

# NUMERICAL CLASSIFICATION OF NATURAL REGIONS OF JAPAN

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*Abstract* Natural regions of Japan were devised through multivariate analysis using several databases related to the natural environmental elements, the preparation of which has rapidly progressed in recent years. The analysis was performed by making each sample area approximately 1 km<sup>2</sup> and using ten environmental elements. Firstly the sample areas were classified separately on the basis of climatic elements, land characteristics, and vegetation types. Then these three classifications were integrated to identify natural regions. For qualitative data, Hayashi's quantification theory III was applied while factor analysis was applied for quantitative data to understand the structure of the natural environment. Sample scores and factor scores were classified into groups by cluster analysis. The result of classification obtained from this was used to make a map of integrated natural regions. The relationship between integrated natural regions and three basic regions was analyzed to clarify the characteristics of each region. As a result, the whole of Japan was classified into ten natural regions, in which the functional relationships of natural environmental elements were clarified.

**Key words:** natural region, geographical database, environmental element, multivariate analysis, Japan

## 1. Introduction

Classifying the world, a country, or a region into homogeneous natural regions has long been a subject of geography (*e.g.* Herbertson, 1904). Classification into natural regions has been considered as fundamental work not only for geographical study but also for applied purposes such as regional planning and environmental management. For instance, in East and West Germany, a map of natural regions of the whole country differentiates between different landforms and soil features. This has been used not only for geographical study but also for various applied purposes (Schmithüsen, 1953; Haase *et al.*, 1984; Haase, 1989).

Natural regions may be defined as "the spatial unification of natural environmental elements". When classifying natural regions in a country, the process of integrating

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natural environmental elements presents problem because of the difficulty of expressing total figure of natural region. In the case of a relatively small area, an overall classification can be done from aerial photo interpretation (Christian and Stewart, 1968). Also, recently, regional classification of environmental units is performed by using satellite images (CSIRO, 1977). However, such "a priori" classification has a weak point in that the description of functional relationships among natural environmental elements in a region are not always obvious.

A more objective method to identify natural regions is by using several natural environmental elements as indices to determine the boundaries. In this case the process to clarify the functional relationships of natural environmental elements is not always obvious. This can be seen clearly in the well known natural regions of the world presented by James (1952). In the natural regions of Japan proposed by Yoshino (1980), regional classification was performed at three spatial levels by combining the boundaries of natural environmental elements including landform, soils, climate and vegetation. However, the functional relationships of natural environmental elements in classified regions is unclear while it has the problem that boundaries are drawn with an arbitrary index.

The identification of natural regions in which such problems are solved is required to maximize their use in regional planning and environmental management not only to present regional differentiation but also to be used as a comprehensive unit of the natural environment. A database related to natural environmental elements, the preparation of which is rapidly advancing at present, is an important key to solve such problems. This is seen as objective definition of natural regions and the environmental structure of regions, which are not "a priori" regional classifications using aerial photos or satellite images or arbitrary classifications performed by combining environmental indices.

Recently an integrated analysis of the natural environment of Japan has been performed by using geographical databases; Digital National Land Information from the Geographical Survey Institute, Japan, Grid Map of Climatic Data from the Meteorological Agency, Japan and Vegetation Datafile from the Environmental Agency, Japan. Based on these databases, the authors defined natural regions using the multivariate analysis (Wildlife Research Center, 1989). This paper describes the classification of natural regions of Japan improving these results by using the method described in this paper.

## **2. Data Analyzed and Method of Study**

### **Outline of the data analyzed**

The data is arranged according to the national grid code system, which has three spatial levels; first grid equivalent to the size of 1/200,000 topographic map, second grid equivalent to the size of 1/25,000 topographical map and third grid obtained by dividing the second grid horizontally and vertically by  $10 \times 10$ . Around the center of Japan, the size of the third grid is approx.  $1 \text{ km} \times 1 \text{ km}$  (the difference in longitude is  $45''$  while the difference in latitude is  $30''$ ). This third grid is the unit for the storage of geographical

**Table 1** Classification of characteristics

Code	Landform classification	Lithologic classification	Soil classification
1	Strong relief mountains (>600m)	Gravel bed	Regosols
2	Medial relief mountains (400-600m)	Sandy sediments	Volcanogeneous regosols
3	Low relief mountains (200-400m)	Muddy sediments	Ando soils
4	Volcanoes	Sedimentary rocks	Brown forest soils
5	Hills	Tephra	Podzolic soils
6	Tephra covered uplands	Volcanic rocks	Red or yellow soils
7	Gravel or rocky uplands	Plutonic igneous rocks or Metamorphic rocks	Lowland soils or Gley soils
8	Lowlands or Natural levees		Peat soils
9	Lakes or Rivers		Others

database.

The Grid Map of Climatic Data of Japan estimated by using the climatic data observed (mean annual temperature, mean monthly temperature of the warmest month, mean monthly temperature of the coldest month, annual precipitation, precipitation in the summer months and precipitation in the winter months) were supplied by the Meteorological Agency, Japan. These data were used as climatic elements.

The data used for the land characteristic classification are the landform, lithology and soils from the Digital National Land Information from the Geographical Survey Institute, Japan. The data are taken from topographic maps with a scale of 1/200,000 published by the National Land Agency, Japan. The categories of each item are combined and simplified for statistical analysis as shown in Table 1.

