CASE STUDY ON INTENSITY OF DAMAGE CAUSED BY DISASTERS IN RECENT JAPAN

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Abstract Damage caused by disasters such as earthquakes, floods and great fires in recent Japan is examined. Intensity of damage is shown not by the absolute value of loss, but by the index value in the form of a damage ratio, such as the sufferer ratio and the ratio of economic losses to the government's annual income. Through these ratios, it is clarified that the small absolute value of loss never means to give the slight socio-economic impact in a small-size local governments.

1. Introduction

Notwithstanding the many governmental efforts to protect the nation from natural hazards, these disasters have not been decreased yet in recent Japan. Disasters, such as floods, earthquakes, great fires, heavy snow and so on, bring much damage to Japan. However, it is not easy to analyse how an area is damaged by disaster.

Damage caused by disasters is usually aggregated in each area by the amount of direct damage, such as the total casualties, the number of collapsed houses, burnt houses and flooded houses, and the sum total of loss. These apparent numbers are used as a index of the greatness of disaster. But from the viewpoint of regional problems caused by disaster, development of some new techniques to discriminate the characteristics of damage is necessary for evaluation of actual damage in each area and for making a pre-disaster prevention plan and a post-disaster reconstruction plan (Nakano, 1977, 1979; Nakabayashi, 1978).

The purpose of this article is to examine some methods of evaluating the intensity of damage caused by some kinds of disaster in recent Japan. The author proposes two indices for measuring the damage intensity added to a region. One is the heavy-sufferer ratio and the other is the ratio of economic loss to annual revenues or rates.

The heavy-sufferer ratio is measured by the ratio of the number of heavy sufferers to the total population in each area. The heavy-sufferers are residents who lost their dwellings during the disaster. Losing one's house constitutes the greatest economic problem for sufferers living in the damaged area.

The loss to rates ratio, or loss to revenues ratio, is attained by measuring the ratio of the total amount of losses to the annual revenues, or rates, in each government. Not only property loss, but also many other indirect losses, such as the decrease of activities in commerce and industry, are contained in the total loss. It is necessary to measure the damage to living facilities and public organization sustaining daily life, for example, the closing of water, gas and electricity supplies, temporary shortage of food and other goods, and so on. However, in studies previously done (Nakabayashi, 1978, 1979 and 1981; Takahashi, 1975), the intensity of such indirect damage could not be emphatically stated, because the method for assessment had not yet been developed. The annual income of rates supports the important parts of annual revenues of a local governments, and indicates capabilities of a local government in maintaining the daily socio-economic conditions. Therefore, although the economic effects of loss of human life and some kinds of indirect damage cannot be measured, the loss to rates ratio will act as a reliable indicator showing the grade of intensity of socio-economic damage including the decline of such economic activities as commerce and industry.

2. Outline of Some Notable Disasters

Preceding the examination, a short sketch will be given here on some notable disasters which consist of a discussion source in this article (Fig. 1).

The Kanto Earthquake of 1923, the greatest recorded earthquake disaster in Japan is characterized by the great fire which followed the shocks of the earthquake. About 312,000 houses were burnt out in Tokyo during the two days following the earthquake. The number of killed and missing reached 58,000 and 10,600, respectively. Most of them fell as victim of the fire.

The Niigata Earthquake of 1964 attracted attention to the weakness of modern cities built on deltaic land. Many buildings and constructions such as roads, railways and banks sank down into the ground and some other buildings were destroyed by liquefaction caused by the shocks. The "Tsunami" attacked the land below sea level and ground floors of 10,300 houses were immersed in water for about two weeks. Oil tanks were broken by the shocks and two of them continued to burn for two weeks in the flooded area.

The Miyagiken-oki Earthquake of 1978 represented the complicated problems of urban life after earthquakes, to us. One of the most severe problems after this earthquake was

