SPATIAL STRUCTURE OF DAMAGE INTENSITY BY DISASTERS IN JAPAN OF THE 1970S

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Abstract The characteristics of the spatial distribution of "damage intensity" caused by disasters in the 1970s was examined by the adoption of the factorial analysis method. As a result of the cluster analysis based on the scores of the principal components analysis, the obtained disastrous divisions in the 1970s are group 1 (high-disastrous areas), group 2 (urbanized areas of building damage type), group 3 (rural areas of snow and fire disaster type), group 4 (metropolitan areas of flood type) and group 5 (non-disastrous areas). The geographical distribution of these groups was shown in Fig. 15. The high-disastrous areas in the 1970s were distributed on the south eastern part and northern part of Japan, which are characterized by the climatic disasters such as typhoons, rainstorms and heavy snowfall, nevertheless four earthquakes occurred during this period.

1. Introduction

Japan is located on the east side of the Eurasian Continent. It consists of a great number of islands spread over 3,000 km in length and is composed topographically of 61% mountains and volcanoes, 12% hills, 11% uplands and terraces, 15% lowlands and 1% others. The population is densely concentrated on only one fourth of the national land. The characteristics of the natural circumstances of Japan, from the viewpoint of natural disasters, are abstracted as follows:

1) Both steep mountains and much rainfall trend to cause flood disasters everywhere. Additionally, the urbanization has been advanced toward the lowlands so rapidly that the rather small scale of rainfall has caused the people to incur the flood disasters recently. The floods of this type are apt to occur in the densely inhabited and working areas of the metropolises.

2) As a result of a variety of topographical and geological conditions, much rainfall has also often caused us to incur not only floods but also landslides, rock and earth slides, washouts and so on.

3) Many earthquakes have occurred in and near the Japanese territory. One type of these earthquakes are those of magnitude 8, or there about, which are focused below the Pacific Ocean, within a 300 km distance from the Japanese Islands. Those occur once every 10 years on the average during the period of 1946 - 1985 and cause damage to the

Pacific regions. The other type is the earthquake of magnitude 7 or less, which occur below the Japanese Islands or the Japan Sea, and cause damage once every 3 years on the average during the same period.

4) There are many volcanoes in Japan, 77 of which are active. Statistically, five active volcanoes have erupted a year on the average (National Land Agency, 1984).

In addition to the above mentioned natural disaster conditions of Japan, the expansion of urbanization has caused the people to crowd into the urban areas, particularly in the built-up areas of metropolises, and this has resulted in an expansion of the built-up area toward lowlands such as floodplains and upward hills, and these are densely crowded with dwellings made mostly of wood. On the other hand, the old inner built-up areas of cities have always been crowded with wood-made houses and various facilities. Therefore,

5) the occurrence of fires and the explosions of gas, oil and other chemical materials have been increasing.

However, these various disasters did not occur equally in every area, so that the damages caused by these disasters were not incurred equally in every area. This means that natural hazards have occurred repeatedly in the same areas and the losses and damages caused by them have repeatedly occurred in the same areas. Therefore, the geographical distribution of various disasters which have occurred up to the present make it able to assess the future occurrence of natural disasters in each area. From this point of view, the World Map of Natural Hazards was published by M.R.G., which was aimed mainly at insurance specialists and engineers to give them assistance in their day-to-day work (Münchener Rückversicherungs-Gesellschaft, 1982). This illustrates the world wide distribution of exposure to the most significant natural hazards, but no consideration was given to the socio-economic conditions of each country as a background of the disaster problem.

Focusing on earthquake disasters, the necessity for the measurement of socio-seismicity and for the assessment and mitigation of earthquake effects on econonic production have been emphasized (Abolafia and Kafka, 1978 ; Paté, 1981). In Japan, there were few studies from this viewpoint. Ohta examined the preliminary evaluation of seismic resistance capacity by administrative provinces based on regional statistic data (Ohta, 1982). This study was conducted by taking into consideration the socio-economic conditions of each area, but only earthquake disasters were dealt with. Additionally, the possibility of occurrence of future earthquakes in every area of Japan has been presupposed.

This paper attempts to explain the spatial structure of disastrous areas in recent Japan by the method of statistical analysis of the annual data of damage and loss caused by various disasters and the various socio-economic data, both of which are aggregated in every Ken area (Administrative Province of Prefectural territory) during the period of 1972 - 1979.

The well-known great disasters during this period are as follows: the rainstorm in July of 1972, the Izu-Hantoh-Oki Earthquake of 1974 (M.6.8), the Ohita-Ken-Chubu Earthquake of 1975 (M.6.4), the heavy snowfall of 1976, Typhoon of No. 17 in 1976, the Great Sakata city Fire of 1976, the heavy snowfall of 1977, the volcanic eruption of Mt.

Usu in 1977, the Izu-Ohshima-Kinkai Earthquake of 1978 (M.7.0) and the Miyagi-Ken-Oki Earthquake of 1978 (M.7.4).

During this period, these various disasters caused us to incur a great loss of life and property in Japan. 1,972 persons were killed or are missing and 8,602 persons were injured in all of disasters. Taking notice of the kinds of disasters, the number of casualties (killed and missing/injured) are as follows: 573 persons/1,978 persons by flood, landslide and other disasters caused by typhoon, 967 persons/1,672 persons by flood, landslide and other disasters caused by rainstorm, 123 persons/801 persons by windstorm, 3 persons/19 persons by tidal waves, 87 persons/3,365 persons by earthquake, 0/0 by Tsunami (seismic sea waves) and 219 persons/767 persons by heavy snowfall.