The Vegetation Datafile is based on research by the Environmental Agency, Japan

**Table 2** Classification of actual vegetation

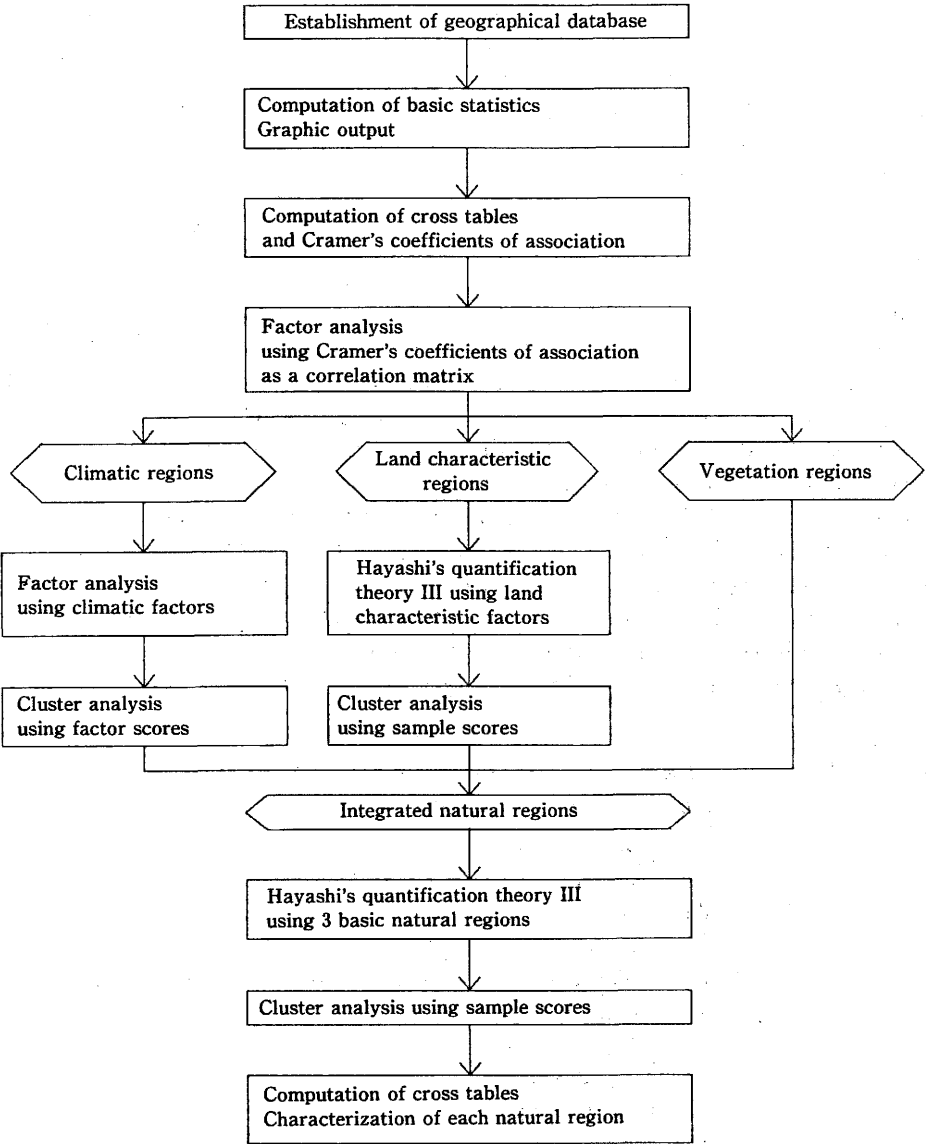
Code	Actual vegetation
V1	Alpine/Subalpine forests
V2	Cool-temperate natural forests
V3	Cool-temperate secondary forests
V4	Warm-temperate natural forests*
V5	Warm-temperate secondary forests*
V6	Plantations
V7	<i>Pinus</i> forests
V8	Grasslands · Dry fields
V9	Paddy fields
V10	Urban landuse · Others

\* including Subtropical natural or secondary forests

aimed at preserving the natural environment. The Datafile is obtained from the second (between 1978 and 1979) and third (between 1983 and 1987) research projects. As this database has a lot of categories (plant communities), these are combined into ten categories to be used as data for statistical analysis as shown in Table 2.

**Method of study**

The authors have applied the method of landscape classification using geographical



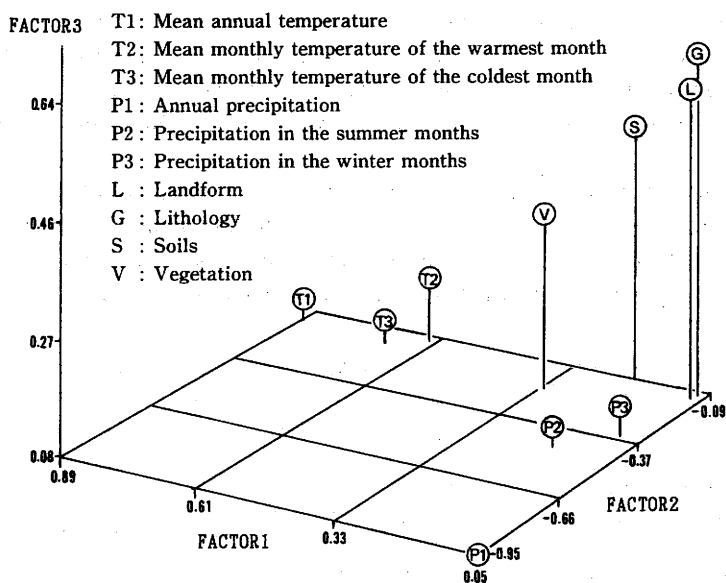
**Fig. 1** Flow chart of analysis in this study

database to the middle reaches of the Tama River Basin as an example to understand the regional environmental structure (Takeuchi and Lee, 1989; Lee *et al.*, 1989). The method is making the most of the Hayashi's quantification theory III (Komazawa, 1982), to be used for qualitative data such as landform, lithology and soils. This is useful for a structural understanding of the regional environment, and drawing a map of environmental units.

A similar analytical method to the above was employed for the present study. The procedure of the analysis taken in this study is shown in Fig. 1. First, the total number of grids for each category in each element was calculated and the grid map was drawn to display the geographical distribution of the element. Next, the cross sum was calculated to understand the relationship among categories of two environmental elements, which was used to calculate Cramer's coefficient of association (between 0 and 1; Kendall and Stuart, 1979) to understand the strength of the relationship between two elements.

To understand the relationship among ten environmental elements taken in this study, a correlation coefficient matrix was derived through factor analysis based on Cramer's coefficient of association. Then, three basic regional classifications of climates, land characteristics and actual vegetation were performed, because the result of factor analysis suggests these three are forming groups.

