A NUMERICAL APPROACH TO THE LANDSCAPE CLASSIFICATION OF MUNICIPALITIES IN SAITAMA PREFECTURE, CENTRAL JAPAN

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Abstract This paper examines the adaptability of a numerical methodology to ecological landscape classification. Saitama Prefecture has been selected as a case study area and municipalities have been taken as basic unit areas. Factor analysis was applied to the data showing an areal percentage of 10 land units and 11 landuse units distributed in 92 municipalities. Seven factors were extracted and they were interpreted by using a rotated factor loading matrix, which suggested the typical combinations of land and landuse. The municipalities were classified into eight landscape types by applying cluster analysis to the factor score matrix, the result of which shows the landscape regionalization of the study area. It was concluded that the result is acceptable and the method could provide a possibility of combining landscape types with socioeconomic characteristics on a municipality basis.

1. Introduction

The author previously presented the method of ecological landscape classification for landscape planning, based on the concept that the landscape as a spatial entity is basically composed of land and landuse (Takeuchi, 1983). "Land unit" and "landuse unit" are fundamental bases for the landscape classification in that method. On the other hand, the author has recently collaborated on rural landuse planning works with social scientists, such as agroeconomist and agrosociologist, who usually use an administrative area as a basic unit in their discussions. As a result, he recognized the necessity of developing a method to classify the landscape, which takes administrative boundaries into account, to harmonize it with socioeconomic analyses.

How to classify the landscape on a higher spatial level, while expressing the dominant characteristics of the landscape, is also one of the most important subjects in landscape science. For this reason, a specific method to integrate areal landscape information should be developed. In this paper, a numerical approach to the landscape classification of municipalities is examined, by combining land and landuse as mentioned above to solve such problems.

Saitama Prefecture, adjoining the Tokyo Metropolis, has been selected as a case to discuss because it is expected to contain various landscape types and is therefore profitable for this study (Fig. 1). 92 municipalities constituting the prefecture have been taken as basic unit areas. Factor analysis and cluster analysis, which are said to be useful for the understanding of geographical regionalization (Goddard, 1970, Okuno and Kohsaka, 1980), have been applied in this study. It is expected that landscape classification can be performed by applying factor analysis and accompanying cluster analysis to the data showing areal distribution of land units and landuse units in these municipalities.

2. Data and Method of Analysis

Saitama Prefecture, located in the central part to the southwestern edge of the Kanto Plain (Fig. 1), has a physiographic structure of highlands (mountains) to the west and lowlands to the east. Hills and uplands are distributed between the two.

With the aid of land classification maps (geomorphological land classification map, subsurface geological map and soil map) published by the Economic Planning Agency (1973), lands of the prefecture are categorized into ten land units; that is, M-P, M-B, H, U-BL, U-A, U-AG, L-GL, N-GL, L-G and L-M, whose elements are described in Table 1. Land units are mapped and their areal occupation in each municipality is measured in percentage. For example, Urawa City, capital of the prefecture, contains 44.6% of U-A, 19.2% of U-AG and 36.2% of L-G.

At the same time, landuses of the study area are categorized into eleven landuse units by summarizing and interpreting the actual vegetation map (Miyawaki *et al.*, 1975). The vegetation map can be treated as a kind of ecological landuse map, which can be advantageous to use when combining landuse units with land units in the ecological landscape classification procedure. Further, a landuse map (Economic Planning Agency, 1973) is used, which can subdivide "paddy field" into A and B types from the agroecological point of view. The

