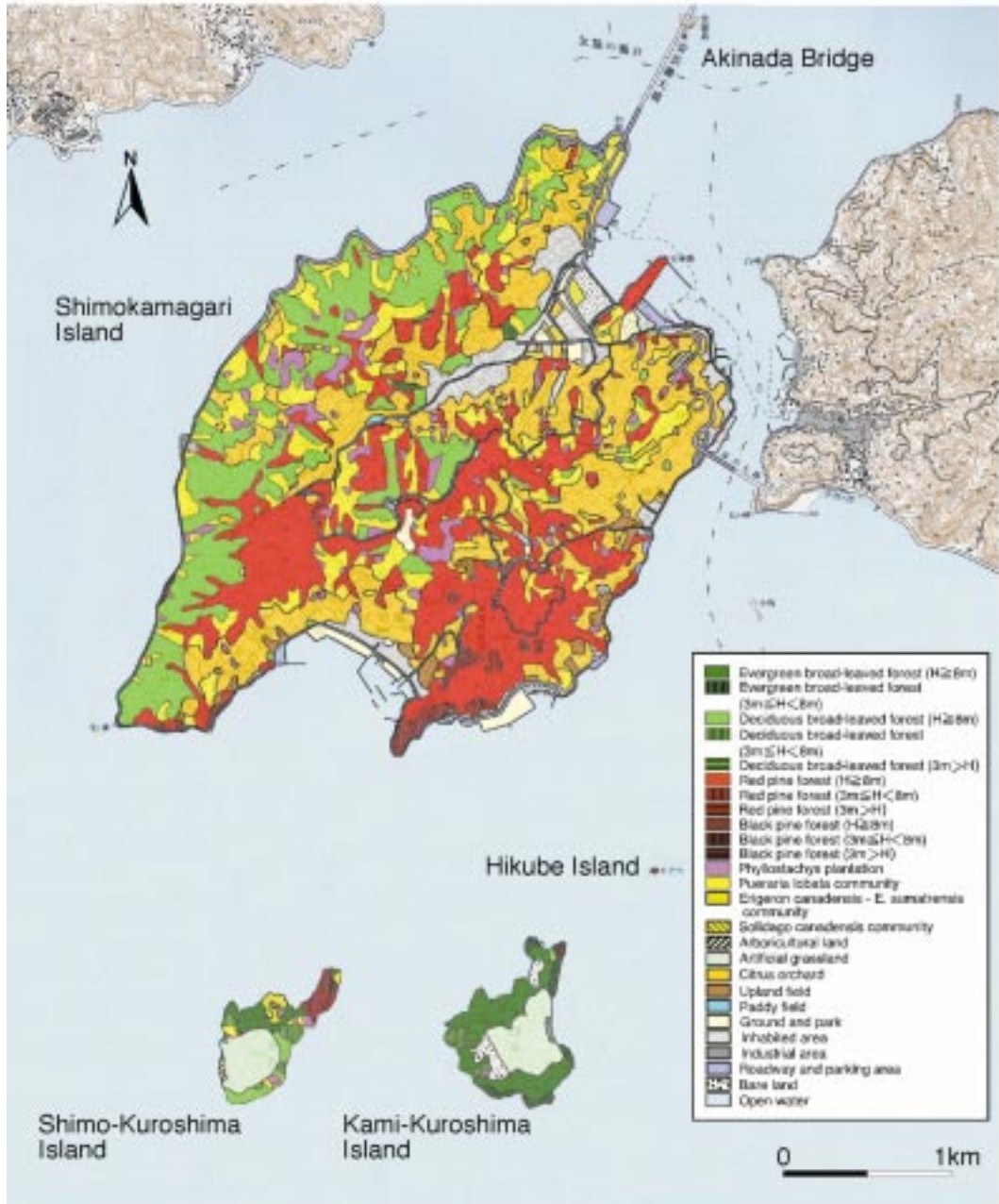


Fig. 2. Physiognomic vegetation map of Shimokamagari-cho.