Concerning the classification of climatic regions, factor analysis is applied since climatic elements are all expressed in quantitative data. The scores of three factors 1, 2



**Fig. 2** Distribution of factor scores of environmental elements obtained by factor analysis

FACTOR1: mainly related to thermal condition

FACTOR2: mainly related to precipitation

FACTOR3: mainly related to edaphic condition

and 3 which were obtained from the factor analysis were divided into ten groups by cluster analysis.

For the classification of land characteristic regions, Hayashi's quantification theory III was applied since land characteristic elements are all qualitative data. The resultant sample score is divided into ten groups using cluster analysis.

For the identification of integrated natural regions, quantification theory III was used again by using the obtained three regional classifications. Here, vegetation data was used directory. The sample score was divided into ten groups by cluster analysis. These were used as the final classification of natural regions. In addition, the relationship between each natural region and climatic, land characteristic and vegetation regions were clarified.

### 3. Results of Analysis

#### Relationship among natural environmental elements

Ten items are selected as natural environmental elements; *i.e.*, mean annual temperature, mean monthly temperature of the warmest month, mean monthly temperature of the coldest month, annual precipitation, precipitation in the summer months, precipitation in the winter months, vegetation classification, landform classification, lithologic classification, and soil classification.

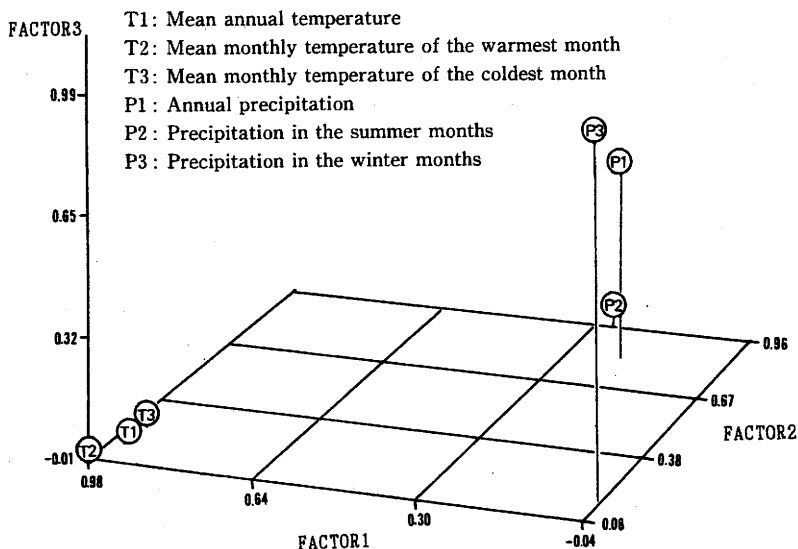
#### *Relationship among natural environmental elements*

Table 3 shows Cramer's coefficient of association among ten natural environmental elements. The highest value in this table is 0.664 showing the relationship between the mean annual temperature and the mean monthly temperature of the coldest month. The second is 0.600 showing the relationship between the mean annual temperature and the mean monthly temperature of the warmest month.

Factor analysis was performed by using Cramer's coefficient of association as a correlation matrix. First, three factors, the characteristic number of which was more than 1, were extracted by the principal component analysis and the varimax rotation which is an orthogonal rotation was performed. The cumulative proportion of these three

**Table 3** Cramer's coefficient of association matrix showing the relationship among environmental elements

	1	2	3	4	5	6	7	8	9	10
1. Mean annual temperature	1.000									
2. Mean temperature of the warmest month	0.600	1.000								
3. Mean temperature of the coldest month	0.664	0.464	1.000							
4. Annual precipitation	0.177	0.153	0.185	1.000						
5. Precipitation in the summer months	0.227	0.181	0.230	0.474	1.000					
6. Precipitation in the winter months	0.146	0.103	0.149	0.347	0.206	1.000				
7. Landform classification	0.152	0.173	0.142	0.174	0.159	0.132	1.000			
8. Lithologic classification	0.160	0.156	0.155	0.150	0.161	0.128	0.413	1.000		
9. Soil classification	0.254	0.243	0.203	0.131	0.134	0.113	0.304	0.344	1.000	
10. Vegetation classification	0.337	0.332	0.308	0.292	0.140	0.168	0.271	0.266	0.305	1.000



**Fig. 3** Distribution of factor scores of climatic elements obtained by factor analysis

factors amounts to 59 %.

The first factor relates to temperature and involves the mean annual temperature, mean monthly temperature of the coldest month and mean monthly temperature of the warmest month. The second factor relates to precipitation and takes account of the annual precipitation, precipitation in the summer months and precipitation in the winter months. The third factor relates to the land characteristics and considers the landform, lithology and soils. The actual vegetation relates to these three factors, however, a specific strong connection is not shown.

From the results of the above analysis, it was decided to perform an integrated classification of natural regions based on three basic regions of climate, land characteristics and actual vegetation.