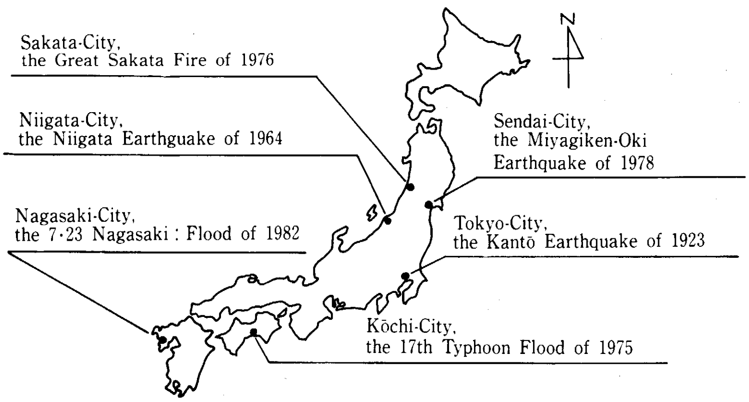


Fig. 1 Location of case study areas

Table 1 Outline of case study areas and disasters

Disaster	EQ of 1923	EQ of 1964		EQ of 1978		GF of 1976	FL of 1975	FL of 1982
Case study area	Tokyo-city	Niigata-city	Kanbayashi-V.	Sendai-city	Naruse-town	Sakata-city	Kōchi-city	Nagasaki-city
Population	2,265,300	356,302	14,296	597,139	12,104	95,890	248,079	449,780
Number of households	483,000	87,439	2,425	219,175	2,647	25,750	82,289	147,596
Sum of sales*	---------	246,713	385	316,055	1,911	97,950	220,408	120,265
Sum of industrial products*	---------	9,603	32	350,907	932	73,133	167,719	35,234
Rates yield*	---------	2,845	49	35,246	196	1,915	9,500	29,331
Revenues* (government income)	40	5,535	142	66,992	1,337	5,011	24,503	79,310
Number of casualties	94,928	131	20	9,313	12	1,004	5	1,016
The dead	68,660	11	0	13	0	1	3	262
The wounded	26,268	120	20	9,300	12	1,003	2	754
Number of damaged houses	311,721	33,390	1,268	77,991	942	974	46,538	24,874
Collapsed	4,222	2,338	126	715	48	0	50	447
Half collapsed	6,336	7,595	538	3,271	141	0	44	746
Partly collapsed and flooded	---------	12,785	604	74,005	753	0	29,512	8,977
Burnt	301,163	389	0	0	0	974	0	0
Flooded up to floors	0	10,283	0	0	0	0	16,932	14,704
Number of sufferers in total	---------	145,680	7,209	272,951	4,255	3,300	140,300	80,318
Heavy-sufferers	1,462,000	91,129	3,827	13,951	889	3,300	51,300	51,290
Economical loss of damage*	2,404	76,500	1,430	111,412	4,994	40,500	24,400	211,960
Houses*	1,464	15,200	537	35,408	2,260	17,900	13,511	31,209
Commerce and industry*	940	20,370	92	56,774	596	21,800	7,081	85,676
The others*	---------	40,930	800	19,230	2,138	800	3,808	95,075
Heavy-sufferer ratio	64.5%	25.6%	26.8%	2.3%	7.3%	3.4%	20.7%	11.4%
Loss to Rates ratio	---------	2.688.9%	2,918.4%	316.1%	2,548.0%	2,114.9%	256.8%	722.6%
Loss to Revenues ratio	6,010.0%	1,382.1%	1,007.0%	166.3%	373.5%	808.2%	99.6%	267.3%
Casualty ratio	4.19%	0.04%	0.14%	1.56%	0.09%	1.05%	0.002%	0.23%

EQ: Earthquake GF: Great Fire FL: Flood * million yen
Heavy sufferers are residents who lost their dwellings (collapsed, half-collapsed, were burnt and flooded up to floors)

shutting down of water, electricity and gas supplies, though the damage to buildings was relatively slight. It again caused people's attention to focus on the fact that the majority of casualties resulted from falling concrete-brick fences.

The Great Sakata Fire in 1976 burnt many shops and goods down to the ground in a vast expanse of built-up area including city core. The ratio of the burnt area to the built-up area was so high that Japanese cities have not experienced such a fire destruction since the period of economic high growth. The fire broke out in a movie theater. About 1,000 buildings including a department store made of concrete were burnt out in only nine hours in night-time. The central shopping district of Sakata-city was completely destroyed, and it took seven years for the central district to be reconstructed through the method of land readjustment planning used by the Sakata city government.

Kochi-city is one of the cities repeatedly damaged by typhoon floods. One of the greatest floods is the 17th Typhoon Flood of 1975, which immersed a vast expanse of the built-up area of Kochi-city in water for three days. The flooded water was deeper in the newly built-up districts mostly located in the land below sea level than in the old built-up area.

Nagasaki-city is located on the slope land and narrow lowland along small rivers and shore line of Nagasaki Bay. The 7. 23 Heavy Rainfall of 1982 caused a deluge. The overflow of water from small streams rushed into the central area of the city. The residential areas newly developed on the slope land collapsed because of the rushing water and the mud flow. This characteristic flood disaster caused the failure of 262 persons's lives.

