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Effect of Flooding on Megalopolitan Land Prices: A Case Study of the 2000 Tokai Flood in Japan

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ABSTRACT

A framework for analyzing the effect of flooding on land prices is proposed based on a case study of the Tokai flood in September 2000. The flood effect was examined by cross-sectional and panel analyses, panel data comprising land price and its attributes. Interesting findings were that land prices in flood-prone areas are lower and have less variance than in other areas. The price of land for commercial use in flood-prone areas is higher than that for residential or industrial land, and the amount and ratio of diminution also are larger. Spatially, of the three areas in the Tokai region studied, land prices in Nishi Ward, Nagoya are the highest, but diminution and the diminution ratio of land prices vary greatly. It is necessary to differentiate flood effects from the location effect on land prices when estimating the scale of the effect of flooding. The Tokai flood effect has a reverse Z-shaped pattern. At onset, the greater the inundation, the greater the decrease rate. In the case of the Tokai flood of 2000, the flood effect appeared in part in 2001 and in entirety in 2002. The mean of the effect in monetary value was -2204.7 yen/m^2 in 2001 and -8888.3 yen/m^2 in 2002, change in the rates being -1.27% in 2001 and -4.7% in 2002. The higher the price, the stronger the impact; whereas, the impact on the rate of land-price change was similar regardless of the price. Even so, it seems that residents prefer cheap land rather than low risk of flooding.

1. INTRODUCTION

Flooding is one of the oldest, most frequent, and severest natural disasters. A study by the Munich Reinsurance Company found that among the major natural catastrophes that occurred in 2000, flooding accounted for 50% of the total economic loss (MunichRe, 2001). The characteristics of floods have altered with urbanization and industrialization, and have become particularly complex with the rise of the megalopolis, a densely populated region with a vibrant market economy, intensive land use, and rapid transportation. Slowly but surely more and more areas are becoming prime targets for natural disasters. The megacity, in particular, is a ticking time bomb (MunichRe, 2001).

Researchers have studied the effects of natural disasters on property values in the affected areas. Some have focused on earthquakes (Palm, 1982; Scawththorn et al., 1982; Brookshire et al., 1985; Beron et al., 1997; and Yamaga et al., 2002), others have concentrated on flooding and floodplain locations (Babcock and Mitchell, 1980; Burby and French, 1981; Muckleston et al., 1981; Sheaffer and Greenberg, 1981; Changnon et al., 1983; MacDonald; Tamai and Ishihara, 1999; Yabe and Murayama, 2000). All these studies attempted to determine the effect of a disastrous event on land prices, but the methods used differ and findings on whether a disastrous event affects land prices are sometimes contradictory. For example, in the case of flooding, most studies have attempted to detect a discount for a floodplain location (i.e., the net effect of all attributes that affect property values), rather than focus primary flood damage. The data available are insufficient to conclude whether flood damage resulting from floodplain activities is reflected in the fair market value of floodplain property (Chao et al., 1998). Some researchers (Chao et al., 1998; Ichikawa et al., 2002) tried to detect primary flood damage, but failed, perhaps because other effects, such as differences in land development history, were not completely excluded. After the Tokai flood of 2000, civil engineers, disaster scientists, and hydrologists conducted many surveys and studies in an attempt to clarify the characteristics of the flood and the direct damage done (Katada and Kuwasawa, 2001; Yamamoto and Iwaya, 2002; Ushiyama and Takara, 2002), but no one looked into the indirect damage, such as the falling off of property values.

In any attempt to ascertain the effect of primary flood damage on land prices in Japan, Korea, or other Asian countries, an important consideration is that the price of a piece of land greatly exceeds the value of any buildings on it. Land prices and building values therefore should be evaluated separately, and property values as the sum of them.

We sought to determine the effect of primary flood damage on land prices, rather than building values; in particular, how a low-probability flood temporally and spatially affects megalopolitan land prices. For this purpose, we established an analytical framework and applied it to the Tokai Flood of 2000. After briefly describing that framework, data sources are introduced. The effect

KEY WORDS: land price, primary flood effect, location effect, reverse Z-shaped pattern, Tokai flood of 2000

of flooding on land prices, as indirect damage caused by the Tokai flood, is discussed based on results for a statistical method and hedonic-approach-based panel analysis. Lastly, we offer concluding remarks, and mention areas of future research.

2. FRAMEWORK FOR ANALYZING THE EFFECTS OF FLOODING ON LAND PRICES

2.1 Changes in land prices in floodplains

Land is nothing but a physical object if not being used. Land price, the product of a market economy is determined by many factors or attributes: the land's physical characteristics and location, social and economic plans for the land, its developmental history, administrative regulations and laws, and the public's perception of the land.

Urban areas are regional or national centers of political, economic and social activities, therefore, land prices usually are higher than in rural areas. As urbanization spreads, floodplains become developed and land prices increase. This floodplain change is shown in Fig. 1. Historically, a city normally took root near a floodplain, land use spreading outward; typically in concentric circles of the central business district (CBD), industrial districts, residential areas, suburbs, and rural areas . Land prices (rents) gradually decreased with the distance from the CBD. With industrialization, the need for land increased. To meet this need, cheaply valued nearby floodplains were rapidly developed. Rural areas and natural floodplains disappeared. River embankments were built to reduce high-probability flooding and to protect residents to some extent. As a result, more and more people moved to urban areas, more and more floodplains were developed, and land prices increased. Historically, therefore, land price based on location was mainly a phenomenon arising from development intensity and not considered an effect of flood risk. Actually, some CBDs of cities, such as Shanghai, China, are located along rivers and are the highest priced land areas. In other words, a flood does not determine land prices but land-price fluctuation.

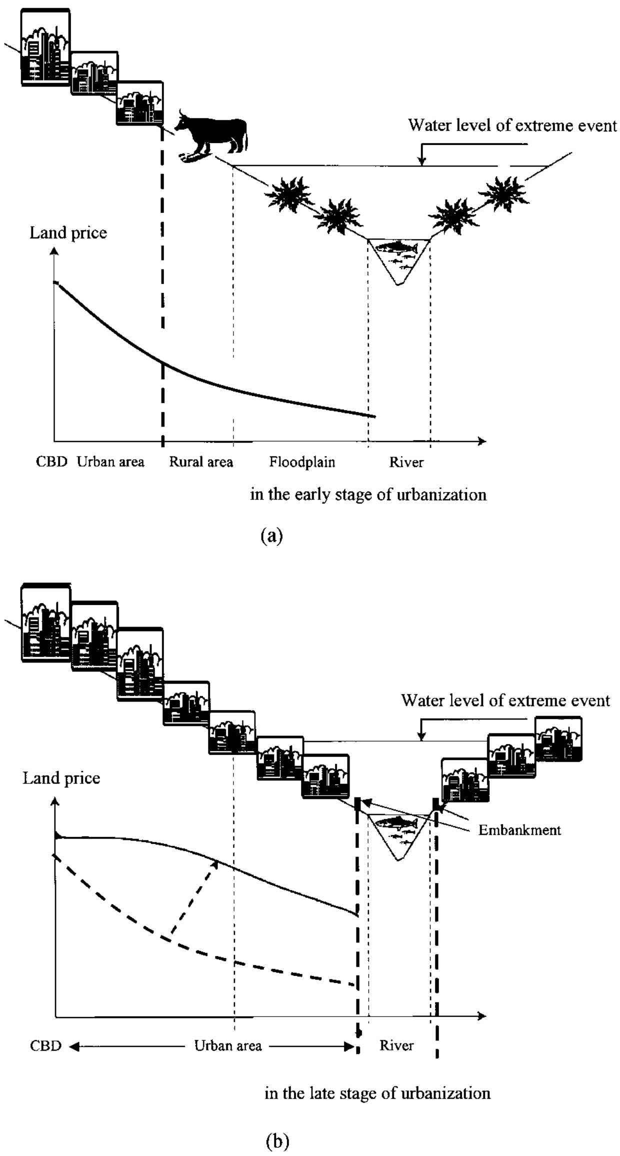


Fig. 1 Evolution of floodplain development

2.2 Analysis framework

The literature on the effects of disastrous events on land prices shows that research methods used to detect the effect of environmental attribute changes on land prices is classifiable basically into two methods: cross-sectional analysis, which focuses on land price change along the time axis at the same point, and hedonic-approach-based panel analysis, which focuses on land price change at different points at various times. Because both methods provide only a partial view of the event's effect on land prices, to see the broad picture, we used both methods.