### **Classification of natural regions using multivariate analysis**

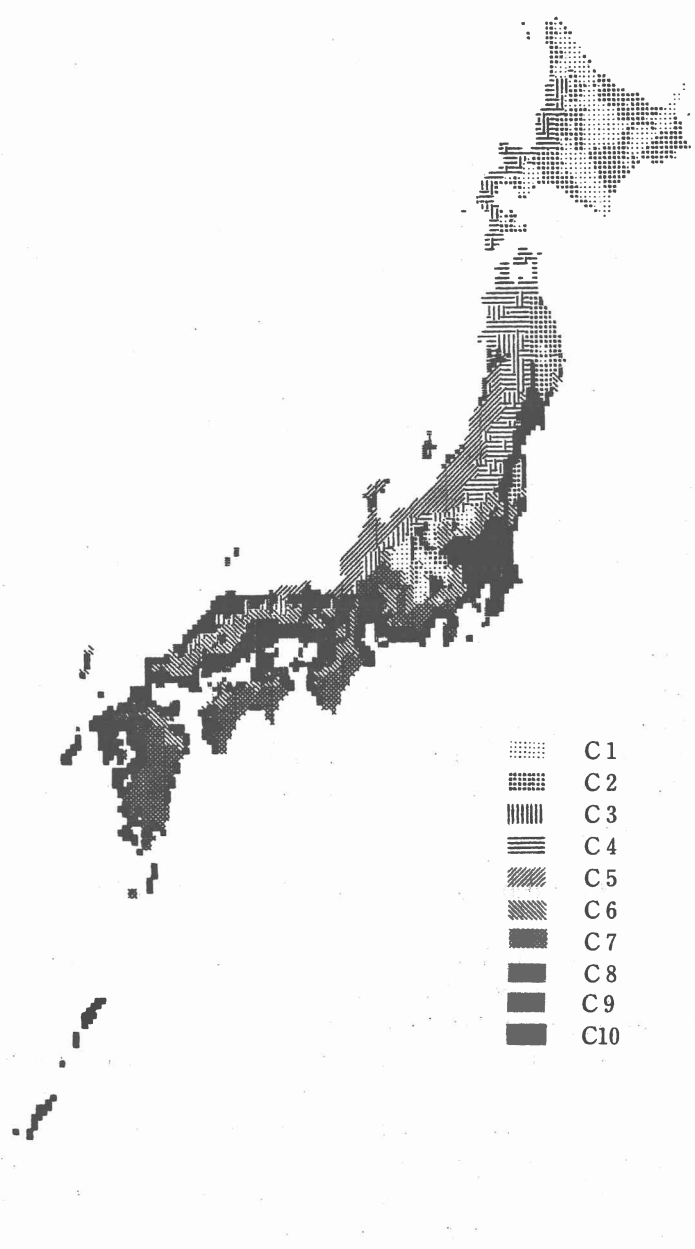
#### *Climatic regions*

Factor analysis was applied by using six environmental elements relating the climatic conditions. First, three axes were extracted by the principal factor method (Fig. 3). The cumulative proportion of these three axes is 99 %.

The first factor relates to the mean annual temperature, mean monthly temperature of the coldest month and the mean monthly temperature of the warmest month. The second factor relates to the precipitation in the summer months and annual precipitation. The third factor shows the difference in precipitation between summer and winter. The precipitation in the summer months is shown as a positive value while the precipitation in the winter months is shown as a negative value.

Cluster analysis (MacQueen's k-means algorithm; MacQueen, 1967) was performed by using the factor score of the above three factors to divide them into ten groups.

According to this result, the map of climatic regions was drawn as shown in Fig. 4. Typical combinations of climatic elements for each climatic region are shown in Table 4. The designations showing the characteristics of each climatic region are shown as follows;



**Fig. 4** Map showing the distribution of climatic regions obtained by factor analysis

**Table 4** Classified climatic regions

Number of climatic regions	C1	C2	C3	C4	C5
Characteristics of the climatic region	Very cool temperature lower precipitation	Cool temperature low precipitation	Cool temperature high winter prec.	Cool temperature higher winter prec.	Moderate temperature high winter prec.
Mean annual temperature (°C)	less than 8.0	between 4.0 and 10.0	between 4.0 and 10.0	between 6.0 and 12.0	between 8.0 and 14.0
Mean monthly temperature of the warmest month (°C)	less than 20.5	between 18.0 and 23.0	between 15.5 and 23.0	between 18.0 and 25.5	between 18.0 and 28.0
Mean monthly temperature of the coldest month (°C)	less than -6.0	less than -2.0	between -10.0 and 0.0	between -6.0 and 0.0	between -4.0 and 4.0
Annual precipitation (mm/yr)	less than 2000	less than 2250	between 1750 and 2500	between 1250 and 2000	2550 or more
Precipitation in the summer months (mm/5 months)	between 600 and 1000	less than 1000	between 600 and 1400	less than 1000	between 800 and 1400
Precipitation in the winter months (mm/4 months)	between 200 and 500	less than 400	between 500 and 900	between 400 and 700	800 or more

Number of climatic regions	C6	C7	C8	C9	C10
Characteristics of the climatic region	Moderate temperature moderate precipitation	Warm temperature higher summer prec.	Warm temperature higher winter prec.	Warm temperature lower precipitation	Very warm temp. high precipitation
Mean annual temperature (°C)	between 8.0 and 14.0	between 10.0 and 18.0	between 10.0 and 16.0	between 8.0 and 16.0	14.0 or more
Mean monthly temperature of the warmest month (°C)	between 20.5 and 28.0	between 20.5 and 28.0	between 23.0 and 28.0	between 23.0 and 28.0	25.5 or more
Mean monthly temperature of the coldest month (°C)	between -2.0 and 4.0	between -2.0 and 6.0	between 0.0 and 6.0	between 0.0 and 6.0	2.0 or more
Annual precipitation (mm/yr)	between 1500 and 2500	2250 or more	between 1750 and 2500	less than 1750	between 1750 and 2500
Precipitation in the summer months (mm/5 months)	between 1000 and 1600	1400 or more	between 800 and 1200	between 600 and 1200	between 1000 and 1600
Precipitation in the winter months (mm/4 months)	between 200 and 500	between 300 and 600	between 400 and 800	less than 400	between 200 and 500