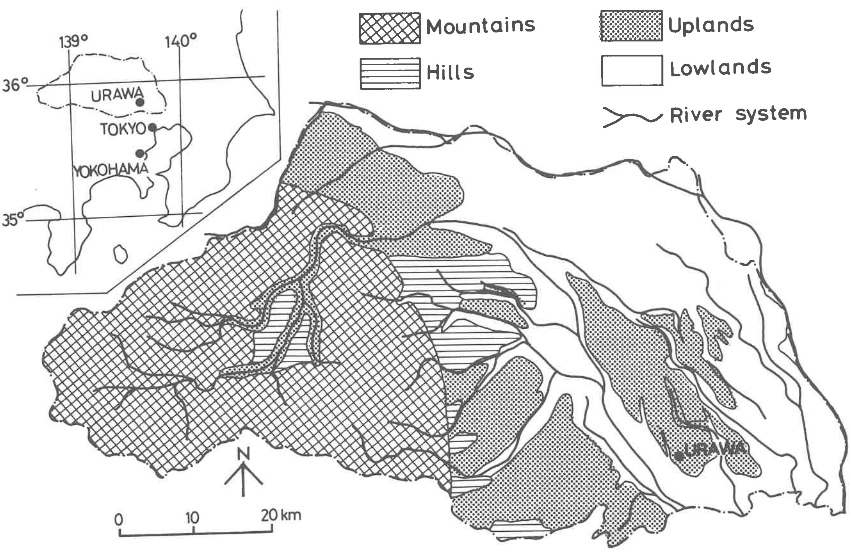

Fig. 1 Location and physiographic structure of Saitama Prefecture

Table 1 Land units of Saitama Prefecture and their classification criteria

Land unit	Landform	Surface geology	Soil
M-P	Mountains	Paleozoic/Mesozoic rocks	Podzolic soils
M-B	do.	do.	Brown forest soils
H	Hills	Tertiary sediments	Brown forest soils
U-BL	Uplands	Sand and gravel bed	Brown lowland soils
U-A	do.	do. (covered with tephra)	Ando soils
U-AG	do. (shallow valley)	do. (covered with tephra)	Ando-gley soils
L-GL	Alluvial fan	Gravel bed	Gray lowland soils
N-GL	Natural levee	Sandy mud sediments	do.
L-G	Deltaic plain	Muddy sediments	Gley soils
L-M	Back marsh	do.	Muck/Peat soils

A type is covered with seasonal water only, while the B type has standing water and is generally muddy.

Categories of the landuse units are natural forest, coppice forest, tall afforestation (mainly that of *Cryptomeria japonica* and *Chamaecyparis obtusa*), low afforestation (mainly that of *Pinus densiflora*), grassland, tree cropping (including mulberry field), dry field, paddy field A, paddy field B, rural settlement and urbanized landuse. They are also measured in areal percentage. Urawa City, for example, has 0.2% of natural forest, 0.4% of tall afforestation, 4.2% of grassland, 10.2% of tree cropping, 12.2% of dry field, 22.0% of paddy field B, 1.1% of rural settlement and 49.6% of urbanized landuse.

These data are listed for 92 municipalities and factor analysis is applied to the data showing areal percentages of 10 land units and 11 landuse units (21 variables). Seven components with eigenvalues greater than 1.0, representing 77.25 percent of the initial variance, are extracted and subjected to the varimax rotation. Consequently, a factor loading matrix and a factor score matrix are obtained. The factor score matrix is used as data which increases a level of understanding regarding the distribution patterns of interpretable high factor scores, but also the landscape classification of municipalities through cluster analysis which is described in greater detail in chapter 4.

3. Interpretation of Factor Loadings and Scores

Factor loading matrix with seven factors is shown in Table 2. In this study, factor loadings greater than ±0.60 and factor scores greater than ±0.50, in particular, those greater than ±1.00, are deemed most critical to interpret the seven factors and to observe the distribution pattern of factor scores in the study area. Distribution of municipalities with interpretable high factor scores for each factor is shown in Fig. 2.