2. Geographical Distribution of Damage Intensity of Recent Disasters in Japan

The author has proposed that the development of new methods and techniques for the evaluation of the actual damage in any area is necessary, when the estimates of damage are made on a regional scale from the viewpoint of disasters as a regional problem. Thereby the indices such as "heavy sufferer ratio" and "loss to revenue ratio" must be used for measuring the damage intensity added to a region (Nakabayashi, 1978, 1984). From the same point of view, the geographical distribution of damage intensity by Prefectural Areas during the period of 1972-1979 can be accurately examined with the use of some indices of the same kind. The indices used in this chapter are as follows:

1) Floor areas of collapsed buildings caused by flood per 100 households
2) Floor areas of collapsed buildings caused by fire per 100 households
3) Floor areas of collapsed buildings caused by earthquake, heavy snowfall and other disasters per 100 households
4) Number of collapsed houses caused by whole disasters per 10,000 households
5) Number of killed, missing and injured persons caused by whole disasters per million residents
6) Reconstruction (Disaster restoration) cost as a proportion of revenues
7) Loss of public constructions as a proportion of local tax income

The scores of these indices are calculated by prefectural areas as the average annual values based on various statistics during the period of 1972-1979. The location and name of each prefectural area is shown in Fig. 1.

Figure 2 shows the geographical distribution of the damage intensity expressed as the floor areas of collapsed buildings by floods. The high values of this index are distributed in the areas located on the south western and the central western part of Japan, because typhoons have usually passed from south western Japan to north eastern Japan. The highest value of this index was counted as 9.54 m^2/100 households a year for Kohchi Prefecture, and the second highest value as 7.19 m^2/100 households for Kagoshima Prefecture.

Figure 3 shows the geographical distribution of the damage intensity expressed as the floor areas of collapsed buildings by fires. The higher values of this index are scattered on the northern part of Japan, particularly on the areas along the Japan Sea. These are

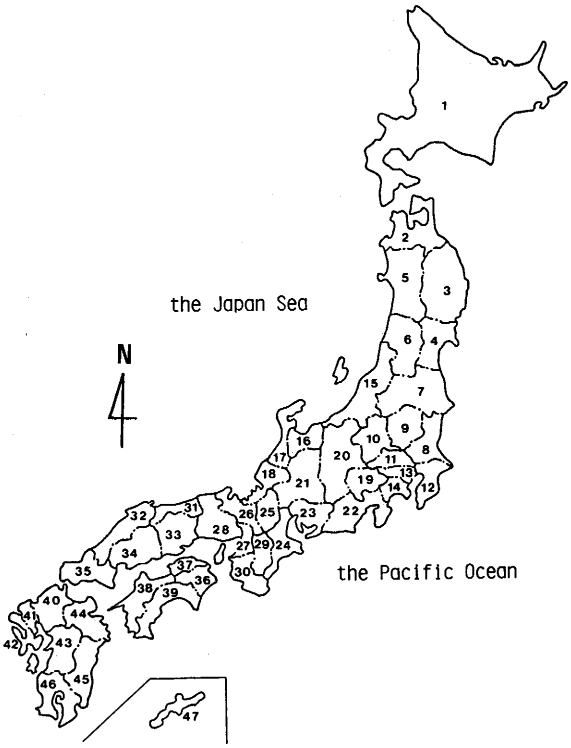


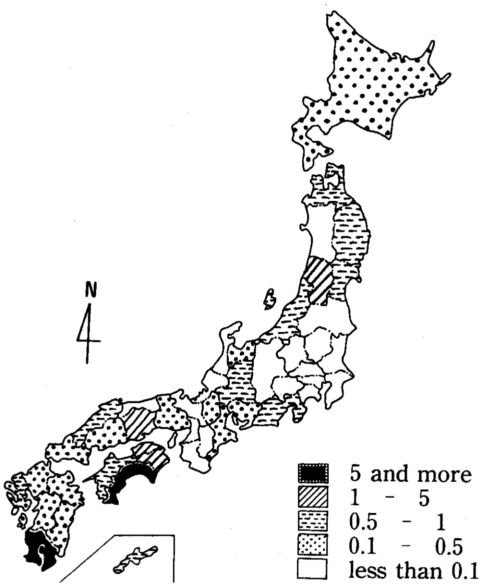
Fig. 1 Location and name of prefectural areas.

1. Hokkaido	2. Aomori	3. lwate	4. Miyagi	5. Akita
6. Yamagata	7. Fukushima	8. lbaraki	9. Tochigi	10. Gunma
11. Saitama	12. Chiba	13. Tokyo	14. Kanagawa	15. Niigata
16. Toyama	17. Ishikawa	18. Fukui	19. Yamanashi	20. Nagano
21. Gifu	22. Shizuoka	23. Aichi	24. Mie	25. Shiga
26. Kyoto	27. Ohsaka	28. Hyogo	29. Nara	30. Wakayama
31. Tottori	32. Shimane	33. Okayama	34. Hiroshima	35. Yamaguchi
36. Tokushima	37. Kagawa	38. Ehime	39. Kohchi	40. Fukuoka
41. Saga	42. Nagasaki	43. Kumamoto	44. Ohita	45. Miyazaki
46. Kagoshima	47. Okinawa.			

also the snowy areas where the people must use more gas and oil heaters to warm than in the south western areas. In addition, the snow severally hinders fire fighting. The highest value of this index counted as 16.2 m^2/100 households of Yamagata Prefecture, as Sakata City where the great city fire incurred a loss of 1,774 houses in 1976 is located in Yamagata Prefecture. The second highest value counted as 11.4 m^2/100 households was for Akita Prefecture.

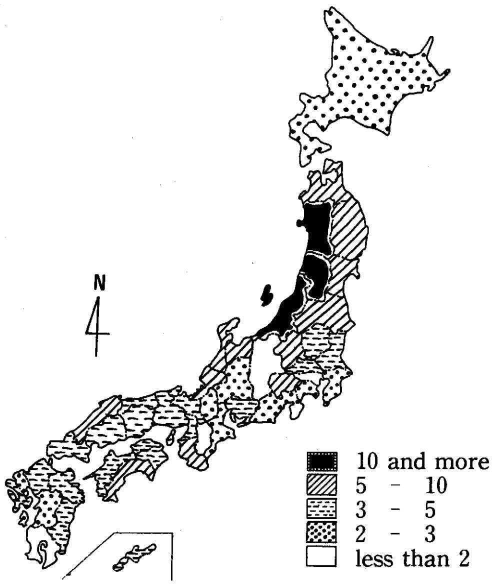
Figure 4 shows the geographical distribution of the damage intensity presented as the floor areas of collapsed buildings by earthquakes, snowfalls and the others.

