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JAPANESE REGIONAL IMBALANCE OF FINANCIAL EXPENDITURE REQUIRED FOR HOUSING RECONSTRUCTION IN MUNICIPAL AND HOUSEHOLD UNITS

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ABSTRACT

This paper discusses the semi-mathematical construction of a set of equations on financial expenditure required for housing reconstruction in macroscopic points and their application to Japan. Some remarkable results are as follows; i) Estimation equations of debt for each household to reconstruct livelihood of seismic disaster victims were made and by applying the equations to all of the municipalities in Japan the regional imbalance of the economic damage risk potential was figured out on the map. ii) For example, in spite of showing a trend to emphasize the heavy damage of the pacific side as strongly depending on seismic input motions, the debts of each household is independent of the hazard map. Namely, the regional imbalance of financial expenditure required for reconstruction of each livelihood is affected by the regional differences in the prices of constructing houses and the average of private property as savings.

1. INTRODUCTION

We have learned from the 1995 Kobe Earthquake that the so-called double loans, which were resulted from reconstruction of houses damaged by the earthquake added to big and long term mortgages on their own houses, financially plagued many earthquake victims with disturbing self-support recovery for long time. In 1998 Japanese government established the Act Concerning Support for Reconstructing Livelihood of Disaster Victims which supports each household damaged by subsidy of up to 3 million yen to financially reduce a milestone around victim's neck. However, we must notice that rebuilding of a house costs an average of 18 million yen at every wooden building in Japan, and therefore a heavy burden of 15 million yen is still remain. In addition to this, it is very hard for each local government to equally govern a kind of financial problem due to the regional inequality of seismic input motions, expected seismic risk, and municipality economic budget affordable to support for victims, etc. Based on the background described above, the purpose of this study is to discuss financial expenditure for housing reconstruction in municipal and household units.

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2. CONSTRUCTION OF EQUATIONS

2.1 Overview of Established Knowledge and Basic Data

Among a lot of papers and reports dealing with the Kobe Earthquake published, we have a special interest in papers by Okada and Takai (1999, 2004) which focus on the structural vulnerability characteristics of wooden-frame dwelling houses. The significant outcomes in their papers are as follows within the scope of our concern;
i) They defined "one dimensional damage scale ranging 0.0 to 1.0 (no damage to total collapse), with illustrated damage pattern chart", which brings clear understanding of the damage states in terms of categorical and discrete scales (See Figure 1).

Category	None/Minor	Moderate	Heavy	Collapse	Total Collapse
Discrete (D)	0.0≦D≦0.2	0.2<D≦0.4	0.4<D≦0.6	0.6<D≦0.8	0.8<D≦1.0
Continuous (x)	x = 0.0 -1.0				
Function Form	Weibull (Density, Cumulative) Distribution Function				

Figure 1 Classification of damage states of wooden dwelling houses with damage pattern chart.

ii) Incorporated the plenty of statistical data on building structure of wooden dwelling houses spreading all over Japan with field survey data on seismic damage to building, they formulated the "nationwide and standard" relationship in household unit among three major variables of the structural scores (s)1, which means earthquake-resistant capacity of building, the damage index (x), which means damage state of building and JMA seismic intensity (I) as degree of input motions to target buildings.

2.2 Estimating the Categorically Classified Damage Features to Wooden Dwelling Houses

In order to deal collectively with the above relationship in municipal unit, Nakashima and Okada (2008) transferred the relationship of three major variables into the power math function as the following:

$$s = \{(I - a(x)) / b(x)\}^{1/c(x)} \qquad (1)$$

Where, x means the damage index, and each coefficients a, b, and c according to x are given in Table 1. The function is shown in Figure 2.