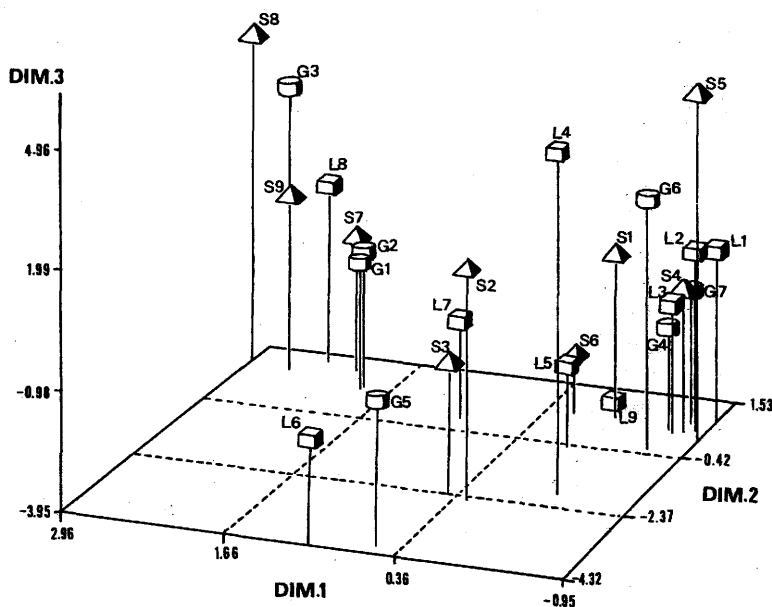
- C1: Very cool temperature - lower precipitation
- C2: Cool temperature - low precipitation
- C3: Cool temperature - high winter precipitation
- C4: Cool temperature - higher winter precipitation
- C5: Moderate temperature - high winter precipitation
- C6: Moderate temperature - moderate precipitation
- C7: Warm temperature - higher summer precipitation
- C8: Warm temperature - higher winter precipitation
- C9: Warm temperature - lower precipitation
- C10: Very warm temperature - high precipitation

#### *Land characteristic regions*

The third grid system divides the whole of Japan into approx. 380,000 areas. As processing the whole of Japan with quantification theory III at the same time was not possible because of the limit of computer capability, first 1 % sample was extracted to perform quantification theory III. Then, by using the category scores which were obtained, the sample score of the remaining 99 % was calculated.

The first axis obtained from the analysis of quantification theory III has an eigenvalue of 0.804 which accounts for 11 % of the total variance, showing the strong relationship with soil classification. The second axis, with an eigenvalue of 0.643, accounts for 9 % of the total variance, showing a strong relationship with lithology. The third axis with an eigenvalue of 0.456 accounts for 6 % of the total variance, showing a strong relationship with the landform classification (Fig. 5).

By using the sample scores of the above three axes, cluster analysis was applied to



**Fig. 5** Distribution of category scores on the axes of Dim. 1, 2 and 3 by Hayashi's quantification theory III, using land characteristic factors

divide them into ten groups. According to this result, the map of land characteristic regions was drawn as shown in Fig. 6. Typical combinations of landform, lithologic and soil features for each region are shown in Table 5. The designations showing the typical combinations of landform and soils of each land characteristic region are shown as