Firstly, four earthquakes caused the people in three areas to incur a rather great loss of property during this period. The Ohita-Ken-Chubu Earthquake of 1975 shook the



(unit : m^2/100 households a year)

Fig. 2 Distribution of damage intensity as floor areas of collapsed buildings by flood (1972-1979).



(unit : m^2/100 households a year)

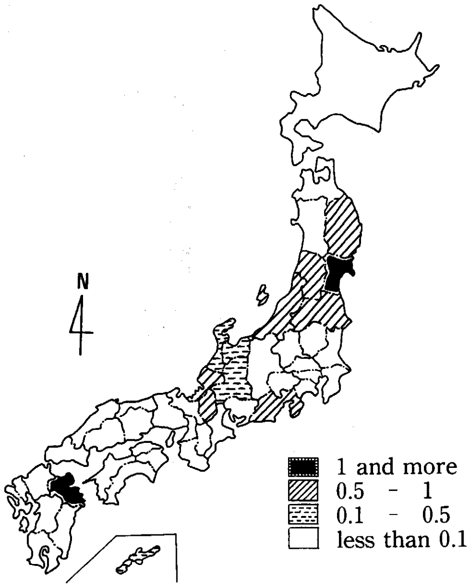
Fig. 3 Distribution of damage intensity as floor areas of collapsed buildings by fire (1972-1979).

houses in Ohita Prefecture. And both the Izu-Hantoh-Oki Earthquake of 1974 and the Izu-Ohshima-Kinkai Earthquake of 1978 shook the houses in the Izu Peninsula district of Shizuoka Prefecture. 55 persons were reported killed or missing, 230 houses collapsed wholly and 856 houses party collapsed as a result of these two earthquakes. In the same year 1978, the Miyagi-Ken-Oki Earthquake caused the people in Miyagi Prefecture and the neighboring Prefectures to incur a loss of life and property of 28 persons killed, 1,383 buildings collapsed wholly and 6,190 buildings collapsed partly.

Secondly, heavy snowfall occurred in the central areas along the Japan Sea in 1976 and 1977. Under the weight of snow, some of the houses collapsed. But the damage caused by the snowfall and other disasters is less than that caused by earthquakes.

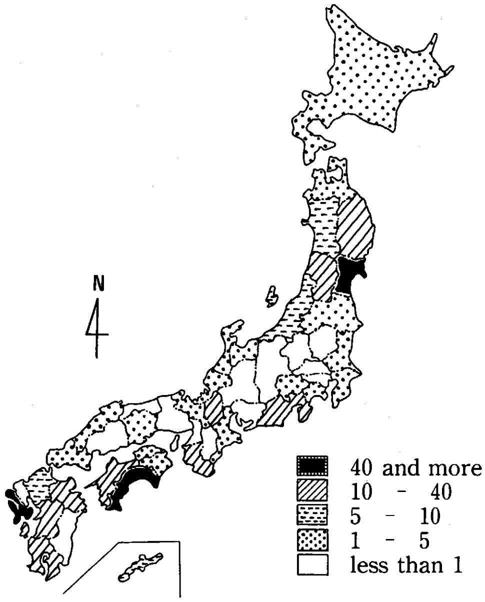
As a result, the highest value of this index measured 11.8 m^2/100 households in Miyagi Prefecture and the second highest value was 1.45 m^2/100 households in Ohita Prefecture.

Figure 5 shows the geographical distribution of the districts characterized by such an index as the total number of collapsed houses by the whole disasters per 10,000 households a year on the average. The number counted as the sum total of houses which collapsed wholly, partly and slightly by disasters. Therefore, this index means the general intensity of property damage in each prefectural area caused by various disasters during this period and does not explain the "heavy sufferers ratio" but similarly the "sufferers ratio". The highest value of this index is distributed in Miyagi Prefecture, where a great loss was suffered by the Earthquake of 1978, that measured 164 houses per 10,000 households a year during these 8 years. The second highest value of this index was



(unit : m²/100 households a year)

Fig. 4 Distribution of damage intensity as floor areas of collapsed buildings by earthquake, heavy snowfall and other disasters (1972-1979).



(unit : houses/10,000 households a year)

Fig. 5 Distribution of damage intensity as the number of collapsed houses by whole disasters (1972-1979).

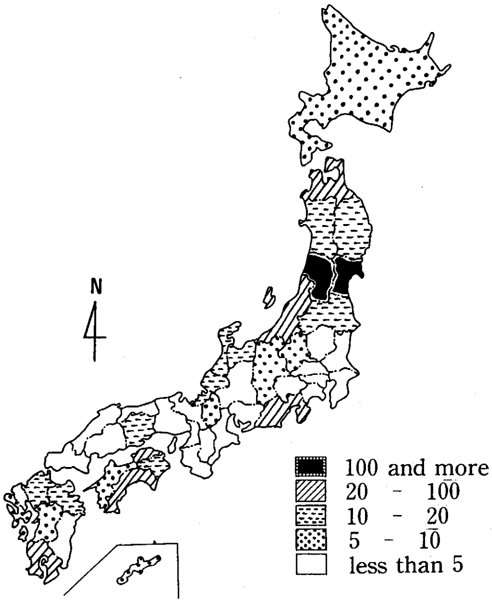
47.6 houses per 10,000 households in Kohchi Prefecture and the third highest value counted as 44.5 houses per 10,000 households in Nagasaki Prefecture. The latter two areas are characterized by losses severally caused by floods from typhoons. And the fourth highest value counted as 18.9 in Kagoshima Prefecture, the fifth as 18.5 in Ehime Prefecture and the sixth as 16.2 of Wakayama Prefecture.

Figure 6 shows the geographical distribution of the areas characterized by the number of casualties, such as the whole sum of the killed, missing and injured persons, per million residents in each area.