When evaluating flooding's effect on land prices by means of cross-sectional or hedonic-approach-based panel analysis, it should be made clear that the evaluation is based on the hypothesis that the land price change trend, excluding the other factors' effects is linear, even though the reality of land price change may not be. Here, the evaluation is implemented by comparison of the trend; the diminution trend in land prices due to the current recession in the Japanese economy.

Fig. 2 outlines the framework for analyzing the effects of flooding on land prices. There are five steps:

1. Identify the purposes and scope of the research.
2. Collect panel data: land prices, land attributes (physical

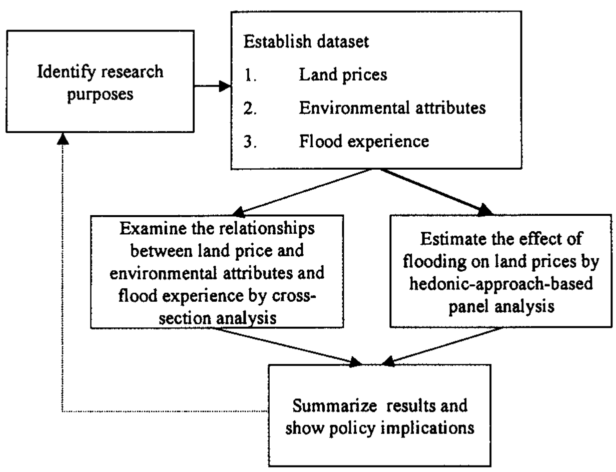


Fig. 2 Framework for analyzing the effects of flooding on land prices.

characteristics, locational attributes, social and economic land planning, land development history, administrative or legal regulations, and environmental quality), inundation situation (inundation depth, duration, and velocity).

3. Statistically analyze the collected data to see whether the land price and its attributes changed and what the relationship is between them if they did .

4. Estimate the effect of flooding on land prices by hedonic-approach-based panel analysis.

5. Summarize the results of steps 3 and 4 and show the implications for land use policies. If the results are not satisfactory, go back to step 1 and re-examine the data and methods until reasonable results are obtained.

In step 4, more attention should be focused on the decrease in land prices than on land price themselves, because the former is more sensitive to statistical testing. This can tell us whether a flood has an impact on land prices. The hedonic approach usually is used to analyze one year's worth of data; but, to obtain the net effect of each land attribute, including the flood, an analysis that stretches over several years is desirable. This is because the net effect of a flood is the effect of primary flood damage on land prices; i.e., a temporal not locational effect on a given location. We developed a hedonic-approach-based panel analysis that considers land-price-change trends and exclusion of the location effect. In this hedonic-approach-based panel analysis, all cautionary aspects of the hedonic approach, such as its conditions, and model forms, are applicable.

3. THE 2000 TOKAI FLOOD AND ANALYSIS DATASET

3.1 The Tokai Flood

In September 2000, heavy rainfall (97 mm hourly precipitation, 567mm total precipitation) inundated the city of Nagoya (population: 2.1 million) in the Tokai area. This has popularly been called the Tokai Flood Disaster of 2000 (Fig. 3). Such high daily precipitation is said to occur only once every 200 years (Kawada, 2002). This flood was one of the severest ever experienced in Japan, causing 10 deaths, 20 serious injuries, and a direct economic loss of 978.3 billion Japanese yen, according to the statistics of the Ministry of Land, Infrastructure and Transport (MLIT). Spatially, Aichi Prefecture accounted for 90% of the total direct economic loss and 89% of the loss related to general property, a much higher ratio than usual. According to the MLIT's statistical data , the average ratio of general-property to total direct economic loss from flooding was 29.8% from 1964 to 1999. In terms of the general property, enterprise and household loss roughly accounted for 50%. As to household loss, building and household articles accounted for more than 50% (Zhai & Sato, 2002). Here, we have focused on the most severely flooded area, which includes Nishi Ward in Nagoya and Shinkawa-cho and Nishibiwajima-cho.

3.2 Data sources

To determine the effects of the Tokai flood on land prices, we collected panel data representing land prices, environmental attributes that contribute to land prices, and flooding experiences (mainly inundation depth) before and after the flood (Table 1).

In Japan, there are several types of land prices, which depend on who is doing the appraisal and how the land is used. The *kouji-chika* (appraised land value), published annually by the MILT on April 1, gives the common land accession standards for the nation and its prefectures. The *kijun-chika* (average residential and commercial land prices), published annually by each prefecture on July 1, provides another set of common land accession standards for the nation and its prefectures. Both the *kouji-chika* and *kijun-chika* focus on urban-planning areas, the latter publication including forestlands outside those areas. In addition, there are the other val-

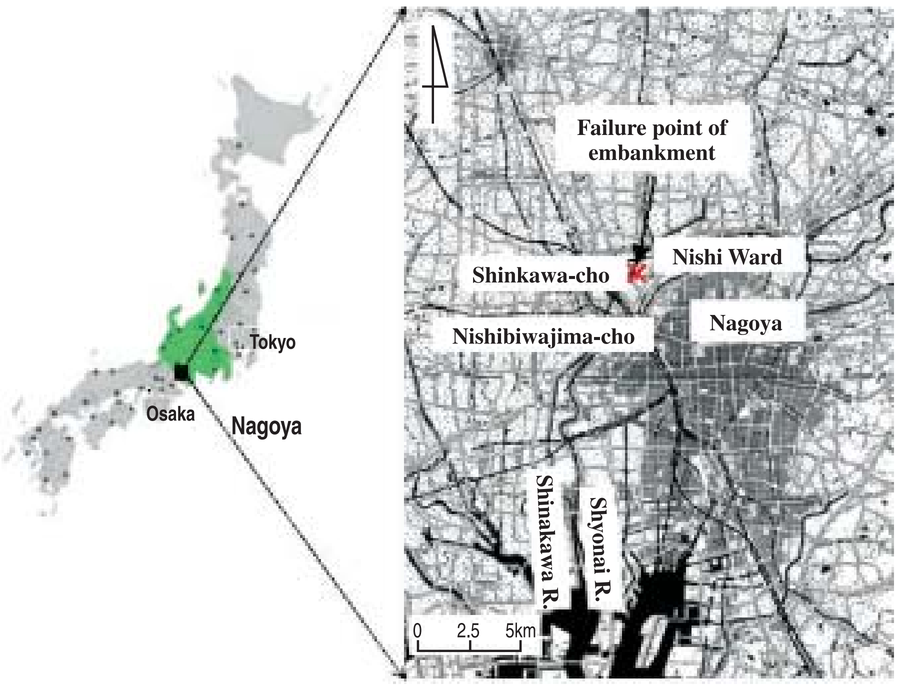


Fig. 3 Area studied

ues: the *rosenka* (prices of land fronting major roads) published by the National Tax Administration Agency, the assessed value of fixed assets of land computed by the Home Affairs Ministry every three years, and the transaction price of real estate. The transaction prices of real estate would be ideal for our purposes, but the sample number is small and prices before flooding are not known. Fortunately, these land pricing systems are highly correlated. For example, *kouji-chika* is an average value of transaction prices in a block (Hidano, 1998). The *rosenka*, gives approximately 80% of the assessed values of fixed land assets, approximately 70% that of *kouji-chika* values (Nikkei Net, 2000). Based on careful examination of the differences between the real and assessed land prices, either can be used to detect trends in how the Tokai flood affected land prices.

Environmental attributes include the land's physical characteristics, infrastructure maintenance status, location, and regulations. Flooding experience mainly is represented by inundation

Table 1 Panel dataset for the analysis.