Factor 1 has high positive factor loadings of U-A and dry field and high negative ones of M-B, coppice forest and tall afforestation. This factor is interpreted as representing the opposition of upland dry field and mountainous forest, high scores of which are concentrically distributed on the middle and western parts of the prefecture, respectively (Fig. 2-1). It is reasonable that mountains have been managed for coppice forest and tall afforestation landuses, which bring little disturbance to the function of retaining water and of preventing

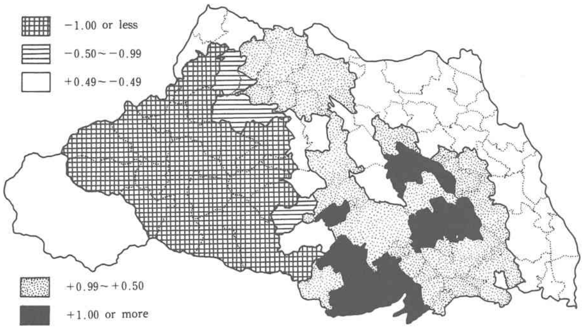

Fig. 2-1 Factor 1

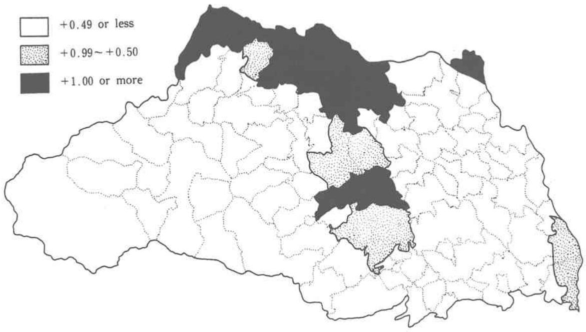

Fig. 2-2 Factor 2

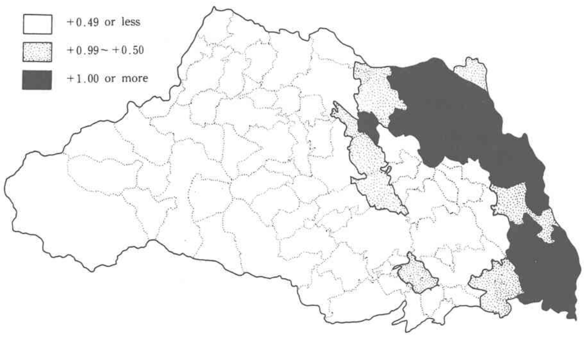

Fig. 2-3 Factor 3

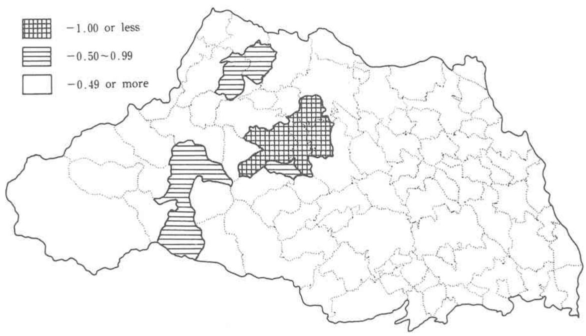

Fig. 2-4 Factor 4

Fig. 2-5 Factor 5

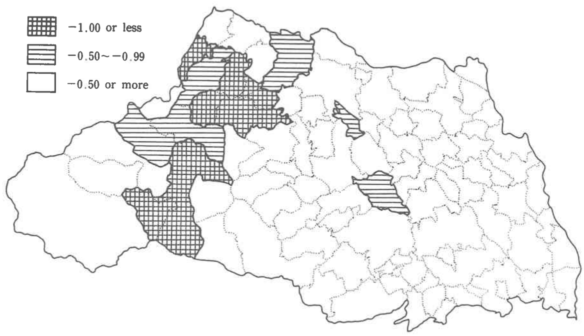

Fig. 2-6 Factor 6

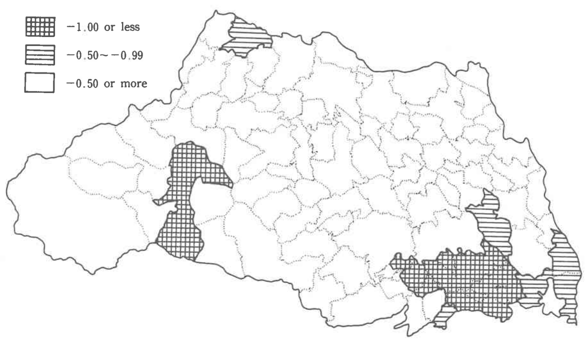

Fig. 2-7 Factor 7

Fig. 2 Distribution of municipalities with interpretable high factor scores for each factor