The areas of the highest value of this index are accidentally distributed in Miyagi Prefecture and the neighboring Yamagata Prefecture. The highest value counted as 759 persons per million residents of Miyagi Prefecture, where about 3,000 persons were injured by the Earthquake of 1978. The second highest value of this index counted as 126 persons per million residents in Yamagata Prefecture, where the Sakata City Fire occurred in 1976. And the third counted as 37.5 persons per million residents in Kohchi Prefecture.

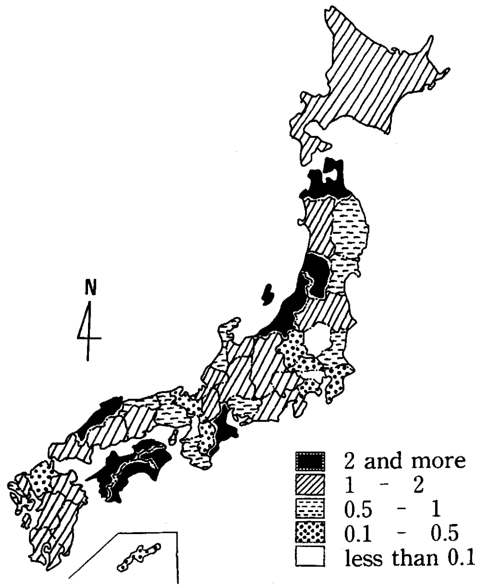
Figures 7 and 8 show the distributions of the areas characterized by similar indices that express the intensities of socio-economic damage as economic losses of properties aggregated in each area.

Figure 7 shows the distribution of areas characterized by the index of the



(unit : persons/million residents a year)

Fig. 6 Distribution of damage intensity as the number of casualties by whole disasters (1972-1979).

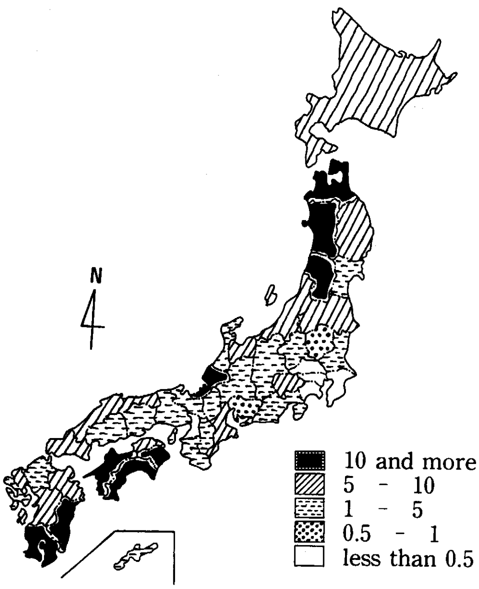


(unit : % as a proportion of annual revenues)

Fig. 7 Distribution of damage intensity as reconstruction costs for the public caused by whole disasters (1972-1979).

reconstruction cost as a proportion of revenues in each prefectural area on the average during the period. This cost means the expenditure estimated for the disaster restoration works of both the private properties and the public constructions. Usually the restoration costs for the public, such as recovery of landslide, reconstruction of bridges, roads, banks, water supply and so on, is more expensive than the costs of the private works, such as rebuilding or repair of dwellings, shops, factories and the other private facilities. Therefore, the value of this index rises higher and higher in the case of the need for public construction works. According to Fig. 7, the areas characterized by the high degree values of this index were scattered over nine Prefectural Areas, which was classified according to the value of 2% and more of the revenues of each. And five of these nine areas are also the areas characterized by the values of the highest degree (10% and more) of such index as the loss of public constructions expressed as a proportion of each annual local tax income.

As a whole, from the viewpoint of socio-economic damage intensity, it can be said that such areas which incurred relatively intensive damage caused by disasters during this period were located both on the south western part of Japan, particularly along the Pacific Ocean, and on the north eastern part of Japan except for Hokkaido Prefecture (see Figs. 7 and 8). And the costs of hazards for developing societies, which were expressed as a proportion of income available, are larger than those of industrial (urbanized) societies, in the same context of Burton's study (Burton *et al.*, 1978).



(unit : % as a proportion of annual local tax income)

Fig. 8 Distribution of damage intensity as losses of public constructions caused by whole disasters (1972-1979).

3. Factorial Ecological Analysis on the Spatial Structure of Damage Intensity by Recent Disasters

The factorial ecological analyses are essentially taxonomic and provide a means of identifying the latent patterns and relations which exist within a multivariate data set. As methods of identifying the spatial structure of damage intensity caused by recent disasters, the principal components analysis and the cluster analysis have been adopted in this paper. As the basis for analysis, 47 indices, which are believed to be indicative of the major patterns of disastrous variation and socio-economic variation as the background of damage intensity in any given region, are abstracted for each of the 47 enumeration areas (Prefectural Areas) in Japan so as to form a raw data matrix (see Table 1).

Principal components analysis

As a result of the principal components analysis, five components accounted for 66% of the input variation. This initial components structure can be simplified by redistributing the explained variance among the five abstracted patterns through a process of rotation. After varimax rotation, the empirical meaning of these dimensions is revealed by an examination of the leading loadings on each component (Table 2).

Component 1 was interpreted as metropolitan dimension. The high positive loadings group a number of measures of affluent socio-economic positions and urbanized