Categories	Sub-categories	Item
Land price		*Kouji-chika* (yen/m^2)
Environmental attributes	Land characteristics	Area (m^2)
	Maintenance status of infrastructure	Gas system
		Sewage system
		Tap water system
		Road width
	Location	Distance from subway station (m)
		Regional land use
	Regulations	Building area ratio
		Floor area ratio
Flood experience		Inundation depth (cm)
Period		Year

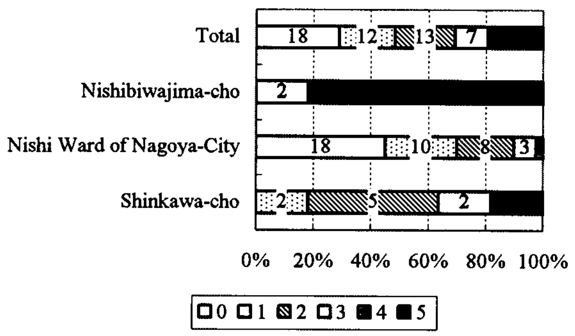


Fig. 4 Spatial characteristics of inundation depth.

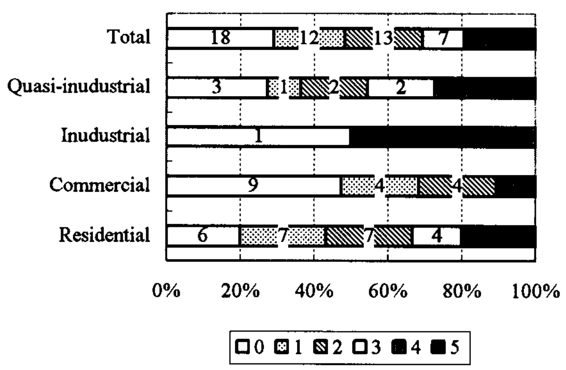


Fig. 5 Inundation depth for various land-use types.

depth: 0 for non-inundation; 1 for 0 to 50 cm inundation; 2 for 50 to 100 cm inundation; 3 for 100 to 150 cm inundation; 4 for 150 to 200 cm inundation; and 5 for more than 200 cm inundation. The inundation depth can be regarded as an approximate reflection of the elevation at the point where land is appraised. The relationship between land price and inundation depth therefore partly represents the primary flood damage effect on land price.

Land prices and environmental attributes were obtained from the *kouji-chika* published by the MLIT in 2002. Inundation depth was estimated by interpolation from the inundation record compiled by the Shinkawa River Administration Association (2001). We obtained 62 samples for each year in the four-year period 1999 to 2002.

Environmental attributes changed little from 1999 to 2002, except for the flood of 2000. There is good balance in the sample numbers for each inundation depth from no inundation to more than 200 cm. For some land-use types, such as industrial, there is a degree lack diversity in distribution. If industrial land is integrated with quasi-industrial land as a single type, then the land price change for each land use can be determined (Figs. 4 and 5).

4. EFFECTS OF THE 2000 TOKAI FLOOD ON LAND PRICES

4.1 Cross-sectional analysis of the flood's effect on land prices

4.1.1 General relation between land price and inundation depth

Fig. 6 gives the relationship between land price and inundation depth. There is a similar trend for each year; land price decreased with the increase in inundation depth both before and after the flood. Because historically the lower the elevation of an area the later land development was in this region, by implication a flood-prone area has low land prices, which can be regarded as lag differences in the intensity of development. Fig. 7 indicates that the greater the inundation depth, the smaller the variance in land prices. This is regarded as due to the socio-economic differentiation and agglomeration that follows urban development. Figs. 8 and 9 present the diminutions and their variances in land prices. The greater the inundation, the less the diminution in land prices, except for 2001 immediately after the Tokai flood when the situation was the opposite. People may prefer cheap land over land with a relatively low flood risk during the present economic recession. Figs. 10 and 11 give the attrition rates in land prices and their variances. The years 2000 and 2002 have similar patterns, whereas

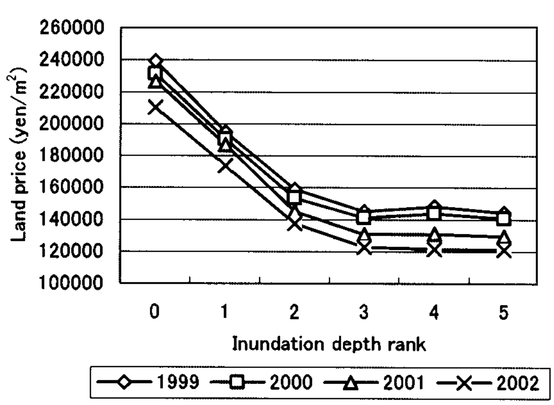


Fig. 6 Land price vs. inundation depth.

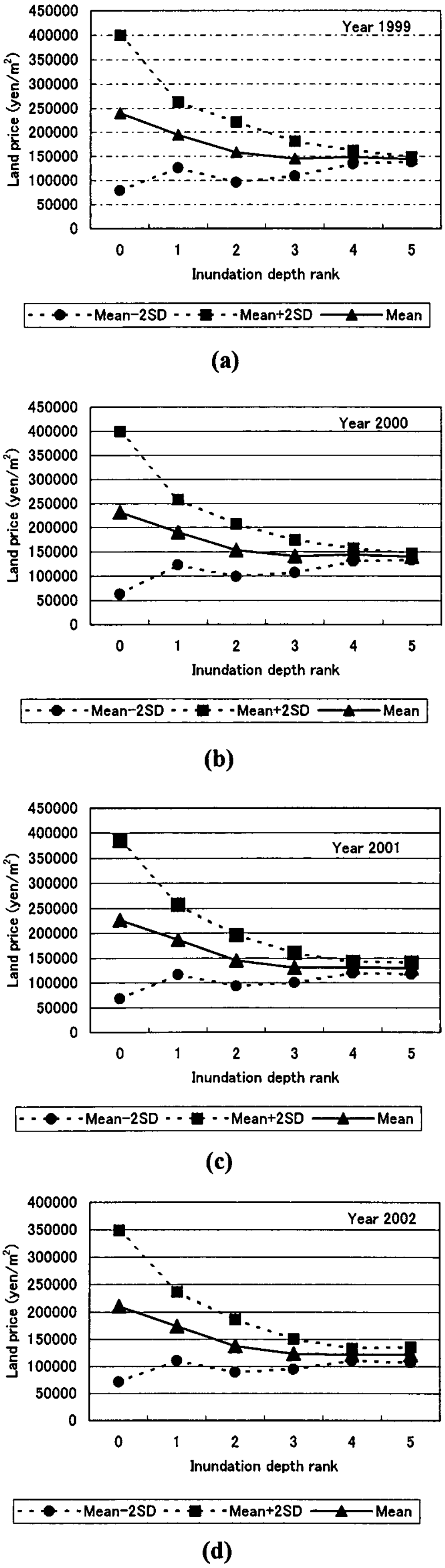


Fig. 7 Land price variance vs. inundation depth.

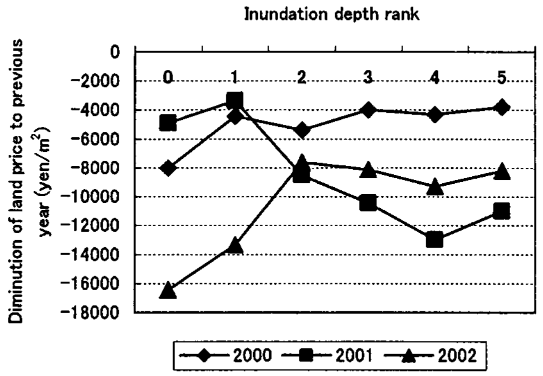


Fig. 8 Diminution of land price vs. inundation depth.