Table1 Coefficients in each damage index classified in Equation (1)

x	x=0.1	x=0.2	x=0.3	x=0.4	x=0.5	x=0.6	x=0.7	x=0.8	x=0.9
a	1.5909	1.2795	0.9283	0.4900	-0.0530	-0.8875	-2.1635	-4.7189	-14.483
b	4.4780	5.0712	5.6077	6.1884	6.8585	7.8079	9.1833	11.879	21.795
c	0.2136	0.1714	0.1446	0.1229	0.1050	0.0865	0.0687	0.0495	0.0243

In case for the average wooden dwelling houses in Japan, the diffusion rate (g(q,s)) of the structural scores (s) changing with building age (q), which means the past year since construction comes to the following equation (2) as the optimal log - normal density function (See Figure 3):

$$\mathbf{g}(q, s) = \frac{1}{\sqrt{2\pi}\,\sigma} \exp\left(\frac{(\ln(s) - \mu)^2}{2\sigma^2} \right) \qquad (2)$$

Where, μ and σ are the average and the standard deviation of the relative frequency of building

distributed respectively in construction year (Table 2).

Table2 Coefficients of classified by built-years

Years	-1950	1951-1960	1961-1970	1971-1980	1981-1990	1991-	All
μ	-1.0968	-0.7598	-0.5854	-0.4018	-0.1862	-0.0303	-0.3678
σ	0.8229	0.7046	0.5579	0.5335	0.5125	0.4809	0.5970

Therefore, the distribution of structural scores in municipal unit can be obtained by multiplying *g(q,s)* with the distribution ratio *T(q)* of houses classified by built-year in a municipality and by summing-up in terms of age *q*:

$$g(s) = \sum_q \left(g(q,s) \times T(q)\right) \qquad (3)$$

The excess probability of damage to building in municipal unit under the situation that the damage state is *x* in assumable input motions *I* is given by substituting Equation (1) into the above equation (3) as follows:

$$P(I,x) = \int_0^s \sum_q \left(\mathbf{g}(q,(I-a(x))/b(x)^{1/c(x)}) \times T(q)\right) \cdot ds \qquad (4)$$

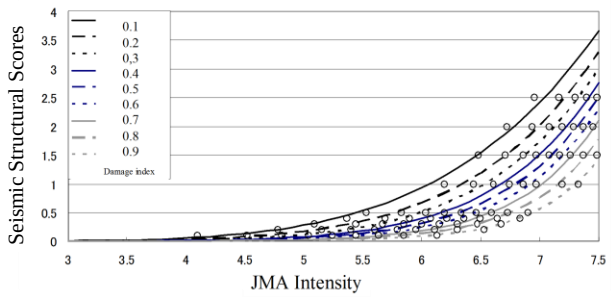

Figure 2 Relation among three major variables[2)]

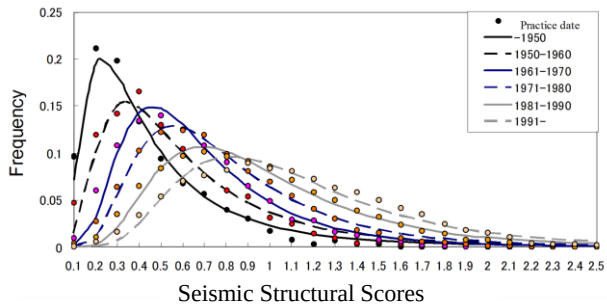

Figure 3 Density function of built-year[2)]

2.3 Estimation to the Amount of Debt

Based on the related studies described in the former chapters, we construct the equations by which the amount of damage for each wooden house that is most widely distributed in Japan can be estimated in considering such regional inequality of seismic occurrence probability. The financial expenditure L_{il} required for housing reconstruction in municipal unit can be expressed as follows:

$$\sum_l L_{il} = \alpha_l \times C(k_j) \times P(I,x) \times k_j \overline{W_j} Z_i \qquad \cdots (5)$$

Where, i means each city, town, or village of which total number is 1,789, and j means the administrative prefectures of Japan of which total number is 47. $k_j \overline{W_j} Z_i$ is the number of households possessed wooden houses damaged. $C(k_j)$ is the average price of wooden house in each prefecture, *P(I,x)* is the occurrence probability of wooden house for the seismic intensity *I* and the damage class *x* proposed by the authors(Nakashima Okada 2008 . α_l means the rate of reconstruction cost of damaged house and construction cost of new building. The amount of debt $\overline{D_{ilm}}$ for each household living in the specified municipality *i* to reconstruct can be expressed as follows:

$$\overline{D_{ilm}} = (L_{il} - R_{il})/(P(I,x) \times \overline{W}jZ_i) - M_{jm} \qquad \cdots(6)$$

Where, R_{il} is the amount of support by the Act described above, M_{jm} is the average of savings for each household living in the specified prefecture j and belonging to the class of annual income m.