3. Difference of Damage Intensity among Various Types of Disasters

Table 1 shows the characteristics of the damage intensity seen in three types of disaster,

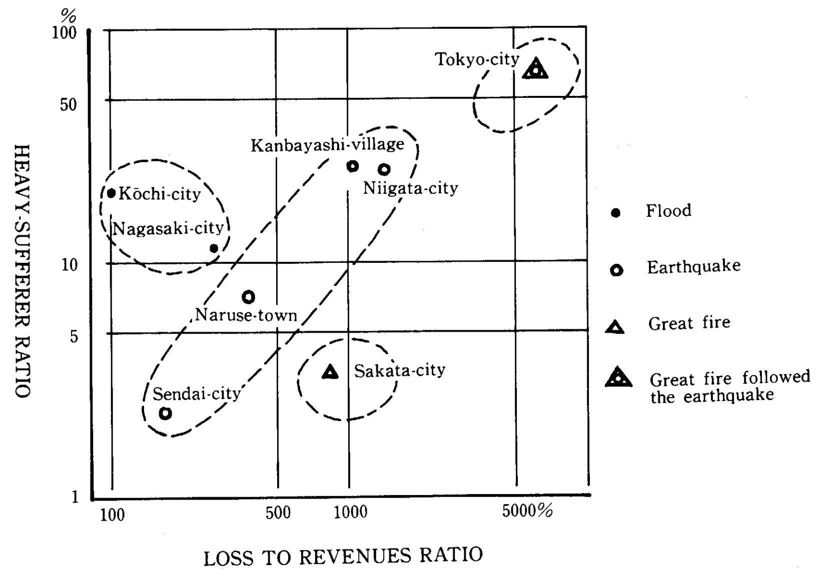


Fig. 2 Character of damage by kinds of disasters

that is, the Niigata Earthquake of 1964 (M. 7.5), the Miyagiken-oki Earthquake of 1978 (M. 7.4), the Great Sakata Fire of 1976, the 17th Typhoon Flood of 1975 in Kochi and the 7. 23 Nagasaki Flood of 1982.

Figure 2 shows the relationship between the heavy-sufferer ratio and the loss to revenues ratio measured in each area of main local governments. These diagrams show that the damage intensity seems to be different to each other among three types of disasters.

The damage due to a flood is characterized by a high value of the heavy-sufferer ratio as compared with a low value of the loss to revenues ratio. Especially, a flood in a built-up area on lowland shows a high value of the sufferer ratio but not so high in the loss to revenues ratio, for example, in the case of Kochi-city damaged by the flood of 1975. On the other hand, Nagasaki-city lost a great number of houses and much property due to rushing water and mud flow on the sloping land of small valleys. It is suggested in the fact that the Nagasaki Flood had a relatively higher value of the economic loss to revenues ratio than the flood of Kochi-city.

On the contrary, the damage caused by fire has a high value of the loss to revenues ratio relatively in comparison with a low value of the heavy-sufferer ratio. Because, a fire is apt to fully burn both the houses and equipped properties together. In the case of the Great Sakata Fire, the economic losses increased for two reasons. The first was that both shops and stock were burned to ashes, and the other was the shortfall of activity in commerce during reconstruction.

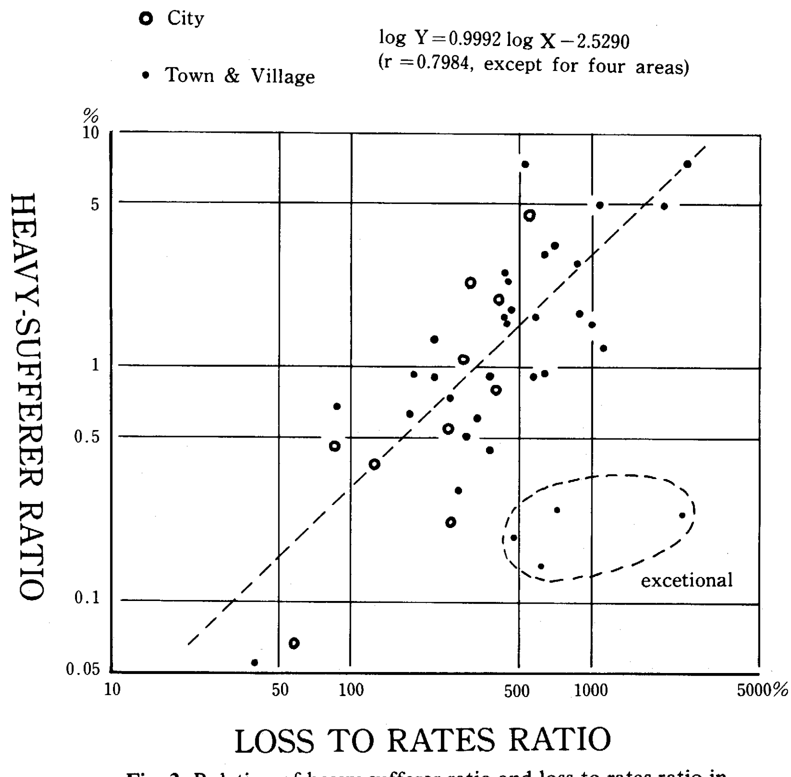


Fig. 3 Relation of heavy sufferer ratio and loss to rates ratio in case of the Miyagiken-Oki Earthquake of 1978