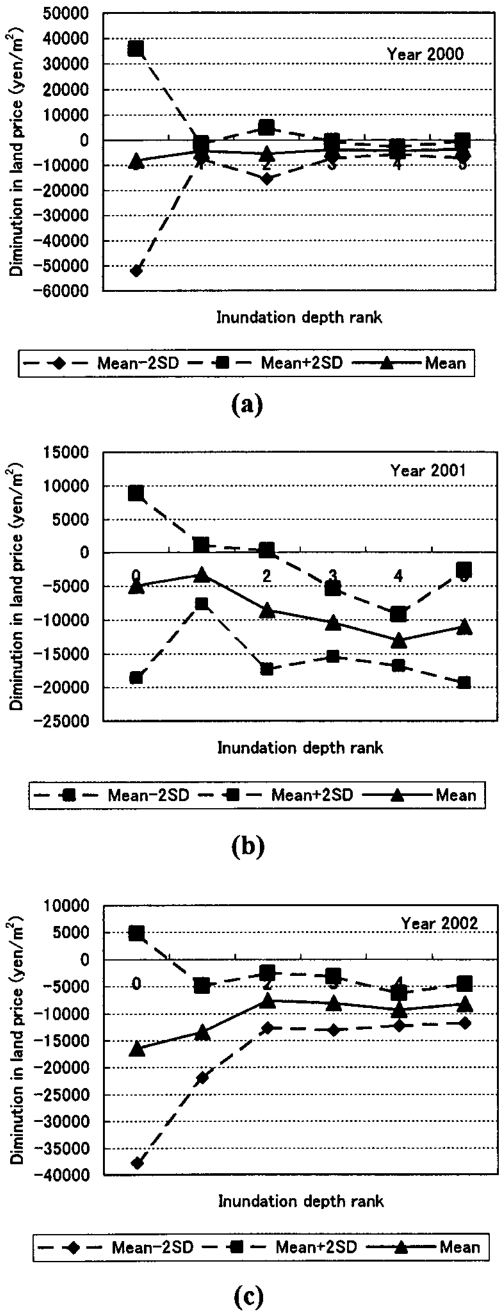


Fig. 9 Variance of diminution in land price vs. inundation depth.

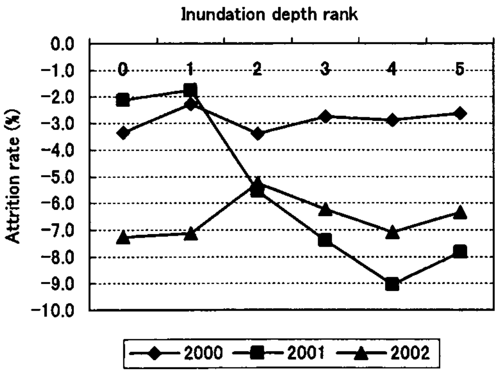


Fig. 10 Attrition rate vs. inundation depth rank.

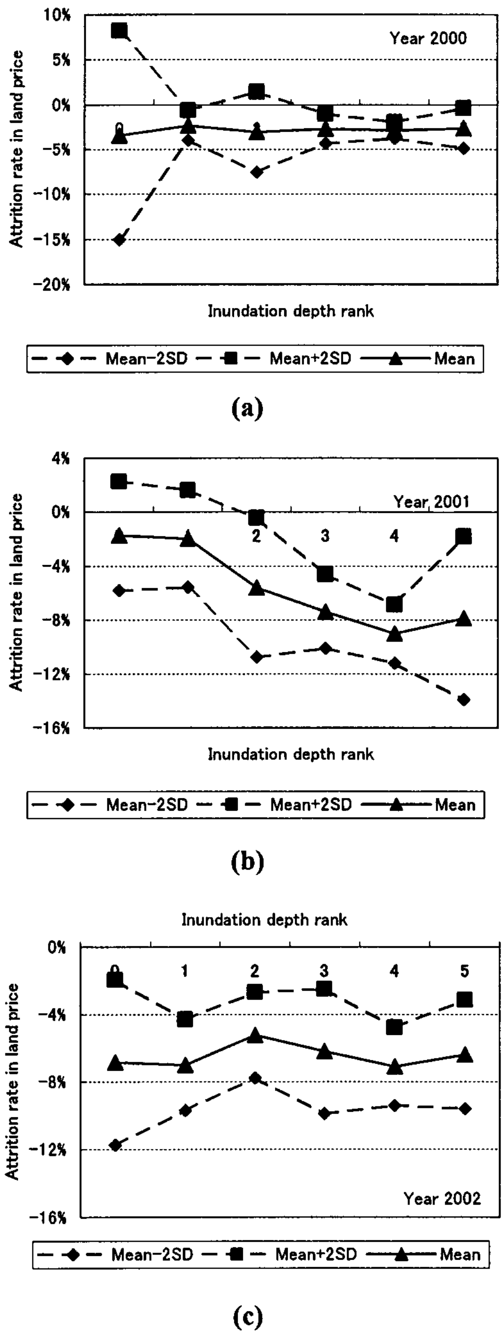


Fig. 11 Attrition rate variance vs. inundation depth rank.

Table 2 Multiple comparisons with the one-way layout model.

Dependant variable	(I) Year	(J) Year	Difference in means (I-J)	Standard deviation	Significance probability
Diminution of land price to previous year	2000	2001	1838.7	1555.3	0.239
		2002	6032.3	1555.3	0.000
	2001	2000	-1838.7	1555.3	0.239
		2002	4193.5	1555.3	0.008
Diminution rate of land price to previous year	2000	2001	0.016	0.005	0.002
		2002	0.035	0.005	0.000
	2001	2000	-0.016	0.005	0.002
		2002	0.019	0.005	0.000

2001 clearly has a decreasing pattern; in 2001, the greater the inundation, the higher the attrition rate. This means that 2001 can be regarded as the transition period from the pre - to post-flood phase. A comparison with the average change rates in total land prices in the Nagoya urban area shows that, in 2000, the rate for the area studied (-2.9%) is nearly equal to that for the Nagoya urban area (-3.0%), whereas in 2002, the decrease rate (-6.6%) in the area studied is greater than in Nagoya (-5.3%). The ratio of these areas' decrease rates changed from 0.966 (-2.9%/-3.0%) in 2000 to 1.245 (-6.6%/-5.3%) in 2002. This suggests that the Tokai flood 2000 aggravated the drop in land prices in the area studied. The similar patterns for 2000 and 2002 suggest that the effect of the flood on land prices had diffused from the inundated to non-inundated areas.

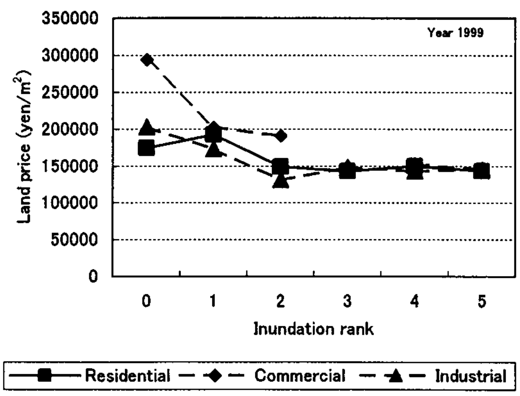
Multiple comparison tests done with a one-way layout model showed that the diminution and the attrition rate for land prices differed significantly from 2000 to 2002 (Table 2). The significance probabilities of diminution in land price were 0.239 for the mean comparison of 2000 vs. 2001, 0.008 for that of 2001 vs. 2002, and 0.000 for that of 2000 vs. 2002, and those of the attrition rates were 0.002 for the mean comparison of 2000 vs. 2001, 0.000 for those of 2001 vs. 2002 and 2000 vs. 2002; indicative that the Tokai flood of 2000 did aggravate the land price decrease, in terms of the attrition rate and the diminution scale. This was particularly true for 2002.

In summary, the flood effect on land price based on the inundation depth in the Tokai flood of 2000 has a reverse Z-shaped pattern (Figs. 8 and 10). In other words, the attrition rate and diminution scale had approximately parallel patterns before and after the flood, but there was a transition period in which their relationships to inundation depth are correlated negatively.