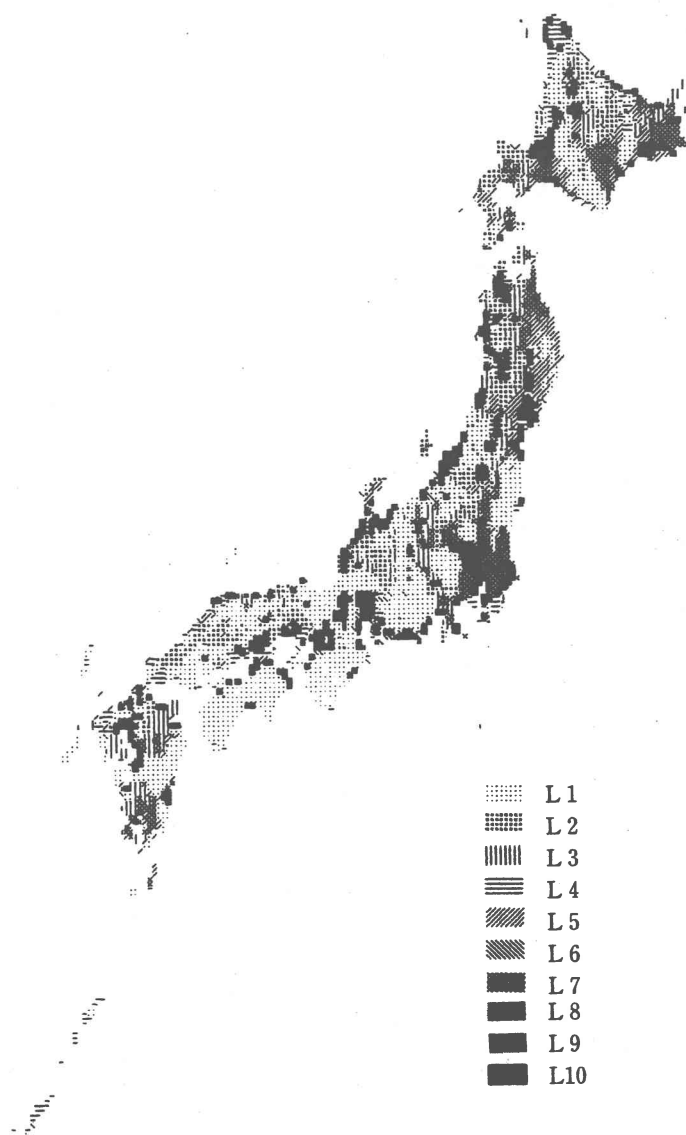


Fig. 6 Map showing the distribution of land characteristic regions

**Table 5** Classification of land characteristics

Number of types	L1	L2	L3	L4	L5
Type of land characteristic regions	Mountains - Brown forest soils	Volcanic mountains - Brown forest soils or Podzolic soils	Mountains - Brown forest soils or Podzolic soils	Hills - Brown forest soils	Hills - Ando soils
Landform features	<ul style="list-style-type: none"> <li>• Low relief mountains</li> <li>• Medial relief mountains</li> <li>• Strong relief mountains</li> </ul>	<ul style="list-style-type: none"> <li>• Low relief mountains</li> <li>• Medial relief mountains</li> <li>• Strong relief mountains</li> </ul>	<ul style="list-style-type: none"> <li>• Medial relief mountains</li> <li>Volcanoes</li> </ul>	<ul style="list-style-type: none"> <li>• Hills</li> <li>Low relief mountains</li> <li>Gravel or rocky uplands</li> </ul>	<ul style="list-style-type: none"> <li>• Hills</li> <li>Low relief mountains</li> <li>Medial relief mountains</li> </ul>
Lithologic features	<ul style="list-style-type: none"> <li>• Sedimentary rocks</li> <li>• Plutonic igneous rocks or Metamorphic rocks</li> </ul>	<ul style="list-style-type: none"> <li>• Volcanic rocks</li> </ul>	<ul style="list-style-type: none"> <li>• Sedimentary rocks</li> <li>• Plutonic igneous rocks or Metamorphic rocks</li> </ul>	<ul style="list-style-type: none"> <li>• Sedimentary rocks</li> <li>• Plutonic igneous rocks or Metamorphic rocks</li> </ul>	<ul style="list-style-type: none"> <li>• Volcanic rocks</li> <li>• Sedimentary rocks</li> <li>• Plutonic igneous rocks or Metamorphic rocks</li> </ul>
Soil features	<ul style="list-style-type: none"> <li>• Brown forest soils</li> <li>Regosols</li> </ul>	<ul style="list-style-type: none"> <li>• Brown forest soils</li> <li>• Podzolic soils</li> </ul>	<ul style="list-style-type: none"> <li>• Brown forest soils</li> <li>• Podzolic soils</li> <li>Ando soils</li> </ul>	<ul style="list-style-type: none"> <li>• Brown forest soils</li> <li>Red or yellow soils</li> </ul>	<ul style="list-style-type: none"> <li>• Ando soils</li> <li>Brown forest soils</li> </ul>

No. of L.C.	L6	L7	L8	L9	L10
Type of land characteristic regions	Mountains or uplands - Brown forest soils	Tephra covered uplands - Ando soils	Gravel or rocky uplands - Ando soils	Lowlands - Gley soils, Lowland soils or Ando soils	Lowlands - Gley soils, Lowland soils or Peat soils
Landform features	<ul style="list-style-type: none"> <li>• Low relief mountains</li> <li>Hills</li> <li>Gravel or rocky uplands</li> </ul>	<ul style="list-style-type: none"> <li>• Tephra covered uplands</li> <li>Volcanoes</li> <li>Hills</li> </ul>	<ul style="list-style-type: none"> <li>• Gravel or rocky uplands</li> <li>Tephra uplands</li> <li>Hills</li> <li>Lowlands or Natural levees</li> </ul>	<ul style="list-style-type: none"> <li>• Lowlands or Natural levees</li> <li>Gravel or rocky uplands</li> <li>Water Areas</li> </ul>	<ul style="list-style-type: none"> <li>• Lowlands or Natural levees</li> </ul>
Lithologic features	<ul style="list-style-type: none"> <li>• Sedimentary rocks</li> <li>Gravel beds</li> <li>Plutonic igneous rocks or Metamorphic rocks</li> <li>Sandy sediments</li> </ul>	<ul style="list-style-type: none"> <li>• Tephra</li> </ul>	<ul style="list-style-type: none"> <li>• Gravel bed</li> </ul>	<ul style="list-style-type: none"> <li>• Gravel bed</li> <li>Sandy sediments</li> </ul>	<ul style="list-style-type: none"> <li>• Gravel bed</li> <li>• Muddy sediments</li> <li>Sandy sediments</li> </ul>
Soil features	<ul style="list-style-type: none"> <li>• Lowland or Gley soils</li> <li>• Brown forest soils</li> <li>Red or yellow soils</li> </ul>	<ul style="list-style-type: none"> <li>• Ando soils</li> <li>Volcanogeneous regosols</li> </ul>	<ul style="list-style-type: none"> <li>• Ando soils</li> </ul>	<ul style="list-style-type: none"> <li>• Lowland soils or Gley soils</li> <li>Ando soils</li> <li>Regosols</li> <li>Brown forest soils</li> </ul>	<ul style="list-style-type: none"> <li>• Lowland soils or Gley soils</li> <li>• Peat soils</li> </ul>

(\* : strongly associated features)

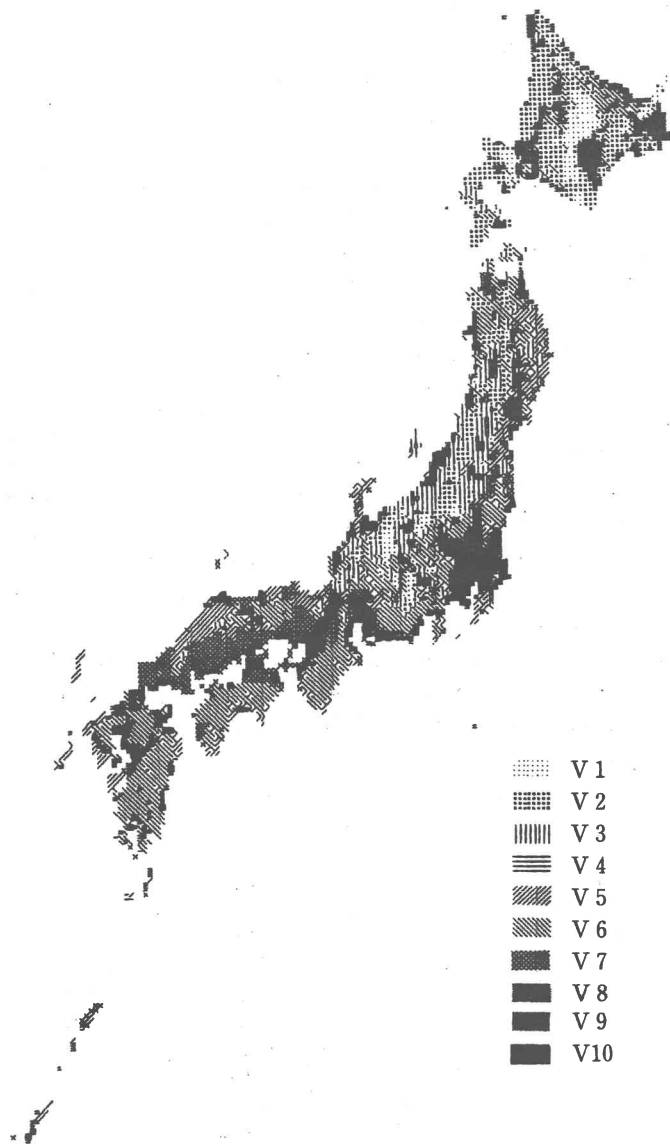


Fig. 7 Map showing the distribution of actual vegetation

follows (Types of landforms and soils not listed here play minor role in classification);