3. APPLICATION TO WHOLE AREA OF JAPAN

3.1 Probabilistic Hazard Maps of Japan as Seismic Input Signal

To attempt a nationwide estimation of the financial damage of building by earthquakes, we should acquire data in advance. One is the data on probable seismic hazard in terms of JMA seismic intensity and these are obtainable for the whole area of 1,798 municipalities in Japan, downloading via the web site as [Browse http://www.jishin.go.jp, for more detail]. Figure 4 shows a seismic hazard map which indicates the maximum surface ground velocities under the probability of 1 % and 10 %, 50 % during 50 years.

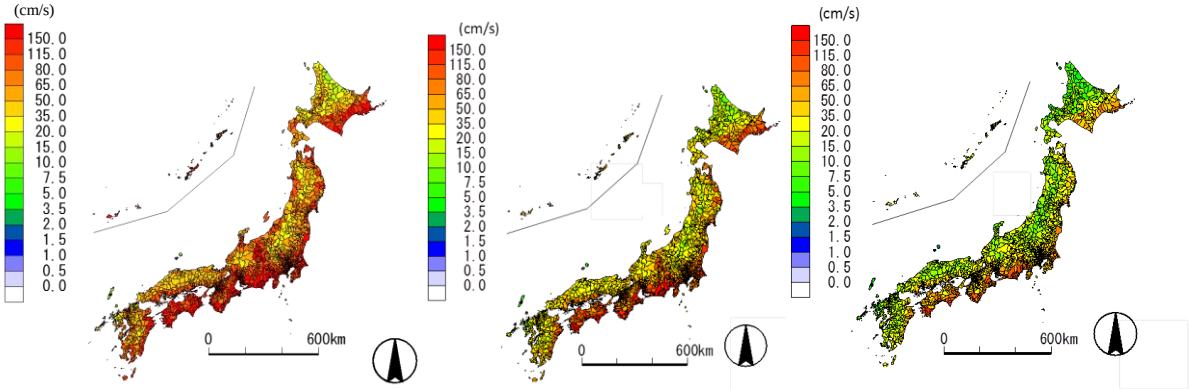

Fig 4(a) P=1% during 50 year **Fig 4(b) P=10% during 50 year** **Fig 4(c) P=50% during 50 year**

Fig 4 Seismic hazard map of Japan published by the Headquarters for Earthquake Research Promotion

3.2 Estimation of the economic damage for Whole Area of Japan

By using Equation (4) and the seismic hazard information shown in Fig. 4, we firstly tried to calculate the number of buildings estimated over the damage index of 0.6, which is equivalent to the damage class from Collapse to Total Collapse defined in Fig. 1. The expected total number of damaged buildings in the whole area of Japan corresponding to the probability of earthquake occurrence of 1%, 10%, and 50% during 50 years are shown in Table 3. It says that the seriousness of disaster differs depending strongly on the probabilities of earthquake occurrence; for example, the estimated number of Collapse and Total Collapse comes up as large as 7,200,000 buildings in the worst case of 1%, and it is near to 500,000 buildings in an overoptimistic case of 50%. Figure 5 illustrates the damage distribution map which indicates the damage number of buildings estimated in the class of Collapse and Total Collapse under the probability of 1 %, 10 %, and 50 % during 50 years, respectively.