4.1.2 Variability of land use types

The flood did not change the fundamental pattern of land use. That pattern shows the differences between land-use types, which decrease with increasing inundation, and the rank orders of the mean land prices (Fig. 12).

The annual diminutions in land prices after the flood were -6166 yen/m^2, -8947 yen/m^2, and -7927 yen/m^2 in 2001, and -9100 yen/m^2, -17263 yen/m^2, and -9000 yen/m^2 in 2002 in the order of residential, commercial, and industrial land use, the values of which generally are more than those in 2000 (-3400 yen/m^2, -10368 yen/m^2, and -3000 yen/m^2) (Fig. 13). With respect to inundation depth, all three land-use types show a similar trend. Diminution in land prices decreased approximately equivalently before the flood (Fig. 13-a), but immediately following it, the decrease become linear (Fig. 13-b), after which there was a linear



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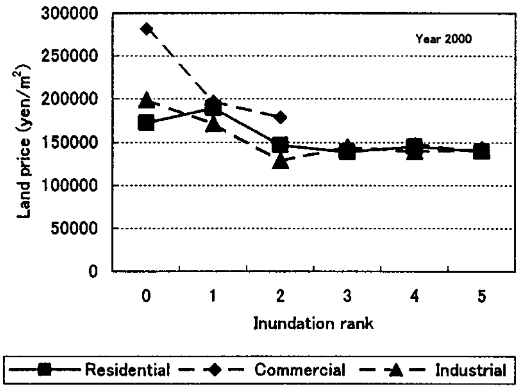

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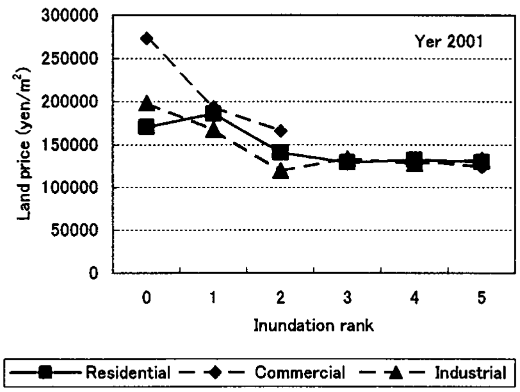

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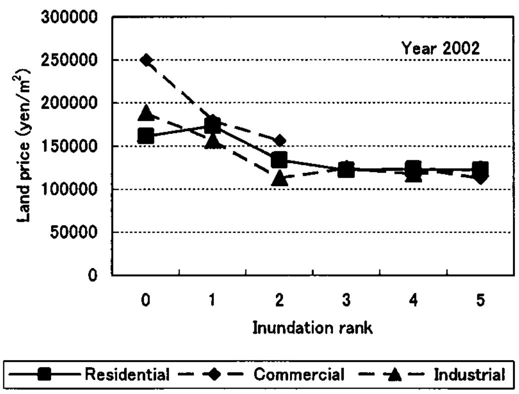

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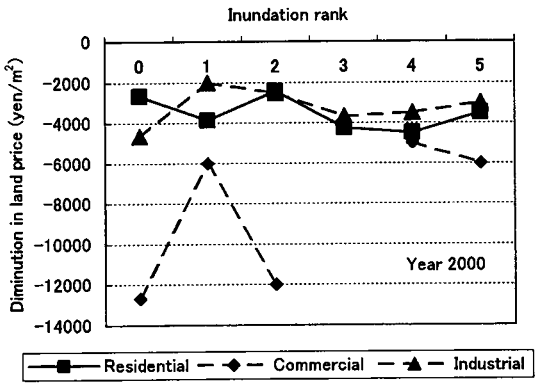
Fig. 12 Differences in land prices of land use types.



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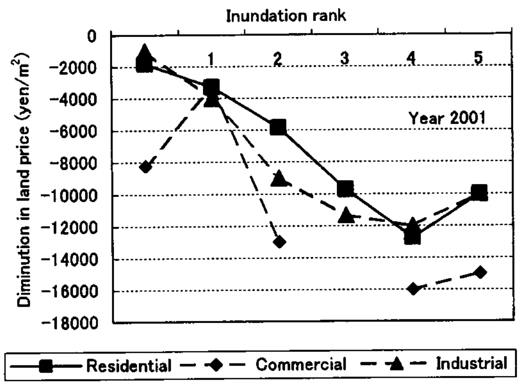

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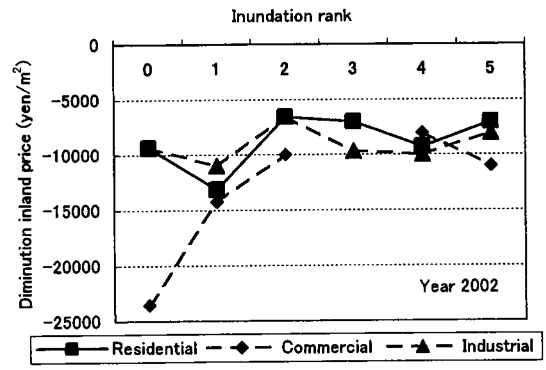

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Fig. 13 Differences in diminution of land prices of land-use types.

increase (Fig. 13-c).

The annual attrition rates of land prices after the flood were -4.3%, -5.6%, and -4.3% in 2001 and -5.8% -7.5%, and -6.2% in 2002 in the order of residential, commercial, and industrial land use, which again generally are higher than in 2000 (-2.1%, -4.7%, and -2.1%) (Fig. 14). With respect to inundation depth, the attrition rates show the same trends as diminution.

4.1.3 Spatial variability

Land prices differ between areas (Fig. 15). Prices in Nagoya's Nishi Ward were higher than in the other two areas; in particular, at slight inundation. The diminution patterns for Shinkawa-cho and

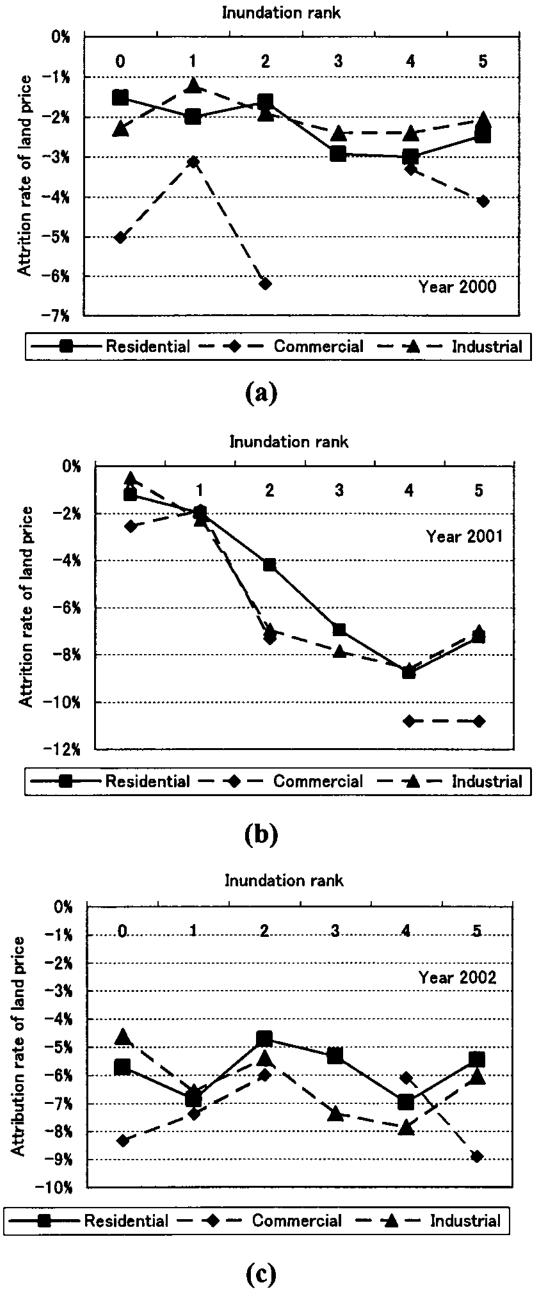


Fig. 14 Difference of attrition rate in land price between land-use types.