Table 1 List of input variables

Number	Definition
1.	Areas of Densely Inhabited District (D.I.D.) as percentage of total area (1980); %
2.	Areas of mountain, forest and grassland as percentage of total area (1980); %
3.	Areas of paddy field as percentage of total area (1980); %
4.	Length of all rivers as ratio of total area (1981); m/m^2
5.	Land price index as 100 of total average price (1978)
6.	Growth ratio of D. I. D. during 1970-1980; %
7.	Floor areas of newly constructed buildings per household on the average (1972-1979); m^2/household
8.	Number of newly constructed houses per household on the average (1980); houses/household
9.	Areas of big scale developments of housing as percentage of total area (-1982); %
10.	Areas of big scale developments of farmland as percentage of total area (-1982); %
11.	Areas of developmests of golf links as percentage of total area (-1982); %
12.	Increasing ratio of population inhabited in districts except D. I. D. (1970-1980); %
13.	Increasing ratio of population inhabited in D. I. D. (1970-1980); %
14.	Percentage of households with dwellings of ownership (1980); %
15.	Population density of D. I. D. (1980); persons/km^2
16.	Percentage of persons engaged in agriculture, fishery and so on (1980); %
17.	Percentage of employees engaged in construction and manufacturing (1980); %
18.	Percentage of employees engaged in commerce, service and so on (1980); %
19.	Total product per person (1980); yen/person
20.	Commercial product per employee (1980); yen/employee
21.	Manufacturing product per employee (1980); yen/employee
22.	Tax income per person on the average (1973-1979); yen/person
23.	Tax income as percentage of revenues on the average (1973-1979); %
24.	Public (construction) works as percentage of total expenditure on the average (1973-1979); %
25.	Reconstruction (disaster restoration) works as percentage of total expenditure on the average (1973-1979); %
26.	Floor areas of scrapped buildings per 100 households on the average (1972-1979); m^2/100 households
27.	Floor areas of collapsed builings by flood per 100 housecolds on the average (1972-1979); m^2/100 households
28.	Floor areas of collapsed buildings by fire per 100 households on the average (1972-1979); m^2/100 households
29.	Floor areas of collapsed buildings by earthquake and other disasters per 100 households on the average (1972-1979); m^2/100 households
30.	Number of killed and missing persons per 10,000 residents on the average (1972-1979); persons/10,000 residents
31.	Number of injured persons per 10,000 residents on the average (1972-1979); persons/10,000 residents
32.	Damage ratio (Number of collapsed buildings per households (units) on the average) (1972-1979); %
33.	Flood ratio (Number of flooded buildings per households (units) on the average) (1972-1979); %

Table 1 (cont.)

34. Percentage of households which suffered from disasters on the average (1972-1979) ; %
35. Number of damaged buildings except dwellings per 10,000 residents on the average (1972-1979) ; buildings/10,000 residents
36. Areas of collapsed farmland as percentage of total farmland on the average (1972-1979) ; %
37. Areas of flooded farmland as percentage of total farmland on the average (1972-1979) ; %
38. Number of collapsed roads per total area on the average (1972-1979) ; places/km^2
39. Number of collapsed rivers per total length of rivers on the average (1972-1979) ; places/km
40. Number of landslides per total area on the average (1972-1979) ; places/km^2
41. Value of losses for public constructions as a proportion of tax income on the average (1972-1979) ; %
42. Value of losses for public construction per total area on the average (1972-1979) ; yen/km^2
43. Value of losses for agriculture, fishery and so on per persons engaged in them on the average (1972-1979) ; yen/person
44. Value of losses for agriculture, fishery and so on per total area on the average (1972-1979) ; yen/km^2
45. Areas of sand prevention districts as percentage of total area (1978) ; %
46. Areas of landslide prevention districts as percentage of tatal area (1988) ; %
47. Areas of dangerous districts of landfall as percentage of total area (1978) ; %

conditions in terms of industrial advancement and population density.

Component 2 was interpreted as the safety against flood, landslide and other disasters caused by typhoon and rainstorm. The negative loadings identify the intensive damage caused by floods, particularly in rural areas.

Variables to do with damage ratio as a percentage of dwelling houses and other buildings, the employee composition for service and commerce industries and the floor areas of collapsed buildings per 100 households, which are indicative of the damage intensity on buildings in urban areas, gave component 3 a distinctive character.

Component 4 and 5 accounted for smaller amounts of the variance. Component 4 was interpreted as damage intensity of farmlands and component 5 was interpreted as the stagnation of urbanization.

The geographical characteristics of these five dimensions are expressed by the rotated component scores, which are calculated for each of the prefectural area of Japan (Table 3). Positive scores relate to positive loadings and negative scores to negative loadings, so that the distribution maps of the leading scores identify those enumeration areas which are most heavily involved in the 'Metropolitanity', 'Safety against floods', 'Damage intensity of buildings', 'Damage intensity of farmlands' and 'Stagnation of urbanization' dimensions respectively.

The areas characterized by the positive scores of the 'Metropolitanity' are distributed in three major metropolitan regions, such as the Tokyo Capital region that consists of Tokyo and its neighboring areas, the Keihan metropolitan region which involves Ohsaka and Kyoto, and the Chukyo metropolitan region includes Nagoya city (see Fig. 9).

The areas characterized by the negative scores of the 'Safety against floods', which means the disastrous areas of flood, are scattered in the central western part of Japan.

Table 2 Leading component loadings

Number	Variable Name	Loading
	Component 1 : 'Metropolitanity'	(24.8 percent explanation)
23.	Percentage of tax income	+0.880
1.	Percentage of D. I. D.	+0.836
19.	Total product per person	+0.815
22.	Taxable income per person	+0.789
5.	Land price index	+0.769
11.	Percentage of areas of golf links	+0.746
15.	Population density of D. I. D.	+0.731
20.	Commercial product per employee	+0.711
9.	Percentage of areas of housing developments	+0.638
12.	Population increasing ratio except D. I. D.	−0.620
41.	Proportion of losses of public constructions	−0.717
14.	Percentage of dwellings of ownership	−0.725
25.	Proportion of restoration costs	−0.771
16.	Percentage of persons engaged in agriculture *etc.*	−0.825

Number	Variable Name	Loading
	Component 2 : 'Safety against floods'	(15.8 percent explanation)
7.	Floor area of newly constructed buildings	+0.596
6.	Growth ratio of D. I. D.	+0.391
26.	Floor area of scrapped buildings per 100 households	+0.381
4.	Length of rivers per total area	−0.440
40.	Number of landslides per total area	−0.469
30.	Number of killed and missing persons per residents	−0.562
27.	Floor area of collapsed buildings by flood	−0.564
39.	Number of collapsed rivers per length of rivers	−0.627
34.	Percentage of suffered households from disasters	−0.647
42.	Value of losses of public constructions per area	−0.697
33.	Ratio of flooded houses	−0.707
44.	Value of losses of agriculture per area	−0.757
38.	Number of collapsed roads per area	−0.762
43.	Value of loss of agriculture per person engaged in it	−0.782

Number	Variable Name	Loading
	Component 3 : 'Damage of buildings'	(9.9 percent explanation)
32.	Ratio of damaged buildings	+0.673
35.	Ratio of damaged buildings except dwellings	+0.650
18.	Percentage of employees engaged in commerce *etc.*	+0.567
31.	Percentage of injured persons	+0.559
29.	Floor area of collapsed buildings per 100 households	+0.529
37.	Percentage of collapsed farmland	+0.403
24.	Proportion of public works to expenditures	−0.401
7.	Floor area of newly constructed buildings	−0.423
4.	Length of rivers per total area	−0.451
14.	Percentage of dwellings of ownership	−0.462
17.	Percentage of employees engaged in manufacturing *etc.*	−0.705

Table 2 (cont.)