Table 3 Estimated Number of Damaged Buildings in the Whole of Japan

Probability of Earthquake Occurrence	1 % during 50 years	5 % during 50 years	10 % during 50 years	50 % during 50 years
Number of Collapse and Total Collapse	7,225,247	5,903,520	2,599,799	489,890

Applying the above results on the damage number of buildings to Equations (5) and (6), we secondly tried to estimate the financial damage of buildings. The nationwide financial expenditure for housing reconstruction respectively corresponding to the probability of earthquake occurrence of 1 %, 10 %, and 50 % during 50 years are given in Table 4. We can see in Table 4 that the seriousness on economic damage differs with the same trend as the damage number of buildings in Fig. 4 depending on the

probabilities of earthquake occurrence; for example, the economic damage comes up as large as 18,818,379 billion yen in the worst case of 1%, and it is near to 1,981,726 billion yen in an overoptimistic case of 50 % during 50 years. Figure 6 sums up a spatial distribution of financial expenditure for housing reconstruction in municipal unit. For example, around 2,500 billion yen, which is beyond an annual budget of Nagoya city, that is, 1,000 billion yen, is necessary to reconstruct the total amount of building damage in Nagoya city, which locates at the center of Japan and is presumable to be attacked by the highest ground severity over 200 cm/sec.

We also create a risk curve, which means a total amount of building damage in municipal unit corresponding to probability basis of earthquake occurrence, through Equation (4) and depict in Figure7 for Shinjuku-Ward, Tokyo and ordinance-designated city representative in each region. It can be seen that there are regional differences in the amount of damage as shown in the fact that Nagoya, Shizuoka, Osaka Cities are nearly 10 times greater than that of Okayama and Sapporo Cities in the comparison of damage costs. Amount of damage in Tokai district where the center city is Nagoya will be expected particularly large under the impact of a strong earthquake hazard. On the other hand, the amount of damage in Osaka City is largely affected not by severity of input hazard but by the great number of buildings gathering within the city limits.

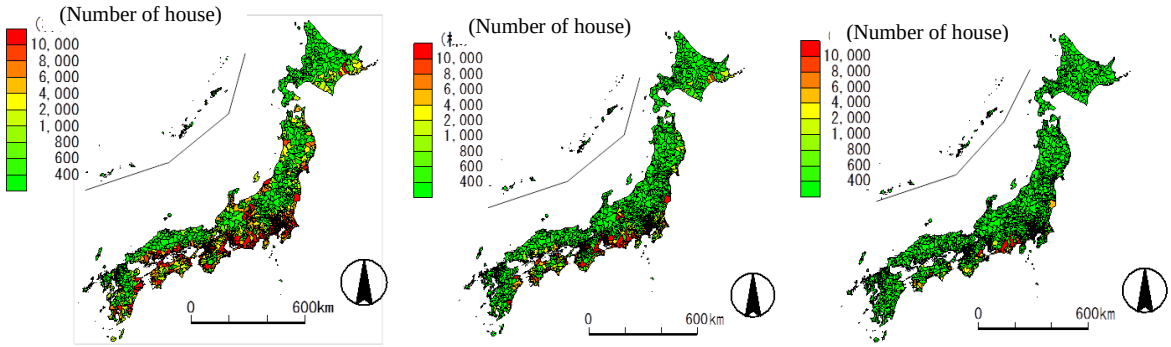

Fig5 (a) P=1% during 50 years **Fig 5(b) P=10% during 50 years** **Fig 5(c) P=50% during 50 years**

Fig 5 Distribution of Buildings Estimated in the Damage Class from Collapse to Total Collapse.

Table 4 Economic Damage in the Whole of Japan

Probability of Earthquake Occurrence	1 % during 50 years	5 % during 50 years	10 % during 50 years	50 % during 50 years
Economic Damage (billion yen)	18,818,379	11,075,999	7,857,152	1,981,726