L1: Mountains - Brown forest soils

L2: Volcanic mountains - Brown forest soils or Podzolic soils

L3: Mountains - Brown forest soils or Podzolic soils

- L4: Hills - Brown forest soils
- L5: Hills - Ando soils
- L6: Mountains or uplands - Brown forest soils
- L7: Tephra covered uplands - Ando soils
- L8: Gravel or rocky uplands - Ando soils
- L9: Lowlands - Gley soils, Lowland soils or Ando soils
- L10: Lowlands - Gley soils, Lowland soils or Peat soils

#### *Classification of integrated natural regions*

Quantification theory III was performed by using the three basic regions, that is, the climatic, land characteristic and vegetation regions, which is shown in Fig. 7, as three variables. Figure 8 shows the distribution of category scores on three axis obtained from the analysis.

The first axis with an eigenvalue of 0.704 accounts for 8 % of total variance. The second axis with an eigenvalue of 0.562 accounts for 6 % of the total variance. These two axes show that climate, in particular, temperature is of prime importance. The third axis with an eigenvalue of 0.506 accounts for 6 % of the total variance, showing the strong relationship with land characteristics. Therefore, it can be said that natural regions of Japan are arranged mainly by the climatic conditions with edaphic and topographic conditions of secondary importance.

The above three axes sample scores were divided into ten groups by cluster analysis. According to this result, a natural region map of the whole of Japan was drawn as shown in Fig. 9. Typical combinations of climatic, land characteristic and vegetation regions for

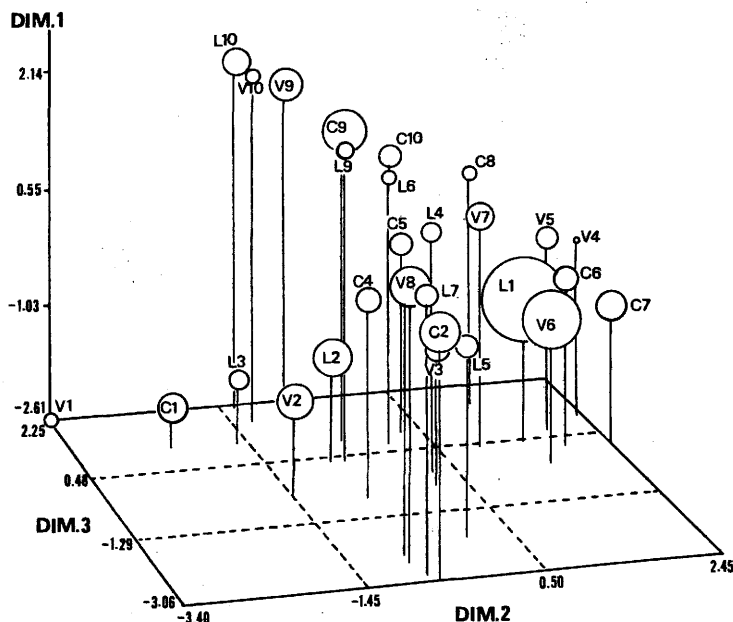
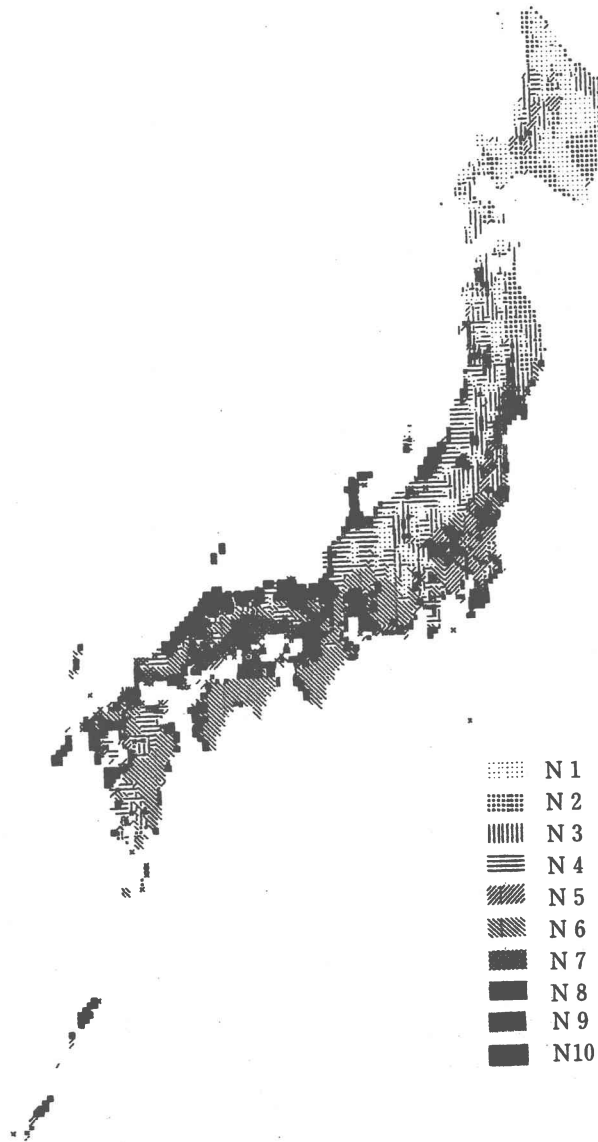


Fig. 8 Distribution of category scores on the axes Dim. 1, 2 and 3 obtained by Hayashi's quantification theory III, using basic natural regions of climate (C), land characteristics (L) and Vegetation (V)

each natural region are shown in Table 6. The characteristics of each natural region obtained as a result are shown as follows;

N1: Natural region with the cold climate distributed from Hokkaido to the mountain-



**Fig. 9** Map showing distribution of integrated natural regions of Japan obtained by the result of Hayashi's quantification theory III  
(Characteristics of each region, see Table 6.)