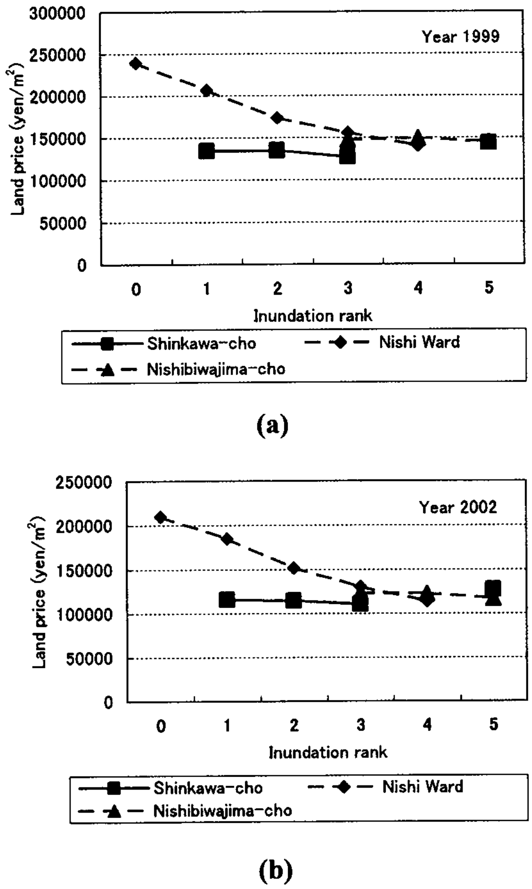


Fig. 15 Spatial differences in land prices.

Nishi Ward with inundation changed from an increasing trend in 2000 to a decreasing one in 2001, then again an increasing one in 2002, whereas Nishibiwajima-cho had a decreasing trend in all three years (Fig. 16). Although the patterns of the attrition rates in 2000 and 2002 were complex, in 2001, except for Shinkawa-cho, they clearly decreased with inundation (Fig. 17).

4.2 Determining the effect of flooding on land prices by hedonic-analysis-based panel analysis

As shown, land prices were affected immediately after the flood, but the effect difference for inundation disappeared in the second year. This can be regarded as due to the diffusion effect of the flood. Temporally, the effect of flooding on land prices was obtained qualitatively by cross-sectional analysis. The hedonic-analysis-based panel analysis described below allows evaluation of that effect.

4.2.1 Hedonic-analysis-based panel analysis

The hedonic approach developed by Rosen (1974) is described in his classic paper. Provided that the land price depends on the attributes of the land, mathematically this relationship is written

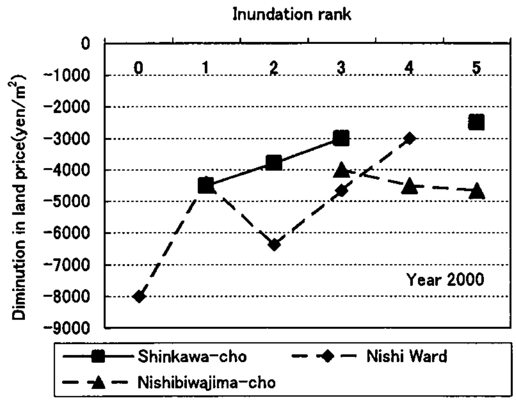
$$p=f\ (a_1, a_1,.....a_n) \tag{1}$$

where P is the land price, $f\,(.)$ an arbitrary function, and a_i represents the attributes of the land. Attributes include the physical aspects and location attributes. The hedonic approach measures the contribution of each attribute to the land price. Mathematically, the hedonic price is the partial derivative with respect to the attribute such that

$$\text{Hedonic} = \frac{\partial p}{\partial a_i} \tag{2}$$

The practical way to empirically calculate a hedonic price is to use a multivariate regression model: a linear or semi-log model or other forms.

When applying the hedonic approach, it is essential to differentiate the primary effect of flooding from the location effect. This is difficult because they are interrelated. In a sense, inundation depth reflects both flood severity and the ground elevation of a building. Cross-sectional analysis of land prices with inundation depth for a given year therefore does not provide sufficient infor-



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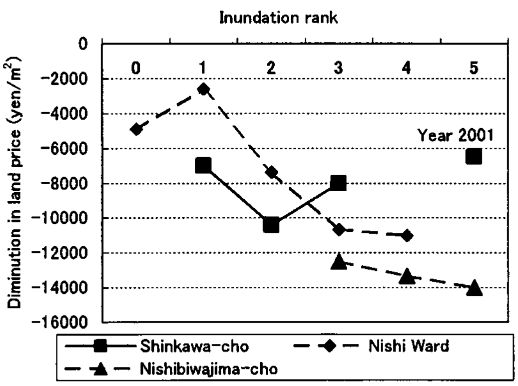

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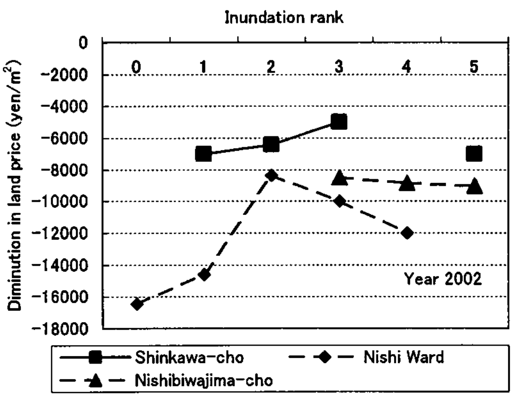

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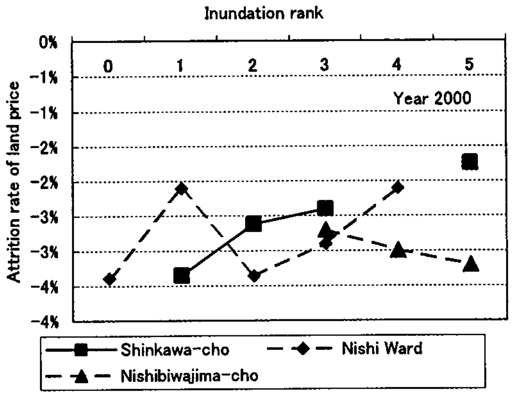
Fig. 16 Spatial differences in land price decreases.



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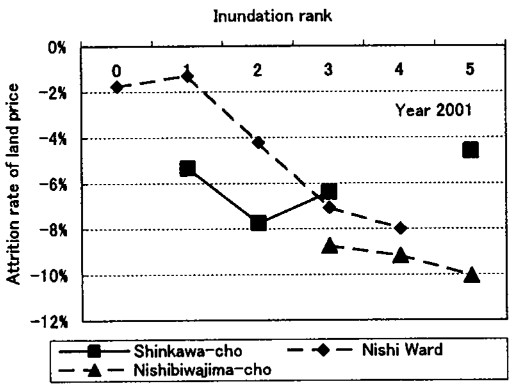
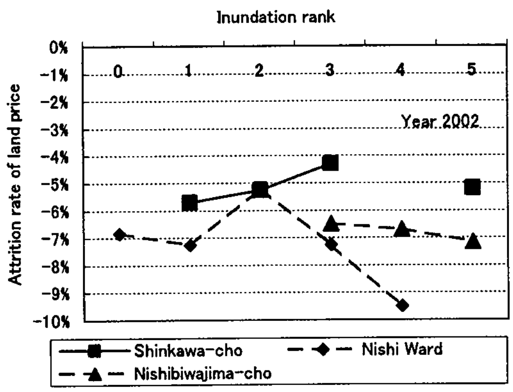


(b)



(c)

Fig. 17 Spatial difference in the attrition rate of land prices.

mation about the effect of flooding on land prices. We established a model by which to detect the primary flood effect by applying the hedonic approach.