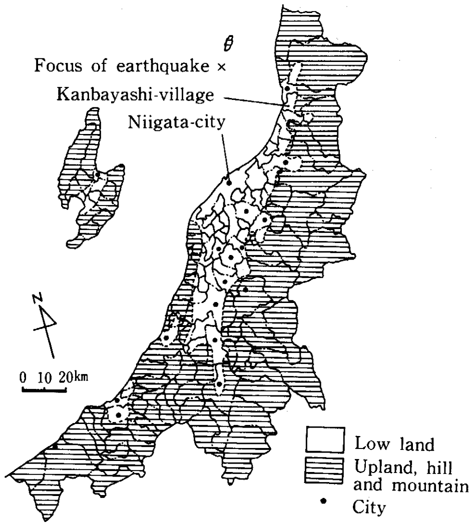


Fig. 4 Distribution of lowland in Niigata Prefecture

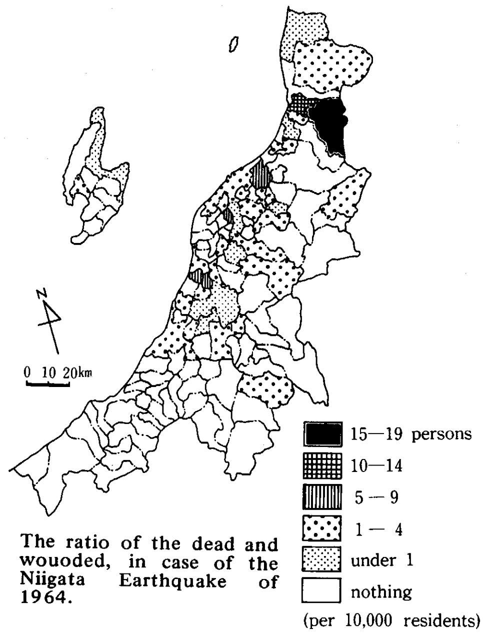


Fig. 5 Areal distribution of the dead and wounded ratios

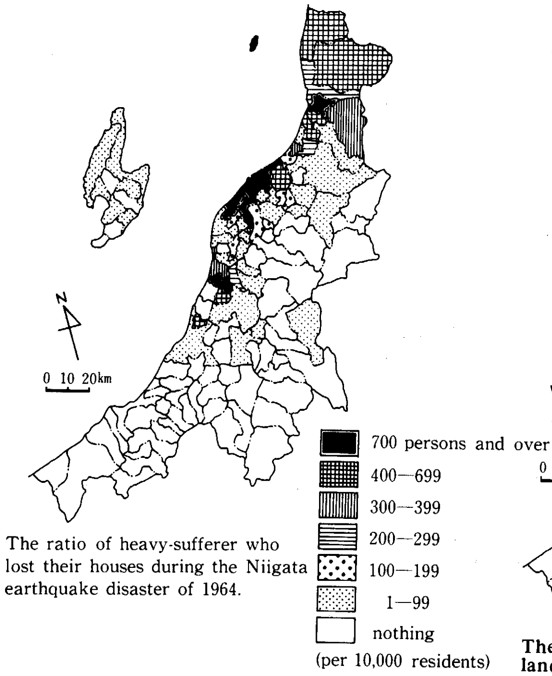


Fig. 6 Areal distribution of the heavy-sufferer ratio

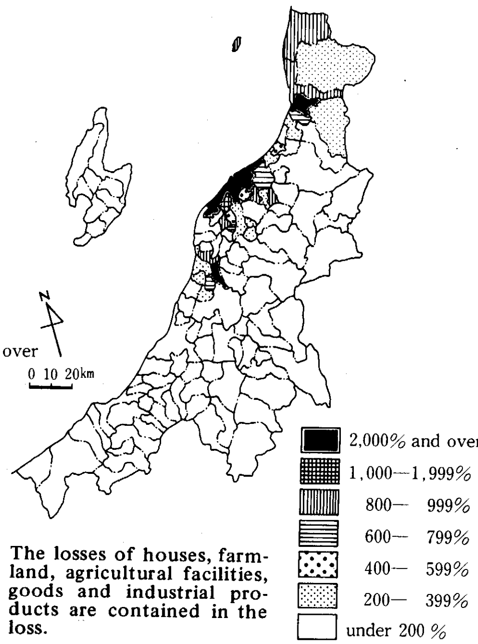


Fig. 7 Areal distribution of the loss to rates ratio

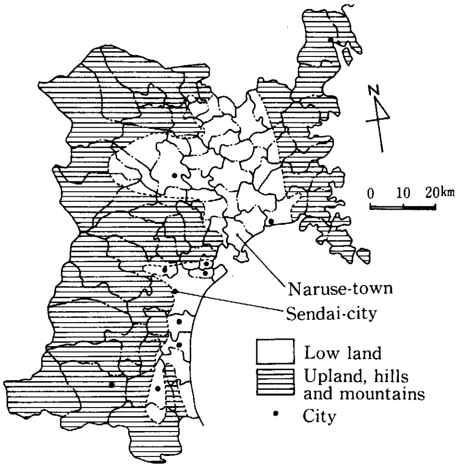
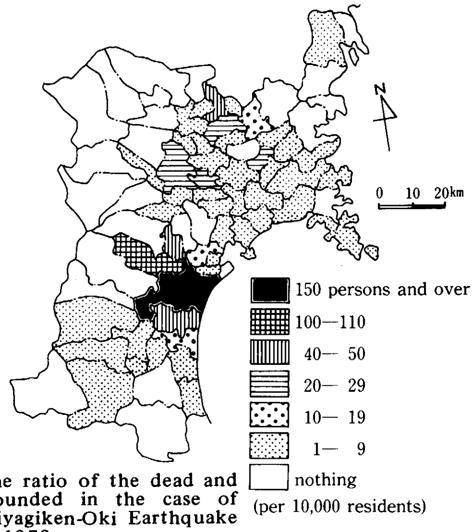
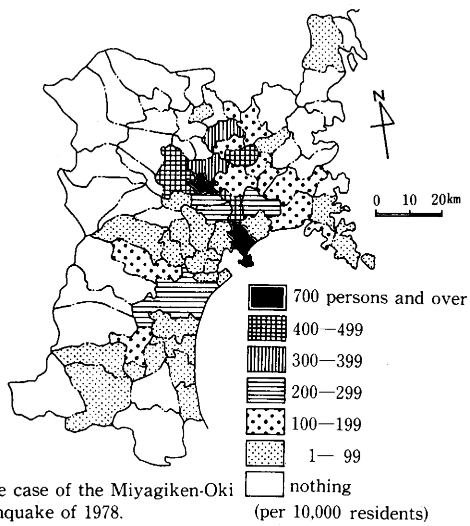


Fig. 8 Distribution of lowland in Miyagi Prefecture



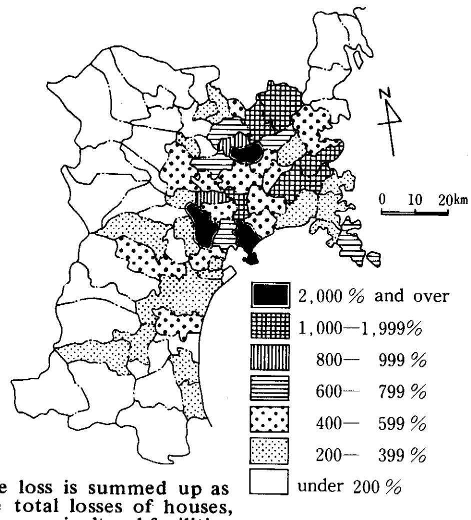
The ratio of the dead and wounded in the case of Miyagiken-Oki Earthquake of 1978.

Fig. 9 Areal distribution of the casualty ratios



In the case of the Miyagiken-Oki Earthquake of 1978.

Fig. 10 Areal distribution of the heavy-sufferer ratio



The loss is summed up as the total losses of houses, farms, agricultural facilities, goods, industrial products public facilities and other architectured constructions, by the Earthquake of 1978.

Fig. 11 Areal distribution of the loss to rates ratio

With regards to the damage due to earthquake, the value of heavy-sufferer ratio generally is in direct proportion to the value of the loss to revenues ratio. In the case of the destruction caused only by shocks, both ratios indicate relatively low values, even if a high absolute value of total losses was recorded in a badly damaged city. The case of Miyagiken-oki Earthquake is an example.

In this type of earthquake damage, the heavy-sufferer ratio and the ratio of loss to rates, that is the main part of revenues, are fundamentally proportionate. Figure 3 shows this tendency, taking the Miyagiken-oki Earthquake of 1978 as an example. In this figure, the values of the two ratios show a clear correlation with the exception of four areas, where the loss to rates ratio was so high due to the destruction of exceptionally big structures such as bridges and banks.

Using this relationship, an estimation of both grade and an absolute value of economic loss in each area seems to be possible when the data of heavy sufferer ratio are given.