Component 4: 'Damage of farmlands'		(8.4 percent explanation)
Number	Variable Name	Loading
36.	Percentage of flooded farmland	+0.477
37.	Percentage of collapsed farmland	+0.468
10.	Percentage of newly developed farmland	+0.273
20.	Commercial product per employee	−0.321
17.	Percentage of employees engaged in maunfacturing, *etc.*	−0.345
3.	Percentage of paddy field	−0.399
7.	Floor area of newly constructed buildings	−0.405
26.	Floor area of scrapped buildings	−0.449
32.	Ratio of damaged buildings	−0.633
35.	Ratio of damaged buildings except dwellings	−0.643
29.	Floor area of collapsed buildings by earthquake	−0.739
31.	Percentage of injured persons	−0.749

Component 5: 'Stagnation of urbanization'		(6.7 percent explanation)
Number	Variable Name	Loading
28.	Floor area of collapsed buildings by fire	+0.567
26.	Floor area of scrapped buildings	+0.300
11.	Percentage of areas of golf links	−0.352
12.	Population increase ratio except D. I. D.	−0.459
21.	Manufacturing product per employee	−0.523
8.	Number of newly constructed dwellings per housecolds	−0.571
6.	Growth ratio of D. I. D.	−0.616
13.	Population increase ratio of D. I. D.	−0.703

These are the areas along the main routes of typhoons. On the other hand, the 'non-disastrous' areas, which are characterized by the positive scores of the 'Safety against floods', trends to be distributed in the north eastern part of Japan (see Fig. 10).

The areas which hold the characteristics of the positive scores of the 'Damage intensity of buildings' are scattered on the southern part and the northern part of Japan. On the other hand, the areas of negative scores are distributed in central Japan with the exception of Tokyo (see Fig. 11).

The distribution pattern of the areas characterized by the positive scores of the 'Damage intensity of farmlands' is similar to the case of the pattern of the above mentioned 'Damage intensity of buildings' (see Fig. 12).

The areas characterized by the positive scores of the 'Stagnation of urbanization' are distributed along the Japan Sea, which are distant from the major metropolises relatively. In addition, this group involves the core areas of two major metropolitan regions, Ohsaka and Tokyo, where the stagnation of population growth has continued since the middle of the 1960s (see Fig. 13).

Grouping by the cluster analysis

The author attempts to extract the types of the disastrous areas of Japan in the 1970s by applying cluster analysis (Furthest Neighbor method) to the scores of the above

Table 3 Size of each principal component

	area	compo.1	compo.2	compo.3	compo.4	compo.5
Group 1	1	1.515	1.130	2.486	1.617	0.950
	46	-2.875	-1.166	2.525	1.372	-0.958
	2	-3.853	0.595	1.765	0.346	0.926
	42	-0.930	0.481	2.599	1.803	1.002
	43	-1.564	0.729	1.327	1.602	0.309
	30	-0.417	-0.734	0.276	1.499	-0.399
	38	-1.919	-2.022	-0.099	0.532	-0.663
	41	-2.933	-0.852	-0.464	1.482	0.234
	44	-1.230	0.133	0.559	0.803	-1.021
	47	0.316	2.999	5.791	6.336	-2.825
	45	-1.933	0.931	0.625	1.627	-0.676
	36	-4.223	-4.738	-1.553	-0.449	-0.660
	37	-3.338	-6.887	-1.037	-1.195	-1.393
	39	-7.313	-8.885	3.544	-0.976	-0.011
Group 2	4	-0.293	3.930	8.080	-9.548	-1.894
	11	4.145	2.264	-0.643	-0.361	-2.076
	12	4.090	1.660	0.004	0.096	-3.837
	29	1.360	1.086	-0.352	1.076	-2.916
	14	8.173	-3.073	0.403	0.062	-1.424
	40	2.245	-1.362	0.851	0.109	-1.419
Group 3	3	-1.904	3.011	1.071	1.105	1.351
	5	-3.383	2.920	0.170	0.198	2.905
	7	-1.543	2.034	-0.613	0.168	1.119
	31	-1.941	1.503	-0.691	0.934	0.737
	32	-3.373	0.530	-0.547	0.937	1.535
	6	-3.594	2.594	-0.155	-1.935	3.416
	15	-2.681	0.989	-1.351	-1.902	2.106
	18	-1.353	1.524	-1.604	-0.532	1.826
	19	-0.555	1.413	-0.370	0.583	1.879
	16	-1.020	1.344	-2.862	-1.730	1.611
	20	-0.344	2.318	-1.833	-0.147	1.583
	21	-1.077	-1.327	-1.601	-0.861	-0.180
Group 5	8	0.353	3.472	-1.843	-0.285	-1.745
	9	1.479	2.938	-2.003	-0.036	-1.487
	25	0.443	3.207	-3.408	-1.912	-2.296
	17	0.136	0.907	-1.110	0.089	-0.626
	10	0.591	3.239	-1.920	-0.194	-0.025
	23	4.163	-0.786	-2.525	-1.595	-0.403
	24	-0.651	-2.198	-2.451	-0.992	-2.015
	33	-0.419	-1.128	-1.258	0.242	-0.280
	35	-0.153	-0.459	-0.951	1.024	-0.372
Group 4	13	10.433	-2.854	2.939	0.140	5.241
	22	0.420	-2.771	-1.500	-1.701	-1.026
	27	9.532	-2.744	0.113	-0.563	2.393
	26	3.595	-0.973	0.554	0.688	1.254
	28	2.322	-4.391	-0.828	-0.276	-0.246
	34	1.603	-0.532	-0.146	0.725	0.495