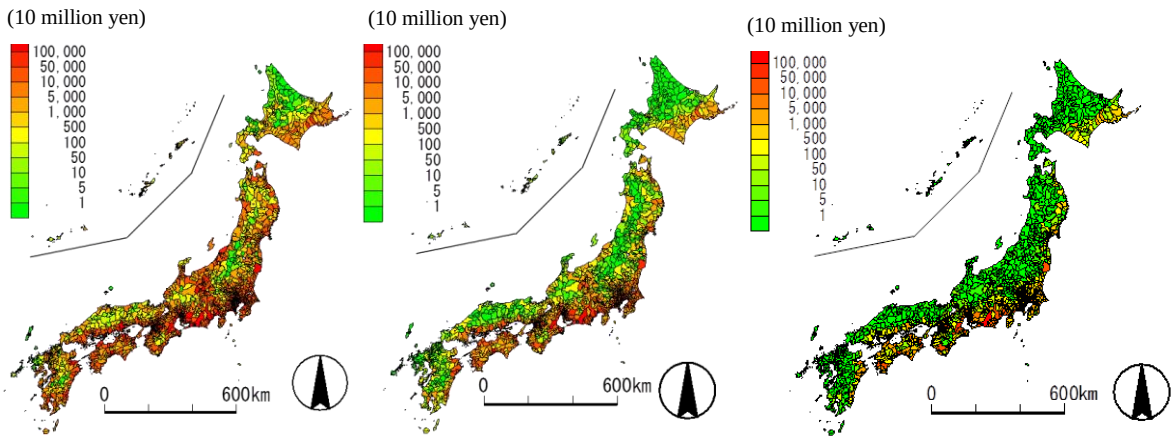

Fig6 (a) P=1% during 50 year **Fig 6(b) P=10% during 50 year** **Fig 6(c) P=50% during 50 year**

Fig 6 Seismic Expenditure for Housing Reconstruction in Municipal Unit.

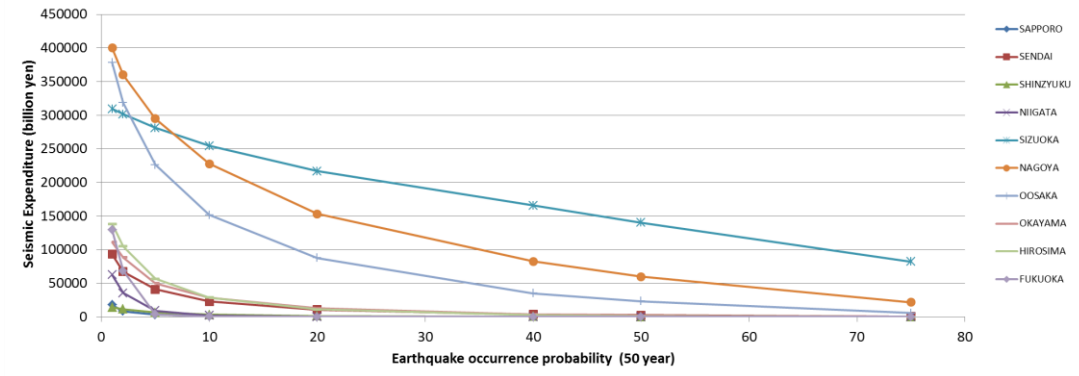

Fig.7 Risk to Economic Damage in Municipal Unit.

3.3 *Estimation of the debts of each household for whole area of japan*

In this chapter we tried to estimate the financial expenditure in household unit and disclose the regional imbalance of individual resilience against seismic disasters. Following the proposed method through Equations (4) to (6), we calculate the financial expenditure of households damaged in the class of Collapse and Total Collapse and illustrate in Figure 9. It shows that the debts of each household is independent of the hazard map in Fig. 4(b) and indicates the regional imbalance of financial expenditure is affected by annual income and savings. Figure 8 showsthe average of savings M_{jm} for each household living in the specified prefecture j and belonging to the class m of 2, 5, and 10 million yen annual income. Even in the same annual income, indebtedness per household differs from region to region. Household indebtedness is more expensive covered with Hokkaido district located at the northern pole island and Kyushu district located at the southern pole island as compared to the center district. The difference is affected by cultural and climate features in the prices of constructing houses and savings.