When using land prices as panel data, it is important to keep in mind that the prices vary due to changes in the economic environment, even though there may be no change in the local environment, e.g. in the infrastructure and regulations. This means that it is necessary to take into consideration the land-price trend when panel data are used. Therefore, in addition to the local environmental factors that determine land prices (including inundation depth), the flood situation and trend in appraisals must be integrated into the dataset as variables such that

Land price =*f* (*local environment attributes of land price, trend, flood situation*) (3)

Mathematically, the relationship is represented in linear and semi-log forms;

$$p = a_0 + \sum_{i}^{n} a_i x_i + bT + cF \quad (4)$$

$$Inp = a_0 + \sum_{i}^{n} a_i x_i + \beta T + \gamma F \quad (5)$$

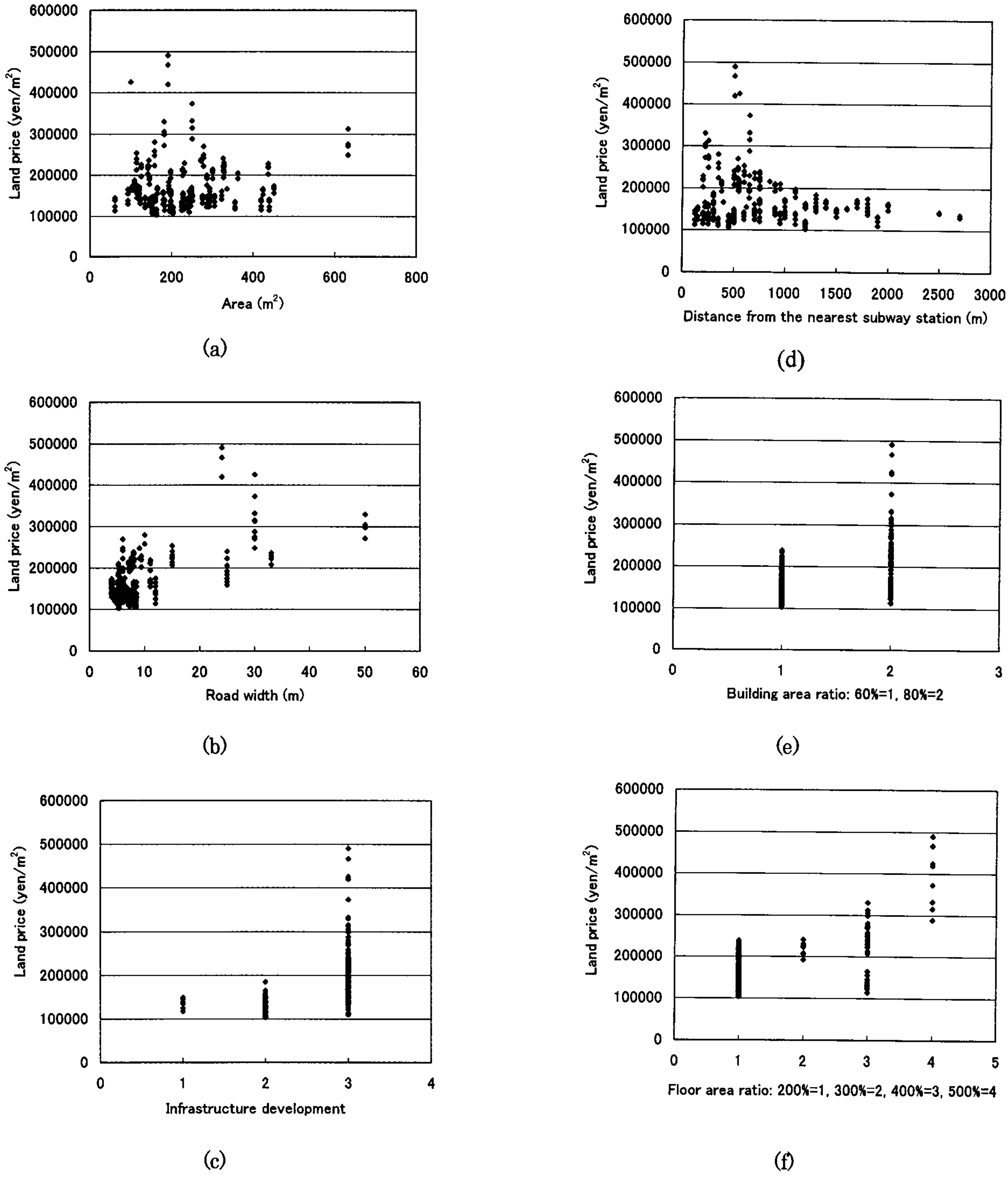


Fig. 18 Relationships between land prices and the determining factors.

where x_i: represents the characteristics of the local environment, including inundation depth; T is the period of the land-price-change trend; F a dummy variable for the flood effect; P the land price; and a, b, c, α, β, γ are parameters.

When applying the hedonic approach, care must be taken because of the strict limitations of its theoretical and statistical conditions (Kanemoto et al., 1989). The former conditions consist of regional openness for free migration, consumer homogeneity, a small project or a small area affected by a project, or no substitutability between production and consumption. This study fundamentally meets these requirements. The latter conditions concern the selection of variables, multi-linearity, choice of functional form, etc.

4.2.2 Relation between land price and its determining factors

Before using hedonic-analysis-based panel analysis to estimate the flood effect on land price, it is necessary to discuss the relationship between land price and its determining factors to find what kind of model should be used. The relationships between land price, its logarithm, and factors other than inundation depth are