But an earthquake is apt to generate various secondary disasters successively after the damage due to shocks. The top-ranked is the generation of synchronous fires following the collapse of structures. They often grow so big as to be illustrated in the case of the Kanto Earthquake of 1923 at Tokyo-city (Fig. 2). If a great fire follows the earthquake shocks, both values of the heavy-sufferer ratio and of the loss to revenues or rates ratio are elevated into terrible levels in general, and the relationship between the two ratios mentioned in Figure 3 will be cancelled in principle.

4. Geographical Distribution of Intensity of Damage Due to Recent Earthquakes

The intensity of damage in each area of suffering can be more actually examined by using the index values than the absolute values which have been commonly used.

Figures 5, 6 and 7 show geographical distribution of various ratios of damage due to the Niigata Earthquake of 1964. Damage intensity is expressed as three kinds of ratios in each local government area. It is elucidated in the figure that the damage is more intensive both in northeastern districts nearest to the focus of the earthquake, and in Niigata-city and its near-by areas located on the lowland composed of thick alluvial soils (Fig. 4).

Figures 9, 10 and 11 show, again, geographical distribution of damage intensity in the case of the Miyagiken-oki Earthquake of 1978. The focus of this earthquake was 130 km east of Sendai-city. In this case, in respect of direct destruction and loss but not casualties, it is very clearly observed that, because of the long epicental distance, the intensively damaged areas are arranged in accordance with the epicentral distance. Those areas are on the lowland composed of thick alluvial soils along the Kitakami River. However, the districts damaged intensively in respect of casualties are big cities.

In both cases, the observed features seem to be somewhat different from those in the maps showing the absolute values (refer Table 1).

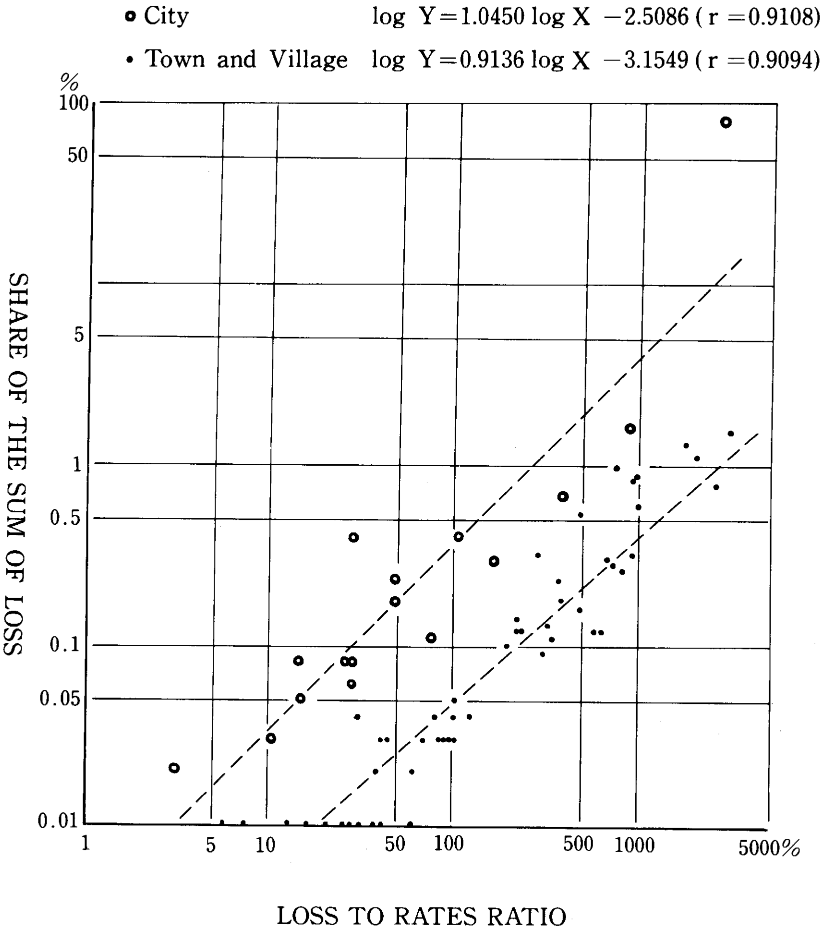


Fig. 12 Relation of the sum of loss and loss to rates ratio in the case of the Niigata Earthquake of 1964