Table 1. Number of patches and total area of vegetation types in Shimokamagari-cho

No. Vegetation type	Height of tree layer	Code of vegetati on type	Islands											
			Shimokamagari			Kami-kuroshima			Shimo-kuroshima			Hikube		
			Area (ha)	Area (%)	Number	Area (ha)	Area (%)	Number	Area (ha)	Area (%)	Number	Area (ha)	Area (%)	Number
1a Evergreen broad-leaved	H 8m	CCt	1.4	0.2	2	19.3	45.3	3	4.5	16.2	2	-	-	-
1b Evergreen broad-leaved	3 H < 8m	CCm	-	-	-	3.6	8.5	5	-	-	-	-	-	-
2a Deciduous oak forest	H 8m	QQt	127.2	16.0	52	0.3	0.6	1	3.1	11.2	3	-	-	-
2b Deciduous oak forest	3 H < 8m	QQm	-	-	-	1.2	2.8	3	2.3	8.2	4	-	-	-
2c Deciduous oak forest	H < 3m	QQs	0.3	0.0	1	0.5	1.1	1	0.2	0.6	1	-	-	-
3a Red pine forest	H 8m	Pdt	198.0	25.0	72	-	-	-	-	-	-	-	-	-
3b Red pine forest	3 H < 8m	Pdm	9.7	1.2	10	-	-	-	3.0	10.6	1	-	-	-
3c Red pine forest	H < 3m	Pds	0.1	0.0	1	-	-	-	-	-	-	-	-	-
4a Black pine forest	H 8m	Ptt	1.5	0.2	4	-	-	-	0.1	0.3	1	0.1	100	1
4b Black pine forest	3 H < 8m	Ptm	-	-	-	-	-	-	0.4	1.3	2	-	-	-
4c Black pine forest	H < 3m	Pts	-	-	-	0.6	1.3	1	-	-	-	-	-	-
5 Phyllostachys plantation		Ph	29.6	3.7	113	0.1	0.3	1	1.0	3.4	4	-	-	-
6 Pueraria lobata community		Pl	97.3	12.3	114	-	-	-	1.3	4.5	6	-	-	-
7 Erigeron canadensis-E. sumatrensis community		EE	6.8	0.9	16	-	-	-	1.4	5.2	1	-	-	-
8 Solidago canadensis		Sc	0.4	0.0	1	-	-	-	-	-	-	-	-	-
9 Arborescultural land		A	1.1	0.1	1	-	-	-	0.6	2.0	2	-	-	-
10 Artificial grassland		AG	1.1	0.1	3	13.0	30.5	1	10.2	36.6	1	-	-	-
11 Citrus orchard		O	198.4	25.0	75	-	-	-	-	-	-	-	-	-
12 Upland field		UF	12.6	1.6	27	-	-	-	-	-	-	-	-	-
13 Paddy field		PF	0.4	0.1	1	-	-	-	-	-	-	-	-	-
14 Ground and park		GP	13.4	1.7	10	-	-	-	-	-	-	-	-	-
15 Inhabited area		IH	39.1	4.9	29	-	-	-	-	-	-	-	-	-
16 Industrial area		IA	1.7	0.2	5	0.4	1.0	1	-	-	-	-	-	-
17 Roadway and parking area		RP	43.6	5.5	1	-	-	-	-	-	-	-	-	-
18 Bare land		B	9.2	1.2	17	3.7	8.6	2	-	-	-	-	-	-
19 Open water		W	0.3	0.0	4	-	-	-	-	-	-	-	-	-
Total			793.4	100	559	42.7	100	19	27.9	100	28	0.1	100	1