Table 2 Rotated factor loading matrix

Name of variables	Factor loadings						
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
M-P	–0.180	–0.103	–0.050	0.006	0.833	–0.093	0.031
M-B	–0.883	–0.200	–0.351	0.063	0.193	0.021	0.040
H	–0.671	–0.003	–0.150	–0.940	–0.032	0.015	0.034
U-BL	–0.207	–0.173	–0.130	0.043	0.082	–0.854	–0.005
U-A	0.697	–0.379	–0.053	0.231	–0.070	0.112	–0.155
L-GL	0.154	0.671	0.236	–0.148	–0.086	–0.113	0.419
N-GL	0.069	0.786	0.090	0.176	–0.017	0.104	–0.079
L-G	0.182	0.039	0.764	0.159	–0.076	0.121	–0.218
L-M	0.031	–0.018	0.692	0.098	–0.023	0.093	0.135
Natural forest	–0.054	–0.063	–0.091	0.017	0.890	0.048	–0.021
Coppice forest	–0.714	–0.229	–0.309	0.037	0.071	–0.169	0.016
Tall afforestation	–0.793	–0.155	–0.332	0.080	0.077	0.113	0.056
Low afforestation	0.041	–0.033	–0.140	–0.945	–0.042	0.038	0.066
Grassland	–0.074	0.258	0.040	0.173	0.515	0.079	–0.574
Tree cropping	0.072	0.252	–0.211	0.017	–0.068	–0.846	0.130
Dry field	0.682	–0.127	–0.340	0.133	–0.042	0.318	0.269
Paddy field A	0.032	0.874	–0.232	–0.048	–0.082	–0.078	0.092
Paddy field B	0.223	–0.032	0.898	0.128	–0.088	0.138	0.103
Rural settlement	0.293	0.417	0.258	0.175	–0.056	–0.118	0.585
Urbanized landuse	0.371	–0.212	0.031	0.136	–0.125	0.014	–0.714

natural disasters. Dry fields have been extensively developed on uplands covered with volcanogeneous Ando soils since the Edo era with the progress of artificial of artificial drainage systems.

All factors except factor 1 have a single pole with high positive or high negative factor loadings. Factor 2 has high positive loadings of L-GL, N-GL and paddy field A and therefore emphasizes paddy field on well drained alluvial fan. Distribution of high positive factor scores is focused on northern and middle lowland areas (Fig. 2-2). Being supported by advantageous soil and water conditions, this area maintains high rice productivity and forms the core agricultural area in this prefecture. Factor 3 has high positive loadings of L-G, L-M and paddy field B and is interpreted as emphasizing paddy field on the poorly drained deltaic plain which dominates eastern lowland areas (Fig. 2-3). Although rice productivity is low in this area, paddy field plays an important role to retaining water so as to prevent natural disasters and few other landuses are suitable.

Factor 4 has extremely high negative loadings of H and low afforestation, emphasizing *Pinus* afforestation on hilly country whose soils are very poor and therefore suitable only for such extensive landuse. Distribution of high negative factor scores are focused on the central part of the study area (Fig. 2-4). Factor 5 has high positive loadings of M-P and natural forest and it can be interpreted as characterizing subalpine natural forest which has been conserved without intensive land utilization for a long time. High positive factor scores are concentrated on southwestern high mountainous areas (Fig. 2-5).

High negative loadings of factor 6 are U-BL (accumulation terrace covered with brown lowland soils) and tree cropping which are combined to some extent in this region. High negative factor scores are distributed on the lower part of mountainous areas and adjacent river terraces where mulberry fields are still maintained in a traditional way (Fig. 2-6). Factor 7 has only one high negative loading of urbanized landuse and its high scores are mainly distributed on the southeastern part of the study area (Fig. 2-7). The area has been subject to the strong influence of urbanization due to the rapid expansion of the Tokyo Metropolis. One geographical exception with a high score can be observed in a municipality in the western mountainous areas, which forms a relatively independent city center.