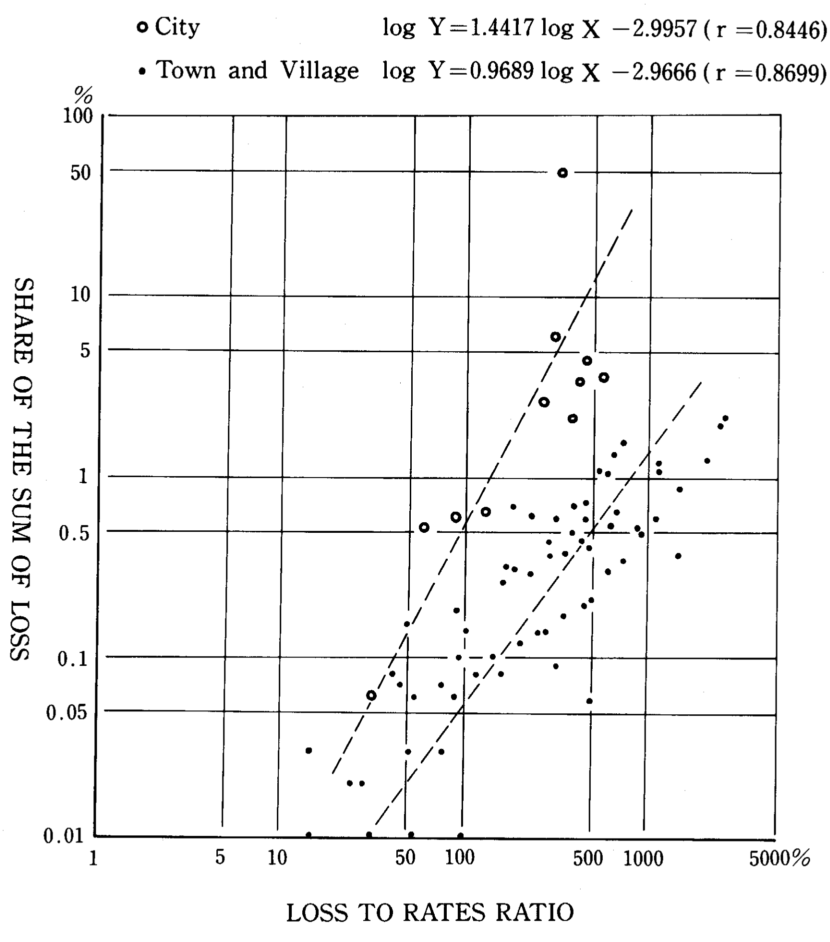


Fig. 13 Relation of the sum of loss and loss to rates ratio in the case of the Miyagiken-Oki Earthquake of 1978