2. Deciduous oak forest (QQt, QQm, QQs)

Deciduous oak forest has several deciduous broad-leaved trees, mainly *Quercus serrata*, *Q. variabilis*, and *Platycarya strobilacea*. It is a widespread vegetation type around the Seto Inland Sea. The forest type is distributed in the western and northern parts of Shimokamagari. Some patches have several evergreen broad-leaved trees under the crown layer, such as *D. trifidus*, *Eurya japonica*, and *Symplocos lucida*. We suggest that the forest type is a seral stage from deciduous broad-leaved forest to evergreen broad-leaved forest. This forest type is divided into three subtypes by the height of the tree layer:

- Tall tree forests (QQt) appear on Shimokamagari, Kami-kuroshima, and Shimo-kuroshima.
- Medium tree forests (QQm) appear on Kami-kuroshima and Shimo-kuroshima.
- Small tree forests (QQs) appear on Shimokamagari, Kami-kuroshima and Shimo-kuroshima.

3. Red pine forest (Pdt, Pdm, Pds)

This vegetation type is dominated by red pine (*Pinus densiflora*), and is a very important element in historical landscapes around the Seto Inland Sea. Red pine forests have two kinds of vegetation structure: one is dominated by *P. densiflora*, and the other is mixed forest of both *P. densiflora* and deciduous and evergreen broad-leaved trees such as *Q. serrata*, *Q. variabilis*, *Rhus succedanea*, *S. lucida*, *D. trifidus*, *Ligustrum japonicum*, and *E. japonica*. The former grows on mountain ledges and rocky land. We assume that the latter will change into deciduous or evergreen broad-leaved forest by natural succession. This forest type is divided into three subtypes by the height of the tree layer:

- Tall tree forests (Pdt) appear on Shimokamagari.
- Medium tree forests (Pdm) appear on Shimokamagari and Shimo-kuroshima.
- Small tree forests (Pds) appear on Shimokamagari.

4. Black pine forest (Ptt, Ptm, Pts)

Black pine (*Pinus thunbergii*) forest grows naturally at coastal sites in Shimokamagari-cho. Its area is small. On Shimokamagari, it includes red pine trees. On Kami-kuroshima and Shimo-kuroshima, it grows on rocky land, and therefore the height of trees is low. This forest type is divided into three subtypes by the height of the tree layer:

- a. Tall tree forests (Ptt) appear on Shimokamagari and Shimo-kuroshima.
- b. Medium tree forests (Ptm) appear on Shimo-kuroshima.
- c. Small tree forests (Pts) appear on Kami-kuroshima.

5. *Phyllostachys* plantation (Ph)

This vegetation type is dominated by *Phyllostachys pubescens* and *P. bambusoides*. People once planted these bamboos near farmhouses and farmlands to supply food and materials and to prevent soil erosion. The bamboos have now spread at various sites, especially near abandoned orchards. Their aggressive growth and invasion make it difficult for farmers to control them.

6. *Pueraria lobata* community (Pl)

This community is dominated by *Pueraria lobata* and grows mainly in abandoned citrus orchards. This vine grows vigorously and invades abandoned fields rapidly, inhibiting natural succession. It is another serious problem for landscape management and ecology.

7. *Erigeron canadensis*-*E. sumatrensis* community (EE)

This community represents "waste land." It establishes on recently abandoned orchards and bare land, and often changes into a *Pueraria lobata* community (Nakagoshi and Ohta 1991). We found this community in a park under construction and in a factory holding area.

8. *Solidago canadensis* community (Sc)

Solidago canadensis is immigrant plant and invades abandoned orchards. It is also often found in *Pueraria lobata* communities. This vegetation type was not identified on vegetation maps until 1990 (Nakagoshi and Ohta 1991).

9. Arboricultural land (A)

This is one of the new land-use types. It represents estate land and trees planted for viewing. On Shimokamagari, an abandoned orchard has been converted to arboricultural land by the planting of Japanese apricot, cherry, and chestnut trees. Black pines have been planted around the harbor on Shimo-kuroshima.