**Table 6** Characteristics of integrated natural regions

Natural regions	N1	N2	N3	N4	N5
Climatic regions	C1: Very cool temperature - lower precipitation C3: Cool temperature - high winter precipitation	C2: Cool temperature - low precipitation	C3: Cool temperature - high winter precipitation C2: Cool temperature - low precipitation	C3: Cool temperature - high winter precipitation C5: Moderate temperature - high winter precipitation	C9: Warm temperature - lower precipitation
Land characteristic regions	L1: Mountains - Brown forest soils or Podzolic soils L2: Volcanic mountains - Brown forest soils or Podzolic soils	L8: Gravel or rocky uplands - Ando soils L7: Teptra covered uplands - Ando soils L5: Hills - Ando soils	L5: Hills - Ando soils L3: Mountains - Brown forest soils or Podzolic soils	L2: Volcanic Mountains - Brown forest soils or Podzolic soils L1: Mountains - Brown forest soils	(No features)
Vegetation regions	V1: Alpine/Subalpine forests V2: Cool-temperate natural forests	V8: Grasslands or Dry fields	V3: Cool-temperate secondary forests V6: Plantations	V3: Cool-temperate secondary forests V6: Plantations	V8: Grasslands or Dry fields

Natural regions	N6	N7	N8	N9	N10
Climatic regions	C6: Moderate temperature - moderate precipitation C8: Warm temperature - higher summer precipitation	C9: Warm temperature - lower precipitation	C9: Warm temperature - lower precipitation	C9: Warm temperature - lower precipitation	C8: Warm temperature - higher winter precipitation
Land characteristic regions	L1: Mountains - Brown forest soils	L6: Mountains or uplands - Brown forest soils	L6: Mountains or uplands - Brown forest soils	L9: Lowlands - Gley soils, Lowland soils or Peat soils	L1: Mountains - Brown forest soils
Vegetation regions	V4: Warm-temperate natural forests V6: Plantations	V7: <i>Pinus</i> forests	V9: Paddy fields	V9: Paddy fields V10: Urban landuse or Others	V4: Warm-temperate natural forests V5: Warm-temperate secondary forests V7: <i>Pinus</i> forests

ous zone of central Japan. It is characterized by the distribution of podzolic soils. The vegetation is alpine/subalpine forests and cool-temperate natural forests.

N2: Mainly uplands in the cool-temperate zones distributed mostly in Hokkaido Island. Ando soils are frequent. The agricultural development in this region has been undertaken after the Meiji era and forests have been cleared and changed to artificial grassland or dry fields.

N3: Natural region distributed in low mountainous zone and hilly areas with cold climate in northeastern Japan. This region is covered with brown forest soils. Vegetation in this region is cool-temperate secondary forests or plantations influenced by human activities.

N4: Natural region distributed on the Sea of Japan side of Honshu Island. Snow zones are included in this region. The landform is volcanic and mountainous and is covered with brown forest soils or podzolic soils. Cool-temperate secondary forests and plantations are dominant in this region.

N5: Slightly warm natural region distributed in the periphery of the Kanto district. This region consists of uplands and lowlands. The soils are gley soils and peat soils. This region was developed for agriculture long ago. Dominant vegetation is grasslands and dry fields.

N6: Natural region distributed mainly in mountainous zones with a warm climate and high precipitation on the Pacific side of southwestern Japan. Brown forest soils are frequent. Warm-temperate natural forests and plantations are distributed over a wide area.

N7: Natural region characteristically seen in the area with a low precipitation in the Inland Sea area between Honshu and Shikoku Islands. Brown forest soils are most common; soil erosion is noticeable. *Pinus* forests are often established on degraded lands.

N8: Natural region in the lowlands of various parts of Honshu Island. This region is distributed along the borders of mountains and hills. The soils are a complex of brown forest soils, lowland soils and gley soils and the vegetation is mostly paddy fields.

N9: Natural region distributed in the lowlands of the Pacific belt zone with fairly warm climate. Lowland soils are common, and gley soils and peat soils can be seen. Paddy fields are distributed over a wide area and there are many urban areas.

N10: Natural region covered with brown forest soils in mountains with warm climate and high precipitation. This region is distributed mainly along the coastal margin of southwestern Japan. Vegetation in this region is warm-temperate natural forests, secondary forests, and *Pinus* forests.

#### 4. Concluding Remarks

In this paper, an attempt to classify natural regions of Japan by using geographical databases was reported. Care was taken to perform the classification of natural regions as objectively as possible. The authors believe that the reproducibility of the results obtained can be assured.

On the basis of this study it is evident that such projects should proceed in four stages. The first consideration is to ensure that the database is comprehensive and includes the important parameters and characteristics. For example, distribution of animals and snowfall should be included in the classification of natural regions in the future. The second is to examine closely and strictly if the classification of natural regions is suitable or not. The third is to examine the method used in this study. The fourth is to determine environmental evaluation and conservation policy based on natural regions to lead to overall environmental management.

Also, the classification of natural regions at a high spatial level, for instance, the natural regions covering the whole earth, is worthy of consideration by the method shown in this paper. Considering the classification of natural regions at a lower spatial level, for instance, the natural regions of the Kanto plain will be able to be performed, so that such classification can lead to regional planning or environmental management. In particular the method would be expected to identify landscape constraints or hazards associated with any proposed land use. For the hierarchical establishment of a classification system, it will be required to examine the natural regions with different spatial levels and scales, the designation of natural environmental elements to each regional classification, and major environmental elements. It is evident that climatic elements will be more important at higher levels while the land characteristic elements will become more important at lower levels.

The classification of natural regions using the multivariate analysis method is also being applied to the Korean peninsula (Kim Yong-Mahn, personal comm.). Expanding this classification of natural regions over east Asia, including the Korean peninsula, will be important so that Japanese natural regions can be related to them and comparative study can be made to assist in regional planning and conservation of specific natural environments.

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