Thus all factors except factor 7 are characterized by both land and landuse, and the distribution of municipalities with interpretable high factor loadings is well concentrated. Therefore, this result is considered to be useful for the landscape classification based on municipality boundaries.

4. Landscape Classification

Landscape types

Prior to the landscape classification of municipalities, the relationship between land units and landuse units is considered with the aid of the rotated factor loading matrix (Table 2). Table 3 represents the simplified relationships extracted from the matrix. If factor loadings

Table 3 Simplified relationship between land units and landuse units, extracted from the rotated factor loading matrix

Landuse unit \ Land unit	M-P	M-B	H	U-BL	U-A	U-AG	L-GL	N-GL	L-G	L-M
Natural forest	++									
Coppice forest		++	+		+					
Tall afforestation		++	+		+					
Low afforestation			++							
Grassland	+						+	+		
Tree cropping				++			+	+		
Dry field		+			++	+	+			
Paddy field A							++	++		
Paddy field B									++	++
Rural settlement							+	+		
Urbanized landuse					+	+				

++: factor loadings of both land unit and landuse unit are greater than ±0.6 in the same direction, +: those greater than ±0.3.

of both land unit and landuse unit are greater than ±0.6 in the same direction, ++ is marked and is considered to express a strong relationship. Similarly, + is marked for the case where both loadings are greater than ±0.3 and is considered to present a considerable relationship.

Table 3 shows that reasonable relationships exist between land units and landuse units from the ecological point of view. Dominant landscape types can be extracted as follows by using ++ as a criterion.

A. subalpine natural foest type (M-P and natural forest),

B. mountainous secondary forest type (M-B and coppice forest/ tall afforestation),

C. hilly *Pinus* forest type (H and low afforestation),

D. terrace tree cropping type (U-BL and tree cropping),

E. upland dry field type (U-A and dry field),

F. well drained lowland paddy field type (L-GL/N-GL and paddy field A) and

G. poorly drained lowland paddy field type (L-G/L-M and paddy field B).

It can be said that landuses are well ordinated according to the spatial arrangement of lands from the high mountain zone to the wet lowland zone.

On the other hand, urbanized landuse has a high factor loading in factor 7 but is weakly related to land units, which suggests that urbanization has occurred relatively apart from land conditions. Therefore, the last type is only set up with the landuse characteristic (urbanized landuse) as

H. urbanized landuse type.

Landscape classification of municipalities

Each municipality can be characterized in terms of its landscape type by using the interpretable high factor scores already presented in Fig. 2. However, to evaluate the seven factors at once and to extract the dominant landscape type of each municipality, a rational landscape classification method should be further applied.

To this end, cluster analysis (the Ward method) is applied to euclidean distances which are calculated from a factor score matrix (92 municipalities × 7 factors). Seven factors, all of which suggest significant landscape features, are equally evaluated.

Fig. 3 represents the relevant portion of a dendrogram obtained by the cluster analysis. Municipalities are combined into eight groups on the step with the inter-group distance of 77.0 in the dendrogram. On this level of step, eight landscape types as mentioned previously correlate well with this grouping result (Fig. 3). The result is so desirable that the eight classified groups can easily be interpreted by means of the eight landscape types. Therefore, the result is acceptable as a criterion for the landscape classification of municipalities in this area.

Consequently, a landscape classification map has been drawn up (Fig. 4). All municipalities have been classified in terms of dominant landscape type. Fig. 4 also seems to express the significant landscape regionalization within the Saitama Prefecture as a whole, since the spatial arrangement of landscape types from the highlands to the lowlands is presented in this map.