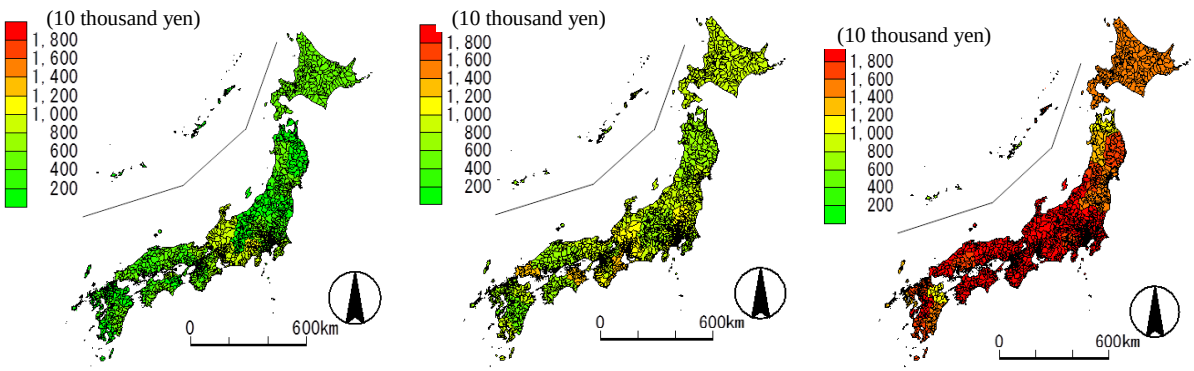

Fig.8(a) in the class of 2 million annual income

Fig 8(b) in the class of 5 million annual income

Fig8 (c) in the class of 10 million annual income

Fig 8 The Savings of Households.

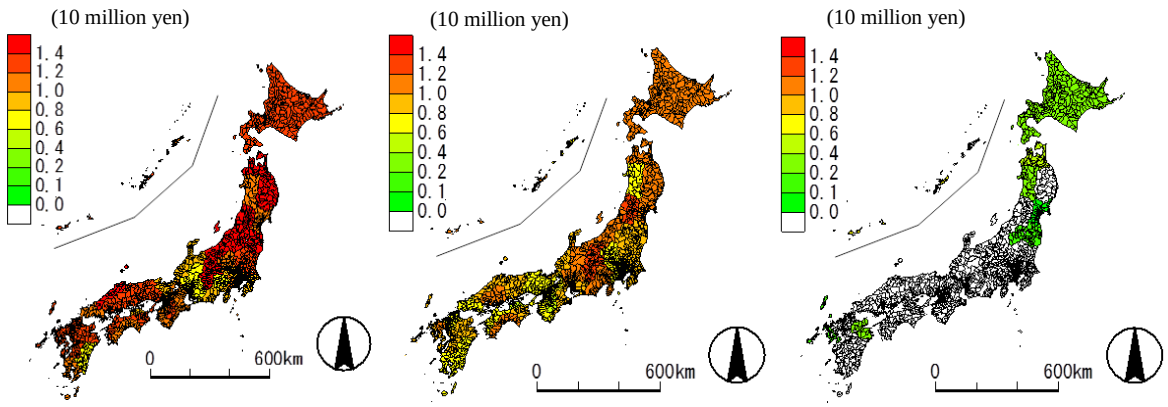

Fig.9(a) 2 million annual income Fig.9(b) 5 million annual income Fig.9 (c) 10 million annual income
Fig.9 Seismic Expenditure for Housing Household Units.

3.4 *Discussion of Strategies*

The debt in expectation is depending upon nation policy on seismic strengthening for non-seismic houses. In 1998 Japanese government established the Act Concerning Support for Reconstructing Livelihood of Disaster Victims which supports each household damaged subsidy of up to 3 million yen to financially reduce a milestone around victim's neck. However, we must notice that rebuilding of house costs an average of 18 million yen in Japan, and therefore a heavy burden of 15 million yen is still remain. In addition to this, it is very hard for each local government to equally govern a kind of financial problem due to the regional inequality of seismic input motions, expected seismic risk, and municipality economic budget affordable to support for victims, etc. Therefore, we will examine the effect of the increase in support funds with fiscal adjustment fund is the savings of administrative finance. The amount of debt $\overline{D_{ilm}}$ for each household living in the specified municipality i to reconstruct can be expressed as follows:

$$\overline{D_{ilm}} = (L_{il} - R_{il} - \mathrm{S_{il}})/(P(I,x) \times \overline{W_j} Z_i) - M_{jm} \qquad \ldots(7)$$