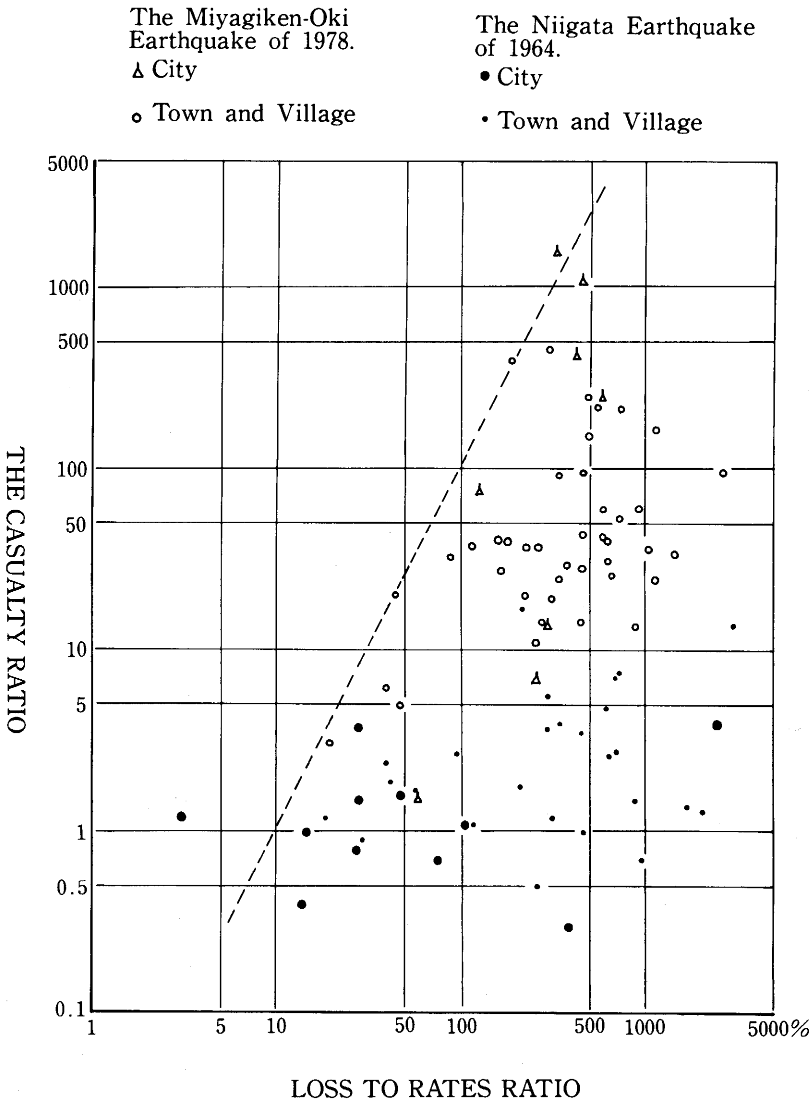


Fig. 14 Relation of the dead and wounded ratio to loss to rates ratio

5. Difference of Intensity of Damage Due to an Earthquake in Urban Area and in Rural Area

In the above description, it is clear that the intensity of damage caused by the shocks of earthquakes not followed by fire is heavily affected by the physical conditions of land in each area. At the same time, the distribution of intensity of damage seems to be closely related to the socio-economic conditions of each area. Usually an absolute value of damage losses tends to attract social concerns. However, though the absolute value of damage losses is small, the damage may affect very severely the society according to social and economic conditions of the area, for example, sparsely inhabited areas or areas having only poor financial capability.

Figures 12 and 13 represent the relationship between the absolute value of total loss and the index value of loss to rates ratio. In these figures, total loss is expressed as a share of the loss of each local government in the total loss of the prefecture. Figures 12 and 13 show the cases of the Niigata Earthquake of 1964 and of the Miyagiken-oki Earthquake of 1978, respectively. It is clear that, in the both cases, the values of loss to rates ratios in urban areas are relatively lower than in rural areas, if both the ratios are compared in respect of the index value. If they are compared in respect of the absolute value, the sum of losses in each urban area is far larger than in rural areas. This will suggest the fact that damage in rural areas gives severer effects than that in urban areas. The large amount of damage losses in each urban area can be borne by more massive capacity of population, finance, and so on. This is one of the reasons why evaluation of damage has to be done using index values. Especially it is indispensable, when they are discussed in relation to regional planning including prevention planning and reconstruction planning.

Figure 14 shows the relationship between the loss to rates ratio and the casualty ratio. Because of the discordance in the data collecting methods of the two prefectural governments, the number of the wounded was a lower-estimate in the case of the Niigata Earthquake of 1964 than in the case of the Miyagiken-oki Earthquake. But the ratio of the wounded is higher in the urban areas than in the rural areas, in both cases. For the Niigata Earthquake, the value of the casualty ratio in the urban area is similar to that in the rural area, though the loss to rates ratio is much lower in the urban area. In the case of the Miyagiken-oki Earthquake of 1978, the value of the casualty ratio is higher in the urban area than in the rural area, though the loss to rates ratio shows a reverse relationship.

From the above it may be assumed that the risk of people getting wounded during a disaster may rise, in accordance with the advance of urbanization. Living conditions are now apparently changing in the urban area of Japan. The number of urban residents living in multi-storied apartment houses is increasing. They have much furniture on a small floor space. If such multi-storied apartment houses are shaken by an earthquake, it appears that many residents are apt to be wounded.

6. Conclusion

The author discussed the evaluation of damage due to disasters and shows that it has to be done by using not the absolute values but the index values. This is especially true from the viewpoint of regional problems caused by disasters and including all prevention and reconstruction planning. In conclusion, the following four points can be mentioned.

First, the two kinds of ratios, the heavy-sufferer ratio and the loss to rates ratio, are useful for measuring the damage intensity of disasters. The intensity of damage to living conditions is measured by using the heavy-sufferer ratio which is calculated by the ratio of residents whose houses collapsed, were burnt or flooded. They lost their basis for living after the disaster. The intensity of economic damage is estimated by using the loss to rates ratio which can be calculated on the basis of the absolute values of losses and revenues, or rates.

Second, the intensity of damage is characteristic among of disaster. Flood disaster raises the heavy-sufferer ratio while the loss to rates ratio is relatively low. Fire disaster, on the contrary, produces high values of loss to rates ratio and low values of heavy-sufferer ratio. Earthquake disaster not followed by a big fire results in proportionate values of loss to rates ratio and heavy-sufferer ratio (Fig. 2).

Third, with regard to damage caused by earthquake, the amount of economic loss due to future earthquakes can be anticipated by using the deduced relationship between the heavy-sufferer ratio and the loss to tax ratio (Fig. 3).

Finally the author would like to propose that attention should be paid more carefully to the regional problems in time of disaster, especially, on studies concerning the people's welfare. It is proved in this article, for example, by the fact that small damage in absolute value in rural areas never means slight impact to the small-size local government. It means in the same context that the costs of hazards for developing societies expressed as a proportion of income available are at least ten times those of industrial nations (Burton *et. al.* 1978).

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