10. Artificial grassland (Ag)

Artificial grassland is planted on slopes and landfill. When roadways are constructed, seeds of exotic plants such as *Eragrostis curvula* are spread for revegetation. *Pueraria lobata* often invades these grasslands.

11. Citrus orchard (O)

Citrus orchards form one of the important elements of the traditional landscapes around the Seto Inland

Sea. They were established on slopes and have terraced shapes. Farmers produce various oranges, especially mandarins. Citrus orchards cover about 25% of Shimokamagari, the biggest area of all vegetation types. This area takes in hedges and water courses in orchards. Therefore, citrus orchards appear to cover larger areas than they do.

12. Upland field (UP)

Small upland fields are scattered on Shimokamagari. Many of them are converted from citrus orchards. People grow subsistence crops there, and some produce cash crops such as strawberries in large vinyl houses.

13. Paddy field (PF)

Paddy fields once occurred in the flat lands on Shimokamagari, but are now found at only one place in a valley.

14. Ground and park (GP)

This vegetation type includes school grounds, parks, tennis courts, and lawns.

15. Inhabited area (IH)

Areas identified by clustered housing were identified as inhabited areas, regardless of any gardens.

16. Industrial area (IA)

This includes areas occupied by factories and ship builders, and construction sites.

17. Roadway and parking area (RP)

At the same time as the Akinada Bridge was built, the main roadways in the coastal zones were extended and widened. New roads for agriculture were also built. This land-use type includes slopes covered with concrete and piers.

18. Bare land (B)

Shimokamagari has a large bare area being turned into a park, and Kami-kuroshima has a landfill site.

19. Open water (W)

Mainly ponds. A limestone quarry on Shimokamagari holds a saltwater pond.

V. Changes of Vegetation in Shimokamagari-cho

The vegetation in Shimokamagari-cho has been changing rapidly. Comparison of the past vegetation maps (1947-1990, Nakagoshi and Ohta 1991) with the latest in Shimokamagari Island shows in Fig. 3. We can find three big changes. One is the decrease in the area of citrus orchards. Area of orchards in 2002 is about half of that in 1976. This reflects the changes of social conditions (Nakagoshi and Ohta 2001). Oranges began to be imported from foreign countries since 1991 in Japan. Population in Shimokamagari-cho has decreased: 4689 in 1970 and 2223 in 2000, but ratio of elderly people who are more than 65 years old has increased: 0.19 in 1970