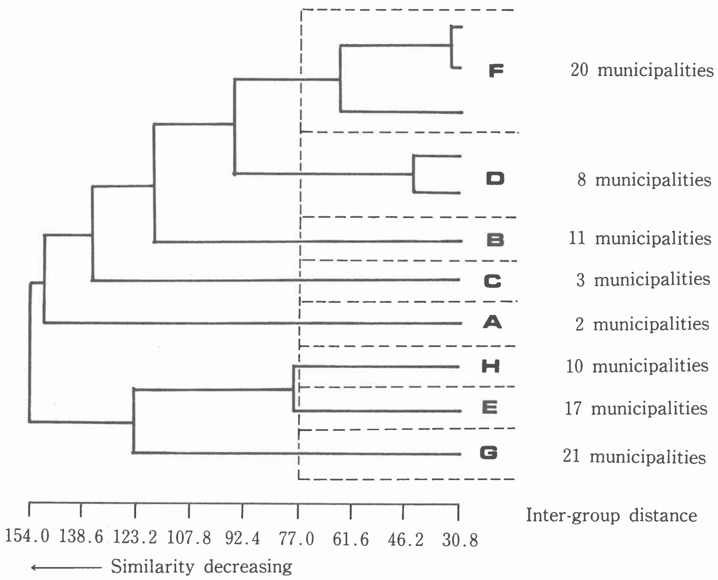

Fig. 3 Relevant portion of a dendrogram obtained by the cluster analysis and landscape types correlated with grouping result

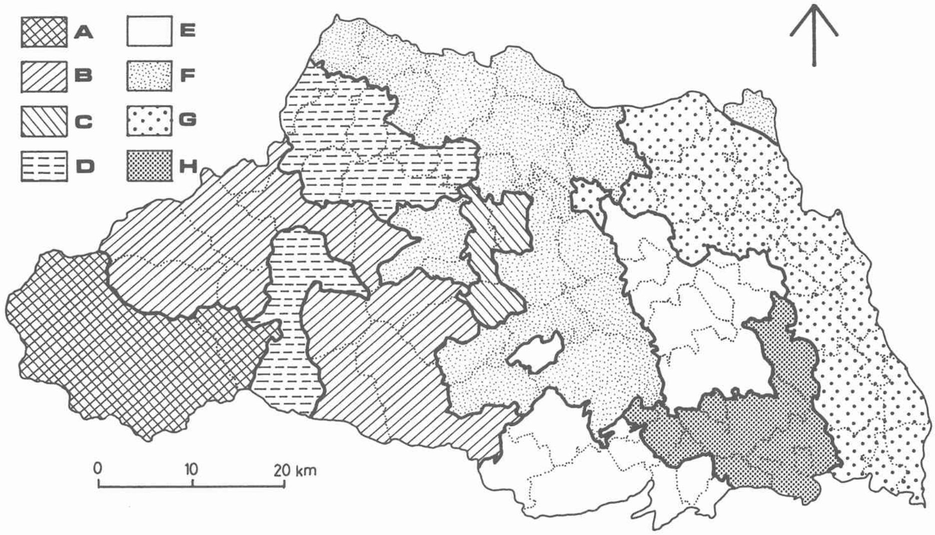

Fig. 4 Landscape classification map of municipalities in Saitama Prefecture

A. Subalpine natural forest type
B. Mountainous secondary forest type
C. Hilly *Pinus* forest type
D. Terrace tree cropping type
E. Upland dry field type
F. Well drained lowland paddy field type
G. Poorly drained lowland paddy field type
H. Urbanized landuse type

5. Concluding Remarks

The result of numerical landscape classification of municipalities as mentioned above is acceptable and correlates well with the concept that landscapes are basically composed of lands and landuses. The result will be utilized as a fundamental basis for comprehensive planning. It is concluded that the numerical method is useful for landscape classification on a municipality basis, and it could provide a possible method of combining landscape types with socioeconomic characteristics.

The method could also be adapted to the other administrative areas. For example, the landscape classification of prefectures on a national level would represent a nation-wide landscape regionalization. Further study is to be requested.

Acknowledgements

The author wishes to express many thanks to Associate Professor Yoshio Sugiura of the Department of Geography, Tokyo Metropolitan University for his kind guidance and advice. This paper is dedicated with sincere thanks to Professor Takamasa Nakano on the occasion of his retirement from Tokyo Metropolitan University, who allowed the author to enjoy academic freedom.

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