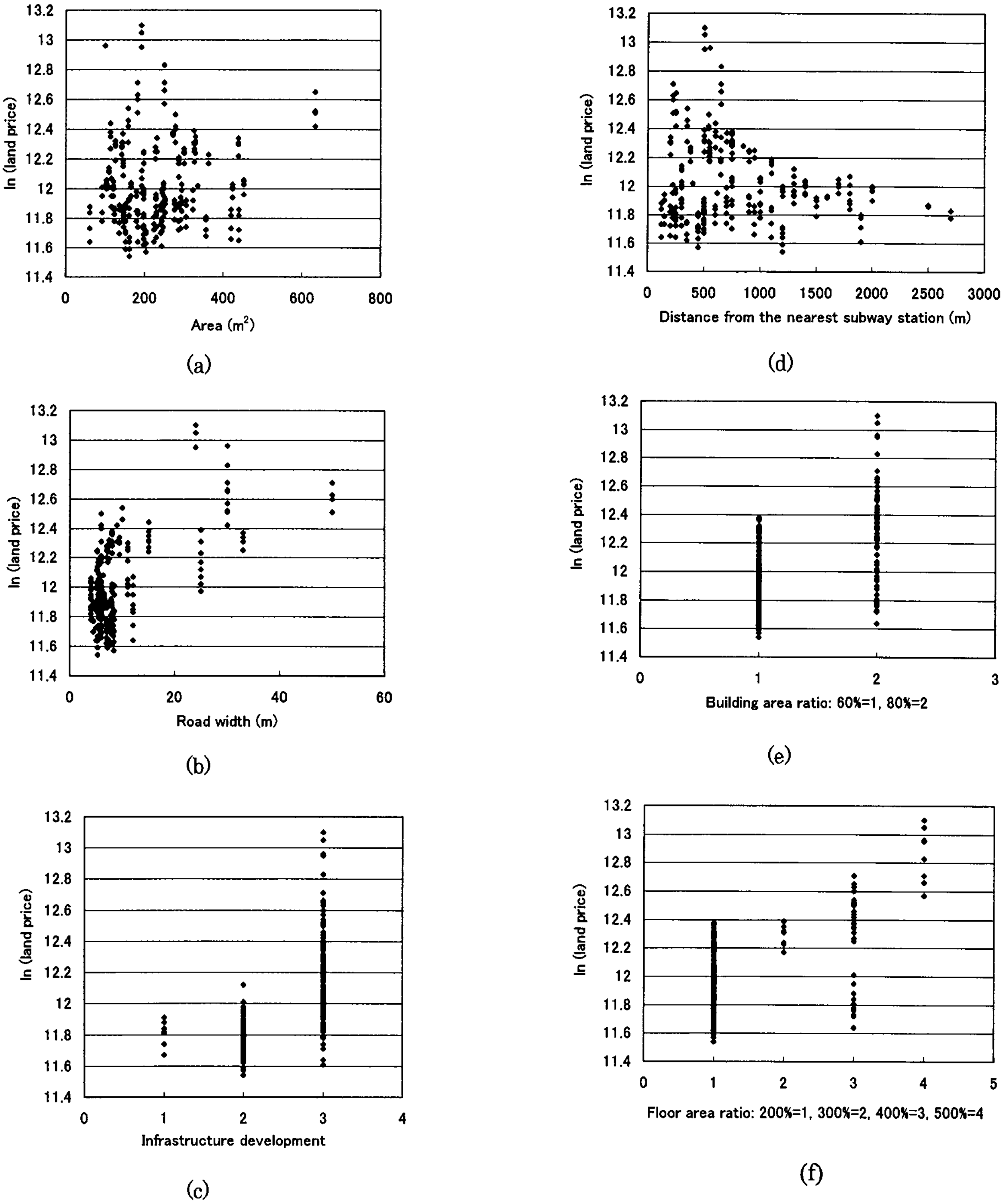


Fig. 19 Relationships between ln (land price) and the determining factors.

plotted in Figs. 18 and 19.

Both land price and its logarithm are closely related to infrastructure development, road width, distance from the nearest subway station, and the building-area and floor-area ratios. That is, land price increases with increases in infrastructure development intensity, road width, and the building - and floor-area ratios, and decreases with increasing distance from a subway station. There seems to be no apparent relationship between land price and the size of the plot of land. This indicates that it is reasonable to use the linear and semi-log forms of the hedonic approach to determine the flood effect on land prices.

4.2.3 Evaluating the flood effect on land price

The proposed models were used to evaluate the flood effect. The coefficients of the flood effect, however, have positive signs, which contradicts common knowledge that a flood may have a negative effect on land prices. To solve the problem of detecting the flood effects and of evaluating them, as an alternative to the proposed model, we used dummy time variables instead of land-price-change trend variables in equations 4 and 5 to run the mod-

Table 3 Panel analysis results for the linear model.

Item	Coefficient	Significance probability
Area	19.4	0.329
Infrastructure development	36058.5	0.000
Road width	1857.2	0.000
Distance from the nearest subway station	-23.7	0.000
Environmental land use: dummy variable for residential land =0		
Commercial land use	-9792.0	0.000
Industrial land use	-114878.3	0.243
Building area ratio	100202.0	0.003
Floor area ratio	25468.7	0.000
Inundation depth (rank)	-8192.1	0.000
Time: dummy variable for 2000=0		
Year 1999	5038.2138	0.365
Year 2001	-7242.918	0.191
Year 2002	-18888.28	0.001 (0.036 in case of 2001=0)
Constant	-30044.9	0.406
R^2=0.751	Adjusted R^2=0.738	

Table 4 Panel analysis results for the semi-log model.

Item	Coefficient	Significance probability
Area	8.68E-05	0.326
Infrastructure development	2.19E-01	0.000
Road width	8.05E-03	0.000
Distance from the nearest subway station	-1.45E-04	0.000
Environmental land use: dummy variable for residential land =0		
Commercial land use	-5.49E-02	0.141
Industrial land use	-3.33E-01	0.020
Building area ratio	3.11E-01	0.035
Floor area ratio	7.52E-02	0.000
Inundation depth (rank)	-4.76E-02	0.000
Year: dummy variable for 2000=0		
Year 1999	3.30E-02	0.181
Year 2001	-4.57E-02	0.064
Year 2002	-1.13E-01	0. 000 (0.007 in case of 2001=0)
Constant	1.12E+01	0.000
R^2=0.788	Adjusted R^2=0.777	

els, then computed how much land prices before the flood differed from those after it, which value was the flood effect.

In the alternative models, besides time, regional land use was set as a dummy variable. Infrastructure development was set as a rank variable because development usually proceeds from piping for tap water, to that for gas, then to a sewage system.

Both the linear and semi-log models well explain the variable dependence of land prices (Tables 3 and 4). The respective adjusted square correlation coefficients are 0.738 and 0.777 for the linear and semi-log models. Concerning land price under current socio-economic conditions, area, infrastructure development, road width, and the building-area and floor-area ratios make a positive contribution (plus sign) to land prices, whereas distance from a subway station and inundation depth (elevation) make a negative one (minus sign). Different surroundings have different effects on land prices. In the current economic recession, land located in areas of commercial and industrial use has decreased much more in price than land for residential land use.

The significance of each variable in the models, however, differs greatly. Infrastructure development, road width, distance from the nearest subway station, and the building-area and floor-area ratios as well as inundation depth significantly determine both models, whereas land area does not at the significance probability level of 0.05 (5%).

Much more attention must be paid to the dummy variable, time. Because it is hypothesized that the change trend in land prices in a given period basically is constant, it may be possible to determine the flood effect by evaluating the dummy year variable which consists of the change trend and flood effect. In both the linear and semi-log models, the significance probabilities of the dummy variables for time decrease from 1999 to 2002, and fall into two groups; the 1999-2001 and 2002 groups at the significance level of 5%. This means that the Tokai flood of 2000 significantly affected land prices, which is in accord with the cross-sectional analysis findings in 4.1.

Because the flood effect is defined as how much the price of land before the flood differed from that after it, excluding the land-price change trend, if the change trend is set as the difference in land prices between 1999 and 2000, the flood effect amounts to -2204.7 yen/m^2 in 2001 and -8888.3 yen/m^2 in 2002, whereas in the change rates were -1.27% in 2001 and -4.7% in 2002.

5. CONCLUDING REMARKS

We first reviewed previous studies of the flood effect on land prices and introduced a framework for analyzing that effect. Its effect on land prices was examined by cross-sectional and panel analyses, the panel data comprising land price and its attributes. The main findings were:

1) Land prices in flood-prone areas are lower and have a smaller variance than in other areas. This is called the location effect which mainly is due to the lag in the intensity of development.

2) The price of land for commercial use is higher than that for residential and industrial use, and the amount and ratio of diminution also are higher.

3) Spatially, land prices in Nishi Ward of Nagoya City are higher than in the other two areas examined, but diminution and the diminution ratio changed markedly.

4) It is very important to differentiate between the effects of flooding and location on land prices when estimating the scale of the flood effect. Many previous studies focused on the location effect; i.e., whether the area of concern was in the floodplain, or on differences in the floodplain.

5) The determined flood effect had a reverse Z-shaped pattern for the Tokai flood of 2000. It appeared partly in 2001 and completely in 2002. This phenomenon may be termed diffusion of the flood effect from inundated to un-inundated areas. At the advent of the flood effect, the greater the inundation, the greater the decrease rate. When the land-price-change trend is set as the difference in land price between 1999 and 2000, the mean flood effects amount to -2204.7 yen/m^2 in 2001 and -8888.3 yen/m^2 in 2002, and the change rates to -1.27% in 2001 and -4.7% in 2002.

6) Residents prefer cheap land to land with a low flood risk.

Unresolved issues requiring future research remain because of insufficient data, in particular, after a flood. First, it is important to validate the diffusion effect of a flood on land prices over a large area. This should be done by means of a GIS quantitative analysis model. Second, although the effect of the Tokai flood of 2000 could be determined, the relationship between flood scale (e.g., a 100-year flood) and the flood effect is still not clear. Third, although the utility of our model for determining the flood effect has been proved, we could not use it fully because of the shortage of data. When it becomes possible to obtain more time-series data, it will be necessary to re-compute the flood effect to clarify the evolution process. Fourth, the effect of flooding on land prices has been proved, but how long that effect lasts has not been determined due to the shortness of the period after the Tokai flood. That necessarily must be followed in real time. Finally, the models used here are linear and semi-log ones but the actual practical model may be nonlinear, more complex. Just as with the behavior of land-price-change trend, developing a new type of model to determine the flood effect on land prices may be urgent.

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