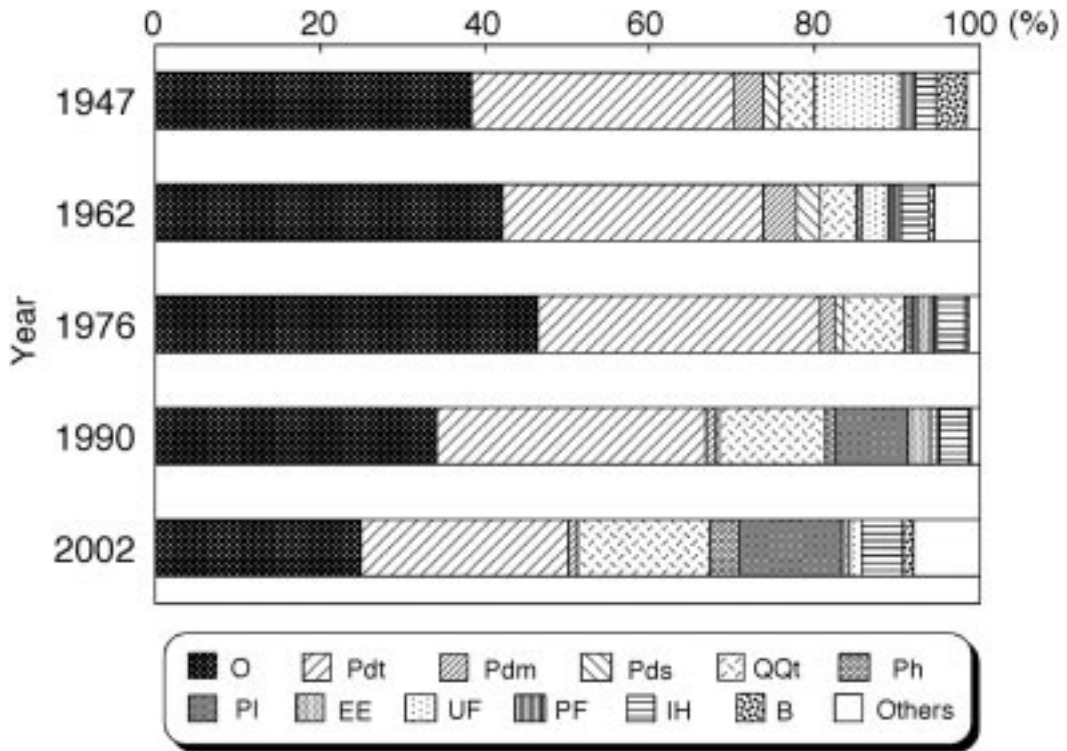


Fig. 3. Areal change of vegetation from 1947 to 2002 in Shimokamagari Island.

and 0.34 in 2000. The *Pueraria lobata* community establishes immediately in abandoned citrus orchards. It invades nearby farmland and shelters some crop pests. It has few kinds of species and resists natural succession, and is not pleasant to look at.

The other changes are the decrease in area of red pine forests and the increase in area of deciduous oak forests. This is closely connected with changes in industry and lifestyles (Nakagoshi and Ohta 1992). Until 1960s, people used the forests for fuel, compost, and building materials. Because of these intensive uses, the comparatively dry climate, and/or the immature soil derived from granite, red pine forests established as secondary forests (Nakagoshi 1988). Because the intensive use of forests has stopped, red pine forests are changing into oak forests (Manabe *et al.* 1988; Kamada and Nakagoshi 1991). Red pine forests still have the largest area on Shimokamagari, but the area is shrinking. The area of deciduous oak forests is increasing under natural succession. In the southern part of Shimokamagari, tall forests of red pine are still widespread. To maintain the traditional landscapes, efforts are being made to conserve the red pine forest by managing the forest. With the abandonment of wood collecting and of bamboo control, the coverage of *Phyllostachys pubescens* is expanding.

In Shimokamagari-cho, human activities have promoted vegetation changes. The building of the Akinada Bridge caused both the depopulation and the increase of abandoned orchards. It also opened the way to immigrant plants. This explains the arrival of *Solidago canadensis*. Following the development of a landscape management plan by the Shimokamagari-cho municipality (Shinji and Takeuchi 2003), parks and roadways to encourage tourism have been created. We can expect more vegetation change in Shimokamagari-cho, and it will

be necessary to make a new plan of landscape management.

However, it is indispensable for landscape management to reflect the will of inhabitant. Ikegami and Nakagoshi (1995) revealed that people in Setoda-cho hoped to conserve the cultural landscape of Seto Inland Sea, such as red pine forests, beautiful shoreline, and terraced orchards. For the conservation of red pine forests and orchards, social and economic assistances may be necessary. In addition, it is important that they are divided into danger or safety zones by changing probabilities, and management must be planned in each zone. Ikegami and Nakagoshi (1998) analyzed the relationship between the red pine forest death and site condition on the maps. We are preparing for the analysis of the relationship between the changes of vegetation and their driving factors from past to present in Shimokamagari-cho. Our map will be compared with the predicted vegetation in 2004 (Nakagoshi and Ohta 2000) and help to check the adjustment of prediction models. More investigation in both vegetation dynamics and inhabitant's idea for future landscape will enable us to suggest the new plan of landscape management.

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* Title is our tentative translation of the original Japanese title.