(1 - 47 : cord number of prefectural areas)

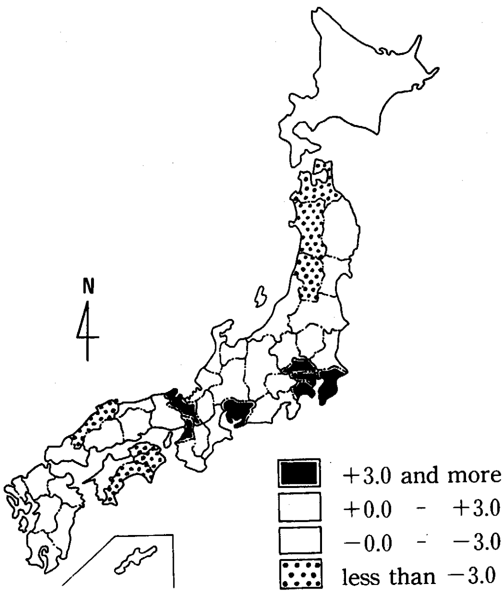


Fig. 9 Distribution of scores of compo. 1 as the 'Metropolitanity'.

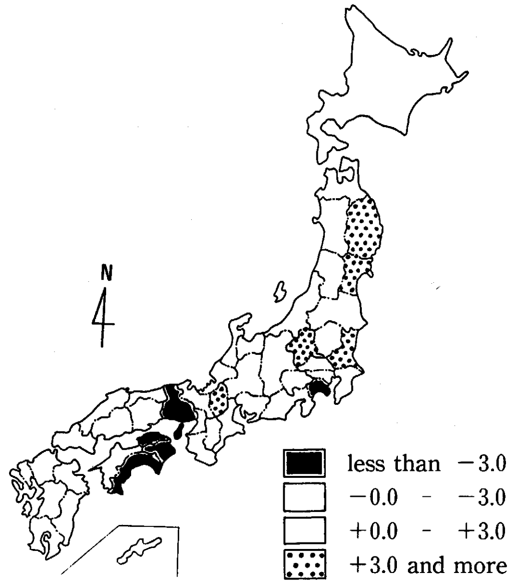


Fig. 10 Distribution of scores of compo. 2 as the 'Safety against floods'.

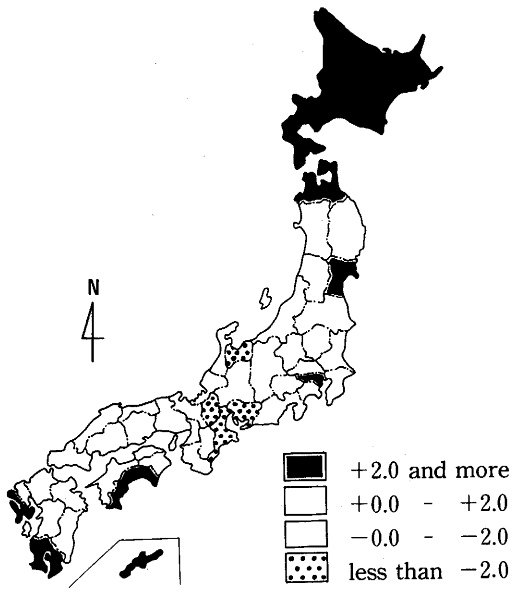


Fig. 11 Distribution of scores of compo. 3 as the 'Damage intensity of buildings'.

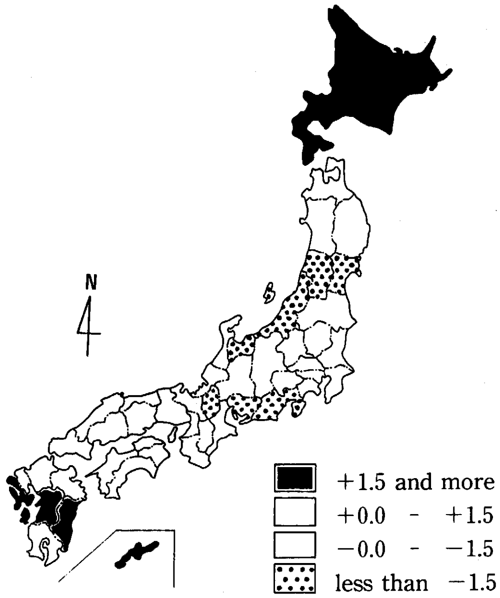


Fig. 12 Distribution of scores of compo. 4 as the 'Damage intensity of farmlands'.

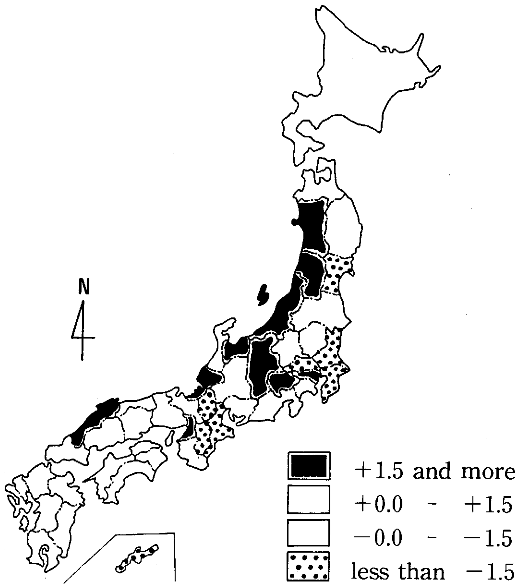


Fig. 13 Distribution of scores of compo. 5 as the 'Stagnation of urbanization'.

mentioned five common factors. A dendrogram of the clustering processes are shown as a linkage tree. According to the grouping processes of each area shown in Fig. 14, the clustering was stopped after the 42th step. As a result, 47 areas were classified into five groups. The size of each principal component in each area is shown in Table 3. According to it, these groups can be characterized as follows (see Fig.15):

Group 1 is the group of 14 prefectural areas which are located on the southern and the northern part of Japan. Group 1 is characterized by the negative scores of the 'Metropolitanity' and 'Safety against floods', and the positive scores of the 'Damage intensity of buildings' and 'Damage intensity of farmlands'. This group can be interpreted as high-disastrous areas in the 1970s, because disasters caused a relatively great loss and damage.