Where, S_{il} is the amount of the public finance adjustment reserved in each municipality (Figure 10), which means a kind of surplus fund capable of throwing to victims. Following the proposed method through Equations (7) we tried to calculate the debt compensated for the public finance adjustment. In Figure 11 the simulated results in each Municipal are shown. The white part of the maps in Figs.11 means the city where the debt in the household for reconstructing damaged house is eliminated by devoting the savings of household and the municipal fund. Covering the savings to the debt does not link to eliminate the burden against household, but it is very important for each household that it may not be considered a double loans. In addition there is a clear difference in the Pacific Ocean side and the Sea of Japan side in debt. Since the large number of households damaged will occur in the Pacific Ocean side where assumable hazard is large, a subsidy for one household supported from the administrative fund is obliged to be small when a destructive disaster strikes and burden of the households is increased as a result of this. Therefore, the households on the Pacific Ocean side face a liability to not be able to cover the burden by the savings.

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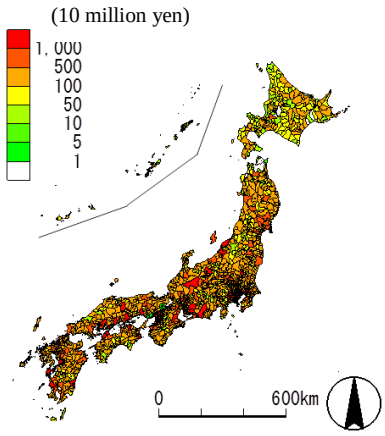

Fig. 10 Public Finance Adjustment

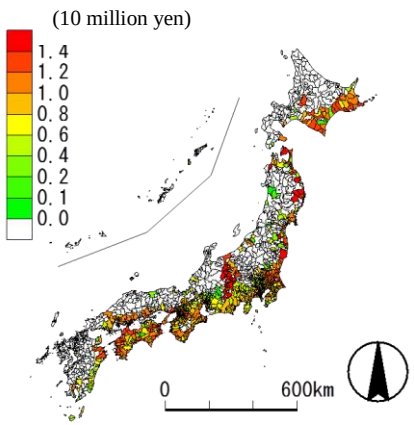

Fig. 11 (a) 2 million annual income

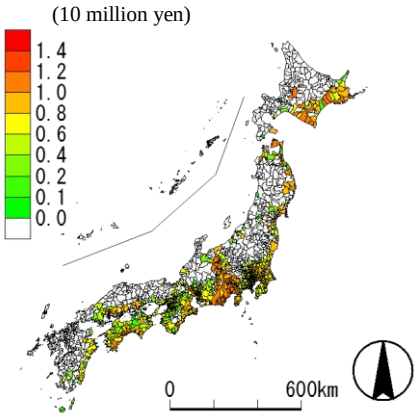

Fig. 11 (b) 5 million annual income

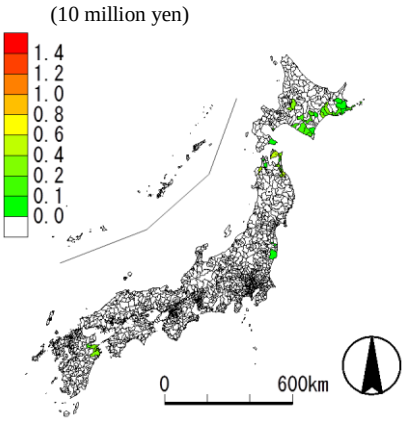

Fig. 11(c) 10 million annual income

Fig. 11 Seismic Expenditure for Housing household units.

4. Conclusions

These results indicate that regional imbalance of financial expenditure for housing reconstruction in municipal and household units. Based on such findings the second phase study has just started to develop the countermeasures targeting the drastic reduction of economic damage.

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