Group 2 consists of 6 prefectural areas which not only are located on the suburbanized areas of major metropolises, but also involve large cities in themselves. This is characterized both by the positive scores of the 'Metropolitanity' and the negative scores of the 'Stagnation of urbanization', and by the positive scores of the 'Damage intensity of buildings', 'Damage intensity of farmlands' and 'Safety against floods'. Therefore, this group is interpreted as the urbanizing areas of the building damage type.

Group 3 is the group of 12 prefectural areas which are distributed in the central and the northern parts of Japan. Group 3 is characterized by the negative scores of the 'Metropolitanity' and the positive scores of the 'Stagnation of urbanization', and also by the positive scores of the 'Safety against floods' and the negative scores of the 'Damage intensity of buildings'. This group is interpreted as the rural areas of snow and fire disasters type in the 1970s, because the positive leading loading of the 'Stagnation of

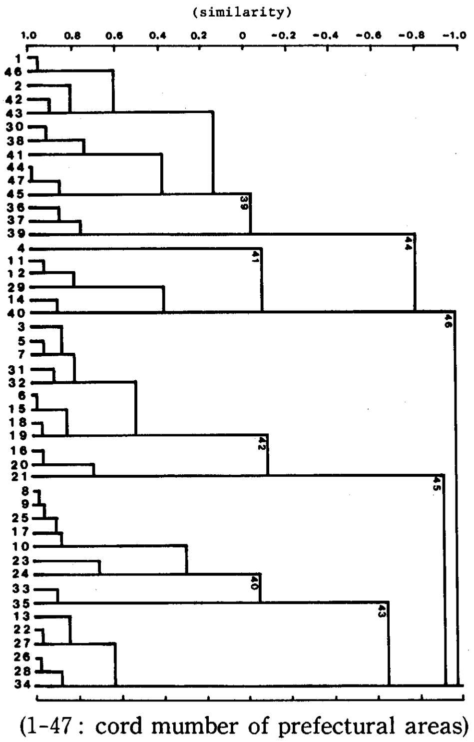


Fig. 14 Dendrogram of the cluster analysis of scores of components.

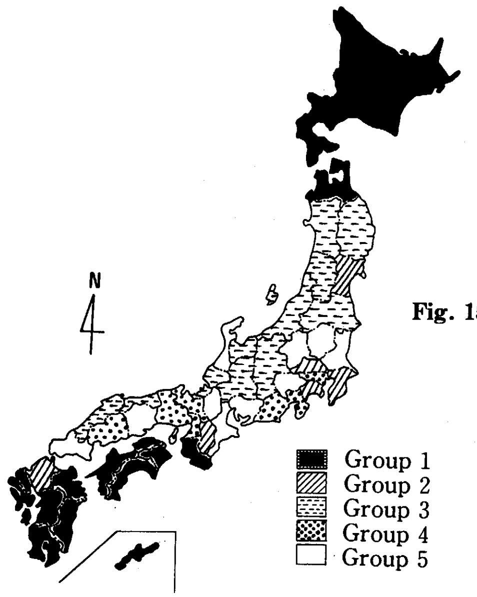


Fig. 15 Spatial structure of damage intensity caused by disasters in the 1970s, expressed as distribution of typical areas grouped by cluster analysis.

Group 1 (high-disastrous areas)
Group 2 (urbanized areas of building damage type)
Group 3 (rural areas of snow and fire disaster type)
Group 4 (metropolitan areas of flood disaster type)
Group 5 (non-disastrous areas).

urbanization' means the number of collapsed houses by fire in areas, which are entirely snowy (refer to Fig. 4).

Group 4 is the group of 6 prefectural areas which not only involve the big cities in themselves, but also are located on the core areas of major metropolises. This is characterized by the positive scores of the 'Metropolitanity' and the negative scores of the 'Safety against floods'. This is interpreted as the metropolitan area of flood disaster type in the 1970s.

Group 5 is the group of the other 9 prefectural areas. This is characterized by the positive scores of the 'Safety against floods' and by the negative scores of the 'Damage intensity of buildings' and 'Damage intensity of farmlands'. Therefore this is interpreted as the non-disastrous area in the 1970s.

4. Conclusion

As the result of this analysis, the spatial structure of the intensity of damage to socio-economic conditions of each area in the 1970s could be identified through the method of factorial analysis based on the indicators expressed not as the absolute values of the usually obvious losses, but as the indices in the form of damage intensity. The high-disastrous areas in Japan of the 1970s are distributed on the south eastern part and the northern part of Japan. These areas are characterized by climatic disasters, particularly typhoon and rainstorm, nevertheless four earthquakes occurred during this period of only 8 years.

However, the result of this study cannot make the 'general' spatial structure of damage intensity in Japan to be observed, because the data, particularly on disasters, used in this study were limited to only the period of 1972-1979. In order to explain the general spatial structure of damage intensity, it is necessary to gather and aggregate the data on disasters for at least the past three or four decades by areas, because some kinds of great disasters, such as earthquake and volcanic eruption, occur in a return period of 50 - 100 years in the same area. But it is too difficult to get the data during these long periods evenly.

In the future, the author should like to attempt to explain the spatial structure of damage intensity caused by disasters in the 1960s and in the 1980s.

Acknowledgements

The author wishes to dedicate this article, with profound respects, to Professor Hiroshi Toya on the occasion of Professor Toya's retirement from Tokyo Metropolitan University.

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(* in Japanese with English abstract ** in Japanese)